The Tactical Management Processes used by Pastoral-Based Dairy Farmers:

A Multiple-Case Study of Experts

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The Tactical Management Processes used by Pastoral-Based Dairy Farmers:

A Multiple-Case Study of Experts

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Appendix I: ***Example Farm Diary –*** *(This information was recorded at half-monthly intervals).*

Date 16/1/xx

Farm State

Cow number

Milking

Dry

Milk production

Cow condition

Cow intakes

Rotation length

Average pasture cover

Pasture growth rates

Pre-grazing residual

Post-grazing residual

Pasture quality

Supplements on-hand

- Hay
- Grass silage
- Maize silage
- Forage crop
- Nitrogen
- Other

Weather (description, including rainfall)

Decision making

Describe the decisions made since the 1/1/xx

Monitoring

Describe the information you have collected since the last period.

Evaluation

Describe any evaluations you have undertaken since the last period.

Appendix II. Description of the three years for Farmer A.

Table 1. Comparison of the three years for Farmer A.

Factor	Year 1	Year 2	Year 3
Start of planning period (25/12/xx)			
Average pasture cover (kg DM/ha)[1]	1700	1800	1650
Cow condition	4.5 (+)	4.8 (+)	4.8
Milk production (kg MS/cow/day)	1.39	1.39	1.22
Milking cow numbers	140	150	174
Cow intakes (kg DM/cow/day)	12.0	12.0	12.0
Stocking rate (cows/pasture ha)[2]	3.04	3.06	2.97
Rotation length (days)[3]	30	30	24
January 1st			
Average pasture cover (kg DM/ha)	1650	1800	1600
Cow condition	4.5(+)	4.8	4.8
Milk production (kg MS/cow/day)	1.39	1.39	1.13 - 1.22
Milking cow numbers	140	144	174
Cow intakes (kg DM/cow/day)	12.0	12.0	12.0
Pre-grazing pasture cover (kg DM/ha)	2000	2300	1700 - 2000
Post-grazing pasture cover (kg DM/ha)	1200	1300	1100 - 1200
Stocking rate (cows/pasture ha)	3.04	2.94	2.97
Rotation length (days)	30	30	24
February 1st			
Average pasture cover (kg DM/ha)	1400	1800	1200
Cow condition	4.5	4.8	4.4
Milk production (kg MS/cow/day)	1.25	1.39	0.87
Milking cow numbers	138	144	160
Cow intakes (kg DM/cow/day)	12.0	11.0	10.0
Pre-grazing pasture cover (kg DM/ha)	1800	2300	1400
Post-grazing pasture cover (kg DM/ha)	1000	1300	1000
Stocking rate (cows/pasture ha)	3.00	2.94	2.74
Rotation length (days)	29 - 30	28 - 30 (30)	24
March 1st[4]			
Average pasture cover (kg DM/ha)	1400	1300	1150
Cow condition	4.5	4.8[5]	4.0
Milk production (kg MS/cow/day)	1.13 -1.22	1.04[6]	0.70
Milking cow numbers	138	142	141[7]
Cow intakes (kg DM/cow/day)	12.0	9.0 - 10.0	9.0 - 10.0

[1] During summer, the figures given for average pasture cover are estimates because Farmer A was not formally monitoring this information.
[2] This is the number of cows divided by the effective area in pasture.
[3] The rotation length is the range over the previous month, and the figure in brackets is the rotation length at the end of the month.
[4] The young stock were given 3.0 ha because they were short of feed as a result of late hay and silage crops.
[5] Average herd condition increased to 5.0 condition score units on the 24th March, and then declined to 4.8 condition score units.
[6] Milk production held at 1.22 kg MS/cow/day through most of February. When the herd went onto the second forage crop on the 28th February, Farmer A reduced milk production to 1.04 kg MS/cow/day.
[7] The herd was put on once-a-day milking on the 23/2/xx and remained on once-a-day milking until drying off.

Factor	Year 1	Year 2	Year 3
Pre-grazing pasture cover (kg DM/ha)	1700 - 1800	1500	1350
Post-grazing pasture cover (kg DM/ha)	1000	1100	950
Stocking rate (cows/pasture ha)	3.00	2.90	2.41
Rotation length (days)	24 - 29 (25)	25 - 28 (25)	24
Date forage crop started	31/1/xx	10/2/xx[8]	28/1/xx
Date forage crop terminated	1/3/xx[9]	23/3/xx	18/3/xx
Date silage started	24/4/xx	15/3/xx	28/1/xx
Date silage terminated	29/4/xx	29/3/xx	19/2/xx
Amount fed	4 bales	17 bales	25 bales[10]
April 1st			
Average pasture cover (kg DM/ha)	1445	1280	1360
Cow condition	4.5 (+)	4.5	4.3
Milk production (kg MS/cow/day)	1.13 - 1.17	1.22	0.78
Milking cow numbers	138	126	140
Cow intakes (kg DM/cow/day)	9.0 - 10.0	9.5	9.0
Pre-grazing pasture cover (kg DM/ha)	1800 - 1900	1700	1550
Post-grazing pasture cover (kg DM/ha)	1100	1100	1100
Stocking rate (cows/pasture ha)	3.00	2.57	2.39
Rotation length (days)	25 - 29 (28)	24 - 25 (25)	24
May 1st			
Average pasture cover (kg DM/ha)	NA	NA	1685
Cow condition	NA	NA	4.7
Milk production (kg MS/cow/day)	NA	NA	0.80
Milking cow numbers	NA	NA	138
Cow intakes (kg DM/cow/day)	NA	NA	13.5
Pre-grazing pasture cover (kg DM/ha)	NA	NA	2150
Post-grazing pasture cover (kg DM/ha)	NA	NA	1400
Rotation length (days)	NA	NA	24
Drying off date	29/4/xx	28/4/xx	20/5/xx
Cow numbers at drying off	129[11]	119	138
Stocking rate (cows/pasture ha)	2.80	2.43	2.36
Milk production (kg MS/cow/day)	1.13	0.84	0.70
Condition score	4.5	4.5 (-)	4.7
Average pasture cover (kg DM/ha)	13xx	1332	1570
Date herd on once-a-day	24/4/xx[12]	13/4/xx	23/2/xx

[8] The second forage crop of 1.5 ha was fed on the 28th February.
[9] The crop was not grazed for 5 days during this period due to muddy conditions.
[10] Farmer A fed 25 large bales of hay with the silage.
[11] Farmer A put 9 cull cows on waste ground on the 5th April and milked them until the 18th April when they were sold to the works.
[12] The rising 3 year old cows were put on once-a-day milking on the 18th April.

Appendix III. The planning heuristics used by Farmer A.

Table 1. Decision rules used by Farmer A to develop his typical plan[13] for the summer-autumn[14].

Activity	Decision Rule	Reason
Specification of summer-autumn stocking rate. **Input type and level rule**	IF date = Christmas, THEN identify cull cows not considered suitable for milking through the summer-autumn and sell them and milk the remainder through the period.	At Christmas Farmer A aims to take as many cows as possible through the summer-autumn period. He identifies culls that he thinks are not suitable to take through this period, and sells them at, or soon after Christmas. These culls are cows with mastitis or a dangerous temperament. Strategic decisions in relation to stocking rate, calving date and supplements dictate the summer-autumn stocking rate.
Specification of rotation length. **Input type and level rules**	Maintain rotation length between 25 - 30 day round from Christmas until drying off is initiated. At drying off, double the rotation length to 60 days.	Farmer A's choice of maximum rotation length relates to the impact of the stocking rate/cow concentration effect. Above a thirty day round, cow density per hectare is such that there is insufficient pre-grazing mass to fully feed the herd. The rate of pasture regrowth is also insufficient to achieve the pre-grazing residuals Farmer A needs to fully feed the herd at the next grazing. On a longer rotation length, pasture cover can get too long (> 2000 kg DM/ha) and reduce pasture growth rates. Under dry conditions, the feed can "bum" off before it is regrazed. At the other extreme, Farmer A does not want a rotation length of less than 25 days because at this rate, average pasture cover declines too quickly, and pasture regrowth is reduced. The rotation length is doubled at drying off to halve cow intakes and to reduce the area the herd grazes to take advantage of the autumn flush.
Specification of milk production targets. **Target specification rule**	Aim to produce 12 - 13 litres/cow/day (1.04 kg MS/cow/day) until at least mid-March under typical conditions.	A herd producing at a higher level of milk production converts feed into pasture more efficiently than a herd producing at a low level of milk production. However, if feed demand is too high, the herd may have to be dried off in early summer and fail to take advantage of the autumn flush. At his level of milk production, Farmer A knows that the herd is maintaining body condition and post-grazing residuals are being maintained at levels which ensure good pasture regrowth. It also ensures a high level of utilisation when the herd is grazing the forage crop.
Specification of intake levels. **Input type and level rule**	Provide the herd with sufficient feed to produce 12 - 13 litres/cow/day (1.04 kg MS/cow/day) until at least mid-March under typical conditions.	A herd producing at a higher level of milk production converts feed into pasture more efficiently than a herd producing at a low level of milk production. However, if feed demand is too high, the herd may have to be dried off in early summer and fail to take advantage of the autumn flush
Specification of condition score targets. **Target specification rule**	Aim to maintain herd condition at a minimum of 4.5[15] condition score units.	The herd must calve at condition score 4.5. In order to reach this target, the herd cannot be at too low a condition score at drying off.

[13] The decision rules for the autumn plan in this table only encompass those used through until drying off.
[14] This was used in years one and two of the study with minor modifications.
[15] During years one and two, field observations and Farmer A's behaviour suggested that this target was 4.5 condition score units even though on tape, Farmer A specified 3.5 - 4.0 condition score units. During year three, the extremely dry year, Farmer A stated that he had reduced his condition score target to 4.0 condition score units.

Activity	Decision Rule	Reason
Activation of forage crop grazing. **Activation rule**	Introduce the forage crop when milk production falls to 13 l/cow/day or 1.13 kg MS/cow/day[16]. IF milk production less than 13 l/cow/day or 1.13 kg MS/cow/day, AND the forage crop is ungrazed, THEN begin feeding the forage crop.	In a typical year, Farmer A expects to graze the forage crop from February 1st to 28th. The end date is set so that the new grass can be sown early to ensure good establishment. Farmer A therefore expects milk production to decline to 1.13 kg MS/cow/day through January as pasture cover declines, at which point, the forage crop is introduced. The forage crop is introduced to the herd relatively early so that the change in diet is relatively gradual. This also allows the forage crop to last for longer than if it was introduced later and made up a larger proportion of the herd's diet. Data from this season suggests that if the proportion of pasture in the diet is too low, metabolic problems can occur when feeding the forage crop. The herd is introduced to the forage crop at a higher level of milk production than what it is maintained at because production tends to drop 0.09 kg MS/cow/day with the change of diet. The forage crop is introduced at a time when pasture growth is at its lowest. It therefore allows cow intakes and production to be maintained while also maintaining post-grazing residuals and average pasture cover. This in turn improves pasture growth rates, particularly after rain.
Specification of the quantity of forage crop fed. **Input type and level rule**	Feed sufficient forage crop to maintain milk production at 12 l/cow/day (1.04 kg MS/cow/day)[17]. The forage crop component should make up roughly 1/3 of the herd's diet.	The forage crop is fed to maintain milk production at 12 - 13 litres/cow/day (1.04 kg MS/cow/day) because Farmer A believes it is more efficient to feed the crop for a shorter period at a higher level of production than for a longer period at a lower level of production. Therefore, although Farmer A recommends 1/3 of the herd's diet be fed as crop, the actual amount depends on the level of pasture the herd is being fed. Farmer A recommends 1/3 of the diet in order to make an impact on feed supply. The crop is fed when production falls to 13 litres/cow/day (1.13 kg MS/cow/day) to allow for a fall in milk production as a result of a change in diet. The crop must also be harvested before the mid March to ensure the new grass is sown on time. One third of the herd's diet is fed because much less than this has little impact on the system. The crop is fed at this stage because the farm is normally in a feed deficit situation.
Specification of the milk production target for supplement feeding. **Target specification rule**	Do not use a milk production target that will result in poor utilisation of supplements or pasture.	Farmer A used a milk production target when feeding supplements (forage crop, silage) that ensured a high level of utilisation. This target also ensured the level of pasture utilisation was high and pasture quality maintained. Farmer A believed that if he used a milk production target of 1.39 kg MS/cow/day when feeding supplements, both supplement and pasture utilisation would be poor. Therefore, supplement and pasture utilisation determine the upper limit of the milk production target over the summer period.
Termination of forage crop grazing and activation of new grass sowing. **Termination rule** **Activation rule**	Graze the forage crop such that the new grass can be sown by mid March. Sow the new grass by mid March.	The earlier the new grass can be sown, the better its establishment. Farmer A aims to sow the new grass by mid March. However, this date appears to be more flexible than other dates in the plan because during the three years, it was sown as late as mid April.

[16] In year two, Farmer A increased this target to 14 l/cow/day or 1.22 kg MS/cow/day because he thought it would be a wet summer, and he could feed the herd at a higher rate.

[17] In year two, Farmer A increased this target to 13 l/cow/day or 1.13 kg MS/cow/day because he thought it would be a wet summer, and he could feed the herd at a higher rate.

Activity	Decision Rule	Reason
Activation of silage feeding. **Activation rule** **In year two, the second forage crop was introduced instead of silage because Farmer A wanted to retain the silage for the early spring, and had grown another 1.0 ha of forage crop to replace the silage.**	Feed the silage after the forage crop when milk production declines to 12 litres/cow/day (1.04 kg MS/cow/day). In this case, the activation rule for the second forage crop was "To feed the second forage crop once the first forage crop was finished, and feed sufficient forage crop to maintain milk production at.	The silage is fed after the forage crop to ensure the herd continue to produce at high levels during a period when pasture growth rates tend to be below feed demand. It also ensures post-grazing residuals and average pasture cover are maintained, enhancing pasture growth rates. Silage does not deteriorate in terms of quality, hence silage is fed after the forage crop. It is not fed before the forage crop in a normal year because there is sufficient pasture cover on-hand to maintain milk production through January.
Specification of the quantity of silage fed. **Input type and level rule**	Feed silage at a rate that maintains milk production at 1.0 kg MS/cow/day (approx. 1/3 of the herd's diet).	This level of milk production ensure efficient conversion of feed to milk and a high level of feed utilisation. One third of the herd's diet is fed because much less than this has little impact on the system.
Activation of empty cow culling. **Activation rule**	IF a cow is empty, AND is producing well, THEN retain the cow until near drying off.	Farmer A prefers to continue milking empty cows rather than cull them once identified because they are more efficient than other cows at converting feed into milk. Without a developing fetus, empty cows produce more milk than pregnant cows per unit of feed consumed.
Place thin, younger cows on once-a-day milking. **Activation rule**	IF the condition of a cow ≤ 3.5 condition score units, AND it is a younger cow (Rising 3 or 4 year), AND it is not on once-a-day milking, THEN dry it off.	This planning rule is used to protect the condition of the younger cows in the herd. Farmer A knows that these cows cannot compete with the older cows for feed when conditions become dry. He therefore plans to put these cows on once-a-day milking when they fall to 3.5 condition score units to reduce their energy demand and hold condition. No set time is specified for when this will occur, but it is normally from February onwards.
Dry off thin, younger cows. **Termination rule**	IF the condition of a cow ≤ 3.5 condition score units, AND it is a younger cow (Rising 3 or 4 year), AND it is on once-a-day milking, THEN dry it off.	Farmer A will dry off the younger cows if they continue to lose condition after they have been placed on once-a-day milking. These cows have the highest genetic merit in the herd, and must be fed so that they reach target condition score by planned start of calving. This is why Farmer A dries them off and grazes them off the farm to regain condition.
Drying off the herd or part of the herd. **Non-termination rule**	Do not dry off part of the herd and continue to milk the remainder.	Farmer A has a policy of keeping the herd together as a unit. Therefore he does not dry off part of the herd and continue milking the remainder. He prefers to milk the entire herd for a shorter period of time, than milk a portion of the herd for longer.
Termination of the lactation (Drying off). **Termination rule**	Dry off the herd when all other options have been exhausted.	Farmer A will dry off the herd when he has exhausted all other options. The drying off decision is irrevocable, and once the herd is dried off, milk production ceases as does the income derived from this. The herd must be dried off at the correct date to ensure the terminating conditions at planned start of calving are met. If these are not met, milk production and reproductive performance will be reduced.

Table 2. Sequencing rules used by Farmer A for the summer and autumn[18] plans in years one and two[19].

Decision rule	Reason
Cull low producing and diseased cows as they are identified.	There is no point retaining low producing cows or those with disease because they tend to be inefficient at converting feed to milk and feed is a limiting resource at this time of year.
Maintain 25 - 30 day round before grazing the forage crop in late January, early February.	In a normal year there is sufficient pasture to delay the grazing of the forage crop until late January, early February. The forage crop is actively growing up until this point and by not grazing it until the specified time yield is maximised.
Remove bull on 26th January.	The bull is left with the herd to mate late cycling cows. Farmer B does not see any point leaving the bull out for more than this number of cycles.
Graze the forage crop before feeding silage.	Silage does not deteriorate over time and can be stored. Once the forage crop reaches maturity, its feed quality declines. The forage crop must also be grazed so that the new grass can be sown by mid March. February is the driest month and the period when the deficit between feed demand and pasture growth is greatest. The forage crop is fed at this point in time to fill this feed deficit.
Sow the new grass after the forage crop has been grazed.	The new grass cannot be sown until after the forage crop has been grazed.
Feed silage after the forage crop.	Once the forage crop is grazed in early March, conditions can still be dry and by feeding the silage at this point, average pasture cover can be maintained at a higher level ensuring higher pasture growth rates, particularly when the autumn rains arrive. Milk production and cow condition is also maintained.
Feed the herd a pasture only diet post-silage.	Autumn rains are likely to occur after the silage has been fed. These rains tend to increase pasture growth rates to the point where they exceed feed demand. Therefore, the forage crop and silage is fed to bridge the feed deficit through until pasture growth rates exceed feed demand.
Pregnancy test the herd 6 - 8 weeks after the bull is removed.	To accurately diagnose pregnancy status, the herd should not be examined for at least six weeks after the bull has been removed.
Cull empty cows just prior to or at drying off.	Farmer A prefers to continue milking empty cows rather than cull them when they are diagnosed because they are more efficient at converting feed into milk. Without a developing fetus, empty cows produce more milk than pregnant cows per unit of feed.
Dry off the herd.	Drying off is an irrevocable decision and once undertaken, milk production, and the generation of income from this activity ceases. Therefore, this decision is delayed for as long as possible and implemented when all other options are exhausted.

[18] The decision rules for the autumn plan in this table only encompass those used through until drying off.
[19] Silage was not used in the summer of year two because Farmer A wanted to use it in the spring.

Table 3. Decision rules used by Farmer A for the summer and autumn[20] plans in year three, the "dry" year.

Activity	Decision Rule	Reason
Specification of summer-autumn stocking rate. **Input type and level rule**	IF increasing herd size next winter, AND date = Christmas, AND the year is dry, THEN delay stocking rate decision until the next herd test and identify cows not considered suitable for milking through the summer-autumn.	Farmer A wanted to increase herd size next winter. However, he did not want to cull animals without some objective production data. He therefore decided to delay the decision until the herd test on January 11th.
Specification of rotation length. **Input type and level rule**	IF the year is dry, THEN maintain the rotation at the minimum length (24 days).	Under dry conditions, Farmer A cannot extend the rotation without reducing cow intake. This would result in lower milk production, a further reduction in cow condition and spontaneous drying off by some cows. The 24 day minimum rotation length for this season instead of 25 days was the result of a change in farm circumstances (more area in crop, increased farm area and a change in paddock numbers).
Activation of culling. **Activation rule**	IF the year is dry, AND a herd test has been completed, THEN dry off and sell definite culls.	Removing poorer producing cows from the herd will free up feed for the remainder of the herd in dry conditions. The removal of high somatic cell count cows is important in dry conditions because these cows create milk quality problems if placed on once-a-day milking which is likely to occur in a dry year.
Specification of milk production target for supplement feeding. **Target specification rule**	IF the year is dry, THEN reduce the milk production target for supplement feeding to 0.87 kg MS/cow/day.	A lower milk production target has a number of effects. Firstly, it reduces cow intakes so feed demand is reduced and therefore what feed is on the farm lasts for longer. Secondly, it delays the first grazing of the forage crop so that it is grazed later in the season. Thirdly, it reduces the rate at which the forage crop is grazed extending its use into the later part of the summer. This increases the likelihood that the herd will still be lactation when the autumn rains arrive. The change in the milk production target, in effect, uses cow condition as a form of supplement.
Specification of condition score target. **Target specification rule**	IF the year is dry, AND the milk production target has been reduced to 0.87 kg MS/cow/day, THEN reduce the herd condition score target to 4.0 condition score units.	If a lower milk production target is used, then cow intakes will be reduced below the normal targets which maintain cow condition over the summer. As such, Farmer A has to reduce his condition score target. In effect, he is using cow condition as a form of supplement.
Activation of forage crop feeding. **Activation rule**	IF the year is dry, AND milk production is at or less than 0.87 kg MS/cow/day, THEN begin feeding the forage crop.	The use of a lower milk production target to activate forage crop feeding delays the grazing of the forage crop, extending its use into the summer.
Activation of silage feeding. **Activation rule**	IF the year is dry, AND the forage crop yield is poor, Then feed silage with the forage crop to extend its use.	This method allows Farmer A to extend the use of the forage crop in a dry year.
Activation of hay feeding. **Activation rule**	IF the year is dry, AND the forage crop yield is poor, AND limited silage is available, THEN feed good quality hay with the silage and forage crop.	This method allows Farmer A to extend the use of the forage crop in a dry year.

[20] The decision rules for the autumn plan in this table only encompass those used through until drying off.

Activity	Decision Rule	Reason
Place thin, younger cows on once-a-day milking. **Activation rule**	IF the condition of a cow ≤ 3.5 condition score units, AND it is a younger cow (Rising 3 or 4 year), AND it is not on once-a-day milking, THEN dry it off.	This planning rule is used to protect the condition of the younger cows in the herd. Farmer A knows that these cows cannot compete with the older cows for feed particularly when conditions become dry. He therefore plans to put these cows on once-a-day milking when they fall to 3.5 condition score units to reduce their energy demand and hold condition. No set time is specified for when this will occur, but in a dry year, this tends to be much earlier than in a normal or good year.
Dry off thin, younger cows. **Termination rule**	IF the condition of a cow ≤ 3.5 condition score units, AND it is a younger cow (Rising 3 or 4 year), AND it is on once-a-day milking, THEN dry it off.	Farmer A will dry off the younger cows if they continue to lose condition after they have been placed on once-a-day milking. These cows have the highest genetic merit in the herd, and must be fed so that they reach target condition score by planned start of calving. This is why Farmer A dries them off and grazes them off the farm to regain condition.
Activation of once-a-day milking for the herd. **Activation rule**	IF the year is dry, AND the milk production target has been reduced to 0.87 kg MS/cow/day, AND the herd is going onto the forage crop, THEN place the herd on once-a-day milking and increase the forage crop ration briefly to hold milk production at target.	If the herd is producing at 0.87 kg MS/cow/day, it will be losing condition. In order to stop the herd losing condition, it must be placed on once-a-day milking. However, when a herd is placed on once-a-day milking, milk production will decline unless cow intakes are increased briefly to prevent this. A forage crop can be used to do this. In a dry year, once-a-day milking keeps more options open to Farmer A than drying off a large proportion of the herd.
Specification of pregnancy diagnosis technique. **Input type and level rule**	IF the year is dry, THEN use ultrasound to diagnose empty cows.	Normally, the empty cows are retained until near drying off because they are the best milk producers. Therefore, in a normal year there is little point identifying these cows until mid- late March. However, in a dry year when feed is short, it is better to cull these cows early and use their feed to better feed the remaining cows and extend the lactation. Ultrasound allows Farmer A to diagnose empty cows at least a month earlier than normal.
Activation of empty cow culling. **Activation rule**	IF the year is dry, AND an empty cow has been identified, THEN cull the cow immediately.	In a dry year, it is more important to feed capital stock than carry empty cows that produce well.
Termination of once-a-day milking, and activation of twice-a-day milking. **Termination rule** **Activation rule**	IF analysis of pre- and post-grazing residuals shows that the herd can be consistently fed 11.0 kg DM/cow/day, AND the herd is on once-a-day milking, AND the month is March, THEN stop milking the herd once-a-day and put the herd on twice-a-day milking.	Farmer A would place the herd back on twice-a-day milking during March if cow intakes could be maintained at 11.0 kg DM/cow/day. At this level, he knew cow condition could be maintained. Farmer A would not make this change in April because it was close to drying off.
Termination of the lactation (Drying off). **Termination rule**	Dry off the herd when all other options have been exhausted.	Farmer A will dry off the herd when he has exhausted all other options. The drying off decision is irrevocable, and once the herd is dried off, milk production ceases as does the income derived from this. The herd must be dried off at the correct date to ensure the terminating conditions at planned start of calving are met. If these are not met, milk production and reproductive performance will be reduced.

Table 4. Sequencing rules used by Farmer A for the summer and autumn[21] plans in year three, the "dry" year.

Decision rule	Reason
Delay culling until herd test.	Farmer A was increasing the herd size next season and could only undertake limited culling. He therefore wanted to obtain objective information before culling cows.
Cull low producing and diseased cows as they are identified.	There is no point retaining low producing cows or those with disease because they tend to be inefficient at converting feed to milk and feed is a limiting resource at this time of year.
Maintain 24 day round before grazing the forage crop in late January.	Farmer A wanted to delay the grazing of the forage crop until late January to increase yield and so that it might last through until mid March. This increased the likelihood that the herd would be in a lactating state when the autumn rains arrived.
Remove bull on 26th January.	The bull is left with the herd to mate late cycling cows. Farmer B does not see any point leaving the bull out for more than this number of cycles.
Graze the forage crop and supplement with hay and silage.	Farmer A used hay and silage to extend the forage crop through until mid March. This increased the likelihood that the herd would be in a lactating state when the autumn rains arrived.
Place the herd on once-a-day milking when they go onto the forage crop.	The milking herd tends to lose condition at the reduced milk production target specified by Farmer A (0.87 kg MS/cow/day) when on the forage crop. Placing the herd on once-a-day milking, should hold herd condition because it reduces energy demand. When a herd is placed on once-a-day milking, it is important that intake is increased for the transition period, otherwise a proportion of the herd will dry themselves off. The forage crop was fed at a higher rate during transition to prevent this occurring.
Pregnancy test the herd 6 - 8 weeks after the bull is removed.	To accurately diagnose pregnancy status, the herd should not be examined for at least six weeks after the bull has been removed.
Cull empty cows as soon as identified.	When feed is limiting, Farmer A preferred to cull his empty cows and divert feed to the remainder of the herd, the majority of which were capital stock that would be retained for the next season.
Maintain 24 day round post-forage crop.	When feed is limiting, and all other supplements are utilised, and the herd is on once-a-day milking, Farmer A's only option is to maintain the herd on the minimum rotation length until drying off.
Dry off the herd.	Drying off is an irrevocable decision and once undertaken, milk production, and the generation of income from this activity ceases. Therefore, this decision is delayed for as long as possible.

[21] The decision rules for the autumn plan in this table only encompass those used through until drying off.

Appendix IV. The method and frequency of data collection used by Farmer A.

Figure 1. A summary of the direct and indirect measures used by Farmer A over early summer.

Factor	Measurement	Method		Frequency	Role	Classification of Role[22]
	Direct Method	Indirect Method				
Production Factors						
Feed Factors		Indicator	Method			
Average pasture cover (APC)	Falling plate meter				Not used	Not used
	Visual assessment			Daily	Used to verify changes in other measures	Confirmatory
	Pre- and post grazing residuals[23]			Daily	Used to verify changes in other measures	Confirmatory
		Milk production	Milk docket	Daily	Used to indicate a change in APC	Short-term predictor
		Cow condition	Visual assessment	Daily	Confirms change in APC	Confirmatory
		Climate Rainfall (≥ 25 mm)	Rain gauge	Daily	Indicates an increase in APC within 2 weeks	Long-term predictor
		Rainfall (< 25 mm) Wind run Temperature Cloud cover	Visual assessment	Daily	Indicates change in APC	Short-term predictor
Pasture growth	Falling plate meter			Not used	Not used	
	Visual assessment			Daily	Used to confirm changes in other measures	Confirmatory
		Pre- & post grazing residuals	Visual assessment	Daily	Indicates a change in pasture growth	Short-term predictor
			Pasture scoring and visual assessment	2 – 5 days[24]	Indicates a change in pasture growth	Short-term predictor
		Intake	Falling plate meter or pasture scoring	2 – 5 days[24]	Indicates a change in pasture growth	Short-term predictor
		Milk production	Milk docket	Daily	Indicates a change in pasture growth	Short-term predictor
		Cow condition	Visual assessment	Daily	Confirms change in pasture growth	Confirmatory
		Climate Rainfall (≥ 25 mm)	Rain gauge	Daily	Predicts increase in pasture growth within two weeks	Long-term predictor
		Rainfall (< 25 mm) Wind run Temperature Cloud cover	Visual assessment		Indicates change before primary measure	Short-term predictor

[22] This shows the role of the direct measures in decision point recognition and triangulation, and the role of the indirect measures in relation to the direct measures (predictive, early warning, confirmatory).
[23] Farmer A visually scores these and calculates the mean. As these are normally the shortest and longest paddocks on the farm, they provide an estimate of APC.
[24] Actual interval dependent on rate of change.

Factor	Measurement	Method		Frequency	Role	Classification of Role[25]
	Direct Method	Indirect Method				
Pasture quality	Visual assessment			Daily	Used to identify problems with pasture quality	**Decision point recognition**
		Milk production	Milk docket, composition	Daily	Confirms change in pasture quality	**Confirmatory**
Crop yield	Yield score & visual assessment			Daily	Used to estimate the amount of feed available	**Decision point recognition**
		Milk production	Milk docket	Daily	Used to confirm break size is adequate and yield estimate is correct	**Confirmatory**
Crop growth	Yield score & visual assessment			Daily	Used to verify other measures	**Confirmatory**
Crop quality and maturity	Visual assessment			Daily	Used to determine when crop maturity is reached	**Decision point recognition**
Livestock factors						
Cow numbers	Visual assessment				Used to predict feed demand	**Long-term predictor**
Average milk yield	Milk docket (l/cow/day)			Daily[26]	Used to identify when cow intakes and/or condition fall below target	**Decision point recognition**
		Intake	Falling plate meter or pasture scoring	2 - 5 days[24]	Used to indicate change in milk production	**Short-term predictor**
		Post-grazing residual	Visual assessment	Daily	Used to indicate change in milk production	**Short-term predictor**
			Falling plate meter or pasture scoring	2 - 5 days[24]		
Individual cow milk yields	Herd test (PI)			Once	)Used to identify	**Decision point recognition**
		Milking time	Visual assessment	Daily	)potential culls)	
Average milk quality	Milk docket (fat/protein)			Daily	Used to verify feed quality assessment	**Confirmatory**
	Bulk count (somatic cell)			Daily	Used to identify milk quality problem	**Decision point recognition**
Individual cow milk quality	Fat/protein Somatic cell count			Once (Herd test)	Used to identify potential culls	**Decision point recognition**
Average herd condition	Condition scoring			Daily	Used to verify other measures	**Confirmatory**
	Visual assessment			Daily	Used to verify other measures	**Confirmatory**
		Milk production	Milk docket	Daily	Used to indicate when the herd is losing condition	**Short-term predictor**
		Residual dry matter levels	Visual assessment	Daily	Used to indicate when the herd is losing condition	**Short-term predictor**
			Falling plate meter or pasture scoring	2 – 5 days[24]		
		Behaviour	Visual assessment	Daily	Used to indicate when the herd is losing condition	**Short-term predictor**
Individual cow condition	Condition scoring			Daily	Used to identify cows that are below target condition	**Decision point recognition**
		Behaviour	Visual assessment	Daily	Used to indicate when the herd is losing condition	**Short-term predictor**

[25] This shows the role of the direct measures in decision point recognition and triangulation, and the role of the indirect measures in relation to the direct measures (predictive, early warning, confirmatory).

[26] Milk volume is monitored daily, but milk production as litres/cow/day is only calculated when there is a significant change in milk volume.

Factor	Measure-ment	Method		Fre-quency	Role	Classification of Role[27]
	Direct Method	Indirect Method				
Intake	Falling plate meter or pasture scoring			2 - 5 daily[24]	Used to identify when intakes fall below target	**Decision point recognition**
	Visual assessment			Daily	)Indicates changes in)milk production and)condition	**Short-term predictor**
		Post-grazing residual	Falling plate meter or pasture scoring	2 - 5 daily[24]	It is used to predict if intakes will fall below target at the next grazing in 25 - 30 days	**Long-term predictor Decision point recognition**
			Visual assessment	Daily	Used to indicate a change in intake	**Short-term predictor**
		Milk production	Milk docket	Daily	Used to verify intake estimate	**Confirmatory**
		Condition	Visual assessment	Daily	Used to verify change in intake	**Confirmatory**
		Behaviour	Visual assessment	Daily	Used to indicate a change in intake	**Short-term predictor**
		Rainfall	Rain gauge	Daily	Significant rainfall events are used to predict (a) a short-term decline in intake and (b) a long term increase in pasture growth rates Short-term prediction of cow intakes	**Decision point recognition Long-term predictor**
		Wind run) Temperature) Cloud cover) Rainfall) (< 25 mm) Weather forecast		Daily		**Short-term predictor**
Reproductive status of the herd	Pregnancy test			Once	)Used to identify)potential culls)	**Decision point recognition**
		Bulling behaviour	Visual assessment	Daily		
External Environment Factors						
Climatic factors						
Climate Rainfall (≥ 25 mm)	Rain gauge			Daily	Significant rainfall events are used to predict (a) a short-term decline in intake and (b) a long term increase in pasture growth rates.	**Decision point recognition Long-term predictor**
Wind run) Temperature) Cloud cover) Rainfall) (< 25 mm) Weather forecast)	Visual assessment			Daily	This is used as an early indicator of changes in pasture growth, average pasture cover, intake, milk production and condition	**Short-term predictor**
Market factors						
Output Price Factors						
Cull cow schedule	Newspaper & stock agent			Intermit-tent	Used for selling decisions	**Decision point recognition**
In-calf cow store price	Newspaper & stock agent			Intermit-tent	Used for selling decisions	**Decision point recognition**
Milk price	Dairy company newsletter			Monthly	Used in option selection decisions	

[27] This shows the role of the direct measures in decision point recognition and triangulation, and the role of the indirect measures in relation to the direct measures (predictive, early warning, confirmatory).

Figure 2. A summary of the direct and indirect measures used by Farmer A over late summer, early autumn.

Factor	Measurement	Method		Frequency	Role	Classification of Role[28]
Production Factors	**Direct Method**	**Indirect**	**Method**			
Feed Factors		**Indicator**	**Method**			
Average pasture cover (APC)	Falling plate meter			10 daily[30]	Used to confirm other measures	**Triangulation**
	Visual assessment			Daily	Used to indicate a change in APC	**Early warning**
	Pre- and post grazing residuals[29]			Every 2-5 days[24]	Used to indicate when APC falling below target in year one	**Decision point recognition**
		Milk production	Milk docket	Daily	Used to indicate a change in APC	**Short-term predictor**
		Cow condition	Visual assessment	Daily	Confirms change in APC	**Confirmatory**
		Rainfall	Rain gauge	Daily	≥ 25 mm indicates (a) a decrease in available pasture and (b) an increase in APC within 2 weeks.	**Long-term predictor**
Pasture growth	Falling plate meter			10 daily	Used to identify trends for planning purposes[31]	**Planning**
	Visual assessment			Daily	Used to indicate a change in pasture growth	**Early warning**
		Pre- & post grazing residuals	Visual assessment	Daily	Used to indicate a change in pasture growth	**Short-term predictor**
			Falling plate meter or pasture scoring	2–5 days[24]		
		Intake	Falling plate meter or pasture scoring	2-5 days[24]	Used to indicate a change in pasture growth	**Short-term predictor**
			Visual assessment	Daily	Used to indicate a change in pasture growth	**Short-term predictor**
		Milk production	Milk docket	Daily	Used to indicate a change in pasture growth	**Short-term predictor**
		Cow condition	Visual assessment	Daily	Used to verify a change in pasture growth	**Confirmatory**
		Climate Rainfall (≥ 25 mm)	Rain gauge	Daily	Useful for predicting pasture growth two weeks out	**Long-term predictor**
		Rainfall (< 25 mm) Wind run Temperature Cloud cover	Visual assessment	Daily	Useful for predicting short-term pasture growth	**Short-term predictor**
Pasture quality	Visual assessment			Daily	Used to decide if action must be taken to control pasture quality	**Decision point recognition**
		Milk production	Milk docket, composition	Daily	Confirms assessment of pasture quality	**Confirmatory**

[28] This shows the role of the direct measures in the decision point recognition and triangulation, and the role of the indirect measures in relation to the direct measures (predictive, early warning, confirmatory).
[29] Farmer A measures these with a falling plate meter and then calculates the mean. As these are normally the shortest and longest paddocks on the farm, it provides an estimate of APC.
[30] The use of objective pasture monitoring and the frequency of its use is dependent on the season.
[31] Pasture growth is measured objectively if conditions are poor during March, and Farmer A wants to analyse the trend in pasture growth.

Factor	Measure-ment	Method		Fre-quency	Role	Classification of Role[32]
Production Factors	**Direct Method**	**Indirect**	**Method**			
Silage quantity & quality	Yield score & visual assessment			As and when necessary	Used to estimate available silage	**Decision point recognition**
		Milk production	Milk docket	Daily	Used to confirm silage yield estimates	**Confirmatory**
Livestock factors						
Cow numbers	Visual assessment				Used to predict feed demand	**Long-term predictor**
Average milk yield	Milk docket (l/cow/day)			Daily[33]	Used to identify when cow intakes and/or condition fall below target	**Decision point recognition**
		Intake	Falling plate meter or pasture scoring	2-5 days[24]	Used to indicate change in milk production	**Short-term predictor**
		Post-grazing residual	Visual assessment	Daily	Used to indicate change in milk production	**Short-term predictor**
			Falling plate meter or pasture scoring	2-5 days[24]		
Individual cow milk yields	Herd test (PI)			Once	)Used to identify)potential culls)	**Decision point recognition**
		Milking time	Visual assessment	Daily		
Average milk quality	Milk docket (fat/protein)			Daily	Used to verify feed quality assessment	**Confirmation**
	Bulk count (somatic cell)			Daily	Used to identify milk quality problem	**Decision point recognition**
Individual cow milk quality	Fat/protein Somatic cell count			Once (Herd test)	Used to identify potential culls	**Decision point recognition**
Average herd condition	Condition scoring			Daily[34]	Used to identify if average herd condition is at or below target	**Decision point recognition**
	Visual assessment			Daily	Used to confirm other measures	**Confirmatory**
		Milk production	Milk docket	Daily	Used to indicate when the herd is losing condition	**Short-term predictor**
		Intake	Falling plate meter, pasture scoring	2-5 days[24]	Used to indicate when the herd is losing condition	**Short-term predictor**
		Residual dry matter levels	Falling plate meter, pasture scoring	2-5 days[24]	Used to indicate when the herd is losing condition	**Short-term predictor**
			Visual assessment	Daily		
		Behaviour	Visual assessment	Daily	Used to indicate when the herd is losing condition	**Short-term predictor**
Individual cow condition	Condition scoring			Daily	Used to identify cows whose condition is at or below target	**Decision point recognition**
		Behaviour	Visual assessment	Daily	Used to indicate when individual cows are losing condition	**Short-term predictor**

[32] This shows the role of the direct measures in the decision point recognition and triangulation, and the role of the indirect measures in relation to the direct measures (predictive, early warning, confirmatory).

[33] Milk volume is monitored daily, but milk production as litres/cow/day is only calculated when there is a significant change in milk volume.

[34] Use dependent on herd condition. If herd condition falls below 4.5 condition score units, it is formally monitored by Farmer A.

Factor	Measurement	Method		Frequency	Role	Classification of Role[35]
Production Factors	**Direct Method**	**Indirect**	**Method**			
Intake	Falling plate meter, pasture scoring			2-5 daily[24]	Used to indicate when intake is below target. Used to indicate a change in milk production and condition	**Decision point recognition** **Short-term predictor**
		Milk production	Milk docket (l/cow/day)	Daily	Used to verify intake estimate	**Confirmatory**
		Residual dry matter	Visual assessment	Daily	Used to indicate a change in intake	**Short-term predictor**
			Falling plate, pasture score	2-5 daily[24]	It is used to predict intake at the next grazing in 25 - 30 days	**Long-term predictor** **Problem recognition**
		Cow condition	Visual assessment	Daily	Used to verify change in intake	**Confirmatory**
		Behaviour	Visual assessment	Daily	Used to indicate a change in intake	**Short-term predictor**
		Rainfall & climate	Rain gauge	Daily	Used to predict change in intake. Also used to predict longer-term change in intake	**Short-term predictor**
			Visual assessment	Daily		**Decision point recognition** **Long-term predictor**
Reproductive status of the herd	Pregnancy test			Once	Used to identify potential culls	**Decision point recognition**
		Bulling behaviour	Visual assessment	Daily	Used to identify potential culls	**Decision point recognition**
External Environment Factors						
Climatic Factors						
Climate Rainfall (≥ 25 mm)	Rain gauge			Daily	Significant rainfall events are used to predict a short-term decline in available dry matter and an increase in pasture growth rates.	**Decision point recognition** **Long-term predictor**
Wind run) Temperature) Cloud cover) Rainfall) (< 25 mm) Weather forecast)	Visual assessment			Daily	This is used as an early indicator of changes in pasture growth, average pasture cover, intake, milk production and condition	**Short-term predictor**
Market Factors						
Output Price Factors						
Cull cow schedule	Newspaper & stock agent			Intermittent	Used for selling decisions	**Decision point recognition**
In-calf cow store price	Newspaper & stock agent			Intermittent	Used for selling decisions	**Decision point recognition**
Milk price	Dairy company newsletter			Monthly	Used in option selection decisions	
Input Price Factors						
Urea price	Stock agent			Once	Used for option analysis	

[35] This shows the role of the direct measures in the decision point recognition and triangulation, and the role of the indirect measures in relation to the direct measures (predictive, early warning, confirmatory).

Figure 3. Important factors monitored by Farmer A over the autumn[36].

Factor	Measure-ment	Method		Fre-quency	Role	Classification of Role[37]
Production Factors	**Direct Method**	**Indirect Method**				
Feed factors		**Indicator**	**Method**			
Average pasture cover	Falling plate meter			5-13 daily	Used to identify when APC fell below targets.	**Decision point recognition**
		Milk production	Milk docket	Daily	Used to indicate a change in APC	**Short-term predictor**
		Pre- and post-grazing residuals	Falling plate meter	2-5 daily[24]	Used to indicate a change in APC	**Short-term predictor**
Pasture growth rate	Falling plate meter[38]			5-13 daily	Used to indicate the start of the autumn flush Used to verify other measures	**Decision point recognition** **Confirmatory**
Livestock Factors						
Cow numbers	Visual assessment				Used to predict feed demand	**Long-term predictor**
Average milk yield	Milk docket (l/cow/day)			Daily[39]	Used to identify when cow intakes and/or condition fall below target	**Decision point recognition**
		Intake	Falling plate meter or pasture scoring	2-5 days[24]	Used to indicate change in milk production	**Short-term predictor**
		Post-grazing residual	Visual assessment	Daily	Used to indicate change in milk production	**Short-term predictor**
			Falling plate meter or pasture scoring	2-5 days[24]	Used to indicate change in milk production	**Short-term predictor**
Individual cow milk yields	Herd test (PI)			Once	)Used to identify potential)culls)	**Decision point recognition**
		Milking time	Visual assessment	Daily		
Average herd condition[40]	Condition scoring			Daily	Used, in conjunction with APC and pasture growth rate information to decide when to dry off the herd	**Decision point recognition**
		Milk production	Milk docket	Daily	Used to indicate a change in condition score	**Short-term predictor**
		Average pasture cover	Falling plate meter	5-13 daily	Used to indicate a change in condition score	**Short-term predictor**
		Behaviour	Visual Assessment	Daily	Used to indicate a change in condition score	**Short-term predictor**
Individual cow condition	Condition scoring			Daily	Used to identify cows whose condition is below target	**Decision point recognition**
		Behaviour	Visual assessment	Daily	Indicates cows that are thin and losing condition.	**Short-term predictor**

[36] Subjective, qualitative measures used in late summer were also used in the autumn, but are not repeated in this figure to avoid repetition.
[37] This shows the role of the direct measures in decision point recognition and triangulation, and the role of the indirect measures in relation to the direct measures (predictive, early warning, confirmatory).
[38] Uses ungrazed paddocks to calculate pasture growth rates.
[39] Milk volume is monitored daily, but milk production as litres/cow/day was only calculated when there was a significant change in milk volume.
[40] Farmer A monitors both the average and the distribution or level of variation.

Factor	Measure -ment	Method		Fre- quency	Role	Classification of Role[41]
Production Factors	**Direct Method**	**Indirect**	**Method**			
Intake	Falling plate meter, pasture scoring			2-5 daily[24]	Used to indicate when intake is below target Used to indicate a change in milk production and condition	**Decision point recognition** **Short-term predictor**
		Milk production	Milk docket	Daily	Used to verify intake estimate	**Confirmatory**
		Residual dry matter	Visual assessment	Daily	Used to indicate a change in intake	**Short-term predictor**
			Falling plate, pasture score	2-5 daily[24]	It is used to predict intake at the next grazing in 25 - 30 days	**Long-term predictor** **Problem recognition**
		Condition		Daily	Used to verify change in intake	**Confirmatory**
		Behaviour	Visual assessment	Daily	Used to indicate a change in intake	**Short-term predictor**
		Rainfall	Visual assessment Rain gauge	Daily	Used to predict change in intake	**Short-term predictor** **Decision point recognition**
External Environment Factors						
Climatic Factors						
Climate Rainfall (≥ 25 mm)	Rain gauge			Daily	Significant rainfall events are used to predict a short-term decline in available dry matter and an increase in pasture growth rates.	**Decision point recognition** **Long-term predictor**
Wind run) Temperature) Cloud cover) Rainfall) (< 25 mm) Weather forecast)	Visual assessment			Daily	This is used as an early indicator of changes in pasture growth, average pasture cover, intake, milk production and condition	**Short-term predictor**
Market Factors						
Output Price Factors						
Cull cow schedule	Newspaper & stock agent			Intermittent	Used for selling decisions	**Decision point recognition**
In-calf cow store price	Newspaper & stock agent			Intermittent	Used for selling decisions	**Decision point recognition**
Milk price	Dairy company newsletter			Monthly	Used in option selection decisions	

[41] This shows the role of the direct measures in the decision point recognition and triangulation, and the role of the indirect measures in relation to the direct measures (predictive, early warning, confirmatory).

Appendix V. Information used in control response selection by Farmer A.

Figure 1. Information collected through the monitoring process that is used to determine the activity implemented at the decision point.

Decision	Factors used in option selection[42]
Feed forage crop (amount and timing)	Milk production Lactating state (once-a-day or twice-a-day) Forage crop yield (weeks grazing) and maturity Forage crop state (ungrazed, being grazed, grazed) Month Rainfall (soil saturation) Muddy conditions/utilisation Nature of summer (dry, wet, typical) Rotation length
Feed silage	Forage crop state (ungrazed, being grazed, grazed) Forage crop yield Forage crop ration Energy balance of ration Milk production Silage availability Feed prediction Rainfall/soil saturation Average pasture cover Pasture growth rate relative to feed demand Nature of previous conditions Milk payout Month Nature of summer Cow condition (herd, younger cows)
Once-a-day milking (individual cows)	Individual cow condition Lactation state (milked twice- or once-a-day)
Shorten rotation	Rotation length Milk production Time of year Supplement availability Rainfall/soil moisture Forage crop state (ungrazed, being grazed, grazed) Crop utilisation
Extend rotation	Milk production Forage crop state (ungrazed, being grazed, grazed) Rainfall/soil moisture Post-grazing residual Silage availability Month Nature of summer Pasture growth rates Likelihood of autumn rains Average pasture cover Average herd condition
Cull cows on low production	Milking time
Cull cows	Average pasture cover prediction Dry cull on farm Value of culls Mastitis Rotation length Herd test date Forage crop yield Supplement availability Cow intake Climatic and feed conditions Date Cow numbers to winter next season Cull cows on milking area Pregnancy status Milk production Imminence of drying off decision Cull cows identified Feed on waste ground available

[42] Includes the problem recognition indicator.

Decision	Factors used in option selection[43]
Dry off individual cows	Individual cow condition and trend Lactation state (milked twice- or once-a-day) Cow intake Average pasture cover and trend (feed conditions) Cow age Cow health Rotation length
Dry off the herd	Rainfall/soil moisture Pasture growth rates Rotation length Average pasture cover Lactation state (milked twice- or once-a-day) Average herd condition and younger cow condition Predicted pasture growth rates Month Predicted feed position Milk production Availability of supplements (forage crop/silage)
Increase milk production target (and intake)	Pasture growth rates Forage crop yield Predicted date forage crop grazed by Date/month Milk production Supplement position Average pasture cover Current climatic conditions Forage crop state Average herd condition
Extend lactation	Average pasture cover Average herd condition Forate crop state Silage availability Month Pasture growth rates Rainfall Milk production
Reduce milk production target	Nature of season Pasture growth rates Average pasture cover and trend Forage crop state and yield Milk production target Rotation length Climatic and feed conditions Cow intake (current and predicted) Supplement availability
Placing the entire herd on once-a-day milking	Average herd condition score and trend Milk production Supplement availability Rotation length Average pasture cover Pasture growth rates Month Forage crop yield Climatic and feed conditions Predicted cow intake Forate crop state
Terminate silage feeding	Pre-grazing pasture cover levels Climatic conditions
Return the herd to twice-a-day milking	Cow intake (pre- and post-grazing residuals) Lactating state Month/date Average pasture cover Average herd condition

[43] Includes the problem recognition indicator.

Appendix VI. Information used in control response selection by Farmer A.

Table 1. Simple mathematical representation of the Farmer A's intake predicting system.

Current post-grazing residual (kg DM/ha)	Post-grazing residual in 25 days (kg DM/ha)	Pasture growth rates (kg DM/ha/day)	Estimated cow intakes (125 cows on 2.0 ha) (kg DM/cow/day)	Percentage of target (12 kg DM/cow/day)
1200	1200	10	4	33%
		20	8	67%
		30	12	100%
		40	16	125%
1300	1200	10	5.6	47%
		20	9.6	80%
		30	13.6	113%
		40	17.6	147%
	1300			
		10	4	33%
		20	8	67%
		30	12	100%
		40	16	125%
1400	1200	10	7.2	60%
		20	11.2	93%
		30	15.2	127%
		40	19.2	160%
	1300			
		10	5.6	47%
		20	9.6	80%
		30	13.6	113%
		40	17.6	147%
	1400			
		10	4	33%
		20	8	67%
		30	12	100%
		40	16	125%

Appendix VII. Decision rules used by Farmer A to initiate or intensify the monitoring process.

General rule

IF indirect measures suggest a factor is trending towards a threshold,
THEN begin formal monitoring of that factor.

IF informal monitoring suggests the state of some variable is outside the comfort zone for that parameter,
THEN measure the parameter more formally.

Specific rules

Decision rules that determine the use of a particular monitoring method

IF the conditions appear to be indicating a dry summer,
THEN adopt the ultrasound method and undertake the pregnancy diagnosis in early February,
Else use the conventional method and undertake the pregnancy diagnosis in late March.

Decision rules that are used to activate or terminate the monitoring of a specific factor

IF milk production falls to 1.04 kg MS/cow/day,
AND the herd has been introduced to the forage crop,
THEN begin monitoring the condition of the younger cows in the herd.

IF indicator cows ≤ 3.5 condition score units,
AND cow condition is not being formally monitored,
THEN begin to monitor cow condition formally.

IF the date is ≥ mid March,
AND the date is ≤ April 1st,
AND the farm is in a poor feed position,
AND herd condition is declining,
THEN initiate objective pasture monitoring of pasture cover and pasture growth rates.

IF the date is ≥ mid March,
AND the date is ≤ April 1st,
AND cow condition is improving,
AND other indicators suggest the feed situation is improving,
THEN delay objective pasture monitoring until around April 1st.

IF the autumn rains occur before April 1st,
THEN begin to objectively monitor pasture cover and pasture growth rates.

IF milk volume changes significantly,
THEN recalculate milk production in litres per cow per day,
ELSE continue to monitor milk volume.

IF post-grazing residuals and expected pasture growth rates suggest cow intake targets will not be met at the paddocks next grazing, THEN begin to consider options and monitor the situation closely.

IF pre- and post-grazing residuals suggest cow intakes are below target,
THEN monitor feeding levels closely over the next 3 - 4 days using milk production and consider options.

Decision rules about monitoring frequency

IF feed conditions are good and/or improving,
AND objective pasture monitoring is being used,
THEN use a monitoring frequency of between 7 - 14 days, but reduce the frequency if conditions deteriorate.

IF feed conditions are poor and/or deteriorating,
AND objective pasture monitoring is being used,
AND the monitoring frequency > 5 days,
THEN reduce monitoring frequency to 5 days,
ELSE maintain monitoring frequency at 5 days.

The use of grouping rules in the monitoring process

IF a paddock is likely to grow less grass than others due to a previous problem,
AND the paddock is soon to be grazed,
AND the herd is being fed supplements,
THEN assess the feed on the paddock before grazing and adjust the supplement level to maintain intakes at target if required.

IF a paddock classification = dry,
AND the paddock is soon to be grazed,
AND the herd is being fed supplements,
THEN assess the feed on the paddock before grazing and adjust the supplement level to maintain intakes at target if required.

Appendix VIII. The decision rules used by Farmer A to implement the plan and manage deviations.

Year One

Decisions that increase feed supply

Reducing the rotation length

During the period after the forage crop had been fed, Farmer A reduced his rotation length to ensure milk production was maintained at 1.04 kg MS/cow/day. He would only reduce his rotation length down to a maximum of 25 days. This option was used because he had decided not to use his silage until drying off. In effect, this contingency plan utilised pasture cover.

IF milk production < target (12 l/cow/day (1.04 kg MS/cow/day) or 13 l/cow/day (1.13 kg MS/cow/day)),
AND crop is grazed,
AND silage is to be retained for drying off,
AND the rotation length is > 25 days,
THEN decrease the rotation length to a minimum of 25 days to hold production at target.

Farmer A noted that rain can make the forage crop muddy and reduce utilisation. To minimise this effect, Farmer A will stop feeding the crop and substitute this with additional pasture, effectively shortening the rotation length.

IF it has rained,
AND the herd is grazing the crop,
AND crop utilisation is affected by the wet conditions,
THEN remove the herd from the crop until conditions improve and shorten the rotation length such that production is maintained at 12 l/cow/day (1.04 kg MS/cow/day).

Use of the crop

In a year of high pasture growth rates, Farmer A said that he could not delay the grazing of the crop too long because he needed to get the paddocks back into new grass in the early autumn. Farmer A must ensure his forage crop is grazed in time to resow the new grass by a specific date. If the forage crop has more grazing days than the time until the resowing process must be initiated, he will increase the rate at which the forage crop is fed to ensure it is grazed in time for resowing.

IF weeks until sowing date for new grass = X,
AND weeks grazing on the crop $\geq X$,
THEN graze the crop at a rate such that it is removed in time to sow the new grass.

Farmer A said that he would not extend the herd's rotation to delay the grazing of the crop in order to increase crop yield. This is because this would reduce per cow milk production below his target of 1.04 kg MS/cow/day.

Farmer A began feeding the forage crop when milk production fell to 1.13 kg MS/cow/day. His aim is then to hold milk production at 1.04 kg MS/cow/day while on the forage crop. He initiates forage crop feeding at 0.085 kg MS/cow/day ahead of target because with the change of diet, he finds milk production declines this amount during the transition to a forage crop/pasture diet.

IF milk production is ≤ 13 l/cow/day (1.13 kg MS/cow/day),
AND the forage crop is ungrazed,
AND recent rainfall is < 25 mm (soil is not saturated),
THEN graze the crop at a rate such that production holds at 12 l/cow/day (1.04 kg MS/cow/day).

Farmer A said that he would graze the crop early if the farm received at least 25 mm of rain at some stage during January, February. Farmer A also said that he would feed more than the planned crop ration of one third of the herds intake if the autumn rains arrived early and he had the bulk of his crop intact. He said that he would also change his rotation length at the same time. This suggests that Farmer A would use his crop to substitute for pasture and slow down his rotation so that the impact of the rain on his pasture cover levels is optimised. Farmer A notes that pasture grows in "bursts" and one has to be ready to take advantage of this by destocking the pasture at the time of the rain. Farmer A notes that feed supply will increase within 2-3 weeks of such a rain event. Farmer A pointed out that when sufficient rain (≥ 25 mm) at this time of the year, the dead matter in the sward decomposes rapidly and this in effect causes cow intakes to decline with a subsequent effect on milk production. In this situation, supplement, in the form of crop or silage must be fed to maintain cow intakes and ensure production does not fall below Farmer A's target of 1.04 kg MS/cow/day. Farmer A does not like to feed more than 40% of the herd's diet as a supplement because too much wastage occurs. However, in year one, which was a wet summer, he fed up to 50% of the herd's diet as forage crop and silage after significant rainfall events.

IF milk production is ≤ 13 l/cow/day (1.13 kg MS/cow/day),
AND the crop is ungrazed,
AND recent rainfall is ≥ 25 mm (soil is saturated),
AND it is a wet summer,
THEN graze the crop at a rate such that production holds at 12 l/cow/day (1.04 kg MS/cow/day) and increase crop ration to around 50 % of diet for 2-3 days, and extend the rotation accordingly.

IF milk production is ≤ 12 l/cow/day (1.04 kg MS/cow/day),
AND the crop is being grazed,
AND recent rainfall is ≥ 25 mm (soil is saturated),
AND it is a wet summer,
THEN increase crop ration to around 50 % of diet for 2-3 days, and extend the rotation accordingly while maintaining production at 12 l/cow/day (1.04 kg MS/cow/day).

The herd went onto the forage crop on the 31st of January because milk production fell to 13 litres per cow per day (1.13 kg MS/cow/day).

IF milk production is ≤ 13 litres/cow/day,
AND the forage crop is ungrazed,
THEN graze the forage crop and provide sufficient feed to maintain milk production at target.

Farmer A noted that rain can make the forage crop muddy and reduce utilisation. To minimise this effect, Farmer A will stop feeding the crop and substitute this with additional pasture, effectively shortening the rotation length. However, when conditions were dry enough to put the herd back on the forage crop, Farmer A found that there was sufficient pasture to maintain milk production above 1.13 kg MS/cow/day, so he did not place the herd back onto the forage crop until milk production returned to this level. The reason, there was sufficient pasture cover on-hand to feed the herd to this level, was that the farm had recently received significant rainfall and therefore pasture growth rates had increased markedly.

IF it has rained,
AND the herd is grazing the crop,
AND crop utilisation is affected by the wet conditions,
THEN remove the herd from the crop until conditions improve and shorten the rotation such that production is maintained at 12 l/cow/day (1.04 kg MS/cow/day).

IF the herd was removed from the crop due to rain,
AND conditions are suitable for grazing the crop again,
AND milk production is ≤ 13 litres/cow/day,
THEN return the herd to the crop and feed sufficient to maintain production ≥ 1.04 kg MS/cow/day.

IF the herd is removed from the crop due to rain,
AND conditions are suitable for grazing the crop again,
AND milk production is ≥ 13 litres/cow/day,
THEN keep the herd on pasture until production ≤ 13 litres/cow/day.

If pasture growth rates have increased due to a significant rainfall event in previous weeks, and the herd is on the forage crop, or about to go onto it. Farmer A does not reduce the rotation length, but rather maintains the current rotation length, and allows the post-grazing residual to increase. This in turn increases the rate of regrowth from paddocks post-grazing.

IF milk production is > 13 l/cow/day,
AND good rain (≥ 25 mm) has fallen in recent weeks,
AND it is February,
AND the crop is ungrazed,
THEN feed the crop and maintain the rotation length to take advantage of the additional pasture growth.

IF milk production is > 13 l/cow/day,
AND good rain (≥ 25 mm) has fallen in recent weeks,
AND it is February,
AND the crop is being grazed,
THEN continue to feed the crop at current levels and maintain the rotation length to take advantage of the additional pasture growth.

<u>Use of silage</u>

Farmer A estimated a feed budget just prior to the completion of the forage crop to determine whether to feed silage after the forage crop, and if so, how much.

IF crop almost grazed,
AND silage available,
THEN complete feed budget to estimate how much silage can be used over the autumn.

Feed conditions were very good after the herd had grazed the forage crop. The average pasture cover was high and improving and above the target specified in the feed budget, pasture growth rates exceeded feed demand, surplus silage was available, and the herd was producing at or above 13 l/cow/day (1.13 kg MS/cow/day). Farmer A decided to increase his production target from 1.04 kg MS/cow/day to 1.13 kg MS/cow/day.

IF the feed situation on the farm is very good (APC ≥ feed budget target),
AND pasture growth ≥ feed demand,
AND the herd is producing well (≥ 13 l/cow/day or 1.13 kg MS/cow/day),
AND crop is grazed,
AND silage is available,
THEN increase the production target to 13 l/cow/day, or 1.13 kg MS/cow/day.

Farmer A noted that if the feed conditions on the farm had not been as good as those experienced in year one, and milk production had fallen below 1.04 kg MS/cow/day, he would have feed the silage. He also noted that if, during this period, significant rainfall fell, he would increase the silage ration to maintain milk production at 1.04 kg MS/cow/day for several days. The decomposition of dead matter following significant rainfall reduces the pasture intakes of the herd. Unless they are provided with supplements, or more area (faster rotation), milk production declines. Farmer A will also extend the rotation at the same time to take advantage of the good growing conditions that result from this level of rainfall. Farmer A does not like to feed more than 40% of the herd's diet as a supplement because too much wastage occurs. However, in year one, which was a wet summer, he fed up to 50% of the herd's diet as forage crop and silage after significant rainfall events.

IF milk production < target (12 l/cow/day (1.04 kg MS/cow/day) or 13 l/cow/day (1.13 kg MS/cow/day)),
AND crop is grazed,
AND silage is available,
AND recent rainfall has not saturated the ground (< 25 mm),
THEN feed sufficient silage to maintain production at target (12 l/cow/day (1.04 kg MS/cow/day) or 13 l/cow/day (1.13 kg MS/cow/day)).

IF milk production < target (12 l/cow/day (1.04 kg MS/cow/day) or 13 l/cow/day (1.13 kg MS/cow/day)),
AND crop is grazed,
AND silage is available,
AND recent rainfall has saturated the ground (≥ 25 mm),
AND it is a wet summer,
THEN feed up to 50 % of the herd's diet as silage for 2 - 3 days and extend the rotation accordingly to take advantage of the extra pasture growth. After that, maintain the extended rotation and feed sufficient silage to maintain production at target (12 l/cow/day (1.04 kg MS/cow/day) or 13 l/cow/day (1.13 kg MS/cow/day).

Conditions became dry while Farmer A was feeding the silage. He noted that one option was to use the silage he had on-hand for the winter/early spring to extend the lactation and replace this with urea, hay or grazing. This was a difficult decision and involved risk. He also noted that it depends on the value of the additional milkfat he could obtain from milking longer.

IF the autumn silage is consumed,
AND milk production is < 1.04 kg MS/cow/day,
AND predictions based on post-grazing residuals and climatic data suggest the herd will have to dry off soon unless supplements are fed,
AND it is early in the season (February/early-March),
AND the milk production is ≥ 0.96 kg MS/cow/day,

AND cow condition is ≥ 3.5 - 4.0,
AND pasture cover is low,
AND the milk payout is good,
THEN use winter/early spring silage to extend lactation and replace this with cost-effective supplements.

In April Farmer A stated that his drying off date was determined on the basis of whether his average pasture cover was above or below target and whether pasture growth rates were increasing rapidly or not. In this case, average pasture cover had declined 50 kg DM/ha in five days. The average condition score of the herd was not relevant to the decision because the herd was at the condition score Farmer A wanted them to calve in. However, he noted that the younger cows in the herd had started to lose condition. Because he had not used his silage through the summer, Farmer A used it at drying off to rapidly increase average pasture cover and extend the rotation.

IF pasture cover has fallen below the drying off target,
AND pasture growth rates are declining quite rapidly,
AND the month is April,
AND the herd is in good condition (≥ 4.5 condition score units),
AND the younger cows were beginning to lose condition,
AND silage is available,
THEN dry off the herd, extend the rotation out to 60 days and feed sufficient silage to maintain cow intakes at 7 kg DM/cow/day.

Grazing off

Farmer A mentioned that grazing off would be a less risky option for extending the lactation than nitrogen. However, he did not like grazing his stock on other farmer's properties and therefore he was unlikely to use this option to extend the lactation. Rather, it was seen as an option for coping with extreme winter feed deficits.

Buy in extra hay

Buying in extra hay was an option Farmer A would use post-drying off to increase pasture cover if the feed budget identifies that the spring target would not be met. However, Farmer A did not view hay as an option that he would use to extend the lactation and delay the drying off decision – because it was not suitable for increasing cow condition.

Decisions that reduce feed supply

Farmer A does not employ contingencies to reduce overall feed supply at this time of year because he is normally in a feed deficit situation and because pasture quality is not an issue on his property at this time of year (seed head has finished flowering, high stocking rate). Feed supply is reduced in a partial way, in that Farmer A will limit the area of pasture the herd grazes per day through rotation length. This in effect reduces cow intakes of pasture, but may not reduce total feed demand as Farmer A may substitute pasture with some form of supplement (crop or silage). This substitution effect is normally used to take advantage of a burst in pasture growth rates as a result of significant rain (≥ 25 mm) either during the summer, or at drying off. However, the substitution effect is often used just to maintain cow intakes because the rainfall causes decomposition of dead matter in the sward, which temporarily reduces cow intakes and subsequent milk production.

Farmer A also deferred feed from one period to another. For example, he decided to use his silage at drying off rather than during March because his feed budget suggested he had adequate feed in the form of average pasture cover at that point in time.

<u>The extension of the rotation</u>

Farmer A said that he would graze the crop early if the farm received at least 25 mm of rain at some stage during January, February. Farmer A also said that he would feed more than the planned crop ration of one third of the herds intake if the autumn rains arrived early and he had the bulk of his crop intact. He said that he would also change his rotation length at the same time. This suggests that Farmer A would use his crop to substitute for pasture and slow down his rotation so that the impact of the rain on his pasture cover levels is optimised. Farmer A notes that pasture grows in "bursts" and one has to be ready to take advantage of this by destocking the pasture at the time of the rain. Farmer A notes that feed supply will increase within 2-3 weeks of such a rain event. Farmer A pointed out that when sufficient rain (≥ 25 mm) at this time of the year, the dead matter in the sward decomposes rapidly and this in effect causes cow intakes to decline with a subsequent effect on milk production. In this situation, supplement, in the form of crop or silage must be fed to maintain cow intakes and ensure production does not fall below Farmer A's target of 1.04 kg MS/cow/day. Farmer A does not like to feed more than 40% of the herd's diet as a supplement because too much wastage occurs. However, in year one, which was a wet summer, he fed up to 50% of the herd's diet as forage crop and silage after significant rainfall events.

IF milk production is ≤ 13 l/cow/day (1.13 kg MS/cow/day),
AND the crop is ungrazed,
AND recent rainfall is ≥ 25 mm (soil is saturated),
AND it is a wet summer,
THEN graze the crop at a rate such that production holds at 12 l/cow/day (1.04 kg MS/cow/day) and increase crop ration to around 50% of diet for 2-3 days, and extend the rotation accordingly.

IF milk production is ≤ 12 l/cow/day (1.04 kg MS/cow/day),
AND the crop is being grazed,
AND recent rainfall is ≥ 25 mm (soil is saturated),
AND it is a wet summer,
THEN increase crop ration to around 50% of diet for 2-3 days, and extend the rotation accordingly while maintaining production at 12 l/cow/day (1.04 kg MS/cow/day).

IF milk production < target (12 l/cow/day (1.04 kg MS/cow/day) or 13 l/cow/day (1.13 kg MS/cow/day)),
AND crop is grazed,
AND silage is available,
AND the month is February or March,
AND recent rainfall has saturated the ground (≥ 25 mm),
AND it is a wet summer,
THEN feed up to 50 % of the herd's diet as silage for 2 - 3 days and extend the rotation accordingly to take advantage of the extra pasture growth. After that, maintain the extended rotation and feed sufficient silage to maintain production at target (12 l/cow/day (1.04 kg MS/cow/day) or 13 l/cow/day (1.13 kg MS/cow/day)).

Farmer A said that if a significant rainfall event occurred in April (autumn rains), then he would dry the herd off, feed them silage and extend the rotation length out to 60 days to take advantage of the "pulse" of autumn growth to build up average pasture cover pre-winter.

IF pasture growth rates are increasing rapidly,
AND recent rainfall has saturated the ground (≥ 25 mm),
AND the herd are in moderate to poor condition (< 4.5 condition score units),
AND producing at moderate to poor levels (< 11 l/cow/day or 0.96 kg MS/cow/day),
AND the month is April,
AND silage is available,
THEN dry off the herd, extend the rotation out to 60 days and feed sufficient silage to maintain cow intakes at 7 kg DM/cow/day.

Farmer A dried off the herd when pasture cover declined below target rapidly (50 kg DM/ha in 5 days) as a result of low pasture growth rates. He said that he would dry off the herd when the average pasture cover fell below target and pasture growth rates were not increasing rapidly. In this situation he said he would feed out silage and extend the rotation length out to 60 days.

IF pasture cover has fallen below the drying off target,
AND pasture growth rates are not increasing rapidly,
AND the month is April,
AND silage is available,
THEN dry off the herd, extend the rotation out to 60 days and feed sufficient silage to maintain cow intakes at 7 kg DM/cow/day.

Deferral of silage feeding

In early March, Farmer A developed a feed budget that showed that given his current average pasture cover, he could maintain the herd's level of milk production above 1.04 kg MS/cow/day through March, and did not need silage prior to drying off. Rather, he could use it at drying off as part of his winter ration to rapidly increase pasture cover pre-winter.

IF APC is such that production can be maintained at ≥ 1.04 kg MS/cow/day through March,
AND the feed budget suggests silage is not required pre-drying off,
THEN continue on the current rotation and feed silage at drying off as part of the winter ration.

Decisions that reduce feed demand

Sell cull cows

Farmer A dried off low producing cows when they were identified. These were cows that produced around 2 l/cow/day and had a very short milking time. The milking time was the indicator used to dry off the cows.

IF an individual cow produces ≤ 2 litres/cow/day (very short milking time),
THEN sell the animal as a cull.

Farmer A completed a feed budget in early April. His falling plate mete showed that average pasture cover had fallen to his target of 1400 kg DM/ha. On this basis, he thought it best to sell his culls as planned in early April. The feed budget predicted that even with selling the culls in early April, the average pasture cover would decline below target during the second half of April and the herd would have to be dried off. This confirmed his decision to sell the culls in early April. He had feed on some waste areas of the farm, and used the culls to clean up these areas prior to selling them to the works. If he had not had the waste ground, the culls would have been sold directly.

IF the April 1 feed budget shows that the average pasture cover will decline below target in April,
AND the cull cows are still on the milking area,
AND waste ground exists with surplus feed,
THEN retain the culls to clean up the waste ground and then sell them.

IF the April 1 feed budget shows that the APC will decline below target in April,
AND the culls are on the waste ground,
AND the feed on the waste ground has been consumed,
THEN sell the culls.

Farmer A tended to retain empty cows until drying off because they produced more milk per unit of feed eaten than in-calf cows (no energy demand for pregnancy). However, if these cows were not producing well, he culled them.

IF a cull cow is empty,
AND producing well,
THEN milk the cow through until within two weeks of drying off drying off,
ELSE cull.

<u>Sell culls early</u>

Farmer A stated that if he had to sell culls early because feed was short, he would prefer to sell at least 20 cows in order to make an impact.

<u>Once-a-day milking</u>

Farmer A placed thin (≤ 3.5 condition score units) cows onto once-a day milking to maintain their condition at this minimum level.

IF a cow is at condition score ≤ 3.5 condition score units,
AND it is not on once-a-day milking,
THEN put it on once-a-day milking and monitor condition.

<u>Dry off individual cows</u>

Farmer A stated that he would dry off thin cows that were on once-a-day milking if their condition declined below 3.5 condition score units.

IF a cow is at condition score < 3.5 condition score units,
AND it is on once a day milking,
AND is still losing condition,
THEN dry off the cow.

<u>Dry off the herd</u>

Farmer A said that if a significant rainfall event occurred in April (autumn rains), then he would dry the herd off, feed them silage and extend the rotation length out to 60 days to take advantage of the "pulse" of autumn growth to build up average pasture cover pre-winter.

IF pasture growth rates are increasing rapidly,
AND recent rainfall has saturated the ground (≥ 25 mm),
AND the herd are in moderate to poor condition (< 4.5 condition score units),
AND producing at moderate to poor levels (< 11 l/cow/day or 0.96 kg MS/cow/day),
AND the month is April,
AND silage is available,
THEN dry off the herd, extend the rotation out to 60 days and feed sufficient silage to maintain cow intakes at 7 kg DM/cow/day.

In contrast to the above comment, what Farmer A did when pasture growth rates increased during mid April was delay drying off, and monitor the situation (average pasture cover and pasture growth rates) at 5 day intervals. At that stage, the farm was also in a good position in terms of feed and cow condition. It appears, rather than dry off, Farmer A took advantage of the high pasture growth rates created by the significant rainfall event to extend the lactation. He dried the herd off when pasture growth rates and average pasture cover started to decline.

The final means by which Farmer A can manipulate feed demand is through drying off. If the farm state becomes such that it can compromise next season's production, Farmer A will dry off the herd. This effectively reduces cow intakes by half. Drying off date is determined by two key factors, pasture cover and cow condition. Cow condition is an important determinant of the drying off date and generally, Farmer A does not want the average herd condition to fall below 3.5 - 4.0 condition score units. If cow condition started to decline below these limits, Farmer A said he would dry off the herd even if the average pasture cover was above target. This season however, the condition of the herd did not fall below 4.5 condition score units.

IF cow condition is < 3.5 - 4.0 condition score
units,
AND all summer-autumn supplements are consumed,
AND average pasture cover is ≥ target,
AND feed conditions are such that condition is expected to continue to decline,
THEN dry off the herd.

Farmer A made the point that he prefers to hold condition rather than take it off during lactation and put it back on post-drying off. However, he noted that this was a function of the season. In year one, the season was wet and feed supply was plentiful. In this situation, Farmer A maintained the average condition of the herd at, or above 4.5 condition score units. He contrasted this with a dry season where condition might fall to 4.0 condition score units at drying off in March, and then Farmer A would have to increase this to 4.5 condition score units over the post-drying off period.

During year one, Farmer A dried off the herd a day earlier than planned when average pasture cover declined below target rapidly (50 kg DM/ha in 5 days) as a result of low pasture growth rates. He said that he would dry off the herd when the average pasture cover fell below target and pasture growth rates were not increasing rapidly. The other factor that triggered the decision was that the younger cows that were on once-a-day milking to hold condition were starting to lose condition. In this situation he said he would feed out silage and extend the rotation length out to 60 days.

IF pasture cover < the drying off target (1400 kg DM/ha),
AND pasture growth rates are declining rapidly,
AND the younger cows on once-a-day milking are losing condition,
AND the month is April,
AND silage is available,
THEN dry off the herd, extend the rotation out to 60 days and feed sufficient silage to maintain cow intakes at 7 kg DM/cow/day.

Grazing off the herd

Grazing off the herd is an option post-drying off to increase pasture cover if the feed budget identifies that the spring target will not be met. It is not an option that is used to extend the lactation and delay the drying off decision.

Decisions that increase feed demand

Increase cow intakes

Farmer A increased cow intakes when the herd was on the forage crop because pasture growth rates were high for February, and he wanted to take advantage of the additional pasture growth, but also graze the forage crop by the end of the month.

IF pasture growth rates > average,
AND forage crop yield ≥ average,
AND analysis of pre-and post-grazing residuals and the quantity of forage crop suggests at a target milk production of 12 litres/cow/day (1.04 kg MS/cow/day), the forage crop will not be grazed by the target date of March 1st,
THEN increase the milk production target to 13 litres/cow/day (1.13 kg MS/cow/day).

Extend the lactation

Farmer A said that he would continue to milk the herd provided average pasture cover and cow condition was above target.

IF average pasture cover is ≥ the target at drying off,
AND herd condition is ≥ target (3.5 - 4.0 condition score units),
AND the crop is grazed,
And the silage is consumed,
AND the month is March or April,
AND pasture growth rates are not increasing rapidly,
AND the soil is not saturated (≥ 25 mm of rain),
THEN continue to milk the herd until either cow condition or average pasture cover decline below target.

On the 11 - 12th April, the farm received significant rainfall, and this caused pasture growth rates to increase from 20 kg DM/ha/day to 35 kg DM/ha/day. In response to this increase in pasture growth rates, Farmer A delayed drying off, and began monitoring the situation (average pasture cover and pasture growth rates) at 5 day intervals. The farm was also in a good position in terms of feed and cow condition. It appears, rather than dry off the herd, Farmer A took advantage of the high pasture growth rates created by the significant rainfall event to extend the lactation. He dried the herd off when pasture growth rates and average pasture cover started to decline after the "pulse" of pasture growth.

IF pasture growth rates are increasing rapidly,
AND recent rainfall has saturated the ground (≥ 25 mm),
AND the herd is in good condition (≥ 4.5 condition score units),
AND producing at good levels (≥ 11 l/cow/day or 0.96 kg MS/cow/day),
AND average pasture cover is ≥ target (1400 kg DM/ha),
AND the month is April,
AND silage is available,
THEN delay drying off the herd for another five days and closely monitor the situation.

Year Two

Decisions that increase feed supply

Decrease rotation length

In early summer, if feed supply begins to decline, the first option Farmer A uses is to shorten the rotation length to increase cow intakes. At this time of the year, Farmer A will try to maintain milk production at the level the herd were producing at, at the start of the planning period (Christmas). This might range between 1.22 – 1.39 kg MS/cow/day depending on the nature of the preceding period.

IF milk production begins to decline below current levels,
AND it is summer,
AND the crop is ungrazed,
AND the herd is on a rotation length > 25 days,
THEN shorten rotation length to a minimum of 25 days to maintain production.

By inference, if the rotation length is already 25 days, then Farmer A allows milk production to decline until it reaches the target that triggers the feeding of the forage crop.

IF milk production begins to decline below current levels,
AND it is early summer,
AND the crop is ungrazed,
AND the herd is on a rotation length = 25 days,
THEN allow milk production to fall until the target for forage crop feeding is reached and respond accordingly.

In early summer, feed supply can decline if significant rainfall (≥ 25 mm) occurs which causes dead matter to decompose. This in turn reduces dry matter availability and hence cow intakes. The Farmer A's first response to significant rainfall is to shorten the rotation length, and then if this is not sufficient, introduce the crop. Milk production appears to trigger a change in rotation length whether it is caused by dry conditions or a significant rainfall event (≥ 25 mm). The only difference is that the cause of the decline in intake and milk production is different, and may have different longer-term consequences, i.e. if the decline is due to dry conditions, the problem will be on-going until rain occurs, whereas, if it is due to a significant rainfall event, then within 2 - 3 weeks, feed supply should improve.

IF milk production is declining,
AND recent rainfall ≥ 25 mm,
AND the crop is ungrazed,
AND the rotation length > 25 days,
THEN shorten the rotation length to a minimum of 25 days to maintain production.

During February, while on the forage crop, Farmer A shortened the rotation length when rain fell. This reduced the rotation length from a 27 - 28 day round, to a 25 day round. In this instance a total of 21 mm fell over about four days and was sufficient to cause a drop in milk production, hence the need to shorten the rotation.

IF milk production falls below target (1.22 kg MS/cow/day in this case),
AND recent rain has fallen,
AND the herd is on the forage crop,
AND the rotation length is > 25 days,
THEN shorten the rotation length to maintain milk production at target.

Feed forage crop

Farmer A stated that he would need 25 mm of rain for him to put the herd on the forage crop when cow intakes drop due to the resultant decomposition of dead matter. He noted that the main point of feeding the forage crop after rain is to stop the decline in milk production. The forage crop does not allow him to take advantage of the pulse of pasture growth in the way he might at drying off because stocking rate is too high. Farmer A also confirmed that he uses the milk docket to determine how much to forage crop to feed the herd.

IF milk production is ≤ 1.13 kg MS/cow/day,
AND rainfall ≥ 25 mm,
AND the crop is ungrazed,
AND the rotation length = 25 days,
THEN feed sufficient forage crop to maintain production at 1.04 kg MS/cow/day.

Farmer A reduced the rotation length while on the forage crop when rain fell in February because cow intakes declined and milk production fell. By inference, if the rotation length was already at 25 days, then the farmer would have to feed additional crop.

IF milk production falls below target (1.22 kg MS/cow/day in this case),
AND recent rain has fallen,
AND the herd is on the forage crop,
AND the rotation length is = 25 days,
THEN feed additional forage crop to maintain milk production at target.

Feed silage

Farmer A reviewed his original plan to feed all the silage to the herd in early spring. Farmer A decided to use up to 25% - 33% of the silage to extend the lactation through to the autumn rains after the second forage crop was grazed. The proportion of the total silage Farmer A said he might use is the proportion that is normally used over autumn. However, this year Farmer A planned to carry this through for use in the early spring. He believed that there had been a fundamental climate shift and springs would now be colder and wetter than normal. Farmer A decided to change his plan because conditions had deteriorated so quickly. He realised that if it remained dry after the forage crop was grazed, the herd would lose condition and he would have to dry off before the autumn rains. He would then have to use the silage to put condition on the herd in late winter. Farmer A admitted that it is more difficult to put condition on the herd in late winter than in the autumn. The alternative was to use silage and hold condition and milk production through to the autumn rains, and then replace the silage with urea or bought-in hay.

IF the forage crop is grazed,
AND conditions are dry,
AND the feed situation is such that it is probable the herd will have to be dried off before the autumn rains,
AND silage for use in early lactation is available,
THEN use up to a third of the silage to maintain milk production at 1.04 kg MS/cow/day through until the autumn rains. Replace the silage that was used with bought-in hay or urea.

Farmer A also decided that if significant rainfall occurred post-forage crop, 20 - 30 bales of silage would be fed to the herd to take advantage of the "pulse" of pasture growth after the rain. If the silage was used, Farmer A would replace it with either bought-in hay or urea.

IF a significant rainfall event occurs (≥ 25 mm),
AND the forage crop is grazed,
AND conditions have been dry,
AND silage for use in early lactation is available,
THEN use a proportion of the silage to take advantage of the rainfall and maintain milk production at 1.04 kg MS/cow/day. Replace the silage that was used with bought-in hay or urea.

The actual silage feeding process was complicated by the occurrence of a metabolic problem that resulted from too little pasture in the herd's diet while on the forage crop. Normally, the response would be to feed more forage crop, or if the rotation length was greater than 25 days, it could be shortened to increase the herd's intake of pasture. As a result, Farmer A had to feed silage with the forage crop for a period of eight days, and then after that silage was fed with pasture for a further six days.

IF the current crop ration is insufficient to meet cow requirements,
AND the rotation length = 25 days,
AND energy balance problems are occurring due to the ratio of forage crop to pasture,
AND silage for use in early lactation is available,
THEN maintain the current crop ration and feed sufficient silage to maintain milk production at target and overcome the metabolic problem. Replace silage with urea or bought-in hay.

The other issue arose in terms of the use of silage and the additional rainfall improving pasture growth rates. Farmer A said that if conditions did not improve he would have to dry off the herd.

IF the pasture cover is insufficient to meet cow requirements,
AND the rotation length = 25 days,
AND pasture growth is <u>not</u> improving,
AND silage for use in early lactation is not available,
THEN prepare to dry off the herd.

IF the pasture cover is insufficient to meet cow requirements,
AND the rotation length = 25 days,
AND pasture growth is improving,
AND there is silage surplus to spring requirements available,
OR if there is not, it can be replaced by nitrogen or bought-in hay,
THEN feed up to one third of the silage to hold production and allow pasture cover to increase.

Decisions that reduce feed supply

Increase rotation length

Farmer A expected to be able to extend the rotation length over late January from 28 to 30 days. This was because feed quality was good, the herd were producing at 1.39 kg MS/cow/day, and Farmer A thought he could graze them a bit harder (extend the rotation) without reducing production.

IF milk production is high (1.39 kg MS/cow/day),
AND post-grazing residuals suggest the herd could graze harder without reducing production,
THEN extend the rotation while maintaining production.

Decisions that increase feed demand

Increase the milk production target

In late January, Farmer A made a change to the plan and increased the milk production target for the forage crop from 1.04 kg MS/cow/day to 1.13 kg MS/cow/day. This meant that the herd would be introduced to the forage crop when milk production fell to 1.22 kg MS/cow/day rather than at the normal target of 1.13 kg MS/cow/day.

IF milk production is high (1.39 kg MS/cow/day),
AND it is late January,
AND the supplement position is good,
AND the pasture cover is high (1800 kg DM/ha),
AND it appears to be a cool, wet summer,
AND the forage crop is ungrazed,
THEN increase the milk production target for initiating forage crop feeding by 0.09 kg MS/cow/day.

The herd went onto the forage crop at 1.22 kg MS/cow/day, but Farmer A decided to maintain production at this level rather than at the revised level of 1.13 kg MS/cow/day because of the time of year, level of production, the amount of forage crop ahead of him, and the belief that it was going to be another cool, wet summer.

IF milk production is ≥ 1.22 kg MS/cow/day,
AND the herd is grazing the forage crop,
AND it is February,
AND the herd is in good condition (≥ 4.5 condition score units),
AND average pasture cover is good (≥ 1400 kg DM/ha),
AND conditions are good for pasture growth,
AND trends indicate that it is a cool, wet summer,
THEN increase the forage crop feeding target by 0.174 kg MS/cow/day.

Extend lactation length

This contingency is achieved through the other options.

Decisions that reduce feed supply

Reduce milk production target

In late February, conditions had become dry and pasture cover had declined to such a level that to maintain milk production at 1.22 kg MS/cow/day Farmer A would have to feed an excessive amount of forage crop. Instead, he decided to reduce the milk production target to the norm of 1.04 kg MS/cow/day to better ration the crop and enhance the likelihood of milking the entire herd through to the autumn rains.

IF the season become dry,
AND pasture growth rates are low ($\leq$ 10 kg DM/ha/day),
AND pasture cover has fallen rapidly,
AND the herd is grazing the forage crop,
AND the milk production target currently being used is higher than the norm,
THEN change the milk production target back to the norm.

Once-a-day milking

In April, once milk production dropped below 1.04 kg MS/cow/day Farmer A knew the herd was losing condition and he put them on once-a-day milking. He did this rather than dry off the herd because pasture growth rates and average pasture cover were ahead of target.

IF the herd condition score is falling below target (indicated by milk production < 1.04 kg MS/cow/day),
AND no supplements are available,
AND rotation length = 25 days,
AND pasture cover is above target,
AND pasture growth is above average,
THEN put the herd on once-a-day milking to hold condition.

Culling

The cull cows were sold when it became obvious that the herd would be dried off in the near future.

IF the drying off decision is imminent,
AND the cull cows are identified,
THEN organise for the culls to go to the works and sell them as soon as possible.

Drying off

When feed became short in March, Farmer A proposed to dry off the thin, low producing cows on the basis of herd test results. Farmer A uses this method when he has no other options for maintaining intakes at target. Cow intakes are monitored every 3 - 4 days. If he finds that cow intakes are below target, then he delays the decision to dry off cows until the next measurement 3 - 4 days later. If conditions have still not improved, he will dry off sufficient cows to ensure the remaining cows are fed to target. Farmer A dried off 14 cows on the 10th March. The criteria for drying these animals off was low production and condition. Ten were dried off on condition, and four on the basis of their herd test results. The cut off point for the herd test results was 5.0 litres/cow/day.

IF current intakes < target,
AND no additional supplements are available,
AND the rotation length = 25 days,
AND the situation has not improved over the last 3 - 4 days,
THEN dry off sufficient cows to feed the remainder to target.

IF cow condition is ≤ 3.5 condition score units,
OR milk production is low (≤ 5.0 litres/cow/day),
AND the feed situation is poor,
AND the cow is a rising three year old,
OR the cow has animal health problems,
THEN dry off the cow and retain it on the young stock block.

Farmer A dried off two thin, low producing rising three year old cows on April 1st.

IF cow condition ≤ 3.5 condition score units,
AND feed conditions are poor,
THEN dry off the cow.

Farmer A dried the herd off when the herd began to lose condition. This was indicated by milk production (0.84 kg MS/cow/day), intake data (8.0 kg DM/cow/day) and his observation of cow condition. Farmer A had used up all other options: there were no supplements available, the rotation length was 25 days, the herd was at target condition score, and average pasture cover was at target. Pasture growth rates were such, that the feed position on the farm was also declining. Thus, with no improvement in conditions and all factors at or below target, Farmer A decided to dry off. He stated that "It [conditions] equaled my plan."

IF the herd is losing condition (as indicated by milk production levels, intakes and appearance),
AND the herd is on once-a-day milking,
AND rotation length = 25 days,
AND no supplements are available,
AND cow condition = target
AND average pasture cover = target
AND pasture growth rates ≤ feed demand,
THEN dry off the herd.

Other decision rules used by Farmer A in year two

<u>Forage crop selection</u>

Farmer A planted his second forage crop three weeks later than his first so that it matured three weeks later. This suggests that crop maturity will determine the sequence with which forage crops are grazed if there is more than one forage crop.

IF there are more than one forage crop,
AND forage crop must be fed to the herd,
THEN feed the most mature crop first.

<u>Stop silage feeding - termination rule</u>

Farmer A used the following rule to terminate silage feeding.

IF the pre-grazing pasture cover in the next paddock to be grazed is sufficient to maintain milk production at 1.04 kg MS/cow/day,
AND conditions are such that this will continue,
THEN cease feeding silage.

Arbitration rule

Farmer A has given the young stock 3.0 ha because feed is short on their block. This was because the hay paddocks that were cut late had not grown to potential in the dry conditions. This is an example of an arbitration rule where the young stock are given priority over the milking herd.

IF feed is short on the young stock area,
AND conditions are dry,
AND no supplements are available,
AND pasture growth rates are low,
THEN provide an additional paddock to the young stock until the feed shortage is overcome.

Year Three

Decisions that increase feed supply

The following decision rules are used to increase feed supply;

Supplements

Timing and amount

Farmer A decided to feed the forage crop when milk production fell to 0.87 kg MS/cow/day.

If milk production $\leq$ target
AND rotation length = minimum,
AND the forage crop is ungrazed,
THEN feed sufficient supplement to maintain milk production at target.

Farmer A doubled the amount of forage crop fed to the herd when it went onto once-a-day milking to hold milk production.

IF the herd is going onto once-a-day milking,
AND the herd is currently grazing the forage crop,
THEN increase the forage crop ration to hold milk production.

Fine tuning forage crop feeding

Farmer A may also increase the forage crop break if there has been some rain, not enough to cause decomposition, but enough to limit how far into the sward, the herd will graze. Farmer A also found that the herd would not eat the turnip bulbs if it had rained. He said that a similar thing happened with the other forage crop. In this situation, Farmer A had to feed more silage.

IF non-significant (< 25 mm) rain has fallen recently,
AND this will reduce cow intakes of pasture,
AND the herd is grazing the forage crop,
AND the herd is being fed silage with the forage crop,
THEN increase the silage ration to maintain cow intakes and milk production at target.

If a paddock ahead of the herd has had a previous history (e.g. badly pugged in winter) that results in it producing less feed than the norm, Farmer A would check it because it was likely to provide less feed than other paddocks. He then adjusted the amount of forage crop fed to the herd so that milk production did not fall. Farmer A also knows that his farm has some areas that are drier than others and he also checks these paddocks. The advantage of a fixed round is that he knows the sequence of paddocks and this never changes over the summer-autumn. This data suggests Farmer A is grouping paddocks as "dry" and "not as dry" on the basis of how well they grow over the summer. These rules are useful for fine tuning the management of the farm.

IF a paddock is likely to grow less grass than others due to a previous problem,
AND the paddock is soon to be grazed,
AND the herd is being fed supplements,
THEN assess the feed on the paddock before grazing and adjust the supplement level to maintain intakes at target as required.

IF a paddock classification = dry,
AND the paddock is soon to be grazed,
AND the herd is being fed supplements,
THEN assess the feed on the paddock before grazing and adjust the supplement level to maintain intakes at target if required.

Feed mix

To extend the use of the forage crop, Farmer A decided to supplement the herd with silage. However, because he only had 25 bales of silage, he also bought some high quality hay in to feed with the silage. The ratio of a bale of each was for practical reasons, i.e. a bale of each was adequate, and two bales of silage and a bale of hay was too much. Farmer A purchased 30 bales of high quality hay to feed with the silage. This suggests Farmer A was making some projection of forage crop yield and the time over which it would last, with and without the silage and hay.

IF forage crop yield is poor,
AND silage is available,
THEN feed sufficient silage with the forage crop to ensure it lasts until mid March.

IF there is insufficient silage to supplement the forage crops until mid March,
THEN buy in high quality hay to feed with the silage.

Effect of significant rain on forage crop feeding levels

At the point that Farmer A put the herd on once-a-day, 40 mm of rain fell. The rain caused the dead matter in the sward to decompose and reduced the pasture intakes of the herd. Farmer A had to increase the amount of forage crop in the herd's diet to counter this effect. During this period, the amount of forage crop that was fed to the herd was doubled.

IF significant rainfall (≥ 25 mm) falls,
AND the herd has just gone onto once-day-milking,

AND the herd is grazing the forage crop,
THEN increase the level of supplement to hold milk production at target.

Nitrogen use

Farmer A stated that he would use more nitrogen than normal to extend the lactation. His reasons were that the new shoulder milk payment system where he is paid more for milk produced on either side of peak (October, November) and because production to date is 25 - 30% down on budget.

IF milk production is considerably below target,
AND the company pays a premium for shoulder milk,
THEN use additional nitrogen to extend the lactation.

Decisions that reduce feed supply

Extend rotation length

The main decision Farmer Ahas made through April was to hold the herd at its current rotation length and feeding level. An alternative was to tighten them up and extend the rotation, but Farmer A believes that at this time of year, the herd is very sensitive to changes in intake, and if he had done this, milk production would have dropped significantly. The trade-off is that if Farmer A reduced his rotation length and shortened his round, he would improve the pasture quality of the paddocks the herd is grazing (less clumps), but he would have less milk production within a given period because the cows are so sensitive to changes in intake at this time of year.

Decisions that increase feed demand

Twice-a-day milking

Farmer A said he would put the herd back onto twice-a-day milking during February or March if pasture growth rates improved to the point where he could feed the herd 11.0 kg DM/cow/day of pasture. At this level, the herd would increase milk production without the risk of losing further condition.

IF analysis of pre- and post-grazing residuals shows that the herd can be consistently fed 11.0 kg DM/cow/day,
AND the herd is on once-a-day milking,
AND the month is February or March,
THEN put the herd on twice-a-day milking.

It appears Farmer A did not put the herd back onto twice-a-day milking in the first half of April because the average condition of the herd was still below target in the first half of April. He also mentions time of year. This is a problem when recording the comments on future actions versus actual actions. This is further complicated because Farmer A is now looking at calving the herd at 5.0 rather than 4.5 condition score units. The following rule may hold for both early and late April, where the condition score target changed in mid April.

IF average pasture cover is such that the herd can be fed 11.0 kg DM/cow/day,
AND the herd is on once-a-day milking,
AND the condition of the herd is ≥ target,
AND the date is before mid April,
THEN put the herd onto twice-a-day milking,

ELSE maintain the herd on once-a-day milking.

Bring on grazers

Farmer A returned nine 9 dry cows from the runoff because feed was tight on the runoff, and conditions had improved on the milking area. Conditions had improved so much so that the dry cows were needed to clean up after the milking herd because they were leaving clumps behind. This is another "arbitration rule" which in this instance, frees up feed on the runoff for the beef cattle because there is sufficient feed on the milking area to carry the dry cows without adverse effect.

IF pasture quality is declining because the milking herd is leaving too high a residual (clumps),
AND dry cows are grazing on the runoff,
AND feed on the runoff has limited feed for the other stock,
THEN shift the dry cows onto the milking area to clean up after the milking herd.

Decisions that decrease feed demand

Milk production target

Farmer A reduced his milk production target for the forage crop because with limited supplements he would have used the forage crop up too quickly (grazed it earlier and at a faster rate). This would have meant that the herd would have finished the crop in three weeks rather than six weeks and the risk was that Farmer A would have had to dry off the herd before the autumn rains. Farmer A expected the herd to lose condition under this system because intakes were below the level required to maintain condition..

IF the forage crop is poor,
AND the silage level is poor (≤ 25% of normal),
AND the rotation length = minimum,
AND conditions are dry,
AND conditions are not improving,
THEN change the milk production target for summer to 10.0 litres/cow/day or 0.87 kg MS/cow/day.

Around mid February when conditions became really dry, there was insufficient pasture cover to maintain milk production at the reduced target. The case farmer decided to reduce the milk production target further to 7.5 litres/cow/day, or 0.7 kg MS/cow/day in order to ensure the forage crop lasted into March.

IF the current level of intake is insufficient to maintain milk production at target,
AND conditions are dry,
AND no other supplement is available,
AND the herd is grazing the forage crop,
AND the current forage crop ration cannot be increased because its use must be extended into March,
THEN temporarily reduce the milk production target to 7.5 litres/cow/day, or 0.7 kg MS/cow/day in order to ensure the forage crop lasts into March, and increase the milk production target when feed conditions improve.

Graze off

Farmer A put the dry cows onto the beef unit because he believed he would make more from turning pasture into milk than using it to grow out his beef cattle. This is an arbitration decision rule where the margin derived from putting feed into different enterprises determines the choice of options.

IF there are dry cows on the milking area,
AND feed on the milking area is in short supply,
AND feed on the beef unit is also in short supply,
AND returns from milk production are greater than returns from beef production,
THEN put the dry cows on the beef unit.

Culling

Timing

Normally, Farmer A culls cows unsuitable for carrying over the summer period at or around Christmas, new year. However, this year, because Farmer A was considering using a block that ran beef cattle for milking cows next season, he did not want to cull cows that he might need when he increased cow numbers. Therefore, because he had organised herd testing on January 11th, he decided to delay the culling decision until he had more objective data upon which he could make the decision.

IF it is Christmas,
AND cow numbers are to increase next season,
AND the number of cows that can be culled is limited,
AND there is a herd test organised for early January,
THEN delay culling decisions until the herd test.

Numbers to be culled

Farmer A culled 14 cows on the 27th January. Ten of these cows were culled on the basis of the herd test results, and the other 4 were cows that had been previously dried off because they had re-occurring mastitis. The Farmer A's aim at that stage was to milk the herd on pasture until the end of January. To do this, he had to reduce cow numbers. However, because he wanted to increase cow numbers next season, Farmer A cannot cull too heavily until he has pregnancy tested the herd. Therefore, the cows that are culled at this stage must be definite culls.

IF the early January herd test is completed,
AND forage crop yields are low,
AND supplement reserves are low,
AND rotation length = minimum,
AND cow intakes are declining,
AND feed conditions have not improved,
THEN select definite culls and sell these as soon as possible.

Criteria for culling

Mastitis

Farmer A dried off four cows that had reoccurring mastitis. The problem with mastitis is that cell count increases as cows come under stress and intakes fall. In such conditions, Farmer A dries off these cows and culls them.

IF a cow has persistent mastitis,
AND conditions are dry,
AND cow intakes are declining,
THEN dry off and cull the cow.

Pregnancy status

Farmer A culled his empty cows once they were identified through ultrasound testing. In the past, high producing empty cows have been retained and milked through until drying off. However, the feed situation did not allow this and these cows were culled soon after they were identified. Around that time the silage was almost finished which meant cow intakes would drop unless some cows were removed from the milking area.

IF empty cows have been identified,
AND the forage crop is poor,
AND the rotation length = minimum,
AND the silage is due to run within the next few days,
AND conditions are dry,
AND cow intakes are expected to drop below target once the silage is completed,
THEN cull all the empty cows.

Farmer A also uses projections of cow intakes to make this decision as was discovered in year two. The objective of this action is actually to maintain the intakes of the milking cows c.f. "options to reduce feed demand".

On the 10th February, the herd was pregnancy tested. Only 10 empty cows were identified and drafted out of the herd onto waste ground, but still milked twice-a-day. They were booked into the works and sold on the 13th February. Farmer A decided not to cull any more cows. His argument was that ten extra cows would make little difference in terms of feed demand (0.5 kg DM/cow/day), but more importantly, in-calf cows are a valuable commodity and better kept alive. Farmer A could sell them for $1000 in the winter, or $300 at the works in February. The value of the 10 cows was another $7000. Farmer A would still have to graze the herd on the milking area, therefore the net savings is probably closer to 0.25 kg DM/cow/day. The lack of feed on the runoff compounded the Farmer A's feed problems.

IF empty cows are identified,
AND no autumn silage is available,
AND rotation length = minimum,
AND forage crop yield is low,
AND the feed situation is very dry,
THEN place the cows on waste ground and sell them to the works as soon as possible.

IF the feed situation is very dry,
AND no autumn silage is available,
AND rotation length = minimum,
AND forage crop yield is low,
AND the value of in-calf cows in the winter is considerably higher than the value of such cows if sold in the summer,
AND the runoff has no surplus feed for dry cows,
THEN do not sell in-calf cows to the works.

Culling at or near drying off

Farmer A sold three dry cows just prior to drying off. These cows had been repeatedly treated for mastitis and Farmer A decided to cull them. Four other culls (empty cows) were sold after drying off. Farmer A continued his practice of culling at or near drying off. (Notes on culling in diary summary, not transcript).

IF drying off is imminent,
AND cull cows remain on the farm,
THEN cull these cows.

Once-a-day milking to protect individual cow condition

Farmer A said he would put cows that were at or below condition score 3.5 onto once-a-day milking. On the 6th February, Farmer A put 8 thin cows on once-day-milking.

IF cow condition ≤ 3.5 condition score,
AND the cow is not on once-a-day milking,
THEN put the cow on once-a-day milking.

Once-a-day milking to protect herd condition

On the 23rd February, Farmer A put the herd onto once-a-day milking to hold condition. The alternative was to dry off a large proportion of the herd and use the feed freed up from doing this to feed the remainder of the herd better. Farmer A preferred to milk the herd once-a-day because it gave him more options. The reason the decision was made was because the herd had lost condition rapidly over February. Farmer A believes that there is still the possibility of taking advantage of growth later in the autumn. Farmer A also believed that he had sufficient time to put condition back on the herd (5 - 6 months).

IF average herd condition ≤ 4.0 condition score units,
AND cow condition is declining,
AND it is February,
AND the forage crop is poor,
AND no additional supplements are available,
AND the rotation length = minimum,
AND conditions are dry,
AND intake is expected to decline,
THEN put the herd on once-a-day milking to hold condition.

Farmer A said that he had to increase cow intakes when he put the herd on once-a-day milking otherwise milk production would have declined considerably and a proportion of the herd would have dried off. This was one reason that Farmer A had to decide to put the herd on once-a-day milking before the forage crop ran out.

IF conditions are such that the herd will need to go onto once-a-day milking,
AND the herd is currently grazing the forage crop,
AND no other supplements are available,
THEN change to once-a-day milking while there is sufficient forage crop to provide additional feed intake to hold milk production during the change-over.

Drying off

Drying off cows to maintain the intakes of the milking herd at or above target

The objective through February is to make the forage crop last as long as possible and maintain production at 0.87 kg MS/cow/day. Cow number were secondary to this goal, and Farmer A said he would reduce cow numbers if feed supply continued to decline, rather than increase feed intake from the forage crop.

IF milk production ≤ 0.87 kg MS/cow/day,
AND the herd is grazing the forage crop,
AND cow intakes are declining,
AND the data suggests that intakes will continue to decline
AND the forage crop yield is poor,
AND the level of silage is poor,
AND rotation length = minimum,
THEN dry off sufficient cows to maintain milk production at 0.87 kg MS/cow/day.

Drying off to protect cow condition

Farmer A dried off thin rising three year old cows that had been put on once-a-day milking, but continued to lose condition. In March, Farmer A said he would dry off any rising three year old cows when they reached condition score 3.5. At that stage, the entire herd was on once-a-day milking. Cows that are dried off will graze the roadside and waste areas. On the 20th February, nine thin cows were dried off. These were the nine cows that were on once-a-day and they were not improving in terms of condition so Farmer A dried them off. These are on the farm and are being fed a diet of 100% hay for several days, and then put on waste areas.

IF cow condition ≤ 3.5 condition score units,
AND the animal is on once-a-day milking,
AND it is still losing condition,
THEN dry off the cow and graze it on waste areas.

IF cow condition = 3.5 condition score units,
AND the herd is on once-a-day milking,
AND the month is March,
AND the cow is a rising three year old,
THEN dry off the cow and graze it on waste areas.

IF cow condition ≤ 3.5 condition score,
AND the cow is on once-a-day milking,
AND cow condition is continuing to decline,
AND conditions are very dry,
THEN dry the cow off.

Drying off the herd to ensure next season's production is not jeopardised

Farmer A decided to dry off on the 15th May because average pasture cover and pasture growth rates had fallen rapidly between the 2nd and 15th May. A feed budget showed that Farmer A would calve onto 1972 kg DM/ha at calving. This was 328 kg DM/ha below target, but Farmer A estimated that he could cover this feed deficit with 2.5 tonnes of urea. The herd was at condition score 4.7, but on once-a-day milking. This meant the herd had to be well fed to hold production and hence cow condition was holding. (It had been improving up until May, but the herd may have had an internal parasite problem that limited further improvement in body condition). Farmer A was also concerned that if the trend in pasture growth rates continued, the average pasture could have declined to 1300 kg DM/ha. The herd had started to "work" harder and milk production was declining. This suggested cow intakes were declining and the herd would begin to lose condition. The initial feed budget completed on April 1st had 3.0 tonnes of urea in the plan. However, at drying off, Farmer A estimated that he would need 2.5 tonnes of urea to meet target. This showed that the decline in average pasture cover had a greater influence on the drying off decision than the average pasture cover.

IF average pasture cover ≤ target,
AND average pasture cover is declining,
AND pasture growth rates are declining,
AND milk production was declining,
AND projections suggest if the trend continues, average pasture cover will drop to low levels in the next two weeks,
AND it is May,
AND the herd is on once-a-day milking,
AND the average herd condition ≥ target,
THEN dry off the herd.

Arbitration rules

Farmer A put the dry cows onto the beef unit because he believed he would make more from turning pasture into milk than using it to grow out his beef cattle. This is an arbitration decision rule where the margin derived from putting feed into different enterprises determines the choice of options.

IF there are dry cows on the milking area,
AND feed on the milking area is in short supply,
AND feed on the beef unit is also in short supply,
AND returns from milk production are greater than returns from beef production,
THEN put the dry cows on the beef unit.

Farmer A returned nine dry cows from the runoff because feed was tight on the runoff, and conditions had improved on the milking area. Conditions had improved so much so that the dry cows were needed to clean up after the milking herd because they were leaving clumps behind. This is another "arbitration rule" which in this instance, frees up feed on the runoff for the beef cattle because there is sufficient feed on the milking area to carry the dry cows without adverse effect.

IF pasture quality is declining because the milking herd is leaving too high a residual (clumps),
AND dry cows are grazing on the runoff,
AND feed on the runoff has limited feed for the other stock,
THEN shift the dry cows onto the milking area to clean up after the milking herd.

Appendix IX. Evaluations undertaken by Farmer A.

Table 1. The evaluations carried out by Farmer A.

Category and instance	Evaluation type	Initiated by	Method of evaluation	Criteria	Criteria met	Unusual situations
Planning						
Planning Decisions						
Use of inputs						
Use of a leafier variety of forage crop	Ex-post evaluation	Outcome of decision known	Comparison to normal variety	Level of utilisation	Yes	New input
Planting an additional paddock of forage crop	Ex-post evaluation	Yield below standard	Historical simulation to compare planting and not planting	Feed supplied by each option	No	Additional input
Management practices						
The use of ultrasound to identify empty cows early	Ex-post evaluation	Outcome of decision known	Compares accuracy to normal practice	Equal to standard	Yes	New practice Extreme season
The decision to go onto once-a-day milking	Ex-post evaluation	Outcome of decision known	Historical simulation of farm state with and without decision	Herd milking in early March	Yes	Unusual practice Extreme season
Choice of targets						
Decision to increase milk production target	Ex-post evaluation	Outcome of decision known	Compared to expectations	Match	No	New practice Extreme season
Planning assumptions	-	-	-	-	-	-
Implementation						
Level of supplement fed, break size for forage crop and pasture	Ex-post evaluation	On-going	Compare to expectations	Match	Mostly	Extreme conditions experienced at times Barkant turnips – yr 3

Category and instance	Evaluation type	Initiated by	Method of evaluation	Criteria	Criteria met	Unusual situations
Control						
Control decisions						
Contingency plan selection						
Use of inputs	-	-	-	-	-	-
Management practices						
The decision to dry off the herd at a specific date	Ex-post evaluation	Outcome of decision known	Comparison of farm state to targets Historical simulation of farm state with and without decision	APC and average herd condition APC and average herd condition	Yes Yes	
Decision to harvest hay & silage late	Ex-post evaluation	Outcome of decision known	Comparison of regrowth to norm	Rate of pasture regrowth	No	Extreme conditions Decision to delay harvest of hay & silage – yr 3
Choice of targets						
Decision to increase milk production target	Ex-post evaluation	Outcome of decision known	Compared to expectations	Match	No	New practice Extreme season
Monitoring system						
Accuracy of monitoring						
Calibration of various measures	Ex-post evaluation	On-going	Deviation from standard	Degree of deviation	Mostly	Extreme conditions experienced at times
Pasture scoring	Diagnosis	)Yield and intake)estimates)differed from	)Compare)estimate to)standard[44]	Estimate similar to standard	No	Extreme season
Forage crop yield and break size estimate	Ex-post evaluation	)those derived)from milk)production data			No	
Number of cows mated to the bull	Diagnosis	Pregnancy test results	Comparison to predictions from previous measures	Degree of match	No	Extreme season[45]
The use of ultrasound to identify empty cows early	Ex-post evaluation	Outcome of decision known	Compares accuracy to normal practice	Equal to standard	Yes	New practice Extreme season

[44] Intake and yield estimates derived from objective milk production data are used as the standard.
[45] The previous spring had been very cold and wet.

Category and instance	Evaluation type	Initiated by	Method of evaluation	Criteria	Criteria met	Unusual situations
Timeliness of monitoring						
Initiation date of objective pasture measurement	Ex-post evaluation	Feed conditions deteriorated quickly	Compared to ideal situation	Provision of trend information	No	Rapid change
Monitoring interval for objective pasture measurement	Ex-post evaluation	Feed conditions deteriorated quickly	Historical simulation to compare 5 day versus 13 day monitoring interval	Minimal difference in APC on hand	No	Rapid change
Accuracy of predictions						
Comparison of short-term predictions to actual pasture growth rates	Ex-post evaluation	On-going	Comparison of actual with prediction	Match	Variable	Extreme conditions are experienced
Overall management of a period						
Management of the autumn period	Ex-post evaluation	Outcome of decision known	Comparison of results to expectations	Degree to which outcome matches expectations	Yes	
Systems performance						
Forage crop yield	Diagnosis	Yield below target	Comparison of yield to standard	Equal to or greater than standard	No	Extreme season
Number of empty cows	Diagnosis	Pregnancy test results	Comparison to predictions from previous measures	Degree of match	No	
Number of cows mated to the bull	Diagnosis	Pregnancy test results	Comparison to predictions from previous measures	Degree of match	No	Extreme season[46]

[46] The previous spring had been very cold and wet.

Table 2. The evaluations carried out by Farmer A.

Category and instance	Initiated by	Method of evaluation Comparison of outcome to:	Criteria	Criteria met	Impact of evaluation	Situation
Planning						
Planning Decisions						
Use of inputs Use of a leafier variety of forage crop	Implementation	Norm	>	Yes	Retain	New practice
Planting an additional paddock of forage crop	Implementation Poor outcome	Mental simulation	>	No	None[47]	New practice
Management practices The use of ultrasound to identify empty cows early	Implementation	Norm	=	Yes	Retain	New practice Extreme
The decision to go onto once-a-day milking	Implementation	Mental simulation	>	Yes	Retain	Unusual practice Extreme
Choice of targets Decision to increase milk production target	Implementation	Expectations	=	No	Discard	New practice Extreme
Planning assumptions	-	-	-	-	-	-
Implementation						
Level of supplement fed, break size for forage crop and pasture	On-going	Expectations	=	Mostly		Sometimes extreme Barkant tumips
Control						
Control decisions						
Contingency plan selection						
Use of inputs Decision to delay shutting up and harvesting of hay and silage	Implementation Poor outcome	Expectations	<	No	Discard	Extreme
Management practices The decision to dry off the herd at a specific date	Implementation	Standards Mental simulation	= >	Yes Yes	Confirm decision	
Choice of targets Decision to increase milk production target	Implementation	Expectations	=	Yes	Retain	New practice Extreme

[47] Farmer A accepted that the climate was the main reason for the low yield and he continued to grow the additional area.

Category and instance	Initiated by	Method of evaluation Comparison of outcome to:	Criteria	Criteria met	Impact of evaluation	Situation
Monitoring system *Accuracy of monitoring*						
Calibration of various measures	On-going	Standards	=	Mostly	Validate or recalibrate	Sometimes extreme
Forage crop yield and break size estimate	On-going	Standards	=	Mostly	Validate or recalibrate	Sometimes extreme
The use of ultrasound to identify empty cows early	Implementation	Norm	≥	Yes	Retained	New practice Extreme
Timeliness of monitoring						
Initiation date of objective pasture measurement	Poor outcome	Mental simulation	>	No	Change practice	Extreme
Monitoring interval for objective pasture measurement	Poor outcome	Mental simulation	>	No	Change practice	Extreme
Accuracy of predictions Comparison of short-term predictions to actual pasture growth rates	On-going	Predictions	=	Variable	Validate or refine system model	Sometimes extreme
Overall management of a period The management of the autumn period	Implementation	Expectations	=	Yes	Confirm	
Systems performance	-	-	-	-	-	-

Figure 3. Examples of evaluations undertaken by the Farmer A.

Category	Year 1	Year 2	Year 3
Monitoring system	Why his pasture scoring was underestimating cow intakes by 20%? Why a cow was empty when he had thought it pregnant?	Why his pasture scoring was underestimating pasture cover by 300 - 400 kg DM/ha? If his estimate of forage crop yield and break size was accurate? If he should have started objectively monitoring average pasture cover earlier in March?	If he had used too long a monitoring interval to monitor average pasture cover and pasture growth during the two weeks prior to drying off? Why cows in the herd had been mated to the bull when he had thought them mated to artificial insemination? If a new method of pregnancy diagnosis, ultrasound, was accurate?
Choice of targets	If his decision to increase the milk production target from 0.6 to 1.22 kg MS/cow/day was correct?	If the higher milk production target that he had changed to was still suitable, given the season had become dry?	
Choice of physical inputs	If his decision to change to a leafier forage crop variety was a correct?	If his plan to only use silage in the early spring was appropriate, given the dry conditions?	If his decision to plant an additional paddock of forage crop was correct?
Systems performance			Why the forage crop yields had been so poor?
Management practices	If his decision to dry off the herd on the 23rd April was correct?	If his decision to dry off the herd on the 28th April was correct?	If his decision to use ultrasound so that he could diagnose the pregnancy status of the herd early was correct? If his decision to put the herd onto once-a-day milking was correct?
Management of a specific period	If his overall management through the autumn was effective?		

Appendix X. Instances of learning undertaken by Farmer A.

Table 1. Instances of learning undertaken by Farmer A.

Instances of learning	Areas of learning	Outcome of learning
Year one		
Farmer A learnt that his new forage crop variety was leafier and as a result had a higher utilisation rate than his previous varieties.	Production system, forage, supplement, forage crop, utilisation. Management system, strategic, planning, activity rules.	Farmer A retained the new forage crop in his plan for year two.
Farmer A leamt that the sward structure changed due to very wet summer conditions and as a result, Farmer A had to recalibrate his pasture scoring.	Environment, biophysical, climate. Production system, forage, pasture. Management system, tactical, control, monitoring.	Farmer A now knew that he may have to recalibrate his pasture scoring in a wet summer.
Farmer A leamt that his herd could produce at a higher level than he thought possible over the summer when feed conditions are very good.	Environment, biophysical, climate. Production system, forage, pasture, livestock, herd.	Farmer A introduced a contingency plan to increase the milk production targets if conditions changed to wet during summer. He also introduced a decision rule to increase his milk production targets in his summer plan if the summer was likely to be wet.
Farmer A leamt that in a very wet summer, he could increase his milk production target to take advantage of the high levels of pasture growth.	Environment, biophysical, climate. Production system, forage, pasture, livestock, herd. Management system, tactical, planning, target selection, contingency plan specification, control, contingency plan selection.	Farmer A retained his contingency plan to increase milk production targets if the summer tumed wet.
Farmer A believed that there had been a climate shift because the previous two springs had been wet, and cold. This made it difficult to feed the herd to appetite over early spring and ensure good levels of milk production and reproductive performance. As a result, he decided to change his plan and retain the silage fed in the summer-autumn for use in the spring. In effect, he assumed that his pasture growth rate assumptions for the early spring were no longer valid due to the shift in climate.	Environment, biophysical, climate. Production system, forage, pasture. Production system, livestock, herd, performance, (milk production, reproductive performance). Management system, strategic, planning, activity rule, input use, planning assumptions.	Farmer A removed silage feeding from the summer plan in year one. He also substituted the summer silage with 1.0 ha of forage crop in the summer plan for year two.
Year Two		
Farmer A leamt that he could not predict climate shift trends, and his decision rule to increase the milk production target when it appeared the summer was going to be wet was risky. The use of a high milk production target in a dry year resulted in the forage crop being grazed early and at a faster rate, increasing the risk of having to dry off the herd before April 1st.	Environment, biophysical, climate. Management practice, tactical, planning, target selection, forecasting, planning assumptions. Management system, tactical control, contingency plan selection.	Farmer A removed the new target selection rule from his planning repertoire and a retum to the use the previous one. He also removed the contingency plan to increase milk production targets if the summer changed to wet conditions.
Year Three		
Farmer A leamt that the herd would not consume Barkant turnip bulbs until they had softened up over 2 - 3 days.	Production system, forage, supplement, forage crop, performance, utilisation. Management system, operational, implementation, input use, forage crop.	Farmer A gave the herd access to the bulbs two days after the leaf had been eaten.
Farmer A leamt that ultrasound could be used to accurately assess the pregnancy status of the herd a month in advance of the normal practice, and allow early culling of empty cows in a dry year.	Management system, tactical, control, monitoring system, method, accuracy. Management system, tactical, planning, activity rules, management practice.	Farmer A adopted ultrasound as the planned method of pregnancy diagnosis in dry years.

Instances of learning	Areas of learning	Outcome of learning
Farmer A changed his attitude towards the use of nitrogen as a means of extending the lactation. He used winter nitrogen in year two and three to extend the lactation and now viewed autumn nitrogen as an option. Prior to that he thought autumn nitrogen would not work given the nitrogen that was released during the autumn flush.	Production system, forage, pasture, performance, nitrogen response, supplement, nitrogen Production system, soils. Management system, strategic, planning, activity rules Values.	Farmer A was now prepared to include autumn and/or winter nitrogen in the autumn plan to extend the lactation. Farmer A had changed his "self-sufficiency" values that previously saw nitrogen as an option of last resort rather than as a regular input.
Farmer A leamt that in a spring that was very wet and followed by dry conditions, his forage crop germination and subsequent yields would be poor.	Environment, biophysical, climate. Production system, forage, supplement, forage crop, performance, yield.	Background knowledge.
Farmer A also learnt that during a wet spring, cows can stop cycling if under nutritional stress. This behaviour can be misinterpreted to mean that such cows are in-calf. The cows then exhibit a "quiet heat" when conditions improve that is difficult to detect. This can results in a higher proportion of the herd being mated to a bull than the farmer's mating records suggested.	Environment, biophysical, climate. Production system, forage, pasture, supplement, livestock, herd. Management system, tactical, control, monitoring.	Background knowledge.
During this particularly dry year, Farmer A learnt to adhere to his tactical management procedures and not panic and move outside of these.	Management system, tactical.	Farmer A confirmed the validity of his procedural rules under extremely dry conditions.
Farmer A learnt that if he harvested hay and silage paddocks late in the spring, subsequent regrowth from these paddocks was poor if the summer turned dry.	Environment, biophysical, climate. Production system, forage, pasture, performance, growth. Management system, tactical, planning, activity rules, input use. Values.	Farmer A changed his management practice to make supplements early, or if this is not possible, buy in the feed. He also changed his values from a "self-sufficiency" philosophy.
Previous Learning[48]		
Farmer A had monitored a wide range of factors in the past, but had identified which factors were most useful for management purposes.	Management system, tactical, control, monitoring.	Selection of fewer, important indicators.
Farmer A developed the target milk production level for supplement feeding because he had leamt that if milk production fell below this level, the herd lost condition, and if the feed situation improved, it was also difficult to increase production again.	Production system, livestock, herd, (milk production and condition). Management system, tactical, planning, target selection. Management system, tactical, control, contingency plan.	Use of milk production target in decision making, development of contingency plan selection rules around the target.
Farmer A learnt that when the herd began grazing into a certain zone of the sward (stalky, poorer quality zone), this indicated that milk production was about to fall below target.	Production system, livestock, herd, performance, milk production. Management system, tactical, control, monitoring system.	This provided an early indicator of when milk production and cow intakes are about to fall below target.
Farmer A leamt that he should place his thin younger cows on once-a-day milking when body condition fell to 3.5 condition score units to protect condition. If this failed, he learnt that he should dry them off.	Production system, livestock, herd, performance, condition. Management system, tactical, planning, target selection. Management system, tactical, control, contingency plan selection.	Use of condition score target in decision making, development of contingency plan selection rules around the target.
Farmer A leamt that he grew more grass over the winter if he practiced on-off grazing.	Production system, forage, pasture, performance. Management system, implementation, management practice.	Introduction of on-off grazing practice into the winter plan.

[48] Learning that was mentioned during the study period, but occurred prior to the commencement of the study.

Table 2. Classification of the learning undertaken by Farmer A.

New management practice[49]	Extreme conditions	Effect on management system	Specific nature of learning	Specific impact on management system
Year 1				
Yes	Yes	Confirmed	The new forage crop was leafier and had a higher utilisation rate than previous varieties.	The new variety was retained in the plan for year two.
No	Yes	Changed	During a wet summer, sward structure changed under good growing conditions changing the calibration between pasture height and mass.	Recalibration of height to mass ratio for the duration of the sward structure change.
No	Yes	Changed	The herd can produce at a higher level than expected over the summer, provided adequate feed is available.	Milk production target increased and control response decision rules adjusted accordingly.
Yes	Yes	Confirmed	A contingency plan that increases target milk production was effective in utilising surplus feed during wet summer conditions.	The increase in the milk production target under wet summer conditions was confirmed as an effective tactic. It was also decided that it could be used as a planning option if, at the start of the planning period, conditions were expected to be wet over the summer
No	Yes	Change	Two wet summers and three wet springs in a row suggested that the climate had changed. Cold, wet springs made it difficult to feed the herd to appetite while wet summers meant less supplement was required.	Summer silage was to be reserved for use in early spring, and an additional 1.0 ha of forage crop was to be grown to replace it.
Year 2				
Yes	No	Discarded	Conditions at the start of summer are not a good indicator of future pasture growth rates. Despite two years of wet summers, this is not a useful predictor of a long-term change in climate. Using a planning rule that increases the milk production target if a wet summer is expected is risky if the wet summer forecasting capability is inaccurate. It reduces the likelihood of milking the herd through to the autumn rains.	The planning rule to increase the milk production target if, at the start of the planning period, conditions were expected to be wet over the summer, was removed. As was the contingency plan to increase milk production target and associated control response selection rules.
Year 3				
Yes	Yes	No	Forage crop yields are poor if December is very dry.	No management response could be identified to overcome this problem. The knowledge was stored and would be used to account for similar problems in the future.
Yes	Yes	No	Barkant tumip bulbs must be left to soften for 2 – 3 days after initial grazing to ensure high utilisation.	The implementation process was changed to allow the herd access to the tumip bulbs two days after their first grazing.
Yes	Yes	No	Ultrasound can accurately diagnose pregnancy status a month earlier than the traditional method. This allows empty cows to be sold, reducing feed demand in a dry year.	Ultrasound was retained as a planned option if conditions were expected to be dry over the summer.

[49] This includes new inputs, management practices, targets, contingency plans, planning assumptions, monitoring processes, contingency plan selection rules etc.

New management practice[49]	Extreme conditions	Effect on management system	Specific nature of learning	Specific impact on management system
Yes	No	No	Nitrogen can be used effectively to extend the lactation.	Nitrogen was retained as a planned option to extend the lactation.
No	Yes	Yes	If cows are under severe nutritional stress during mating they may stop cycling. When the stress is removed, they may exhibit a silent heat which is not observable. As such, the monitoring system may indicate the cows were mated to artificial insemination when they were not.	No management response could be identified to overcome this problem. The knowledge was stored and would be used to account for similar problems in the future.
No	Yes	No	The management system used over the summer was effective in coping with dry conditions.	This confirmed the effectiveness of Farmer A's management system.
No	Yes	No	Regrowth from hay & silage paddocks is poor under dry conditions if they are cut late.	Specified a date by which hay and silage had to be harvested by in the plan. Introduced contingency plans to make supplements early, and if this is not possible, buy-in feed.

Appendix XI. Description of the three years for Farmer B.

Table 1. Comparison of the three years for Farmer B.

Factor	**Year 1**	**Year 2**	**Year 3**
January 1st			
Average pasture cover (kg DM/ha)	2000	1700	2000
Cow condition	4.5 - 5.0	4.10	4.75
Milk production (kg MS/cow/day)	1.31	1.04	1.31 - 1.36
Cow intake (kg DM/cow/day)	14.0	12.0	13 - 14[50]
Cow numbers	323	320	327
Stocking rate (cows/pasture ha)[51]	3.6	3.3	3.4
Rotation length (days)	21 - 22	23 - 24	23 - 24
Calf numbers	0	84	0
February 1st			
Average pasture cover (kg DM/ha)	1980	1600	1700
Cow condition	4.4	3.8	4.65
Milk production (kg MS/cow/day)	1.17 - 1.18	1.04	1.10
Cow intakes (kg DM/cow/day)	13.0	12.0	14.0
Cow numbers	323	320	319
Stocking rate (cows/pasture ha)	3.6	3.3	3.3
Rotation length (days)	21 - 22	23 - 24	23 - 24
Calf numbers	0	84	0
March 1st			
Average pasture cover (kg DM/ha)	1990	1530	1450
Cow condition	4.0	3.8	4.25
Milk production (kg MS/cow/day)	1.06 - 1.08	0.96 - 1.04	1.04
Cow intakes (kg DM/cow/day)	12.5	11.0	11.0 - 13.0
Cow numbers	319	270	319
Stocking rate (cows/pasture ha)	3.6	2.8	3.3
Rotation length (days)	32	23 - 24	23 - 24
Periods when the forage crop was fed	1 - 18th February 1 - 5th March	28th January to 8th March	8th February until 6th March
Area (ha)	5.2	3.2	8.0
Yield/ha (kg DM/ha)	7,000[52] 3,500[53]	10,000	5,000[54]
Periods when grass silage fed	19 - 29th February, 6th March to 7th April	10 - 27th January	20th December to 22nd March
Amount fed (wet tonnes)	120	75	500
Date urea applied to pasture	NA	5th March	NA
Amount applied (Tonnes)	0	4.0	0

50 Included 3.0 - 4.0 kg DM/cow/day of grass silage.
51 Based on the number of cows on-hand divided by the effective area in pasture.
52 At first grazing.
53 At second grazing.
54 Forage crop yield increased to 10,000 kg DM/ha over the period it was grazed.

Factor	**Year 1**	**Year 2**	**Year 3**
April 1st			
Average pasture cover (kg DM/ha)	1840	1480	1950
Cow condition	4.0	4.2	4.1
Milk production (kg MS/cow/day)	1.06 - 1.08	0.99 - 1.01	1.04
Cow intakes (kg DM/cow/day)	12.0	11.0	15.0
Cow numbers	319	242	319
Stocking rate (cows/pasture ha)	3.6	2.5	3.3
Rotation length (days)	42	23 - 24	23 - 24
Period of Maize silage feeding	8th April to 5th May	NA	7th March to April 13th
Amount (wet tonnes)	100	0	350[55]
Period of green feed maize feeding	NA	11th April to 5th May	NA
Amount (wet tonnes)	0	125	0
Period cut grass fed	NA	6 - 20th May	NA
Amount fed (kg DM)	0	10,000	0
May 1st			
Average pasture cover (kg DM/ha)	2014	1650	2700
Cow condition	4.5	4.6	4.4
Milk production (kg MS/cow/day)	1.01 - 1.04	1.01 - 1.08	1.20
Cow intakes (kg DM/cow/day)	14.0	15.0	16.0
Cow numbers	230	233	297
Stocking rate (cows/pasture ha)	2.6	2.4	3.1
Rotation length (days)	60	30 - 34 [56]	30 - 35
Drying off date	13th May	26th May	27th May
Cow numbers at drying off	230	172	206
Stocking rate (cows/pasture ha)	2.6	1.8	2.2
Milk production (kg MS/cow/day)	1.01	1.01 - 1.04	1.01
Condition score	4.6	5.0	4.6
Average pasture cover (kg DM/ha)	1926	1800	2000
Date herd on once-a-day	6th May	20th May	20th May
Rotation length at drying off (days)	100	100	100

[55] In mid December, Farmer B thought that he would be able to use all the maize silage during the autumn. However, after discussions with the owner later in the season, Farmer B was asked to leave 100 wet tonnes of the maize silage in the stack. This reduced the amount of maize silage he could use through the autumn to 250 wet tonnes.

[56] The rotation was extended out to 50 days as culls and thinner cows were dried off and removed from the property in early May.

Appendix XII. The planning heuristics used by Farmer B.

Table 1. Decision rules used by Farmer B to develop his plan[57] for the summer-autumn[58] in year one.

Planned event	Decision rule	Reasons behind the rules
Select summer stocking rate **Input type and level rule**	Select the stocking rate at which the herd can be fed such that production can be maintained at, or above 1.04 kg MS/cow/day through until mid March. Assess the average pasture cover, climatic conditions, pasture growth rates and supplements on-hand, around late December. Estimate the likely forage crop yield. From this decide on the number of cows that can be taken through the summer.	Farmer B wants to take as many cows as possible through the summer to take advantage of the autumn rains. He believes that the most efficient use of feed is to run enough cows to produce at 1.04 kg MS/cow/day. Cull cows are sold prior to the start of the summer period.
Maintain the herd on a 21 - 22 day rotation until milk production falls to 1.13 kg DM/ha/day. **Sequencing rule** **Input type and level rule** **Termination rule**	Graze pasture before feeding the forage crop IF date ≥ January 1st, AND the forage crop is ungrazed, AND milk production > 1.13 kg MS/cow/day, THEN maintain the rotation length at 21 - 22 days.	Farmer B used pasture before the forage crop so that the forage crop could reach optimum yield. IF Farmer B used a faster rotation, the herd would overgraze the sward, limiting pasture regrowth, particularly after rain. The farm is susceptible to over-grazing because of the high stocking rate. This method also stops the sward opening up allowing weed species to invade. The majority of the farm is in 4.0 ha paddocks which suits a 21 - 22 day rotation.
Feed the forage crop when milk production falls to 1.13 kg MS/cow/day. Feeding should occur from early February for four weeks. When grazing the forage crop, maintain milk production at 1.04 kg MS/cow/day. **Activation rule** **Input type and level rule**	Feed the forage crop in late January, early February IF milk production ≤ 1.13 kg MS/cow/day, AND the forage crop is ungrazed, THEN feed sufficient forage cop to maintain milk production at 1.04 kg MS/cow/day.	The forage crop must be grazed at this point in time or it loses quality as it matures. Farmer B used Japanese millet because it is more flexible than tumips. It can be fed over a longer period, regrazed, or made into silage if not required. The forage crop is fed during a period when feed demand normally exceeds pasture growth due to dry summer conditions. The forage crop is used to maintain milk production at target and ensure the post-grazing residual is maintained above a minimum level. This prevents over-grazing, increases pasture growth rates and ensures pastures respond quickly to rain. The forage crop allows Farmer B to increase post-grazing residuals.
Maintain milk production at 1.04 kg MS/cow/day on the supplement. **Input type and level rule**	IF the herd is being fed supplements, AND it is summer, THEN feed sufficient supplement to maintain milk production at 1.04 kg MS/cow/day.	Farmer B believes that if milk production falls below 1.04 kg MS/cow/day, the herd is being underfed and will lose condition rapidly. This does depend to some extent on the stage of lactation. At this level of milk production, the herd leave behind a post-grazing residual that enhances pasture growth and prevents over-grazing.

[57] The decision rules for the autumn plan in this table only encompass those used through until drying off.
[58] This was used in years one and two of the study with minor modifications.

Planned event	Decision rule	Reasons behind the rules
Feed grass silage after the forage crop at the start of March for four weeks. **Sequencing rule** **Activation rule** **Input type and level rule**	Feed the grass silage after the forage crop. IF the forage crop is grazed off, AND the pre-grazing pasture cover is insufficient to maintain milk production at 1.04 kg MS/cow/day, THEN feed sufficient grass silage to maintain milk production at 1.04 kg MS/cow/day.	Grass silage does not deteriorate over time, but the forage crop does. Quality declines as the crop matures. The grass silage is fed during a period when feed demand normally exceeds pasture growth due to dry summer conditions. The forage crop is used to maintain milk production at target and ensure the post-grazing residual is maintained above a minimum level.
Use the grass silage to extend the rotation out to 35 - 42 days. **Input type and level rule**	IF grass silage is being fed to the herd, AND the rotation length is < 35 - 42 days, AND the pre-grazing pasture cover is such that the rotation can be extended without dropping milk production below target, THEN extend the rotation, ELSE increase the ration of grass silage so that the rotation can be extended out to 35 - 42 days.	Farmer B used the grass silage to extend the rotation out to 35 - 40 days. This is possible in a wet year, but Farmer B finds that in a dry year, the rotation may only be extended out to a 25 - 28 day round. Farmer B believed that a longer round, in combination with adequate post-grazing residuals, at this time of year increased pasture growth rates.
Regraze the forage crop for a week when it is ready, then continue to feed the grass silage. **Sequencing rule** **Termination rule** (of silage) **Activation rule** **Input type and level rule**	IF the forage crop is ready to be regrazed, AND the herd is being fed silage, THEN substitute the silage for forage crop and maintain milk production at or above 1.04 kg MS/cow/day.	The forage crop Japanese millet regrows after grazing and Farmer B expects one or two additional grazings off the crop.
Pregnancy test the herd 6 - 8 weeks after the bull is removed. **Activation rule**	IF the bull is removed on date = X, THEN pregnancy test the herd 6 - 8 weeks after this date.	To accurately diagnose pregnancy status, the herd should not be examined for at least six weeks after the bull has been removed.
Sell cull cows in early April after pregnancy diagnosis. **Sequencing rule** **Activation rule**	Sell the cull cows after pregnancy diagnosis. IF it is early April, AND the cull cows have been identified, THEN sell the cull cows.	Farmer B does not want to cull in-calf cows, so he delays culling until he knows exactly which cows are in-calf. Farmer B stated that culling is a form of supplement, and by culling, he can increase the feed supply to the rest of the herd.
Dry off thin rising three year old and induction cows **Termination rule**	Dry off the thin induction and rising three year old cows in late March, early April. IF the condition of a cow is ≤ threshold, AND the cow is to be induced, OR the cow is a rising three year old, THEN dry off the cow.	To ensure the induced cows are in good condition at calving, the thin ones are dried off. Similarly, thin rising three year old cows are dried off in late lactation to ensure they calve in good condition. The date at which Farmer B expects to undertake this management practice depends upon the season. In a wet summer, it will be in late March, early April, but in a dry year, it may start as early as January.

Planned event	Decision rule	Reasons behind the rules
Feed maize silage after the grass silage and prior to drying off. **Sequencing rule** **Activation rule** **Input type and level rule**	Feed the maize silage after the grass silage has been fed. IF milk production is ≤ 1.04 kg MS/cow/day, AND the forage crop is grazed, AND the grass silage is fed out, THEN feed the maize silage at such a rate that milk production is held at 1.04 kg MS/cow/day.	The maize silage is used to increase average pasture cover and cow condition pre-winter. It is a good feed for holding or increasing cow condition in late lactation.
Termination rule	Stop feeding maize silage once the drying off process is initiated. IF the drying off process is to be initiated, AND the herd is being fed maize silage, THEN stop feeding maize silage.	To effectively dry off the herd, cow intakes must be reduced rapidly. This is achieved through the cessation of maize silage and increasing the rotation length.
Dry off the herd **Sequencing rule** **Termination rule**	Dry off the herd after all other options are exhausted. Dry off the herd on the date estimated through the feed budget analysis.	The herd is dried off to ensure sufficient average pasture cover is on-hand to meet targets at calving and at balance date. The drying off date is also used to ensure the herd calve at target condition score.

Table 2. Sequencing rules used by Farmer B for the summer and autumn[59] plans in year one.

Decision rule	Reason
Cull low producing and diseased cows as they are identified.	There is no point retaining low producing cows or those with disease because they tend to be inefficient at converting feed to milk and feed is a limiting resource at this time of year.
Maintain 21 - 22 day round before grazing the forage crop in late January, early February.	In a normal year there is sufficient pasture to delay the grazing of the forage crop until late January, early February. The forage crop is actively growing up until this point and by not grazing it until the specified time yield is maximised.
Remove bull in early February.	The bull is left with the herd to mate late cycling cows. Farmer B does not see any point leaving the bull out for more than this number of cycles.
Graze the forage crop before feeding silage.	Silage does not deteriorate over time and can be stored. Once the forage crop reaches maturity, its feed quality can decline. The forage crop must also be grazed so that the new grass can be sown by mid March. February is the driest month and the period when the deficit between feed demand and pasture growth is greatest. The forage crop is fed at this point in time to fill this feed deficit.
Sow the new grass after the forage crop has been grazed.	The new grass cannot be sown until after the forage crop has been grazed.
Feed silage after the forage crop.	Once the forage crop is grazed in early March, conditions can still be dry and by feeding the silage at this point, average pasture cover can be maintained at a higher level ensuring higher pasture growth rates, particularly when the autumn rains arrive. Milk production and cow condition are also maintained.
While on the grass silage, extend the rotation length out to 35 - 42 days.	Conditions improve through March, and as average pasture cover increases, silage can be used to extend the rotation. while at the same time maintaining post-grazing residuals, cow intakes, milk production and cow condition. This is not possible in February which is normally the driest month. A combination of a longer rotation length with high post-grazing residuals is expected to increase pasture growth rates.
Regraze the forage crop when it is at the correct yield part-way through the silage feeding period.	Japanese millet regrows after its initial grazing. It should be ready for a second grazing part-way through the silage feeding period. It goes to seed and can lose quality if not grazed at the correct time, whereas silage does not deteriorate over time.
Feed maize silage over the autumn after the grass silage has been fed.	Maize silage increases cow body condition and is used in the autumn to increase cow condition. It is fed after the silage to increase both average pasture cover and cow condition prior to drying off.
Pregnancy test the herd 6 - 8 weeks after the bull is removed.	To accurately diagnose pregnancy status, the herd should not be examined for at least six weeks after the bull has been removed.
Cull empty cows in early April after pregnancy diagnosis.	Farmer B does not want to cull in-calf cows, so he delays culling until after pregnancy diagnosis. As the schedule declines over the autumn, Farmer B prefers to sell his empty cows once identified. He expects that total milk production will not change much as the feed the culls did eat is now used by the remainder of the herd, improving per cow milk production over the period post-culling.
Dry off thin, younger cows.	The younger cows tend to lose condition over the summer, and reach a level in the autumn at which point they need to be dried off in order to increase their condition up to target by calving.
Dry off the herd.	Drying off is an irrevocable decision and once undertaken, milk production, and the generation of income from this activity ceases. Therefore, this decision is delayed for as long as possible and implemented when all other options are exhausted.

[59] The decision rules for the autumn plan in this table only encompass those used through until drying off.

Table 3. Decision rules used by Farmer B to develop his plan[60] for the summer-autumn in year two.

Planned event	Decision rule	Reasons behind the rules
Set stock the calves across the entire farm over the summer-autumn. **Activation rule** **Input level rule**	IF calves are run on the milking area, AND it is summer, THEN setstock the calves over the entire farm.	To ensure high rates of liveweight gain, the calves were setstocked across the entire farm. Setstocking ensures high intakes and minimises stress.
Select summer stocking rate **Input level rule**	Select the stocking rate at which the herd can be fed such that production can be maintained at, or above 1.04 kg MS/cow/day through until mid March. Assess the average pasture cover, climatic conditions, pasture growth rates and supplements on-hand, around late December. Estimate the likely forage crop yield. From this decide on the number of cows that can be taken through the summer.	Farmer B wants to take as many cows as possible through the summer to take advantage of the autumn rains. He believes that the most efficient use of feed is to run enough cows to produce at 1.04 kg MS/cow/day. Cull cows are sold prior to the start of the summer period.
Maintain the herd on a 23 - 24 day rotation feeding solely pasture until three weeks before the end of the month. **Sequencing rule** **Input level rule**	IF average pasture cover and expected pasture growth rates are insufficient to maintain the herd at target milk production until the end of January, AND grass silage is available, AND grass silage is insufficient to fully feed the herd until the end of January, AND no other supplements are available, THEN maintain the herd on their current rotation length allowing milk production to fall below target and begin feeding the silage at the point when it can be used to feed the herd to target until the end of January.	IF Farmer B used a faster rotation, the herd the farm would be in a worse position at the start of the next round because average pasture cover would have been reduced more quickly. Extending the rotation would reduce cow intakes and post-grazing residuals. Low post-grazing residuals limit pasture growth rates. Farmer B preferred to feed grass silage later rather than earlier, because if he fed it early, and then ran out, the drop in cow intakes and milk production would be much more dramatic than that which would occur if he delayed the silage feeding. The other risk of feeding the grass silage early is that Farmer B may have been tempted to then feed the forage crop early when the grass silage ran out.
During this period, allow milk production to fall below 1.04 kg MS/cow/day. **Target setting rule** **Input level rule**	IF average pasture cover and expected pasture growth rates are insufficient to maintain the herd at target milk production until the end of January, AND grass silage is available, AND grass silage is insufficient to fully feed the herd until the end of January, AND no other supplements are available, THEN ignore the milk production target for the period when the herd is grazing solely pasture and draw on cow condition as an alternative supplement.	In a dry year, Farmer B knows he cannot feed the herd to target. Therefore, he uses cow condition as another form of supplement to ensure he can carry as many lactating cows as possible through the summer.

[60] The decision rules for the autumn plan in this table only encompass those used through until drying off.

Planned event	Decision rule	Reasons behind the rules
Feed grass silage before the forage crop. **Sequencing rule** Feed grass silage at the point when it can be used to feed the herd to target until the end of January. **Activation rule** **Input level rule**	IF average pasture cover and expected pasture growth rates are insufficient to maintain the herd at target milk production until the end of January, AND grass silage is available, AND grass silage is insufficient to fully feed the herd until the end of January, AND no other supplements are available, THEN maintain the herd on their current rotation length allowing milk production to fall below target and begin feeding the silage at the point when it can be used to feed the herd to target until the end of January.	Farmer B feeds grass silage in January before the forage crop in a dry year because the forage crop is still actively growing at this point in time whereas the grass silage yield will not change with time. Therefore the grass silage is fed to optimise the dry matter yield from the forage crop. Farmer B still wants to maintain milk production above 1.04 kg MS/cow/day when feeding supplements in order to minimise loss of body condition.
While feeding silage and the forage crop, maintain the herd on a 23 - 24 day rotation unless the feed situation improves. **Input level rule**	IF grass silage is being fed prior to the forage crop, AND conditions are dry, AND the current rotation length is 23 - 24 days, AND supplement is limited, AND post-grazing residuals are at, or below target, THEN maintain the rotation length at 23 - 24 days until feed conditions improve.	Farmer B did not have sufficient feed on hand to extend the rotation while maintaining post-grazing residuals and cow intakes at target. If post-grazing residuals were reduced, then pasture regrowth would be inhibited. Any reduction in cow intakes would reduce milk production and cow condition.
Feed the forage crop at the end of January after the grass silage at a level that maintains milk production at 1.04 kg MS/cow/day. **Sequencing rule** **Activation rule** **Input level rule**	Feed the forage crop in late January, early February IF the grass silage has been fed, AND it is a dry year, AND it is late January, THEN feed the forage crop at such a rate that milk production is held at 1.04 kg MS/cow/day.	At this point in time, Farmer B has optimised yield given his other constraint that he must have the forage crop grazed by the end of the month to ensure the new grass is planted at the correct time. The forage crop is used to maintain milk production at target and ensure the post-grazing residual is maintained above a minimum level. This prevents over-grazing, increases pasture growth rates and ensures pastures respond quickly to rain. The forage crop allows Farmer B to increase post-grazing residuals.
In a dry year make the forage crop last until the end of February, and reduce cow numbers if necessary to maintain milk production at 1.04 kg MS/cow/day. **Termination rule** **Input level rule**	IF it is a dry year, AND a forage crop is available, AND the grass silage has been used, AND the level of other supplement on the farm is limited, THEN ensure the forage crop lasts for the month of January and dry off cows to ensure milk production is held around 1.04 kg MS/cow/day.	IF the forage crop was fed at a faster rate, Farmer B believed that it would be used more quickly and then when it was finished there would be little feed available for the herd. The alternative approach forces Farmer B to dry off cows to ensure milk production is maintained at 1.04 kg MS/cow/day. As such, it increases the likelihood of having a proportion of the herd in a lactating state at the end of February. The milk production target ensures higher post-grazing residuals and therefore higher pasture growth rates. At this level of milk production, intakes are sufficient to limit the rate at which the herd loses condition.

Planned event	Decision rule	Reasons behind the rules
Remove the bull in early February. **Termination rule**	IF date = early February, THEN remove the bull	Farmer B allows the bull to remain with the herd for a specified period to ensure later cycling cows are mated.
Dry off thin cows if there is insufficient feed to maintain milk production at 1.04 kg MS/cow/day. **Termination rule**	IF intakes are predicted to fall below target, AND it is a dry year, AND the herd is grazing the forage crop, AND no additional supplement is available, AND the condition of the herd is < 4.0, THEN dry off sufficient thin cows to ensure the remaining cows are fed to target, and graze them off the milking area.	If Farmer B did not dry off the thin cows through February, the forage crop would be used more quickly, and when it was finished there would be no further supplements with which to augment the herd's diet. In this situation, Farmer B would have to dry off the herd. As such, he would not have cows in a lactating state in March/April to take advantage of the autumn rains.
Complete the grazing of the forage crop by the end of February. **Termination rule**	Terminate forage crop grazing by the end of February.	To ensure the new grass is well established, it must be planted by mid March. Therefore, the forage crop must be grazed off by the end of February to allow time for cultivation and sowing.
Maintain the herd on a 23 -24 day rotation after the forage crop unless the feed situation improves. **Sequencing rule** **Input level rule**	IF average pasture cover is low, AND supplements are unavailable, THEN maintain rotation length at 23 - 24 days until the feed position improves.	Farmer B needs some form of supplement or high average pasture covers so that he can extend the rotation without reducing cow intakes and post-grazing residuals. In a dry year, with limited supplements, this is not possible until the autumn rains arrive and pasture growth rates increase rapidly.
Dry off thin cows if there is insufficient feed to maintain milk production at 1.04 kg MS/cow/day and graze them off the farm. **Termination rule**	IF intakes are predicted to fall below target, AND it is a dry year, AND the herd is grazing the forage crop, AND no additional supplement is available, AND the condition of the herd is < 4.0, THEN dry off sufficient thin cows to ensure the remaining cows are fed to target, and graze them off the milking area.	This practice achieves three end points. First, it removes thin cows from the herd so that their condition can be improved in time for calving. Second, it ensures the lactating cows are fed to target, minimising the loss of condition. Third, it ensures higher post-grazing residual's are maintained, which in turn results in higher pasture growth rates.
Pregnancy test the herd 6 - 8 weeks after the bull is removed (Normally mid - late March). **Sequencing rule** **Activation rule**	IF the bull is removed on date = X, THEN pregnancy test the herd 6 - 8 weeks after this date.	To accurately diagnose pregnancy status, the herd should not be examined for at least six weeks after the bull has been removed.
Sell cull cows in early April after pregnancy diagnosis. **Sequencing rule** **Termination rule**	Sell the cull cows after pregnancy diagnosis IF it is early April, AND the cull cows have been identified, THEN sell the cull cows.	Farmer B does not want to cull in-calf cows, so he delays culling until he knows exactly which cows are in-calf. Farmer B stated that culling is a form of supplement, and by culling, he can increase the feed supply to the rest of the herd.
Dry off the herd. Date unknown, but is very dependent on pasture growth over the summer-autumn and the acquisition of other feed sources. **Sequencing rule** **Termination rule**	Dry off the herd after all other options are exhausted. Dry off the herd on the date estimated through the feed budget analysis.	The herd is dried off to ensure sufficient average pasture cover is on-hand to meet targets at calving and at balance date. The drying off date is also used to ensure the herd calve at target condition score.

Table 4. Sequencing rules used by Farmer B for the summer and autumn[61] plans in year two.

Decision rule	Reason
Cull low producing and diseased cows as they are identified.	There is no point retaining low producing cows or those with disease because they tend to be inefficient at converting feed to milk and feed is a limiting resource at this time of year.
Maintain 23 - 24 day round until three weeks before the end of January.	Estimates suggested the average pasture cover and pasture growth rates were insufficient to feed the herd on a solely pasture diet until the end of January. There was 3 weeks silage available, and Farmer B wanted to delay grazing the forage crop until the end of January to maximise yield. A decision was made to feed the herd on pasture for the first ten days of January and then feed silage. Feeding silage first would result in a large decline in cow intakes for about ten days after it was finished and until the time the forage crop could be grazed. This would cause a large reduction in milk production per cow which would require a lot of feed to retum to normal levels once the herd went onto the forage crop.
Feed the silage before the forage crop.	The forage crop will increase in yield through time, whereas silage remains static. Therefore it is better to use silage to maintain milk production and allow the forage crop to increase in yield if some form of supplement has to be fed before the end of January.
Graze the forage crop after feeding silage.	The forage crop will increase in yield through time, whereas silage remains static. Therefore it is better to use silage to maintain milk production and allow the forage crop to increase in yield if some form of supplement has to be fed before the end of January.
Remove bull in early February.	The bull is left with the herd to mate late cycling cows. Farmer B does not see any point leaving the bull out for more than this number of cycles.
Sow the new grass after the forage crop has been grazed.	The new grass cannot be sown until after the forage crop has been grazed.
Dry off thin, younger cows.	In a dry year, the thin, younger cows will lose condition more quickly. When these reach the threshold, they should be dried off to ensure they have time to retum to target condition by calving. This will also free up feed for the remainder of the herd.
Pregnancy test the herd 6 - 8 weeks after the bull is removed.	To accurately diagnose pregnancy status, the herd should not be examined for at least six weeks after the bull has been removed.
Cull empty cows in early April after pregnancy diagnosis.	Farmer B does not want to cull in-calf cows, so he delays culling until after pregnancy diagnosis. As the schedule declines over the autumn, Farmer B prefers to sell his empty cows once identified. He expects that total milk production will not change much as the feed the culls did eat is now used by the remainder of the herd, improving per cow milk production over the period post-culling.
Dry off the herd.	Drying off is an irrevocable decision and once undertaken, milk production, and the generation of income from this activity ceases. Therefore, this decision is delayed for as long as possible and implemented when all other options are exhausted.

[61] The decision rules for the autumn plan in this table only encompass those used through until drying off.

Table 5. Decision rules used by Farmer B to develop his plan[62] for the summer-autumn[63] in year three.

Planned event	Decision rule	Reasons behind the rules
Initiate summer plan early. **Sequencing rule**	If the feed situation becomes serious in December, and there is sufficient supplement on-hand, and there are constraints on culling and/or grazing off dry cows, then initiate the summer plan ahead of schedule.	One option over December if conditions become dry is to destock through culling or drying off thin cows and grazing them off. However, in year three, Farmer B did not want to cull cows until he knew their pregnancy status as he wanted to increase cow number for the following season. He could not graze cows off on the runoff because silage had just been harvested and the paddocks needed several weeks to recover. However, Farmer B did have a considerable quantity of grass silage on-hand. He estimated that there was sufficient to feed the herd from late December through until when the forage crop would be ready to graze in early March. The grass silage would be used to maintain milk production, cow condition, average pasture cover and post-grazing residuals.
Select summer stocking rate. **Input type and level rule**	Select the stocking rate at which the herd can be fed such that production can be maintained at, or above 1.04 kg MS/cow/day through until mid March. Assess the average pasture cover, climatic conditions, pasture growth rates and supplements on-hand, around late December. Estimate the likely forage crop yield. From this decide on the number of cows that can be taken through the summer.	Farmer B wants to take as many cows as possible through the summer to take advantage of the autumn rains. He believes that the most efficient use of feed is to run enough cows to produce at 1.04 kg MS/cow/day. Cull cows are sold prior to the start of the summer period.
Maintain the herd on a 23 - 24 day rotation and feed sufficient silage to maintain milk production above 1.04 kg MS/cow/day. **Sequencing rule** **Input type and level rule**	IF analysis of pre- and post-grazing residuals suggests pasture growth rates are declining and as a result, cow intakes will continue to decline, AND the rotation length = minimum, THEN maintain the herd on the current rotation length. IF it is late December, AND analysis of pre- and post-grazing residuals suggests pasture growth rates are declining and as a result, cow intakes will continue to decline, AND there is sufficient grass silage on-hand to feed the herd from late December until early March when the forage crop will be ready to graze, THEN initiate grass silage feeding and provided sufficient grass silage (3 - 4 kg DM/cow/day) to maintain milk production ≥ 1.04 kg MS/cow/day.	IF Farmer B used a faster rotation, the herd the farm would be in a worse position at the start of the next round because average pasture cover would have been reduced more quickly. Extending the rotation would reduce cow intakes and post-grazing residuals. Low post-grazing residuals limit pasture growth rates. Farmer B had estimated that he had sufficient grass silage to feed the herd from late December until early March. His indicators suggested pasture cover, cow intakes, post-grazing residuals and milk production would decline rapidly over the next 3 - 4 weeks unless he took some action. Given that he did not want to cull the herd, nor graze any cows off, he decided to feed the grass silage. This would help maintain cow intakes, post-grazing residuals, average pasture cover, milk production and cow condition. Because the farmer was leaving the farm, there was no advantage in retaining the grass silage for use during another period. From March on, he had other options such as the forage crop, maize silage, culling and grazing off. His priority was to maintain the pasture in an actively growing state and ensure as many cows as possible made it through to March in a lactating

[62] The decision rules for the autumn plan in this table only encompass those used through until drying off.
[63] This was used in years one and two of the study with minor modifications.

Planned event	Decision rule	Reasons behind the rules
		state. Farmer B aimed to hold milk production at, or above 1.04 kg MS/cow/day because this minimised loss of condition in the herd and maintained post-grazing residuals at a reasonable level. Farmer B noted that this "*was not a hard and fast rule*" and that milk production might fall below this level, and he expected to lose some condition over the summer, especially if it remained dry.
Remove the bull in early February. **Termination rule**	IF date = early February, THEN remove the bull	Farmer B allows the bull to remain with the herd for a specified period to ensure later cycling cows are mated.
Dry off thin cows if their condition falls below target from February onwards. **Termination rule**	IF individuals cows condition is ≤ target, AND the month ≥ February, THEN dry off the cow and place it on the runoff to increase condition.	Farmer B did not want to dry off any thin cows until February in order to allow the silage paddocks sufficient time to recover. Given the current condition of the herd and the feed position, he believed that he would not have to dry off thin cows until February. His plan was then to dry off cows as their condition declined to target and then place them on the runoff to increase condition for calving. IN year three, Farmer B had increased his condition score target at calving from 4.75 to 5.00 condition score units. He therefore had to ensure his thinner cows were removed from the herd at a point in time that allowed them to put on sufficient condition to meet target.
Feed the forage crop at the beginning of March after the grass silage at a level that maintains milk production at 1.0 kg MS/cow/day. **Sequencing rule** **Activation rule** **Input type and level rule** Finish feeding the forage crop by the 7th March. **Termination rule**	IF the forage crop yield is poor, AND analysis of pre- and post-grazing residuals suggests pasture growth rates are declining and as a result, cow intakes will continue to decline, AND there is sufficient grass silage on-hand to feed the herd to requirements, THEN use the grass silage first, and delay the grazing of the forage crop for as long as possible. IF it is early March, THEN feed the forage crop at such a rate that milk production is held at 1.04 kg MS/cow/day. Terminate forage crop grazing by the end of February. IF estimates suggest the forage crop will provide a weeks grazing, AND there is sufficient silage on-hand to feed the herd through until early March, AND the forage crop must be grazed by the 7th March, THEN plan to begin grazing the forage crop at the start of March.	The forage crop was used after the grass silage because it increases in yield with time, whereas, the grass silage yield does not change. Farmer B decided that with his current level of grass silage and the poor nature of his forage crop, that his best option was to allow it to grow for as long as possible to maximise yield. He estimated that the forage crop would provide a weeks grazing for the herd. He wanted to have the new grass resown by the start of April, and this limited how long he could leave the forage crop ungrazed. In order to ensure the new grass was sown on time, Farmer B had to graze the forage crop at the start of March. The forage crop is used to maintain milk production at target and ensure the post-grazing residual is maintained above a minimum level. This prevents over-grazing, increases pasture growth rates and ensures pastures respond quickly to rain. The forage crop allows Farmer B to increase post-grazing residuals. The milk production target ensures higher post-grazing residuals and therefore higher pasture growth rates. At this level of milk production, intakes are sufficient to limit the rate at which the herd loses condition.
Sow the new grass by mid March. **Sequencing rule** **Activation rule**	The new grass should be sown by mid March after the forage crop has been grazed.	Good establishment of new pastures requires that they are sown in March.
Maintain the herd on a 23 -24 day rotation after the forage crop unless the feed situation improves. **Sequencing rule** **Input type and level rule**	IF average pasture cover is low, AND supplements are unavailable, THEN maintain rotation length at 23 - 24 days until the feed position improves.	Farmer B needs some form of supplement or high average pasture covers so that he can extend the rotation without reducing cow intakes and post-grazing residuals.

Planned event	Decision rule	Reasons behind the rules
Feed maize silage after the forage crop to maintain milk production at, or above 1.04kg MS/cow/day and hold or increase cow condition. **Sequencing rule** **Activation rule** **Input type and level rule**	IF the forage crop has been grazed, AND analysis of pre- and post-grazing residuals suggests cow intakes and milk production will decline below target, AND maize silage is on-hand, THEN feed sufficient maize silage to maintain milk production at, or above 1.04 kg MS/cow/day and hold or increase condition.	Farmer B uses maize silage during the autumn to extend the lactation, maintain or increase cow condition and increase average pasture cover.
Pregnancy test the herd 6 - 8 weeks after the bull is removed in late March. **Sequencing rule** **Activation rule**	IF the bull is removed on date = X, THEN pregnancy test the herd 6 - 8 weeks after this date.	To accurately diagnose pregnancy status, the herd should not be examined for at least six weeks after the bull has been removed.
Herd test in early April after pregnancy diagnosis. **Sequencing rule** **Activation rule**	IF the herd is to be pregnancy tested in late March, AND herd test information is required for culling decisions, THEN herd test in early April.	Herd testing provides important information for culling purposes. As culling occurs after pregnancy diagnosis, it is useful to undertake a herd test around the same time.
Sell cull cows around mid April after pregnancy diagnosis and herd testing. **Sequencing rule** Termination rule	Sell the cull cows after pregnancy diagnosis and herd testing. IF it is early April, AND the herd has been pregnancy tested, AND the herd has been herd tested, AND the cull cows have been identified, THEN sell the cull cows.	Farmer B does not want to cull in-calf cows because he wants to increase herd size for next season. Therefore he planned to delay culling until after pregnancy diagnosis and herd testing so that he knows exactly which cows are in-calf and which cows to retain for next season.
Harvest the 8.0 ha maize crop for maize silage. **Activation rule**	IF the maize crop is mature, THEN harvest it for maize silage.	Maize silage must be harvested a the right stage of maturity to maximise yield and quality. This normally occurs around mid April in the Manawatu.
Dry off the herd in May. **Sequencing rule** **Termination rule**	Dry off the herd after all other options are exhausted and the feed budget shows that the target of 2000 kg DM/ha at June 1st will be met.	This season Farmer B believes with the level of supplements on-hand, he can milk through until May. However, because he is moving to a new farm, he must leave the farm with an average pasture cover of 2000 kg DM/ha on June 1st. This target will dictate his drying off date. His cow condition target for calving will influence his decision to dry off thin cows through the autumn and it may also dictate the drying off date.

Table 6. Sequencing rules used by Farmer B for the summer and autumn[64] plans in year three.

Decision rule	Reason
Cull low producing and diseased cows as they are identified.	There is no point retaining low producing cows or those with disease because they tend to be inefficient at converting feed to milk and feed is a limiting resource at this time of year.
Maintain 23 - 24 day round and feed silage.	If conditions are dry, and there is sufficient silage to supplement the herd from late December until the end of February, and there is enough forage crop and maize silage to feed the herd from March until drying off, then feed the silage through that period. The silage will increase post-grazing residuals and improve pasture growth rates. It will also hold milk production and cow condition. The forage crop is still growing and therefore delaying the use of the forage crop will increase yield. The alternative is to feed the silage after the forage crop, but this would allow average pasture cover to decline and as a result, cow intakes, milk production and cow condition.
Feed the silage before the forage crop.	The forage crop will increase in yield through time, whereas silage remains static. Therefore it is better to use silage to maintain milk production and allow the forage crop to increase in yield particularly if the forage crop is very poor, and there is a plentiful supply of silage.
Remove bull in early February.	The bull is left with the herd to mate late cycling cows. Farmer B does not see any point leaving the bull out for more than this number of cycles.
Dry off thin, younger cows.	In a dry year, the thin, younger cows will lose condition more quickly. When these reach the threshold, they should be dried off to ensure they have time to return to target condition by calving. This will also free up feed for the remainder of the herd.
Graze the forage crop after feeding silage.	The forage crop will increase in yield through time, whereas silage remains static. Therefore it is better to use silage to maintain milk production and allow the forage crop to increase in yield if some form of supplement has to be fed before the end of January.
Sow the new grass after the forage crop has been grazed.	The new grass cannot be sown until after the forage crop has been grazed.
Feed maize silage over the autumn after the grass silage has been fed.	Maize silage increases cow body condition and is used in the autumn to increase cow condition. It is fed after the silage to increase both average pasture cover and cow condition prior to drying off.
Pregnancy test the herd 6 - 8 weeks after the bull is removed.	To accurately diagnose pregnancy status, the herd should not be examined for at least six weeks after the bull has been removed.
Cull empty cows in early April after pregnancy diagnosis.	Farmer B does not want to cull in-calf cows, so he delays culling until after pregnancy diagnosis. As the schedule declines over the autumn, Farmer B prefers to sell his empty cows once identified. He expects that total milk production will not change much as the feed the culls did eat is now used by the remainder of the herd, improving per cow milk production over the period post-culling.
Dry off the herd.	Drying off is an irrevocable decision and once undertaken, milk production, and the generation of income from this activity ceases. Therefore, this decision is delayed for as long as possible and implemented when all other options are exhausted.

[64] The decision rules for the autumn plan in this table only encompass those used through until drying off.

Appendix XIII. The method and frequency of data collection used by Farmer B.

Figure 1. A summary of the direct and indirect measures used by Farmer B over summer.

Factor	Measurement	Method		Fre-quency	Role	Classification of Role[65]
Production Factors	**Direct Method**	**Indirect**	**Method**			
Feed Factors[66]		**Indicator**	**Method**			
Average pasture cover (APC)	Falling plate meter			Fortnightly	Used to verify changes in other measures	**Triangulation**
	Visual assessment			Daily	Used to verify changes in other measures	**Early warning**
	Pre- and post grazing residuals[67]			Daily	Used to indicate change in APC	**Early warning**
		Milk production	Milk docket	Daily	Used to indicate a change in APC	**Short-term predictor**
		Cow condition	Condition scoring	Daily	Used to confirm change in APC	**Confirmatory**
		Climate	Rain gauge, visual assessment	Daily	)Used to predict likely)change in APC over)the next fortnight	**Longer-term predictor**
		& Pasture growth data	Falling plate meter	Fortnightly	)	
Pasture growth	Falling plate meter			Fortnightly	Used to verify changes in other measures and predict pasture growth over the next two weeks	**Triangulation Longer-term predictor**
	Visual assessment			Daily	Used to confirm changes in other measures	**Early warning**
		Pre- and post-grazing residuals	Pasture scoring and visual assessment	Intermittent	Used to indicate changes in pasture growth rates	**Short-term predictor**
		Milk production	Milk docket	Daily	Indicates a change in pasture growth	**Short-term predictor**
		Intake	Pasture scoring	Daily	Indicates change in pasture growth rates	**Short-term predictor**
		Cow condition	Condition scoring	Daily	Confirms change in pasture growth	**Confirmatory**
		Climate	Rain gauge Visual assessment	Daily	Predicts increase in pasture growth within two weeks	**Longer-term predictor**
Pasture quality	Visual assessment			Daily	Used to identify problems with pasture quality	**Decision point recognition**
		Milk production	Milk docket	Daily	Used to confirm change in pasture quality	**Confirmatory**

[65] This shows the measures used for decision point and triangulation, and the role of the indirect measures in relation to the direct measures (predictive, early warning, confirmatory).

[66] The falling plate meter was only used over the early summer in year one.

[67] Farmer B visually scores these and calculates the mean. As these are normally the shortest and longest paddocks on the farm, they provide an estimate of APC.

Factor	**Measurement**	**Method**		**Fre-quency**	**Role**	**Classification of Role**[68]
Crop yield	Yield score & visual assessment			Daily	Used to estimate the number of weeks grazing for the herd	**Decision point recognition**
		Milk production	Milk docket	Daily	Used to confirm break size is adequate and yield estimate is correct	**Confirmatory**
Crop growth	Yield score & visual assessment			Daily	Used to verify other measures and determine when to graze along with maturity information	**Triangulation Decision point recognition**
Crop quality and maturity	Visual assessment			Daily	Used to determine when crop maturity is reached	**Decision point recognition**
Silage quantity & quality[69]	Yield scoring & visual assessment			Daily	Used for planning purposes and decisions in relation to supplements	**Planning Decision point recognition**
		Milk production	Milk docket	Daily	Used to confirm estimates of silage yield and quality	**Confirmatory**
Livestock factors						
Cow numbers	Visual assessment				Used to predict feed demand	**Long-term predictor**
Average milk yield	Milk vat (l/cow/day)			Daily	Used to identify when cow intakes and/or condition fall below target	**Decision point recognition**
		Intake	Pasture scoring	When it changes	Used to indicate change in milk production	**Short-term predictor**
		Post-grazing residual	Visual assessment	Daily	Used to indicate change in milk production	**Short-term predictor**
Individual cow milk yields	Herd test			Twice	)Used to identify)potential culls	**Decision point recognition**
Average milk quality	Milk docket (fat/protein)			Daily	Used to verify feed quality assessment	**Confirmatory**
	Bulk count (somatic cell)			Daily	Used to identify milk quality problem	**Decision point recognition**
Individual cow milk quality	Fat/protein Somatic cell count			Once (Herd test)	Used to identify potential culls	**Decision point recognition**
Average herd condition	Condition scoring			Daily	Used to identify when condition was approaching target	**Decision point recognition**
	Visual assessment			Daily	Used to identify when condition was approaching target	**Early warning**
		Milk production	Milk docket	Daily	Used to indicate when the herd is losing condition	**Short-term predictor**
		Post-grazing residuals	Visual assessment	Daily	Indicates change in cow condition	**Short-term predictor**
Individual cow condition	Condition scoring			Daily	Used to identify cows that are below target condition	**Decision point recognition**

[68] This shows the measures used for decision point and triangulation, and the role of the indirect measures in relation to the direct measures (predictive, early warning, confirmatory).

[69] Includes both pasture and maize silage.

Factor	Measurement	Method		Fre-quency	Role	Classification of Role[70]
Intake	Pasture scoring			When it changes	Used to identify when intakes fall below target and to verify other measures	**Decision point recognition Triangulation**
	Visual assessment			Daily	Indicates change in intake	**Early warning**
		Post-grazing residual	Pasture scoring	Daily	)Used to indicate a)change in intake	**Short-term predictor**
			Visual assessment	Daily	)Used to predict cow)intakes in 3 – 4 weeks	**Long-term predictor**
		Milk production	Milk docket	Daily	Used to verify intake estimates and indicate change in intake	**Confirmatory Short-term predictor**
		Cow condition	Condition scoring	Daily	Used to confirm change in intake	**Confirmatory**
		Pasture growth data	Falling plate meter	Fortnightly	Used to predict likely intakes in two weeks time	**Longer-term predictor**
		Climatic data	Rain gauge Visual assessment	Daily	Used with pasture growth rate data to predict intakes in two weeks time	**Longer-term predictor**
Per hectare feed demand (kg DM/ha/day)[71]	Pasture scoring Falling plate meter			When it changed	Used to predict future feed deficits	**Longer-term predictor**
Reproductive status of the herd	Pregnancy test			Once	)Used to identify)potential culls and late)calving cows	**Decision point recognition**
		Bulling behaviour	Visual assessment	Daily		
External Environment Factors						
Climatic factors						
Climate Wind run) Temperature) Cloud cover) Rainfall) Weather forecast)	Rain gauge Visual assessment			Daily	Used to predict changes in average pasture cover, pasture growth and cow intakes two weeks in advance	**Longer-term predictor**
Market factors						
Output Price Factors						
Cull cow schedule	Newspaper & stock agent			Intermittent	Used for selling decisions	**Decision point recognition**
In-calf cow store price	Newspaper & stock agent			Intermittent	Used for selling decisions	**Decision point recognition**
Milk price	Dairy company newsletter			Monthly	Used in option selection decisions	
Input Price Factors						
External feed sources	Newspaper, local farmers			Intermittent	Used to identify feed sources to fill feed deficits or extend lactation	**Decision point recognition**

70 This shows the measures used for decision point and triangulation, and the role of the indirect measures in relation to the direct measures (predictive, early warning, confirmatory).
71 This figure was calculated by multiplying cow intake by stocking rate.

Figure 2. Important factors monitored by Farmer B over the autumn[72].

Factor	Measure-ment	Method		Fre-quency	Role	Classification of Role[73]
Production Factors	**Direct Method**	**Indirect**	**Method**			
Feed factors		**Indicator**	**Method**			
Average pasture cover	Falling plate meter			Fortnightly	Used to identify when APC fell below targets.	**Decision point recognition**
		Milk production	Milk docket	Daily	Used to indicate a change in APC	**Short-term predictor**
		Pre- and post-grazing residuals	Pasture scoring	Daily	Used to indicate a change in APC	**Short-term predictor**
Pasture growth rate	Falling plate meter[74]			Fortnightly	Used in the drying off decision	**Decision point recognition**
Silage quantity & quality[75]	Yield scoring & visual assessment			Daily	Used for planning purposes and decisions in relation to supplements	**Planning Decision point recognition**
		Milk production	Milk docket	Daily	Used to confirm estimates of silage yield and quality	**Confirmatory**
Livestock factors						
Cow numbers	Visual assessment				Used to predict feed demand	**Long-term predictor**
Average milk yield	Milk vat (l/cow/day)			Daily	Used to identify when cow intakes and/or condition fall below target	**Decision point recognition**
		Intake	Pasture scoring	When it changes	Used to indicate change in milk production	**Short-term predictor**
		Post-grazing residual	Visual assessment	Daily	Used to indicate change in milk production	**Short-term predictor**
Individual cow milk yields	Herd test			Twice	)Used to identify)potential culls	**Decision point recognition**
Average herd condition[76]	Condition scoring			Daily	Used, in conjunction with APC and pasture growth rate information to decide when to dry off the herd	**Decision point recognition**
		Milk production	Milk docket	Daily	Used to indicate a change in condition score	**Short-term predictor**
Individual cow condition	Condition scoring			Daily	Used to identify cows whose condition is below target	**Decision point recognition**

[72] Subjective, informal measures used in late summer were also used in the autumn, but are not repeated in this figure to avoid too much repetition.
[73] This shows the role of the direct measures in the control process (Planning, problem recognition, triangulation), and the role of the indirect measures in relation to the direct measures (predictive, early warning, confirmatory).
[74] Uses ungrazed paddocks to calculate pasture growth rates.
[75] Includes both pasture and maize silage.
[76] Case farmer monitors both the average and the distribution or level of variation.

Factor	**Measure-ment**	**Method**		**Fre-quency**	**Role**	**Classification of Role**[77]
Intake	Pasture scoring			When it changes	Used to identify when intakes fall below target and to verify other measures	**Decision point recognition Triangulation**
	Visual assessment			Daily	Indicates change in intake	**Early warning**
		Post-grazing residual	Pasture scoring	Daily	Used to indicate a change in intake	**Short-term predictor**
			Visual assessment	Daily	Used to indicate a change in intake	**Short-term predictor**
		Milk production	Milk docket	Daily	Used to verify intake estimates and indicate change in intake	**Confirmatory** **Early warning**
		Cow condition	Condition scoring	Daily	Used to confirm change in intake	**Confirmatory**
		Pasture growth data	Falling plate meter	Fortnightly	Used to predict likely intakes in two weeks time	**Longer-term predictor**
		Climatic data	Rain gauge Visual assessment	Daily	Used with pasture growth rate data to predict intakes in two weeks time	**Longer-term predictor**
External Environment Factors						
Climatic Factors						
Climate Wind run) Temperature) Cloud cover) Rainfall) Weather forecast)	Rain gauge Visual assessment			Daily	Used to predict changes in average pasture cover, pasture growth and cow intakes two weeks in advance	**Longer-term predictor**
Market Factors						
Output Price Factors						
Cull cow schedule	Newspaper & stock agent			Intermittent	Used for selling decisions	**Decision point recognition**
In-calf cow store price	Newspaper & stock agent			Intermittent	Used for selling decisions	**Decision point recognition**
Milk price	Dairy company newsletter			Monthly	Used in option selection decisions	
Input Price Factors						
External feed sources	Newspaper, local farmers			Intermittent	Used to identify feed sources to fill feed deficits or extend lactation	**Decision point recognition**

[77] This shows the role of the direct measures in the control process (Planning, problem recognition, triangulation), and the role of the indirect measures in relation to the direct measures (predictive, early warning, confirmatory).

Appendix XIV. Information used in control response selection by Farmer B.

Table 1. Information collected through the monitoring process that is used to determine the activity implemented at the decision point.

Decision	Factors used in option selection[78]
Feed forage crop (amount and timing)	Milk production Rate of forage crop growth Date Pasture growth rates Forage crop maturity Forage crop state (available and ungrazed, being grazed, finished) Forage crop previously grazed Physiological state - non-reproductive, reproductive Grass silage state (available and unused, being fed, finished) Silage ration Date of forage crop grazing Increase in forage crop yield Date forage crop must be grazed to ensure new grass sown on-time.
Feed grass silage (amount and timing)	Forage crop state (ungrazed, being grazed, finished, rate of growth, maturity, suitable yield and maturity for regrazing) Milk production Date Date of forage crop grazing Ability to cull cows Predicted cow intakes Availability of thin cows that can be cried off Grass silage state (available and unused, being fed, finished) Amount of silage Rotation length Pre-grazing pasture cover level Type of summer (dry, wet, typical) Rainfall Previous prolonged dry spell Increase in forage crop yield Climatic conditions (cool, windy)
Feed maize silage (amount and timing)	Grass silage state (available and unused, being fed, finished) Average pasture cover and trend Forage crop state (ungrazed, being grazed, finished) Proportion of diet fed as grass silage Amount of maize silage available Maize silage state (available and unused, being fed, finished) Month Culling date Date thin cows dried off Stocking rate Average herd condition and trend Predicted cow intakes Rotation length
Harvest forage crop	Crop maturity Feed conditions
Extend rotation	Current rotation length Pasture quality and trend Post-grazing residual Maize silage being fed Milk production Silage state (available and unused, being grazed, finished) Pre-grazing pasture cover level Culling date Stocking rate Month Date thin cows dried off Type of summer (wet, dry, typical)

[78] Includes the problem recognition indicator.

Decision	Factors used in option selection[78]
Terminate grass silage feeding	Grass silage state (being fed, finished) Forage crop state (ready for second grazing)
Terminate maize silage feeding	Maize silage state (available and unused, being fed, finished) Amount used Initiation of drying off decision
Cull cows	Date/month Post-pregnancy testing Culls identified Date Conditions (dry, wet, typical) Predicted cow intakes Milk production State of summer supplement (available, being fed, consumed) Cow condition Schedule expectations Predictions of total milk yield post-culling Margin between Works and in-calf cow value Feed situation
Dry off individual cows	Date Individual cow condition Conditions (dry, wet typical) Bull out Feed budget results Milk production Reproductive performance of the herd Availability of feed on the runoff Rotation length Predicted cow intakes Supplement availability Grazing availability for dry cows Average herd condition and trend
Dry off the herd	Average pasture cover and trend Average herd condition Pasture growth rates Feed budget results Likelihood of conditions improving Pasture growth rate trend Date winter grazing contract for the herd due to start Feed conditions Date Availability of supplements
Extend lactation	Feed budget prediction Average pasture cover at planned drying off date Average herd condition
Use of winter grazing to extend lactation	Cost of winter grazing Lactating state of herd
Maintain rotation length	Milk production Date Rotation length Cow intake Herd being fed silage Average pasture cover and trend Available silage Herd being fed forage crop
Urea application	Rainfall Month Pasture response to rainfall Forecast for further rain Current feed position
Purchase of greenfeed maize and maize silage crops	Availability locally Current feed position Price per unit
Feeding greenfeed maize	Post-grazing residual Supplement on-hand Month State of maize silage (available and unused, being grazed, finished) Conditions (dry, wet, typical)

Decision	**Factors used in option selection**[79]
Reduce forage crop area	Date Forage crop state (ungrazed, being grazed, finished) Cow numbers Average pasture cover and trend Pasture growth rates Predicted pasture growth rates Milk production Average herd condition Predicted cow intakes
Reduce rotation length	Cessation of maize silage feeding Predicted cow intakes Rotation length
Reduce maize silage ration	Post-grazing residual Pasture growth rates Average pasture cover and trend Pasture quality and trend Proportion of diet fed as supplement Supplement has to be fed prior to drying off Rotation length

[79] Includes the problem recognition indicator.

Appendix XV. A representation of the process used by Farmer B to predict cow intake in 25 days.

Table 1. Simple mathematical representation of the Farmer B's intake predicting system.

Current post-grazing residual (kg DM/ha)	Post-grazing residual in 25 days (kg DM/ha)	Pasture growth rates (kg DM/ha/day)	Estimated cow intakes (125 cows on 2.0 ha) (kg DM/cow/day)	Percentage of target (12 kg DM/cow/day)
1400	1400	10	4	33%
		20	8	67%
		30	12	100%
		40	16	125%
1500	1400	10	5.6	47%
		20	9.6	80%
		30	13.6	113%
		40	17.6	147%
	1500			
		10	4	33%
		20	8	67%
		30	12	100%
		40	16	125%
1600	1400	10	7.2	60%
		20	11.2	93%
		30	15.2	127%
		40	19.2	160%
	1500			
		10	5.6	47%
		20	9.6	80%
		30	13.6	113%
		40	17.6	147%
	1600			
		10	4	33%
		20	8	67%
		30	12	100%
		40	16	125%

Appendix XVI. Decision rules used by Farmer B to initiate or intensify the monitoring process

General rule

IF indirect measures suggest a factor is trending towards a threshold,
THEN begin formal monitoring of that factor.

IF informal monitoring suggests the state of some variable is outside the comfort zone for that parameter,
THEN measure the parameter more formally.

Specific rules

Decision rules that are used to activate or terminate the monitoring of a specific factor

Cow intakes were monitored when a change occurred in milk production or supplement use. Conversely, if milk production and supplement was relatively stable, then monitoring was terminated until another change occurred.

IF milk production per cow changes,
OR a supplement is added to, or removed from the herd's diet,
THEN activate the monitoring of cow intakes,
ELSE terminate cow intake monitoring until such a change occurs.

Farmer B noted importantly, that he did not use average herd condition targets over the summer for management purposes, but rather, he relied on his individual cow condition targets ensure the condition of the herd did not fall too low. In year three, he began to actively monitor the condition of the herd in March when the condition of the herd had fallen from 4.65 condition score units at the start of February to 4.25 condition score units. He stated that time of year initiated the active monitoring and that he was particularly interested in the condition of the younger cows in the herd. Farmer B was more aware of cow condition at that point in time, because up until that pint in time, he had not dried off any of the younger cows on condition. He noted that he monitors their condition when drenching at milking time, or when he is feeding them supplements on the feed pad. He stated that he does not write down this information.

IF date = March,
AND the condition of the younger cows in the herd is not being actively monitored,
AND average herd condition has fallen from 4.65 to 4.25 condition score units over February,
AND no rising three year old cows have been dried off,
THEN actively monitor condition of younger cows in the herd.

The following decision rules were used by Farmer B to activate and terminate condition score monitoring in year one.

IF the condition of the herd is ≤ 4.0 condition score units,
AND it is March,
THEN begin monitoring cow condition formally.

IF milk production is < 1.04 kg MS/cow/day,
OR milk production declines at ≥ 0.061 kg MS/cow/day,
THEN begin formally monitoring condition score.

IF the condition of the herd is ≥ 4.5 condition score units,
AND it is late lactation,
AND the thin cows rising three year old cows have been dried off,
AND the herd is being fed to target,
THEN cease monitoring cow condition formally.

In year two, Farmer B only measured average pasture cover objectively twice during the summer-autumn, and in each case the information was used to assess the likely drying off date, i.e. the information was used for planning and plan revision, but not for the monitoring of intermediate targets *per se*. This can be represented in a decision rule.

IF the feed budget shows the farm is in a good feed position,
AND there is limited time to objectively monitor average pasture cover because of some major project,
AND the feed budget predicts a drying off date in June,
AND the other indicators suggest that the feed position is at or above target,
THEN delay the next objective monitoring until the project is completed, the feed position deteriorates, or information is required to revise the plan.

Decision rules that determine monitoring frequency

The following decision rule shows the impact of conditions and rate of change on the frequency of objective average pasture cover monitoring

IF the feed budget shows the farm is in a good feed position,
AND there is limited time to objectively monitor average pasture cover because of some major project,
AND the feed budget predicts a drying off date in June,
AND the other indicators suggest that the feed position is at, or above target,
THEN delay the next objective monitoring until the project is completed, or the feed position deteriorates.

The use of grouping rules in the monitoring process

IF a paddock is likely to grow less grass than others due to a previous problem,
AND the paddock is soon to be grazed,
AND the herd is being fed supplements,
THEN assess the feed on the paddock before grazing and adjust the supplement level to maintain intakes at target if required.

Appendix XVII. The decision rules used by Farmer B to determine what response to take after a decision point had been recognised.

Year One

Increase Feed Supply

Feed forage crop

Farmer B stated that he would feed the forage crop when milk production fell to 1.13 kg MS/cow/day. He also said that if the forage crop was still actively growing when milk production fell to this level, he would feed grass silage instead of forage crop to increase the crop yield. In the case of year one, the crop reached maturity a week before expected due to extremely good growing conditions, and Farmer B was forced to feed it before milk production fell to his pre-determined target in order to maintain quality.

IF milk production is ≤ 1.13 kg MS/cow/day,
AND the forage crop is mature,
THEN begin feeding the forage crop at a level that maintains milk production at or above 1.04 kg MS/cow/day.

IF milk production is ≤ 1.13 kg MS/cow/day,
AND the forage crop is not mature and growing actively,
AND surplus grass silage is available,
THEN begin feed the silage at a level that maintains milk production at or above 1.04 kg MS/cow/day until the forage crop is ready.

IF the forage crop is mature,
AND milk production is ≥ 1.13 kg MS/cow/day,
THEN feed the forage crop at a level that maintains milk production at or above 1.04 kg MS/cow/day.

IF milkfat production ≤ 1.04 kg MS/cow/day,
AND the forage crop is mature,
AND grass silage is being fed,
THEN stop feeding grass silage and substitute with forage crop such that milk production is maintained at or above 1.04 kg MS/cow/day.

Farmer B fed the forage crop at a higher rate than normal because pasture growth rates were above average. As such, it was grazed at a faster rate than originally planned.

IF pasture growth rates >> average,
AND the herd is grazing the forage crop,
THEN increase the milk production target to 1.17 kg MS/cow/day and feed sufficient forage crop to maintain production at this level.

Farmer B regrazed the forage crop on March 1st for 5 days when it started to go to seed.

IF the forage crop is beginning to go to seed,
AND it has been grazed previously,
AND the herd is being fed grass silage,
THEN terminate grass silage feeding and graze the forage crop at a level that maintains milk production at or above 1.04 kg MS/cow/day.

Feed grass silage

Farmer B fed grass silage after the forage crop. The amount of grass silage fed in any one day depended upon the amount of feed in a particular paddock and the area Farmer B provided the herd. Farmer B gradually reduced the area of pasture fed to the herd over the summer-autumn in order to extend the rotation. The case farmer's aim was to feed at least 12.0 kg DM/cow/day. Thus, the amount of silage fed during the summer-autumn ranged from 2.0 - 5.0 kg DM/cow/day. The grass silage was used to extend the rotation out to 35 - 42 days in a wet summer. However, Farmer B admitted that in a dry year he may only extend the rotation out to 25 - 28 days. In a year where the forage crop was growing actively, but milk production had fallen to 1.13 kg MS/cow/day, Farmer B would feed grass silage before the forage crop to optimise crop yield.

IF the forage crop has been grazed,
AND surplus grass silage is available,
THEN begin feeding the grass silage such that milk production is maintained at or above 1.04 kg MS/cow/day.

IF the rotation length $<$ 35 - 42 days,
AND the herd is being fed grass silage,
AND it is a wet summer,
THEN extend the rotation out to 35 - 42 days and feed sufficient silage to maintain milk production at or above 1.04 kg MS/cow/day.

IF the rotation length $<$ 25 - 28 days,
AND the herd is being fed grass silage,
AND it is a dry summer,
THEN extend the rotation out to 25 - 28 days and feed sufficient silage to maintain milk production at or above 1.04 kg MS/cow/day.

Farmer B increased the level of grass silage fed to the herd when cold windy conditions created a wind chill effect and milk production fell to 0.96 kg MS/cow/day.

IF milk production is $<$ 1.04 kg MS/cow/day,
AND conditions are cold and windy,
AND the herd is being fed grass silage,
THEN increase the silage ration so that milk production is increased to at least 1.04 kg MS/cow/day.

IF milk production is $\leq$ 1.13 kg MS/cow/day,
AND the forage crop is not mature and growing actively,
AND surplus grass silage is available,
THEN begin feed the silage at a level that maintains milk production at or above 1.04 kg MS/cow/day until the forage crop is ready.

Feed maize silage

Farmer B began feeding the maize silage once the grass silage had been finished in early April.

IF the grass silage has been finished,
AND maize silage is available for the autumn,
THEN feed sufficient maize silage to maintain milk production at 1.04 kg MS/cow/day.

Farmer B used a combination of the maize silage and destocking (sale of culls and drying off thin cows) to extend the rotation out to 60 days.

IF the stocking rate has been reduced through culling or drying off thin cows,
AND it is April,
AND the rotation length is < 60 days,
AND maize silage is being fed,
THEN continue to feed the same total amount of silage as fed to the larger number of cows and reduce the pasture area to extend the rotation whilst maintaining milk production at 1.04 kg MS/cow/day.

Decrease Feed Supply

Harvest forage crop

Farmer B said that in a very good growing season he could harvest the forage crop as silage.

IF the forage crop is mature,
AND feed conditions are such that the forage crop is not required,
THEN harvest the forage crop for silage.

Extend rotation length

Farmer B extended the rotation length if the pre-grazing pasture cover in a paddock was more than sufficient to feed the herd to target.

IF the pre-grazing pasture cover is more than sufficient to feed the herd to target,
THEN feed the herd sufficient area to maintain milk production at or above target and extend the rotation.

Farmer B used grass silage to extend the rotation out to 35 - 42 days in a wet summer. However, Farmer B admitted that in a dry year he may only extend the rotation out to 25 - 28 days.

IF the rotation length < 35 - 42 days,
AND the herd is being fed grass silage,
AND it is a wet summer,
THEN extend the rotation out to 35 - 42 days and feed sufficient silage to maintain milk production at or above 1.04 kg MS/cow/day.

IF the rotation length < 25 - 28 days,
AND the herd is being fed grass silage,
AND it is a dry summer,

THEN extend the rotation out to 25 - 28 days and feed sufficient silage to maintain milk production at or above 1.04 kg MS/cow/day.

Farmer B used a combination of the maize silage and destocking (sale of culls and drying off thin cows) to extend the rotation out to 60 days.

IF the stocking rate has been reduced through culling or drying off thin cows,
AND it is April,
AND the rotation length is < 60 days,
AND silage is being fed (maize or grass),
THEN continue to feed the same total amount of silage as fed to the larger number of cows and reduce the pasture area to extend the rotation whilst maintaining milk production at 1.04 kg MS/cow/day.

Terminate grass silage feeding

Farmer B terminated grass silage feeding when the forage crop was ready for a second grazing.

IF the forage crop is beginning to go to seed,
AND it has been grazed previously,
AND the herd is being fed grass silage,
THEN terminate grass silage feeding and graze the forage crop at a level that maintains milk production at or above 1.04 kg MS/cow/day.

Terminate maize silage feeding

Farmer B terminated maize silage feeding when he had used up the amount he had allocated for the autumn, or had initiated the drying off process.

IF the drying off process is to be initiated,
OR the autumn quota of maize silage has been fed out,
THEN terminate the feeding of maize silage.

Increase Feed Demand

Extend the lactation

If the feed budget shows there is sufficient feed to extend the lactation, Farmer B will delay drying off.

IF the feed budget analysis shows the lactation can be extended,
THEN extend the lactation and monitor average pasture cover and cow condition.

Reduce Feed Demand

Culling

In early April, Farmer B sold the culls after the herd had been pregnancy tested in late March, and the empty cows had been identified.

IF the empty cows and other culls have been identified,
AND it is early April,
THEN sell the cull cows.

Farmer B has completed another herd test and has identified the low producers, but because feed conditions, cow condition and milk production were good, and he had summer supplement, he did not cull any of these cows. Farmer B does not like to cull low producing cows until he has herd tested and identified the empty cows. However, if feed became limiting, Farmer B would cull a proportion of the low producing cows. The number would be dictated by how many Farmer B thinks he can safely cull given the number of empties he has. He does not want to end up in the situation where he has to buy-in replacements. Farmer B noted that this season is the longest he has kept the bulk of the herd in milk, and that often he has to cull in December or January.

IF low producing cows have been identified from herd test data,
AND the herd has been pregnancy tested,
AND conditions are dry,
AND the summer supplement is consumed,
AND cow condition is approaching the minimum target,
AND milk production is below target,
THEN cull a proportion of the low producing cows such that allowance is made for the number of likely empty cows in the herd,
ELSE continue milking the low producing cows until feed conditions deteriorate.

Drying off thin cows

Farmer B dried off a mob of thin induction and rising three year old cows in early April at an average condition score of 3.5 condition score units. Farmer B dried off a mob of thin induction and rising three year old cows in late April at an average condition score of 3.75 condition score units. The target changed because Farmer B aimed to have the thin cows at target condition score by early June. He believed that it was too difficult to increase cow condition through the winter.

IF it is early April,
AND there is a mob of induction and rising three year old cows that are around a condition score of 3.50 condition score units,
THEN dry off the mob and place them on grazing to increase their condition score to target by June.

IF it is late April,
AND there is a mob of induction and rising three year old cows that are around a condition score of 3.75 condition score units,
THEN dry off the mob and place them on grazing to increase their condition score to target by mid June.

If conditions turn dry, Farmer B would dry off his thin heifers rather than his empty cows because the empty cows produce more milk, not having a developing foetus. Farmer B has a group of 20 - 30 thin heifers that are between 3.0 and 3.5 condition score units. Farmer B dries these animals off on the basis of feed position and time of year, i.e. the closer to drying off, the higher the cut-off target, so that he has time to get them back to his target condition score for calving. He has just completed a rough feed budget which shows he can milk through to the 20th May. This suggests he can continue to feed the thin heifers well enough to hold condition.

IF there is a mob of rising three year old cows whose condition is $\leq$ 3.5 condition score units,
AND it is March,
AND conditions are dry,
AND the feed budget shows that feed is limiting,
THEN dry off the thin cows.

IF there is a mob of rising three year old cows whose condition is ≤ 3.5 condition score units,
AND it is March,
AND conditions are wet,
AND the feed budget shows that the entire herd can be milked through into May,
THEN retain the thin cows until their condition score falls below target in April.

Drying off

The decision to dry off the herd was made after Farmer B reviewed the feed budget in early May. He reassessed the amount of feed on the grazing block and decided there was only enough to graze 200 cows for five rather than six weeks. When this was entered into the feed budget, Farmer B estimated that he had to begin drying off the herd a few days earlier than the previous feed budget suggested. Conditions were not improving and therefore Farmer B initiated drying off on the 6th May. The herd was dry by the 13th May.

IF the feed budget analysis suggests the drying off date is immanent,
AND it is unlikely conditions will change prior to this date,
THEN dry off the herd on the planned date.

Normally, Farmer B dries off when average pasture cover declines to the targets set by the feed budget. Farmer B also considers trends in pasture growth rates and the condition of the herd.

IF average pasture cover ≤ target,
AND average herd condition ≤ target,
AND pasture growth rate data suggests pasture growth is declining,
THEN dry off the herd.

Winter grazing

Farmer B was always searching for additional winter grazing. This grazing would allow him to extend the lactation. He would purchase additional grazing if he could obtain it for around $5.00/cow/week or less.

IF winter grazing is available for ≤ $5.00/cow/week,
AND the herd is still milking,
THEN use the grazing to extend the lactation and estimate the additional milking days through the feed budget.

Year Two

In a dry summer, the hierarchy of options used by Farmer B was i) use pasture cover, ii) use cow condition, iii) use grass silage, iv) use forage crop. In a wet summer, the hierarchy was different e.g. i) use pasture cover, ii) use forage crop, iii) use grass silage, iv) use cow condition.

Increase Feed Supply

Rotation length

Farmer B planned to maintain the herd on a 23 - 24 day rotation until the 10th January when he would feed grass silage. This plan was put in place because feed was short. Farmer B had also relaxed his milk production target because he knew he would have to sacrifice cow condition and milk production through until January 10th because average pasture cover was too low.

IF milk production < 1.04 kg MS/cow/day,
AND the date < 10th January,
AND rotation length = minimum,
THEN maintain the herd on the current rotation length until the 10th January, and then feed sufficient grass silage to maintain milk production ≥ 1.04 kg MS/cow/day.

During the summer, Farmer B would not reduce the rotation length below 23 - 24 days because this would reduce average pasture cover too rapidly, and while increasing cow intakes over the short-term, would place the farm in a worse position long-term.

IF rotation length = minimum,
AND cow intakes ≤ minimum,
THEN maintain the rotation length until the feed position improves.

During January, Farmer B stated that he did not have enough grass silage to extend the rotation length. At that point in time, average pasture cover was relatively low and declining.

IF the herd is being fed silage,
AND the rotation length = minimum,
AND average pasture cover is low,
AND pasture cover is not increasing,
AND limited silage is available,
THEN maintain the rotation length until the feed position improves.

In February, Farmer B knew that average pasture was not increasing while he was feeding the forage crop, and therefore he could not extend the rotation length.

IF the herd is grazing the forage crop,
AND average pasture cover is not increasing,
AND milk production = target,
AND the rotation length = minimum,
Then maintain the rotation length at 23 - 24 days until the feed position improves.

Feed grass silage

Farmer B planned to feed his grass silage before the forage crop on January 10th. He stated that he would delay the feeding of the grass silage if milk production was at or above 1.04 kg MS/cow/day. One of the case farmer's problems over January was his lack of grass silage. He noted that if he had had 300 tonnes of grass silage on hand, he would not have had a problem.

IF date = January 10th,
AND milk production < 1.04 kg MS/cow/day,

THEN feed the grass silage at such a rate that milk production is ≥ 1.04 kg MS/cow/day, ELSE maintain herd on current rotation length and feed them a diet made up solely of pasture.

Feed forage crop

The grass silage was finished on the 27th January. Farmer B wanted the forage crop to last until the end of February. Farmer B then fed the forage crop at such a level that milk production was maintained at 1.04 kg MS/cow/day. He noted however, if his analysis indicated that the herd could not be fed to target, he would dry off thin cows to ensure the remaining cows were fed to target. To ensure the forage crop lasted until the end of February, Farmer B divided the area by the number of days. In this case he had 3.2 hectares and needed 32 days grazing. Therefore, he could feed the herd 0.1 hectares per day to ensure it lasted that length of time, and then just dry off cows as required if average pasture cover continued to fall.

IF X days grazing are required from the forage crop,
AND the forage crop covers Y hectares,
THEN calculate the area that should be fed to the herd each day by dividing Y by X.

IF the grass silage has been consumed,
AND forage crop is available,
THEN feed the forage crop at the required rate and if required, dry off sufficient thin cows to maintain milk production ≥ 1.04 kg MS/cow/day.

Farmer B stated that even if the feed situation improved over January, he would still graze the forage crop no later than early February because of his need to graze the crop off in time to sow his new grass in early March.

IF date = early February,
AND the forage crop is ungrazed,
THEN graze the forage crop at such a rate that it is removed by the end of February.

Urea Application

Farmer B decided to apply 40 kg urea/ha or around 20 kg N/ha across the whole farm on March 5th. The decision was made because the farm had recently received 14 mm of rain and further rain was forecast because a tropical cyclone was passing over the north of New Zealand. The key trigger for the decision was that more than 12.5 mm of rain had fallen, the pasture had responded to the rain, and there was the probability of further rain. Farmer B saw the saw the urea as one means of generating additional feed. If the farm had not received 14 mm of rain, Farmer B would not have made the decision.

IF more than 12.5 mm of rain has fallen recently,
AND it is March,
AND the pasture has responded to the rain,
AND more rain is forecast to fall,
AND the farm is in a poor feed position (average pasture cover and supplements),
THEN apply 20 kg N/ha as urea to increase feed supply.

Purchasing greenfeed maize and maize silage crops

Farmer B had discussed the option of buying the two maize crops off a neighbour in the spring. Farmer B offered to purchase them if they were not suitable for grain given the spring had been cold and wet. He wanted one crop for maize silage (4.5 ha) and one crop for greenfeed maize (6.0 ha) that would be fed to the herd in the paddock. Farmer B negotiated a price with the owner and paid $1250/ha for the two crops. The owner did not want to sell the crop on a cents per kilogram of dry matter basis and set a per hectare figure. Farmer B considered that the cost of the feed was cheap, but at that stage he did not know what the yield was, other than it is better than he expected.

Farmer B estimated a price per kilogram for the maize crops and then compared this to a reference figure or industry standard for maize and on this basis decided to purchase the feed. He did not use a partial budget to estimate the likely costs and returns from purchasing the crops. Farmer B admitted that at the price he had paid, the maize crop was an inexpensive form of supplement.

IF a maize crop is available for purchase locally,
AND the farm is short of feed,
AND the price is ≤ $X/unit,
THEN purchase maize crop.

Feeding greenfeed maize and extending the rotation

Farmer B purchased 6.0 hectares of greenfeed maize from a neighbour. He identified an opportunity and decided to buy the crop. Farmer B sought the help of the local maize growing contractor to ensure he harvested the maize at the correct time. When Farmer B first fed the greenfeed maize on the 11th April, he fed sufficient crop to extend the rotation out from 25 days to 30 - 34 days whilst maintaining intakes at around 15 kg DM/cow/day and post-grazing residuals of 14 - 1500 kg DM/ha. Prior to this, the herd was grazing down to around 1200 kg DM/ha. Farmer B mentioned the need to feed additional greenfeed to extend the rotation. He also mentioned that there was a trade off between grass growing days (rotation length), and post-grazing residual. If he had left the rotation length at 25 days, the post-grazing residual would have been much higher at 1600 kg DM/ha as opposed to 1400 kg DM/ha. The compromise is obtaining more grass growing days (extending the rotation) versus compromising cow intakes. Farmer B had to make a decision on rotation length that gave him high intakes, high residuals, and a larger number of grass growing days. Prior to this, Farmer B did not have the level of supplements on-hand to extend the rotation length.

The rate of supplementation with greenfeed maize (5 - 6 kg DM/cow/day) was determined by pragmatic reasons, that is the quantity the silage wagon could hold in one load. It was a practical consideration. This then left the decision as to how much area of pasture Farmer B should give the herd, which in effect is the rotation length. Farmer B wanted to extend the rotation, but at the same time he wanted to increase the post-grazing residual. He knew that the herd was currently going into paddocks with a pre-grazing pasture cover of 2200 kg DM/ha. His options were then to feed the herd 3.0 hectares per day, or 2.0 hectares per day, given he wanted to extend the rotation from his current rotation length of 23 - 24 days (4.0 hectares per day). He noted that at 2.0 ha per day (a 47 day rotation), the herd would graze down to 1100 - 1200 kg DM/ha, which was below the target post-grazing residual he was aiming for. Whereas at 3.0 hectares per day, the herd would graze down to 1400 kg DM/ha, the post-grazing residual Farmer B was aiming for. This data shows the complex interaction that occurs between stocking rate or cow numbers, area grazed or rotation length, pre- and post-grazing residuals and cow intakes. In effect, with the cow numbers he had, the level of supplement being fed, and the pre-grazing pasture cover levels on the farm, Farmer B had to utilise a 30 day rotation and provide the herd with an intake of 15 kg DM/cow/day to obtain his desired post-grazing residual. Farmer B believed that he would grow more grass on a shorter rotation with a higher residual, than on a longer rotation with a lower residual. He also noted that if he went to the 47 day rotation, the herd would be fed less, they would leave lower residuals, but the herd would not return to those paddocks until after they were dried off.

IF the post-grazing residual is < 1400 kg DM/ha,
AND there is sufficient supplement on-hand to increase and the post-grazing residual,
AND it is April,
THEN estimate the rotation length that will increase post-grazing residuals to 1400 kg DM/ha, given the supplement ration, and the number of lactating cows on-hand.

On the 23rd April, Farmer B stated that he would maintain the current rotation length of 30 - 34 days while feeding the greenfeed maize for one round to increase the post-grazing residual, and then use the higher residuals to extend the rotation.

IF greenfeed maize is being fed,
AND conditions have been dry,
THEN maintain the current rotation length for one round and increase the post-grazing residuals with the greenfeed maize, and then on the second round, use these higher residuals to extend the rotation length.

Decrease Feed Supply

Reduce forage crop area

On February 15th, Farmer B decided to reduce the area of forage crop fed to the herd from 0.10 hectares to 0.065 hectares to obtain another weeks grazing. He did this because conditions and average pasture cover had not improved through February despite feeding the herd forage crop and reducing cow numbers. The herd were also producing at around 1.043 kg MS/cow/day, suggesting cow intakes could be reduced. This reduced cow intakes by about 1.0 kg DM/cow/day, but Farmer B was prepared to sacrifice some condition and milk production to extend the grazing of the forage crop. As such, Farmer B relaxed the milk production target from 1.04 to 0.96 kg MS/cow/day. The herd was at 4.1 condition score units at the time the decision was made, and declined to 3.8 condition score units by the time the forage crop was grazed on March 8th. Farmer B was also willing to compromise his sowing date for the new grass, and changed his planned date for sowing from the 1st to the 10th of March. He did not attempt to extend the grazing of the forage crop for more than a week for two reasons, the first was because he did not want to sow his new grass any later, and the second was that the break size for the forage crop could not be reduced much more for practical reasons.

IF it is mid February,
AND the herd is grazing the forage crop,
AND cow numbers have been reduced considerably,
AND average pasture cover has not improved,
AND pasture growth rates are low,
AND forecasted pasture growth rates are not expected to improve,
AND milk production is > 1.04 kg MS/cow/day,
AND the condition of the herd > 4.0 condition score units,
AND analysis of post-grazing residuals shows that the existing number of cows cannot be fed to target once the forage crop is finished at the end of February,
THEN reduce the forage crop area fed to the herd to a level that maintains milk production ≥ 0.96 kg MS/cow/day.

Increase Feed Demand

Extend the lactation

The feed budget completed in March and revised again in April predicted that the herd could be milked through until June 10th. This is almost a month longer than the normal drying off date of mid May.

Reduce Feed Demand

Culling

The herd was pregnancy tested on the 1st April and the heifers on the 11th April. Although Farmer B estimated he had 70 cows to cull, he only culled ten cows on the 18th April. He said that given his feed position, he was not too concerned about culling the ten cows, and it took another weeks to sell the cows after the heifers had been pregnancy tested. It appears at the time this was not a critical decision. Farmer B culled nine empty milking cows and one dry empty cow reducing the milking herd to 233 cows. He identified 30 empties (6.8%) out of the 435 cows and heifers pregnancy tested which was better than Farmer B expected. Farmer B decided to cull the ten worst empties, and retain twenty to over-winter[80]. Farmer B planned to sell the remaining 40 culls as in-calf cows because they were worth a lot more than if he sold them as cull cows in the works ($350/hd). Farmer B planned to milk these through into May because the farm is in a good feed position and then cull them. The ten poorest empty cows were sold at that point because Farmer B believed the schedule would fall over the next two months, and he was better off selling them now. He did not believe the net gain from milk production would compensate for the fall in the value of the cull cow because the remainder of the herd would increase their per cow production in response to the additional feed provided from culling the ten cows. After culling the ten cows, total milk production per day remained the same.

IF the empty cull cows have been identified,
AND the schedule is expected to fall,
AND total milk production is not expected to fall once the cull cows are sold,
THEN cull the empty cows.

IF the in-calf cows have been identified,
AND the margin between works cows and in-calf cows is large,
AND the feed situation on the farm is good,
THEN retain the in-calf culls cows until drying off and sell them store.

Farmer B sold 39 culls on the 11th May. The decision to cull the cows was made on May 2nd, but it took another 9 days to dry them off and sell them. These cows were either old, had a low production index or high somatic cell count, or were late calving cows that were likely to be induced. The decision was made to cull the 39 cows because firstly, a buyer had contacted the case farmer, and secondly because Farmer B believed that the price of in-calf cows was falling. Market information suggested the price for in-calf cows was declining because there was more on-hand than originally expected. As such, the cow price had declined $300/head over the last few months. Farmer B received $450/head for his in-calf cows because they were culls. These animals were worth $350/head in the works. The feed situation on the farm had no influence on the culling decision.

IF cull in-calf cows are on hand,
AND a buyer has shown an interest in the culls,

[80] These were be mated the following spring.

AND market information suggests the price for in-calf culls is in decline,
THEN sell the in-calf culls.

Grazing off the calves

Farmer B decided to graze the calves off in early February. This was because feed conditions had continued to deteriorate and the case farmer's analysis of post-grazing residuals suggested he would have to dry around 40 cows to ensure the remaining cows were fed to target. Farmer B could secure good grazing for the calves and decided to graze them off so that he could better feed the herd. Importantly, prior to this, the calves were the most important livestock class on the farm, and the herd was ranked second in terms of preferential feeding.

IF analysis of post-grazing residuals shows that the existing number of cows cannot be fed to target over the next month, and that intakes will fall by a further 25 - 33% in a months time,
AND replacement calves are grazed on the milking area,
AND good grazing can be obtained for the replacement calves,
THEN graze the calves off the milking area.

Drying off thin cows

Farmer B did not want to dry off thin cows in January because the bull was still out, and he was not confident that the herd's reproductive performance would be adequate because of the effects of the cold wet, spring. Otherwise he might have dried off sufficient dry cows to ensure the remaining cows were fed to target through early January.

IF it early January,
AND milk production < 1.04 kg MS/cow/day,
AND date < 10th January,
AND the bull is still out,
AND the reproductive performance of the herd might have been poor through the previous spring,
AND there are cows in the herd at ≤ 3.5 condition score units,
AND rotation length = minimum,
THEN continue on the current rotation length until date = 10th January,
ELSE, dry off sufficient thin cows to increase milk production to 1.04 kg MS/cow/day.

Farmer B noted that in a more extreme year, he would have dried off thin cows in January when their condition fell to 3.5 condition score units.

Farmer B dried off 45 thin cows on the 7th February. He did this for a number of reasons. Firstly, by predicting cow intakes on the basis of post-grazing residuals and likely pasture growth rates, he determined that if he retained the same number of cows through February, when the forage crop was finished, although his average pasture cover would be similar to that in early February, cow intakes would fall by 25 - 33 %. This analysis also shows that by removing 45 cows, Farmer B can increase the intakes of the remaining cows to his target of 12 kg DM/cow/day. By drying off the thin cows, he also protected their condition and that of the milking herd, and allowed post-grazing residuals to increase, therefore increasing pasture growth rates. The bull was removed on the 3rd February, which meant Farmer B could dry off the thin cows without concern for reproductive performance. Farmer B noted that one constraint to this decision was the number of cows the grazier could take. In this case the grazing was sufficient for the 45 cows Farmer B decided to graze off.

IF analysis of post-grazing residuals shows that the existing number of cows cannot be fed to target over the next month, and that intakes will fall by a further 25 - 33% in a months time,
AND the bull has been removed from the herd,
AND no additional supplements are available,
AND grazing for the dry cows can be secured,
THEN dry off sufficient thin cows to ensure the remaining cows are fed to target over the next month.

On March 9th, seventeen lease cows were returned to the home farm. With the exception of two cows, these are in good condition. The farmer who leased the cows had agreed to pay a grazing fee for the lease cows through until June 1st. Farmer B has decided to milk the 15 of the 17 cows because they are in good condition and instead he will graze off 15 of his thinner cows. He has also decided, given the level of average pasture cover on the farm, to dry off and graze off another 30 thin cows which are 3.5 condition score units or less. Farmer B used his analysis of his post-grazing residuals, and expectations of pasture growth rates to determine the number of cows he needed to remove from the milking area. The case farmer's aim is to remove all the thin cows so that the average condition of the lactating cows increases to 4.0 condition score units or above. He also wants to carry sufficient cows such that their feed demand, at an intake that will maintain cow condition, is equal to the current level of pasture growth (25 kg DM/ha/day). Farmer B wants to set the number of cows that he can milk through to mid May. At the reduced stocking rate (2.2 - 2.3 cows/ha), the herd should be able to increase milk production and condition once the autumn rains arrive and pasture growth rates increase to around 30 kg DM/ha/day. Be removing all the thin cows, Farmer B has a buffer of 0.5 condition score units which he could draw on if it got really dry through March. His aim however, is to maintain cow condition at 4.0 condition score units until the autumn rains arrive. If conditions became drier, Farmer B admitted that cow condition would decline further. He also admitted that by reducing numbers further, his milk production for the remainder of the summer-autumn would be limited. Farmer B stressed that condition score is driving the decision. He also noted that if he had not had grazing, he would have had to dry off more cows and keep them on the home farm. The trade off Farmer B is making is grazing cows away versus ensuring sufficient lactating cows are on to take advantage of the autumn rains when they come. Therefore, he has taken the minimum number of grazers to the point where he thinks there is sufficient feed on-hand, and expected pasture growth rates will be such, that he can maintain the condition of the remaining cows on the milking area until the autumn rains arrive. The objective is to keep his options open so that he can take advantage of the autumn rains if it arrives.

IF analysis of post-grazing residuals shows that the existing number of cows cannot be fed to target over the next month,
AND milk production is declining below target,
AND cow condition is declining,
AND there are a number of cows ≤ 3.5 condition score units,
AND no further supplement is available,
AND it is March,
AND grazing is available,
THEN reduce cow numbers by drying off and grazing thin cows such that feed demand matches pasture growth rates at an intake level such that the herd can hold condition through until the autumn rains arrive.

Farmer B dried off 22 thin cows on the 2nd May. Farmer B selected any cows under condition score 4.0 and dried them off and placed them on grazing on the 2nd May. The decision was made solely on the basis of the condition of the herd because the feed situation at the time was good. Farmer B dried the thin cows off so that he would have time to increase their condition to 4.75 condition score units by early June.

IF individual cow condition ≤ 4.0 condition score units,
AND it is early May,
THEN dry off the cow and place it on grazing to increase condition up to 4.75 condition score units by early June.

It appears that cow intakes played an important role in the tactical management of year two. When the case farmer's calculations predicted that cow intakes could not be maintained at or above target, he arranged to dry off sufficient cows to ensure those remaining were fed to target. He noted that this analysis was undertaken in year one, but was not used to anywhere near the same extent because feed was plentiful throughout most of the summer-autumn.

Drying off

Farmer B dried off the herd on the 26th May because he had organised eight weeks of grazing for the herd over the winter, and to take advantage of it, he had to have the herd off the farm by the end of May, so that they could return to the farm by late July. Feed and cow condition was not a factor in this decision. A feed budget completed on April 27th suggested the herd could be milked through until June 10th, and the 172 cows that were still milking were at condition score 5.0 at drying off.

IF eight weeks of grazing has been organise for the herd,
AND it is due to start calving on August 1st,
AND feed is plentiful,
AND it is late May,
THEN dry off the herd so that full use can be made of the grazing.

Year Three

<u>Increase Feed Supply</u>

Grass silage feeding

In early February, Farmer B doubled the amount of silage fed to the herd from 4.0 to 6 .0 - 8.0 kg DM/cow/day. Prior to this point, the farm had received 35 mm of rain and more was expected. Average pasture cover had declined to the point that the herd was going into 1900 kg DM/ha and grazing down to 1400 kg DM/ha. Pasture intake had declined and the case farmer's minimum of 1.0 kg MS/cow/day was threatened. Cow condition was declining, and importantly, the post-grazing residuals were likely to fall below 1400 kg DM/ha. The herd was then fed 12 - 13 kg DM/cow/day of which only 6.0 kg DM/cow/day was pasture and the remainder was silage. The aim was to increase post-grazing residuals and take advantage of the rain, maintain milk production above 1.0 kg MS/cow/day and minimise the loss in condition. Farmer B also increased the silage ration because he knew he had another two weeks grazing from the forage crop. He also knew that he could obtain a higher forage crop yield if he delayed the grazing of the crop for another 2 - 3 weeks. Farmer B will now graze the forage crop two weeks earlier. This allows him to double the level of grass silage feeding, because he had originally planned to feed the silage through until the end of February, and then graze the forage crop. Given Farmer B had 300 wet tonnes of silage on-hand, he expects to have some grass silage over which he can use after the forage crop. The doubling of the amount was also undertaken for practical reasons in that he could now feed two rather than one silage wagon of grass silage per day.

IF the forage crop yield has increased, and it will provide another two weeks grazing,
AND it is early February,
AND the forage crop will now be grazed two weeks earlier in mid February,
AND there is sufficient grass silage to feed the herd until the end of the month at current rations,
AND analysis of pre- and post-grazing residuals and expected pasture growth rates predicts cow intakes, milk production and post-grazing residuals will decline below target,
THEN double the silage ration so that it is used by mid February.

In early February, as pasture growth rates and average pasture cover declined, Farmer B had two choices, feed additional supplement, or reduce demand. The level of pasture provided on the 23 - 24 day rotation had fallen to 6.0 kg DM/cow/day, and the silage ration of 4.0 kg DM/cow/day was insufficient to meet target intakes and milk production level. That level of feeding would also push the post-grazing residual below the optimum of 1400 kg DM/ha. Farmer B did not want to cull any cows and the thin cows were still above his threshold of 3.5 condition score units. Therefore, he could not reduce feed demand. Alternatively he could feed the forage crop, but it was still actively growing after the rain, and it had just received a side dressing of nitrogen. However, he did have a plentiful supply of grass silage. Farmer B therefore decided to double the grass silage so that he could milk the 319 cows through into the autumn.

IF analysis of pre- and post-grazing residuals, and climatic and pasture growth rate data suggest the herd will be underfed at its current level of supplementation,
AND culling is not possible until after pregnancy diagnosis,
AND the crop cannot be grazed because it is actively growing,
AND there are no cows ≤ 3.5 condition score units that can be dried off and grazed off,
AND the rotation length = minimum,
AND the grass silage supply is sufficient to fully feed the herd,
THEN double the ration of grass silage such that milk production is ≥ 1.0 kg MS/cow/day.

Farmer B learnt that if significant rain fell after a prolonged dry spell, he should double the grass silage ration for a week to maintain cow intakes, milk production and cow condition.

IF significant rain falls (≥ 50 mm),
AND the farm has been through a prolonged dry spell,
AND the herd is being fed grass silage,
THEN double the grass silage ration to maintain cow intakes.

Forage crop feeding

At the start of February, Farmer B estimated that the forage crop yield had increased to the point where his calculations suggested that it would provide another two weeks grazing. His plan had been to delay the grazing of the forage crop until the end of February to maximise yield. He could not delay it any longer than this because he wanted the paddocks resown by late March. He therefore decided to graze the forage crop two weeks earlier in Mid February.

IF a re-evaluation of the forage crop yield suggests it will provide an additional two weeks grazing,
AND it was planned to be grazed on March 1st,
THEN initiate the grazing two weeks earlier.

The decision to feed the forage crop involved three main factors. On the one hand, Farmer B wanted to maximise yield, and therefore delay the grazing of the forage crop for as long as possible. Against that, he had a limit at which he must sow his new grass to ensure good establishment (his "end date"). This required some calculations in terms of how long the forage crop would last if grazed, and how this fitted in with the "end date". The other factor was the increasing dry conditions. Farmer B found that the pasture component of the diet was declining rapidly and the double ration of silage was not going to be adequate in the near future. He did not feel comfortable with feeding the herd comprising of mainly grass silage. Therefore he decided to provide the herd with a diet of grass silage, forage crop and pasture. He decided to give the herd a load of grass silage, a break of forage crop and maintain the herd on a 23 - 24 day rotation. The primary trigger for the decision was the need to graze the forage crop in order to ensure the new grass was sown at the correct time.

IF analysis of the forage crop yield suggests it needs to be grazed now in order to ensure the new grass is sown at the correct date,
AND analysis of pre- and post-grazing residuals indicates cow intakes will decline below target in the near future,
AND the herd is currently being fed 8.0 kg DM/cow/day of grass silage,
THEN feed the herd a combination of forage crop and silage such that milk production is maintained above 1.0 kg MS/cow/day and the forage crop is removed in time for the new grass to be sown at the correct time.

Farmer B reassessed the forage crop yield every so often and adjusted the area fed to the herd. He wanted to feed the herd of 319 cows 5.0 kg DM/cow/day and he estimated the yield was 5000 - 6000 kg DM/ha. His calculations suggested he feed 0.3 ha/day to achieve this intake. This was not a qualitative decision, but rather a quantitative decision.

Feeding maize silage

When the forage crop finished, Farmer B began feeding the maize silage. The reason he did this was because there was insufficient pasture cover on-hand to fully feed the herd. Farmer B also wanted to provide a balanced diet and therefore did not want to feed additional grass silage. Farmer B also wanted to increase the condition of the herd, therefore, he wanted to feed enough maize silage to increase cow condition.

IF the forage crop has been finished,
AND the herd is currently being fed around one third of its diet in grass silage,
AND analysis of pre- and post-grazing residuals suggests there is insufficient pasture to feed the herd to requirements,
AND the average condition score of the herd is < 4.5 condition score units,
AND there is a considerable quantity of maize silage available,
THEN begin feeding maize silage along with the grass silage, and feed sufficient maize silage to increase the condition of the herd.

Once the grass silage was finished in late March, Farmer B increased the maize silage to 7.0 kg DM/cow/day, and the herd received 8.0 kg DM/cow/day of pasture, a total intake of 15 kg DM/cow/day. His aim was to increase production to around 1.20 kg MS/cow/day and increase cow condition. Although pasture growth rates in late March were over 50 kg DM/ha/day, the resultant lush grass did not appear to provide sufficient energy to maintain cow condition, and even at intakes of 13 - 14 kg DM/cow/day, the herd was still losing condition. The "lushness" of the pasture did not change until the first week in April when Farmer B believed that production was a true reflection of cow intakes.

IF the grass silage has finished,
AND analysis of pre- and post-grazing residuals suggests there is insufficient pasture to feed the herd to requirements,
AND cow condition is still declining,
AND conditions are such that average pasture cover is increasing rapidly,
AND there is a considerable quantity of maize silage available,
THEN feed sufficient maize silage to increase the condition of the herd.

Reduce rotation length

When the maize silage ran out, Farmer B reduced the rotation length so that intake per cow per day did not decline even though 4.0 kg DM/cow/day of maize silage had been removed. To provide sufficient feed to replace the maize silage, Farmer B had to effectively provide the herd with around another hectare of pasture. This reduced the rotation length from around 35 days to 23 - 24 days.

IF the supplementation of the herd with maize silage has just stopped,
AND analysis of pre- and post-grazing residuals suggests there is insufficient pasture to feed the herd to requirements,
AND the rotation length is > 23 - 24 days,
THEN shorten the rotation length so that cow intakes are maintained at their current level on pasture.

Autumn nitrogen

Farmer B did not use autumn nitrogen because the owner did not want it used on her property.

Decrease Feed Supply

Reduce maize silage ration and extend rotation

On the 5th April, Farmer B reduced the maize silage from 7.0 kg DM/cow/day to 4.0 kg DM/cow/day because of the increase in pasture cover and hence the pasture component of the herd's diet. The other point was that the pasture quality had changed, it had "hardened up" and the herd was producing more milk and cow condition was increasing again. Prior to this, the herd was losing condition and milk production was only just above 1.0 kg MS/cow/day despite very high intakes (15 kg DM/cow/day) and post-grazing residuals (1550 kg DM/ha/day). Farmer B could have continued to feed 7.0 kg DM/cow/day, but two main reasons stopped him. The first was that he was obliged to leave 100 tonnes of maize silage in the stack for the owner. The herd was also wasting more of the maize silage because feeding levels were so high. The second, and more important reason was that pasture quality was declining due to the high residuals and patchy grazing by the herd. To improve pasture quality, Farmer B reduced the maize ration and extended the grazing rotation. This reduced the post-grazing residual and provided a more even residual. Farmer B reduced the input of maize silage to the point that it held cow condition and maintained milk production above 1.0 - 1.1 kg MS/cow/day. The maize silage had to be used up (except for 100 tonnes) before drying off, hence Farmer B did not stop feeding it. One alternative was to keep feeding the maize at the higher ration and graze a much smaller area. The latter option was preferable given there was only enough maize for about a weeks feeding at the reduced ration.

IF post grazing residuals > 1700 kg DM/ha,
AND pasture growth rates are high (> 50 kg DM/ha/day),
AND average pasture cover is increasing rapidly ($\geq$ 20 kg DM/ha/day),

AND pasture quality is deteriorating as a result,
AND the herd is being fed a large proportion of its diet as supplement,
AND the supplement has to be used before drying off,
AND the herd is on a fast rotation (23 - 24 days),
THEN reduce the level of supplementation, and extend the rotation length such that cow condition and milk production are maintained, but the post-grazing residual is reduced to a level (around 1600 - 1700 kg DM/ha) that maintains pasture quality.

Extend the rotation

After the maize silage had been reduced from 7.0 to 4.0 kg DM/cow/day, the average pasture cover continued to increase. As a result, the post-grazing residual increased and pasture quality continued to be an issue. As a result, Farmer B continued to extend the rotation to ensure the herd maintained pasture quality. The proviso being that the herd maintains condition and milk production remains above 1.0 kg MS/cow/day.

IF the post grazing residual is increasing above 1700 kg DM/ha,
AND pasture quality will deteriorate as a result,
AND the herd is being fed maize silage,
AND the maize silage has to be used up before drying off,
THEN extend the rotation such that the post-grazing residual is reduced back to an adequate level, whilst maintaining cow condition and milk production.

<u>Increase feed demand</u>

Increase cow intakes

Once the grass silage was finished in late March, Farmer B increased the maize silage to 7.0 kg DM/cow/day, and the herd received 8.0 kg DM/cow/day of pasture, a total intake of 15 kg DM/cow/day. Cow intakes were therefore increased from 13 kg DM/cow/day in early March to 15 kg DM/cow/day in late March. The case farmer's aim was to increase production to around 1.20 kg MS/cow/day and increase cow condition. The lush grass the had grown over March did not appear to provide sufficient energy to maintain cow condition, and even with a high supplementation of maize silage, the herd were still losing condition. This did not change until the first week in April.

Extend the lactation

The case farmer's feed budget suggested he dry off the herd on May 10th at an average pasture cover of 2300 kg DM/ha. However, pasture cover was around 2450 kg DM/ha at this date, and Farmer B was only milking 206 cows, rather than the 319 cows predicted in the plan. He therefore decided to extend the lactation until pasture cover fell to a level that required the herd to be dried off. At that point in time, the herd was at condition 4.5 and condition was increasing. This was half a condition score below what their target for planned start of calving. At that level, Farmer B was not concerned about condition, and it did not influence the drying off decision. Farmer B believed he could put half a condition score on the herd by planned start of calving.

IF at the planned drying off date, average pasture cover is > target,
AND average herd condition is ≥ 4.5 condition score units,
THEN extend the lactation until average pasture cover declines to target, at which point dry off the herd.

Decrease feed demand

Culling

In early January, Farmer B had identified 8 cows that had not been mated to the bull and were assumed to be empty. The feed situation had not improved and although the herd was being fed 4.0 kg DM/cow/day of grass silage, average pasture cover and cow intakes were declining. Farmer B believed that the cull cow price would not improve if the dry conditions persisted and he believed they would. Therefore, he could see no point keeping these empty cows and they were culled in around the 10th January.

IF empty cows have been identified,
AND it is early January,
AND conditions are dry,
AND the herd is being fed grass silage,
AND cull cow prices are expected to fall,
AND analysis of climatic, pasture growth rates and pre and post-grazing residuals indicates cow intakes are going to decline over January,
THEN sell the cull cows.

In mid April, the herd was pregnancy tested. Farmer B also identified 22 empty cows. Of these, he decided to retain 6 four-year-old cows and carry them over. The remaining 16 were sent to the works in early May. The reason for this was that they were going to have little impact on the feed situation, or total milk production, whereas the schedule was falling. Farmer B decided to sell them.

IF the cull cows are identified,
AND it is late April,
AND the schedule is expected to decline,
THEN cull the cows.

Dry off thin cows

Farmer B dried off 22 thin cows on the 18th April. These had been selected on the 10th April and it took 8 days to dry them off. The cows he selected were under 3.8 condition score units or close enough to his normal cut-off point of 3.75 condition score units. The cut off point was based on the case farmer's view of how long he had to get these cows up to condition score 5.0. He decided he had six weeks and he could put on up to 1.5 condition score units over that period. The thin cows were then placed on the runoff and fed ad-lib until the end of May.

IF condition score ≤ 3.75 condition score units,
AND it is early April,
AND there is feed on the runoff to graze the thin cows,
THEN dry off the cows and put them on the runoff to increase cow condition to 5.0 in six weeks.

In early May, the 16 cull cows were sold and Farmer B sorted out all thin cows under condition score 4.0 and as a result, dried off 75 thin cows on the 2nd May. These were sent to the runoff to increase condition on the 10th May. Average pasture cover was not an issue through May because it was so high. The main issue was drying off thinner cows to ensure they reached a target condition score of 5.0 by calving.

IF condition score ≤ 4.0 condition score units,
AND it is early May,

AND there is feed on the runoff to graze the thin cows,
THEN dry off the cows and put them on the runoff to increase cow condition to 5.0 before calving.

Drying off the herd

From the start of May until mid May, average pasture cover declined from 2700 kg DM/ha to 2300 kg DM/ha. After mid May, average pasture cover continued to decline and because he had to leave the farm on June 1st with an average pasture cover of 2000 kg DM/ha, Farmer B decided to begin drying off the herd on the 20th May. Farmer B had no further supplements on-hand, and the condition of the herd (4.6 condition score units) was still below his target for planned start of calving (5.0 condition score units). It took a week to dry off the herd, and it was removed from the property on the 27th May. The declining average pasture cover, and the need to meet the target of 2000 kg DM/ha at June 1st drove the decision.

IF average pasture cover is declining towards target,
AND it is late May,
AND no further supplements are available,
AND the condition of the herd is below target,
THEN begin drying off the herd.

Appendix XVIII. Evaluations undertaken by Farmer B.

Table 1. The evaluations carried out by Farmer B.

Category and instance	Evaluation type	Initiated by	Method of evaluation	Criteria	Criteria met	Unusual Situations
Planning						
Planning Decisions						
Use of inputs						
The timing of feeding Japanese millet	Ex-post evaluation	Poor utilisation of crop at grazing	Comparison to simulation if fed earlier	Match	No	New input & very rapid growth prior to grazing
The use of Japanese millet	Ex-post evaluation	Yield below expectations	Comparison to expectations and norm	Match	No	New input
The use of maize silage	Ex-post evaluation	Decision implemented for several weeks	Comparison of herd performance to expectations	Match	Yes	New input
Grazing the calves off-farm	Ex-post evaluation	Actual liveweight below target	Comparison to standards	Match	No	New grazier
Grazing the calves on the milking area	Ex-post evaluation	Actual liveweight ahead of target	Comparison to standards	Match	Yes	New practice
Level of supplement on-hand in the previous spring	Ex-post evaluation	Poor performance over the spring	Compared actual to simulated situation with additional reserves	Match in productivity and profitability	No	Extreme conditions
New forage crop variety	Ex-post evaluation	Poor yield	Comparison to previous forage crops	Match	No	New variety Extreme conditions
Practice of using cow condition as a supplement over summer	Ex-post evaluation	Shift to the use of a high level of supplement over the summer	Reflected on his current practice versus maintaining cow condition	Outcome	No conclusion reached	New supplement practice
Delay grazing forage crop until March 1st and sow new grass later than normal	Ex-post evaluation	Option implemented	Historical simulation with and without decision	Impact on feed situation	Positive for forage crop, unsure for new grass	Very dry December
Management practices	-	-	-	-	-	-
Choice of targets Choice of condition score target at calving	Diagnosis	High empty rate	Comparison of empty rate of heifers to rest of herd	Match	Yes	Extreme conditions through previous spring
Planning assumptions						
Feed input decisions Validity of pasture growth rate assumptions	Ex-post evaluation	On-going	Comparison of actual to expected	Match given conditions	Yes	Second year on the farm

Category and instance	Evaluation type	Initiated by	Method of evaluation	Criteria	Criteria met	Unusual Situations
Implement-ation						
The level of supplement feeding & grazing area allocation	Ex-post evaluation	On-going	Comparison of actual milk production to expectations	Match	Mostly	Extreme conditions experienced at times
Allocation of grazing area	Diagnosis	Milk production fell below target	Comparison to standard	Match	No	Worker implemented plan incorrectly
Method of feeding maize silage	Ex-post evaluation	Milk production and cow intakes fell below target	Comparison to expectations	Match	No	New method
Control						
Control decisions						
Contingency plan selection						
Use of inputs						
Quantity of supplement made in the spring	Ex-post evaluation	Lack of supplement on-hand at the start of summer	Comparison to previous year and requirements	Match	No	Extreme season
Grazing the calves off the milking area on higher quality land	Ex-post evaluation	Liveweight results	Comparison to targets	Match	Yes	New grazier
			Comparison to previous year	Must exceed this	Yes	New grazier
Use of urea in March	Ex-post evaluation	Implementation of option	Observation of colour of pasture	Colour changes to dark green	Yes	New practice
The use of cut pasture	Ex-post evaluation	Implementation of option	Comparison to expectations	Match	Yes	New practice
Doubling silage ration after significant rainfall	Ex-post evaluation	Decline in cow intakes and milk production after significant rainfall	Historical simulation of system performance with and without decision	Impact on milk production	Yes	Very dry February
Management practices						
Sale of cull cows at planned date	Ex-post evaluation	Implementation of the decision	Comparison of actual and expected increase in APC	Match	Yes	
Drying off thin cows as planned	Ex-post evaluation	Implementation of the decision	Comparison of actual and expected increase in APC	Match	Yes	
			Mental simulation of, with and without decision, and comparison of outcome at calving	Match to target condition score	No, if decision not made	
Choice of targets	-	-	-	-	-	-

Category and instance	Evaluation type	Initiated by	Method of evaluation	Criteria	Criteria met	Unusual Situations
Monitoring system						
Accuracy of monitoring						
Calibration of various measures	Ex-post evaluation	On-going	Deviation from standard	Degree of deviation	Mostly	Extreme conditions experienced at times
Accuracy of silage yield estimates	Diagnosis	Milk production did not match cow intakes	Deviation from standard	Match	No	New silage storage method
Timeliness of monitoring						
Date cow liveweight monitoring was initiated in the spring	Ex-post evaluation	Farmer B reflecting	Comparison of what he did with what was ideal	Match	No	Extreme spring when the process was initiated
Accuracy of predictions						
Comparison of short-term predictions with actual pasture growth rates	Ex-post evaluation	On-going	Comparison of actual with prediction	Match	Variable	Extreme conditions are experienced
Overall management of a period						
Summer plan	Ex-post evaluation	End of summer	Comparison to expectations	Match	Yes	Dry, but not extreme
Summer control	Ex-post evaluation	End of summer	Comparison to expectations	Match	Yes	Dry, but not extreme
Systems performance						
Reproductive performance	Diagnosis	Identification of 20% empty rate	Comparison to expectations	8% empty rate	No	Extreme conditions
Milk production in mid March	Diagnosis	Production fell below target	Comparison to target	1.04 kg MS/cow/day	No	Extreme conditions
Milk production in mid April	Diagnosis	Production fell below target	Comparison to target	1.04 kg MS/cow/day	No	Worker implemented plan incorrectly
Pasture growth rates in May	Diagnosis	Fall in average pasture cover despite drying off	Comparison to expectations	Expected average pasture cover to hold or increase	No	Below average pasture growth rates
Liveweight of replacement stock	Ex-post evaluation	Liveweight of stock below target	Comparison to standards	Match	No Yes Yes	New grazier New practice[81] New grazier
Forage crop yield	Ex-post evaluation	Poor yield	Comparison to previous crop yields	Match	No	Very dry December
Milk production	Diagnosis	Milk production declined below standard	Comparison to standard	Match	No	New silage storage method[82]
Milk production	Diagnosis	Milk production	Comparison to	Match	No	Very dry

[81] Grazed on the milking area.
[82] The bulk density of the silage was less than in the past and therefore Farmer B over-estimated silage yield, and hence cow intakes.

Category and instance	Evaluation type	Initiated by	Method of evaluation	Criteria	Criteria met	Unusual Situations
		declined below standard	standard			February followed by heavy rainfall
General farm performance	Diagnosis	Poor farm performance relative to neighbouring farms	Comparison of productivity ratios to other farms in the district	Match	No	Recently converted from an arable farm

Table 2. The ex-post evaluations carried out by Farmer B.

Category and instance	Initiated by	Method of evaluation Comparison of outcome to:	Criteria	Criteria met	Impact of evaluation	Situation
Planning						
Planning Decisions						
Use of inputs						
The timing of feeding Japanese millet	Implementation Poor outcome	Mental simulation	>	No	Change timing	New practice Extreme
Use of Japanese millet	Implementation Poor outcome	Expectations & norm	= >	No No	Discard Discard	New practice
The use of maize silage	Implementation	Expectations	=	Yes	Retain	New practice
Grazing the calves off-farm	Implementation Poor outcome	Standards	≥	No	Change practice	New practice
Grazing the calves on the milking area	Implementation Good outcome	Standards	≥	Yes	Retain	New practice
Level of supplement on-hand in spring	Poor outcome	Mental simulation	>	No	Change level	Extreme
New forage crop variety	Poor outcome	Norm	≥	No	Retain[84]	New practice Extreme
Delay grazing forage crop until March 1st and sow new grass later than normal	Implementation	Mental simulation	>	Yes[83]	Confirm decision	New practice Extreme
Management practices	-	-	-	-	-	-
Choice of targets	-	-	-	-	-	-
Planning assumptions						
Validity of pasture growth rate assumptions	On-going	Expectations	=, given conditions	Yes	Confirm validity	New farm
Implementation						
The level of supplement feeding & grazing area allocation	On-going	Expectations	=	Mostly	Confirm or change	Extreme sometimes
Method of feeding maize silage	Implementation Poor outcome	Expectations	=	No	Discard	New practice

[83] Unsure of impact on new grass.
[84] Farmer B believed the poor outcome was not due to the new variety, but the extreme conditions and will use the forage crop next season.

Category and instance	**Initiated by**	**Method of evaluation** **Comparison of outcome to:**	**Criteria**	**Criteria met**	**Impact of evaluation**	**Situation**
Control						
Control decisions						
Contingency plan selection **Use of inputs** Quantity of supplement made in the spring Grazing the calves off the milking area on higher quality land Use of urea in March The use of cut pasture Doubling silage ration after significant rainfall	 Implementation Poor outcome Implementation Good outcome Implementation Implementation Implementation	 Norm Standards Previous year Expectations Expectations Mental simulation	 ≥ ≥ > = = >	 No Yes Yes Yes Yes Yes	 Change practice Retain Retain Retain Retain Retain	 Extreme New practice New practice New practice New practice Extreme
Management practices Sale of cull cows at planned date Drying off thin cows as planned	Implementation Implementation	Expectations Mental simulation	= >	Yes Yes	Confirm decision Confirm decision	No No
Choice of targets	-	-	-	-		-
Monitoring system *Accuracy of monitoring* Calibration of various measures	On-going	Standards	=	Mostly	Validate or recalibrate	Sometimes extreme
Timeliness of monitoring Date cow liveweight monitoring was initiated in the spring	Implementation	Ideal	=	No	Change[85] date	New practice Extreme
Accuracy of predictions Comparison of short-term predictions with actual pasture growth rates	On-going	Prediction	=	Variable	Validate or refine system model	Sometimes extreme
Overall management of a period **Summer plan** **Summer control**	Implementation Implementation	Expectations Expectations	= =	Yes Yes	Confirm Confirm	No No
Systems performance Liveweight of replacement stock Forage crop yield	Implementation Poor outcome Poor outcome	Standards Norm	≥ =	No Yes Yes No	Change Retain Retain Confirm[86]	New practice New practice New practice New practice Extreme

[85] If used again.
[86] Confirmed poor forage crop yield due to climate, rather than variety.

Figure 3. Examples of evaluations undertaken by Farmer B.

Category	Year 1	Year 2	Year 3
Monitoring system	On-going evaluation of the monitoring system.	On-going evaluation of the monitoring system. Date at which he started monitoring cow liveweights.	On-going evaluation of the monitoring system. Why silage yield was over-estimated?
Choice of targets	The condition score target at planned start of calving.		
Planning assumptions	The validity of his pasture growth rate assumptions.	The validity of his pasture growth rate assumptions.	The validity of his pasture growth rate assumptions.
Choice and use of physical inputs	The activation date for grazing the Japanese millet. Subsequent use of Japanese millet in year two. The use of maize silage as an autumn supplement.	The grazing of his replacement stock on sand country. His decision to graze the replacement stock on the milking area. His final choice of grazier. The level of supplements he had on-hand in the previous spring. The ability of his maize silage reserve to cope with a decline in spring pasture growth rates. The quantity of supplements he made in the previous spring. His decision to use urea in March. His decision to purchase, cut and cart pasture. Choice between urea, greenfeed maize, maize silage, and drying off cows.	Should he continue his policy of using cow condition as a supplement over the summer? The use of maize silage to increase post-grazing residuals through February. The use of additional pasture silage to increase cow intakes after significant rain fell in February. The decision to delay grazing the forage crop to increase yield and therefore delay new grass sowing.
Systems performance	Why the herd had a 20% empty rate? Why milk production declined below target in mid March? Why milk production declined below target in mid April? Why pasture growth rates were below average in early May?	Overall performance of the farm compared to others in the district.	Why milk production and condition score was below expectations in late February? Why milk production was below expectations in March? Why the forage crop yield was poor?
Implementation	Implementation of the grazing plan.		An evaluation of a new method of feeding maize silage.
Management practices	The decision to sell culls in early April as opposed to later. The decision to dry off the thin cows in April as opposed to milking them for longer.		
Management of a specific period	Re-evaluation of the autumn feed budget near drying off.	Re-evaluation of the autumn feed budget near drying off. Control of the summer plan.	

Appendix XIX. Instances of learning undertaken by Farmer B.

Table 1. Instances of learning undertaken by Farmer B.

Instances of learning	Areas of learning	Outcome of learning
Year one		
Farmer B leamt that the Japanese millet did not perform to expectations, or as well as his normal forage crops.	Production system, forage, supplement, forage crop, performance, yield. Management system, strategic, planning, activity rules, input use.	Farmer B replaced the Japanese millet with his normal variety in the following year's plan.
Farmer B leamt about the use of Japanese millet as a forage crop. He also leamt that the utilisation of the forage crop was a function of height, and that he had to graze it before it became too tall. He leamt that in seasons where growing conditions were good, the forage crop would reach a grazeable height earlier than in a normal season.	Environment, biophysical, climate. Production system, forage, supplement, forage crop, performance, utilisation. Management system, tactical, control, monitoring, indicator, contingency plan selection.	Farmer B developed a contingency plan to graze Japanese millet early if it reached a certain height before planned grazing date.
Farmer B leamt that maize silage did maintain the condition of the herd in late lactation.	Production system, forage, supplement, silage, maize, production responses. Management system, strategic, planning, activity rules, input use, planning assumptions.	Farmer B retained maize silage in the plan for year two.
Farmer B also leamt that conditions could become cool and windy enough in March to create a wind chill effect, increasing the maintenance requirements of the herd.	Environment, biophysical, climate. Production system, livestock, herd, performance, maintenance. Management system, tactical, control, contingency plan selection.	Farmer B leamt that a wind chill effect was possible over summer, and that if it was experienced, he had to implement a contingency plan to increase the feed intake of the herd to ensure target milk production was met.
Farmer B leamt that his pasture growth rate assumptions were valid given allowance for the conditions during year one.[87]	Production system, forage, pasture. Management, strategic and tactical, planning, planning assumptions.	The validity of the planning assumptions for pasture growth were confirmed.
Farmer B leamt that his young stock did not perform well on the new grazier's property.	Production system, livestock, young stock, forage, pasture. Management, strategic, planning, activity rules.	Farmer B planned to graze his young stock on the milking area in year two.
Year Two		
Farmer B leamt that urea applied in March could be used to generate additional feed under the correct conditions.	Environment, biophysical, climate. Production system, forage, pasture, nitrogen response, supplement, nitrogen. Management system, tactical, control, planning, contingency plan specification, contingency plan selection, input use.	Farmer B added this option to his repertoire of contingency plans.
Farmer B leamt that he could cut and carry pasture from a neighbour's airstrip and feed it to the herd as a milking supplement.	Production system, livestock herd, performance. Management system, tactical, planning, contingency plan specification, control, contingency plan selection, input use.	Farmer B added this option to his repertoire of contingency plans.

[87] This learning was on-going as Farmer B evaluated the validity of his pasture growth rates on an on-going basis.

Instances of learning	Areas of learning	Outcome of learning
Farmer B learnt that during a cold, wet spring, if he did not have a large quantity of supplement on-hand, it took a long time for systems performance to improve.	Environment, biophysical, climate. Production system, livestock, herd, performance. Production system, forage, pasture, performance, growth rate. Management system, strategic, planning, activity rules, input use.	Farmer B incorporated a quantity of maize silage in his plan as insurance. There was sufficient supplement to counter a 30% decline in pasture growth rates through August and September.
Farmer B leamt that in a cold, wet spring such as in year one, he had to be more proactive in ensuring he generated adequate supplements.	Environment, biophysical, climate. Production system, forage, pasture, performance, supplement, silage yield. Management, tactical, control, contingency plan selection, input use.	Farmer B put in place contingency plans to ensure sufficient supplements were secured in a cold, wet spring.
Farmer B learnt that if he was going to obtain useful information about cow liveweights, then he should begin monitoring this at calving rather than from mid September on.	Management system, tactical, control, monitoring system, timeliness.	Farmer B changed the date at which he would start weighing the herd if he did it again.
Farmer B leamt that graziers on sand country cannot rear replacement stock as well as graziers on better country. The grazier he had last year, who farmed sand country did not rear his replacement stock to a suitable standard.	Environment, biophysical, climate. Production system, (livestock, soils, forage). Management system, strategic, planning, activity rules, input use.	Farmer B planned to source grazing on more productive country.
Farmer B leamt that his farm was not performing as well as others in the district. Diagnosis of the problem identified that the farm's drainage system was inadequate and the cold, wet springs experienced over the last two years had exacerbated the drainage problem.	Environment, biophysical, climate. Production system, soils. Management, strategic, planning, activity rules, input use.	Farmer B had the farm mole ploughed.
Year Three		
Farmer B leamt that if conditions were very dry through December, the subsequent yield of his forage crop in February was very poor.	Environment, biophysical, climate. Production system, forage, supplement, forage crop, performance, yield.	Background knowledge.
Farmer B leamt that using supplement to delay the grazing of the forage crop, increased yield appreciably. He learnt also that grazing the forage crop into early March did not significantly inhibit the establishment of his new grass.	Production system, forage, supplement, forage crop, performance, yield. Management system, tactical, planning, activity rules, input use.	Farmer B added this repertoire to his planning options.
Farmer B leamt how to estimate grass silage yield for a new storage process.	Production system, forage, supplement, silage, yield. Management system, tactical, control, monitoring system, accuracy.	Farmer B acquired additional rules of thumb for estimating supplement yield.
Farmer B leamt how to estimate the yield for a new forage crop.	Production system, forage, supplement, forage crop, yield. Management system, tactical, control, monitoring system, calibration.	Farmer B acquired additional rules of thumb for estimating forage crop yield.
Farmer B learnt that if a considerable amount of rain (≥ 50 mm) fell after a prolonged dry spell, cow intakes declined because of decomposition in the sward. Supplements had to be fed for a week after the rain to hold cow intakes and milk production.	Environment, biophysical, climate. Production system, forage, pasture, performance, quality. Production system, livestock , herd, intake. Management system, tactical, planning, target selection. Management system, tactical, control, (indicator, contingency plan selection, input use).	Farmer B developed a contingency plan selection rule, that if 50 mm of rain or more fell after a prolonged dry spell, then he had to feed additional supplements to maintain cow intakes and milk production.

Instances of learning	Areas of learning	Outcome of learning
Farmer B leamt that under conditions of very high pasture growth rates in autumn, the quality of the pasture changed, such that it contained less energy per unit of dry matter than at other times of the year. Under such conditions, additional pasture and/or supplements had to be fed to maintain cow condition and milk production.	Environment, biophysical, climate. Production system, forage, pasture, performance, quality. Management system, tactical, control, contingency plan selection, input use. Management system, tactical, control, monitoring, accuracy.	Farmer B realised that monitoring rainfall data was important other than for predicting pasture growth rates. He also developed a new contingency plan selection rule to cope with these extreme conditions.
Farmer B leamt that in an extremely good autumn with high pasture growth rates, pasture quality could create a problem, particularly when maize silage was being fed.	Environment, biophysical, climate. Production system, forage, pasture, performance, quality. Management system, tactical, planning, target selection. Management system, tactical, control, (indicator, contingency plan selection, input use).	Farmer B leamt that under such conditions, he needed contingency plan selection rules that specified a reduction in supplement use, and/or an extension of the rotation length, to maintain pasture quality. He leamt that if post-grazing residuals were above 1700 kg DM/ha, then pasture quality problems occurred.
Farmer B leamt that delaying placing the herd on a new break increased the herd's intake of maize silage, but reduced both their pasture and total intake.	Production system, livestock, herd, performance, intake. Management system, operational, implementation, use of inputs.	Farmer B leamt that although this approach did increase maize intake, it reduced pasture and total intake and defeated the purpose of the change.

Table 2. Classification of the learning undertaken by Farmer B.

New management practice	Extreme conditions	Effect on management system	Specific nature of learning	Specific impact on management system
Year 1				
Yes	Yes	Change	Under good growing conditions, Japanese millet grows taller than expected. This creates utilisation problems.	A contingency plan was proposed to graze Japanese millet when it reached a certain height to ensure a high utilization.
Yes	Yes	Change	Japanese millet did not perform better than previously grown forage crops.	Japanese millet was replaced by a brassica in year two.
Yes	No	Confirmed	Maize silage is effective for extending the lactation and maintaining cow condition.	Maize silage was retained as an input in the plan for year two.
No	Yes	Change	Conditions could become extremely cold over the summer-autumn. Under such conditions, cow intakes had to be increased.	A contingency plan was introduced to increase cow intakes under such conditions.
Year 2				
Yes	Yes	Confirmed	Urea can be used to increase feed supply in March.	The contingency plan to use urea was retained as an option for future use.
Yes	Yes	Confirmed	Harvested pasture can be used to extend the lactation.	The contingency plan to use harvested pasture was retained as an option for future use.
No	Yes	Change	A large reserve of feed is required to mitigate the effects of a cold, wet spring.	A reserve of maize silage was set aside for early spring that could cope with a 30% decline in early spring pasture growth rates.
No	Yes	Change	Unless action is taken to ensure adequate supplement is on-hand for the summer, minimal supplement will be made in a cold, wet spring.	Pro-active contingency plans were set in place to ensure a minimal amount of summer supplement was made or procured.
Yes	Yes	Change	Useful information was lost because cow liveweight monitoring was initiated too late.	If cow liveweight is to be monitored in the future, it would be initiated at calving, not mid September.
Yes	No	Change	Young stock performance was poor on sand country.	The young stock were shifted to the milking area.
New farm	Yes	Yes	The farm was performing poorly because drainage was inadequate.	The farm was mole drained.
Year 3				
No	Yes	None	Forage crop yields are poor if conditions were dry through December.	No management response could be identified to overcome this problem. The knowledge was stored and would be used to account for similar problems in the future.
Yes	No	Change	If silage is made a different way, the bulk density changes and yield estimates, using normal heuristics are wrong.	The calibration formula for converting volume to dry matter was changed.
Yes	No	Change	New forage crop varieties may require quite different yield calibration formulae from the current varieties.	The calibration formula for converting height to dry matter was changed.
No	Yes	Change	If very dry conditions are followed by ≥ 50 mm of rain, the pasture can decompose and cow intakes fall unless supplemented.	A contingency plan was introduced that increased cow intakes if significant rain fell after a dry spell.
No	Yes	Change	If pasture growth rates are very high in the autumn, the dry matter content of the feed may be low and additional feed may need to be fed to hold milk production and condition.	A contingency plan was introduced to increase cow intakes under such conditions.
No	Yes	Change	If pasture growth rates are very high in the autumn, pasture quality may	A set of contingency plans were introduced to ensure

New management practice	Extreme conditions	Effect on management system	Specific nature of learning	Specific impact on management system
			become a problem if post-grazing residuals exceed 1700 kg DM/ha	post-grazing residuals remained at or below 1700 kg DM/ha.
Yes	No	Discard	The case farmer leamt that delaying placing the herd on a new break increased the herd's intake of maize silage, but reduced both their pasture and total intake.	The new implementation method was replaced with the previous approach.

Appendix XX. Farmer A – Summary of Year One

Description of year one

The farm was a much better state than normal at the start of the summer with an average pasture cover of 2000 kg DM/ha and a herd at condition score of at least 4.5 condition score units (Table 1). Pasture growth rates were above average for most of the summer autumn period as a result of above average rainfall. As such, this season could be described as atypical, with much better growing conditions than would be expected in a normal summer-autumn.

Table 1. Comparison of the three years for case study one.

Factor	Year 1	Year 2	Year 3
Start of planning period (25/12/xx)			
Average pasture cover (Kg DM/ha)[1]	1700-1800	1800	1650
Pasture quality	Good	Good	Poor
Cow condition	4.5 (+)	4.8 (+)	4.8
Milk production (kg MS/cow/day)	1.39	1.39	1.22
Milking cow numbers	140	150	174
Rotation length (days)	30	30	24
Effective area (ha)	48.0	52.0	63.0
Stocking rate (cows/ha)	3.0	2.9	2.8
Forage crop area (ha)	2.0	3.0	4.5
Silage (bales)	100	103	25
Hay (bales)[2]	2400	1488	2592[3]
Rotation length (days)	30	30	24
January 1st			
Average pasture cover (Kg DM/ha)	16 - 1700	1800	1600
Cow condition	4.5+	4.8	4.8
Milk production (kg MS/cow/day)	1.39	1.39	1.13 - 1.22
Milking cow numbers	140	144	174
February 1st			
Average pasture cover (Kg DM/ha)	1350 - 1400	1800	1200
Cow condition	4.5	4.8	4.4
Milk production (kg MS/cow/day)	1.25	1.39	0.87
Milking cow numbers	138	144	160
Rotation length (days)	29 - 30	28 - 30 (30)	24

[1] During summer, the figures given for average pasture cover are estimates because the case farmer was not formally monitoring this information.
[2] In standard bale equivalents (15 kg DM/bale). One round bale is equivalent to 12 standard bales.
[3] There were 2040 bales bought prior to Christmas, 192 were made in January on the runoff, and 360 bales were purchased in January.

Factor	Year 1	Year 2	Year 3
March 1st[e]			
Average pasture cover (Kg DM/ha)	1350 - 1400	1300	1150
Cow condition	4.5	4.8[h]	4.0
Milk production (kg MS/cow/day)	1.13 - 1.22	1.04[i]	0.40
Milking cow numbers	138	142	141[4]
Rotation length (days)[a]	24 - 29 (25)	25 - 28 (25)	24
Date forage crop started	31/1/xx	10/2/xx[f]	28/1/xx
Date forage crop terminated	1/3/xx[c]	23/3/xx	18/3/xx
Date silage started	NA[d]	15/3/xx	28/1/xx
Date silage terminated		29/3/xx	19/2/xx
Amount fed		17 bales	25 bales
April 1st			
Average pasture cover (Kg DM/ha)	1445	1280	1360
Cow condition	4.5 (+)	4.5	4.3
Milk production (kg MS/cow/day)	1.13 - 1.17	1.04	0.78
Milking cow numbers	138	126	140
Rotation length (days)[a]	25 - 29 (28)	24 - 25 (25)	24
May 1st			
Average pasture cover (Kg DM/ha)	NA	NA	1685
Cow condition	NA	NA	4.7
Milk production (kg MS/cow/day)	NA	NA	0.80
Milking cow numbers	NA	NA	138
Rotation length (days)[a]	NA	NA	24
Drying off date	23/4/xx	28/4/xx	15/5/xx
Cow numbers at drying off	129[g]	119	138
Milk production (kg MS/cow/day)	1.13	0.84	0.70
Condition score	4.5	4.5 (-)	4.7
Average pasture cover (Kg DM/ha)	1342	1332	1570
Date herd on once-a-day	24/4/xx[b]	13/4/xx	23/2/xx
Rotation length at drying off (days)	28	25	24
Urea planned for winter	0.0 tonnes	1.5 tonnes	2.5 tonnes

[e] The young stock were given 3.0 ha because they were short of feed as a result of late hay and silage crops.
[h] Average herd condition increased to 5.0 condition score units on the 24th March, and then declined to 4.8 condition score units.
[i] Milk production held at 1.22 kg MS/cow/day through most of February. When the herd went onto the second forage crop on the 28th February, the case farmer reduced milk production to 1.04 kg MS/cow/day.
[4] The herd was put on once-a-day on 23 February and remained on once-a-day milking until drying off.
[a] The rotation length is the range over the previous month, and the figure in brackets is the rotation length at the end of the month.
[f] Second forage crop of 1.5 ha fed on the 28th February.
[c] The crop was not grazed for 5 days during this period due to muddy conditions.
[d] Not fed until the herd were dried off.
[g] The case farmer put 9 cull cows on waste ground on the 5th April and milked them until the 18th April when they were sold to the works.
[b] R. 3yr cows on once-a-day on 18 April.

The Plan

Planning horizon

During the study, two planning horizons were identified for the summer-autumn period. The first, is from around Christmas until mid March, and the second is from Mid March until calving (15th July). Interestingly, the case farmer stated that 60 - 65% of his production is achieved by Christmas and the remaining 35 - 40% over the summer-autumn. At Christmas, the case farmer sets the summer rotation length and the number of cows he intends to milk through the summer autumn based on the feed supply on the farm around Christmas. Christmas is a period subsequent to a period when the case farmer has been concentrating on the control of the spring flush and the making of supplements in the farm of silage. Silage paddocks that were harvested in November have come back into the round. Climatically, the farm is moving from a period of high pasture growth rates to a period of low pasture growth as a result of dry summer conditions.

Mid March is the point around which the autumn rains are likely to occur in a typical year and is the point when the farm moves from summer conditions to autumn conditions. With the arrival of the autumn rains, pasture growth rates increase and the farm moves from a period where feed demand exceeds pasture growth to one where pasture growth exceeds feed supply. This point in time is also important because a critical event, drying off, occurs soon after this date (Typical date: 15th April) and decisions made at this time have a large influence on production in the subsequent spring. As a result, the case farmer initiates a formal planning process using a feed budget on April 1st. This date is chosen firstly, because by this point in time the farm will have normally received (or not received) the autumn rains, and pasture cover would have increased through late March. The case farmer made the comment that there is little point planning for the next spring "*until he has feed to work with*". The drying off process, in combination with the pulse of feed generated by the autumn flush, allows the farmer to increase his pasture cover rapidly. The importance of these rains is such, that if they occur earlier than mid March, the case farmer will initiate the next planning phase at this point. The drying off decision is critical because it influences the level of pasture cover and the condition of the herd pre-winter. These factors are critical in ensuring the farm is well set up for the following spring. The drying off decision is also irrevocable. If it is made too early, then income from further milk production in the current season is foregone. The case farmer also chose this date to initiate the formal planning process because the sward changes as the farm moves from summer to autumn conditions. The autumn sward can be measured more accurately, allowing the case farmer to take objective measurements that can be used for formal planning and control purposes. The case farmer does not delay the point at which he undertakes formal planning any later than April 1st because of the imminence of the drying off decision (normally mid to late April).

The termination point in this second planning phase is calving. This is a critical obligatory event on a dairy farm. Prior to this the case farmer is managing a non-lactating herd to ensure it is in good condition and has sufficient feed for calving. From the start of calving, the case farmer is managing both dry and lactating animals, and his aim is to fully feed the lactating animals through until pasture growth exceeds feed demand.

The case farmer also undertook a formal feed plan on March 9th just prior to the completion of the grazing of the forage crop. This was initiated because the case farmer thought that with the cold, wet springs over the last two years, he might be better off retaining the autumn silage and feeding it next spring. The excellent feed position in early March provided the opportunity for him to not feed the silage and use the high average pasture cover and good growing conditions instead. He undertook the feed budget to test the feasibility of this option. In effect, a strategic change had triggered the need for a formal planning process. The case farmer also initiated a formal planning exercise using a partial budget in early April to determine the economics of using nitrogen to extend the lactation.

The case farmer also has a number of shorter-term event-based planning horizons within these two longer-term horizons, e.g. the period over which the crop is fed, and the period from April 1 until drying off are viewed as a distinct periods, within the broader tactical plans.

Hierarchies of plans

During the study period, two major tactical plans were identified. One was used from Christmas until mid March and the second from mid March until calving. However, within these planning periods, it appeared that the case farmers had shorter-term planning horizons that were about 2-4 weeks in duration for such activities as feeding the forage crop in February and drying off the herd during April. The case farmers also used formal planning techniques to investigate options. One of these plans covered the period from March 9 until calving, therefore encompassing both tactical periods.

Values, goals and targets

Little mention of values, or their influence on the tactical management process was made by the case farmer. However, he said that he did not use options such as nitrogen and grazing off the herd as part of his normal plan because "*its just the way I am*". Instead, these were options of last resort. This appeared to reflect the case farmer's "low input" philosophy - he wanted to minimise the cost of bought-in feed to his farming system. As such, his values limited the options or "modes" open to him.

There was little evidence of the process of goal formulation in relation to the case farmer's tactical management. The goals appeared to have been formulated at an earlier date. The goals could be separated into two high level goals for each planning period and then a set of targets that were used for control purposes. The summer goal is subservient to the autumn goal. This subservience is dictated by the terminating conditions for the summer period, i.e. the summer goal must be achieved within the constraints imposed by the terminating conditions for the start of the autumn planning period. These terminating conditions in turn are dictated by the terminating conditions for the autumn plan which are an average pasture cover of 2200 kg DM/ha and an average herd condition of 4.5 condition score units at planned start of calving. These terminating conditions constrain the activities in each planning period because the case farmer believes that conditions at calving have a much greater influence on production (and hence profitability) than feeding decisions made through the summer-autumn.

The goal for the summer period is to ensure the maximum number of milking cows make it through to the autumn rains while optimising milk production. The case farmer used two targets for control purposes through the summer - milk production (litres/cow/day) and cow condition. He does not use average pasture cover as a target for most of the summer due to problems of accuracy. The case farmer wants the herd to produce a minimum of 12 - 13 litres/cow/day (1.04 kg MS/cow/day) throughout as much of the summer as possible. The case farmer based this production target on a rule of thumb that it should be 60% of his peak production (22 litres /cow/day this year). He selects the number of cows to carry over the summer on the basis of his feed situation (pasture, supplements and crop) and state of the herd (production levels and cow condition) at Christmas and his production target.

The milk production target is chosen for a number of reasons. Firstly, at lower production levels (e.g. < 0.96 kg MS/cow/day) the herd starts to lose body condition. Similarly, at lower production levels the herd is slow to respond to additional feed. The farmer believes that feeding animals well at a higher level of production for a shorter period is more efficient than feeding the animals less for a longer period of time. Although not mentioned by the farmer, he may be using the concept of marginality. The marginal value of feed is greatest from animals producing at a high rate (as opposed to a low rate). The opposite side to this is that if the animals use too much feed because they are producing at a very high level, then if feed becomes short, the herd would have to dry off, and hence the farmer would not be in a position to take advantage of autumn growth.

The case farmer admits that there is some risk involved with his strategy. He must compromise between stocking rate (number of cows carried), production level per cow and lactation length. The milk production target is used to determine when to feed the forage crop and the silage over the summer period. When feeding the forage crop, the case farmer increased the target to 1.13 kg MS/cow/day to allow for a 0.09 kg MS/cow/day decline in production that normally occurs when the herd changes diet. The most interesting point was that the case farmer changed his target of 1.04 kg MS/cow/day to 1.13 kg MS/cow/day later in the season because conditions were extremely good in relation to average pasture cover and pasture growth.

The second target used by the farmer to control the summer period is cow condition. The farmer monitors the condition of his thinner and younger cows. Animals that have a body condition of 3.5 condition score units are put on once-a-day milking to hold condition. If condition falls below this level, then the animals are dried off. This target is used to ensure the herd meets the condition score target set at the start of calving. The case farmer aims to maintain the herd at or above 3.5 - 4.0 condition score units over the summer.

Once the case farmer had fed off the forage crop, he completed a gross feed budget to determine how much silage he could feed out post-forage crop. This feed budget showed that he could meet his targets at calving provided his average pasture cover did not fall below 1400 kg DM/ha over the remainder of the summer-autumn period. The case farmer used this target, along with his other targets, for decision making up until he completed his formal feed budget on April 1st.

The autumn goal is achieved by carrying 140 cows through the period and ensuring these produce at a high level (≥ 12 l/cow/day) for as long as possible into the summer. The case farmer believes that it is more efficient for his herd to produce at a high level for a shorter period, than at a lower level for a longer period. However, his objective is to have the 140 cows in a lactating state at mid March. Therefore, the case farmer's milk production target has a proviso, that the level (12 l/cow/day) is for "*as long as possible*". The period at which this level of production can be maintained is a function of the season. To achieve this level of production, the herd must be fed around 10 - 12 kg DM/cow/day. The herd are on a 25 - 30 day rotation and supplements (forage crop and silage) are fed to maintain this level of production through the driest period, February. The farmer aims to maximise pasture production through the summer to ensure the herd can be adequately fed. He believes that this can be achieved if average pasture cover is maintained above 1400 kg DM/ha. However, he admits this is an ideal level and in most seasons, it falls below this level. Supplements are used to maintain average pasture cover for as long as possible into the summer. The case farmer uses a 25 - 30 day rotation as he believes this is optimum for summer conditions. The case farmer also takes advantage of significant rainfall events (≥ 25 mm) during summer through the use of supplements and temporarily extending the rotation, to allow maximum pasture growth to occur post-rainfall. Low producing cows (≤ 2.0 l/cow/day) are culled to divert feed to the remainder of the herd.

The case farmer also aims to maintain average herd condition above a target of 3.5 - 4.0 condition score units. Condition, as opposed to average pasture cover is the primary concern of the case farmer in late summer. This is an important terminating condition that the case farmer tries to achieve at the end of the period. In an extremely dry year, the case farmer will dry off the herd in response to condition rather than average pasture cover. Therefore, the terminating conditions the case farmer aims for at April 1st is to have as many of the original 140 cows in a lactating state as possible, and the herd at a minimum condition score of 3.5 - 4.0 condition score units. The average condition of the herd is maintained through the milk production target. The case farmer believes that the herd will not lose condition provided it is producing at or above target. If cow condition does begin to decline, thin cows are placed on once-a-day milking to hold condition. In extreme conditions these animal would be dried off if they continued to lose condition.

Analysis of the goal identifies some goal conflicts between cow numbers, production levels, cow condition and average pasture cover. The case farmer said he would prefer to milk at a higher level for a shorter period, than at a lower level for longer to achieve the same level of production. However, he admits that there is the risk that he has to dry off before the autumn rains and forego additional milk production. The cow number goal is in conflict with the milk production target, i.e. with less cows the herd could milk for longer at the target level. No conflict exists between the cow condition and milk production targets because of the relationship between milk production, intake and cow condition. However, conflict exists between the pasture growth goal and the milk production target and cow number goal. The "ideal" pasture cover target is secondary to the cow number goal and milk production target. Again, due to the interaction between the various production factors, the case farmer knows that he will have to dry the herd off on condition before average pasture cover becomes an issue. Average pasture cover drives intakes which in turn drives milk production and condition score. If condition score has reached the state that the case farmer has to dry off the herd, then milk production and average pasture cover will also be at a very low level. To achieve the terminating conditions at next calving, cow condition as opposed to average pasture cover is more critical in late summer. This is because the case farmer believes it is more difficult to increase cow condition than pasture cover over the autumn, winter.

The case farmer calculated, using a gross feed budget, the summer terminating conditions required to ensure his autumn goal is not jeopardised in March after the crop was fed to the herd. His aim was to maintain average pasture cover above 1400 kg DM/ha until April 1st, at which time, he completed a formal feed budget to determine his likely drying off date.

The goal for the autumn period is to optimise milk production without jeopardising next spring's production. However, milk production is secondary to ensuring the spring targets are met. The case farmer normally dries the herd off mid April, so the impact of this period on total annual production in the current season is minimal. However, its impact on the following season can be considerable. During autumn, the case farmer uses average pasture cover targets generated by his feed budget for management purposes. The feed budget is used to determine the average pasture cover he needs at May 1st (1400 kg DM/ha this year) in order to meet his calving targets. In a normal year, the condition of the herd rather than average pasture cover will determine the drying off date. However, this year, cow condition never fell below the target for calving. As such, the average pasture cover target was the critical target for this year. Alternatively, the occurrence of the autumn rains may trigger the drying off decision. Normally, there is a period of rapid pasture growth after the autumn rains. The case farmer will dry off the herd, double the rotation length, and in effect halve the area it grazes to maximise the effect of such growth.

Although milk production is an important target over summer, it is not used as a target during the autumn. Milk production is used as an indirect measure of cow condition, pasture cover, pasture growth rates and cow intakes during summer, when objective methods cannot measure pasture mass accurately. However, during autumn this is possible, and the case farmer changes to an objective measure (falling plate meter) and uses this in conjunction with a formal feed budget.

The case farmer's targets at calving are an average pasture cover of 2200 kg DM/ha and a condition score of 4.5 for the herd. These targets are based on experience. If the average pasture cover was less than 2200 kg DM/ha then the herd would be underfed during early lactation leading to problems in relation to milk production, cow condition and reproductive performance. If the average pasture cover was higher than the target, then many of the paddocks would be at a pasture cover of over 3500 kg DM/ha. Regrowth from these paddocks would be poor and during the second round post-calving, insufficient feed would be grown to meet demand. Therefore he aimed to ensure average pasture cover did not exceed 2300 kg DM/ha over the winter. The case farmer believes that he can cope with a variation in average pasture at calving of between 2000 - 2400 kg DM/ha. Within this range, cow condition held priority over pasture cover at calving, and if it appeared the case farmer was going to calve onto 2000 kg DM/ha, then he would not take condition off the herd in late lactation to meet his target of 2200 kg DM/ha.

Of particular interest, is the fact that the case farmer changes his pasture cover target for calving in year one. Prior to this, he had aimed to calve onto 2000 kg DM/ha. However, during the previous year's mating, the case farmer had synchronised his rising two year heifers. This meant that feed demand in early lactation had increased considerably in comparison to previous years. To compensate for this, the case farmer had increased his target average pasture cover by 200 kg DM/ha.

The case farmer believes that calving with the herd at a condition score of less than 4.5 condition score units would create problems in terms of milk production and reproductive performance. Conversely, the case farmer does not believe that the benefits from calving at condition score 5.0 outweigh the costs which are effectively a shorter lactation. Interestingly, the case farmer admitted that he had not calved his herd at condition score 5.0. The case farmer stressed that average pasture cover was more important at calving than cow condition. His greatest problems were likely to occur if he had cows in good condition and a low average pasture cover.

The case farmer has a production target of 45,240 kg MS for the season. However, he does not have monthly targets, and he does not expect to achieve this objective due to variation in pasture growth as a result of climatic variation. Similarly, the summer milk production target of 12 l/cow/day is expected to be met while the forage crop and silage are being fed, but after this the case farmer knows that further milk production will be dependent on pasture growth, which is highly variable at that time of year.

Planning method

The case farmer used two forms of planning during the study period. For most of the summer, he used a predefined plan that set out a sequence of activities that were designed for a typical year. Embedded within this plan were a set of sub- or contingency plans that the case farmer could use should conditions deviate from normal. The predefined plan was based on previous years' experience and the case farmer's choice of the schedule of activities in the plan could be represented in the form of decision rules (Table 2). This plan was not formally documented. The process used by the case farmer was a combination of qualitative and quantitative planning. Around Christmas, the case farmer assesses the feed position on the farm in terms of average pasture cover, pasture growth rates, pasture quality, cow condition and current milk production per cow, silage on-hand, and the state and estimated final yield of the forage crop. He calculates the yield of the silage and the likely yield of the forage crop and then estimates how many weeks "feeding" these are likely to provide to the herd over the period Christmas to mid March. He also evaluates the level of average pasture cover and current pasture growth rates and climatic conditions to assess how long the herd can be fed on pasture alone. This provides the case farmer with a rough estimate of the weeks feeding he has for each of these options. On this basis he decides whether he is facing a "typical" or "dry" summer. In effect, he runs a mental simulation (rough mental feed budget) to test the feasibility of his "typical" plan given the current farm state. If he classifies conditions as "typical", where "typical" is a situation where the farm state is normal, or better than normal, then he will implement his "typical" summer plan. However, if the conditions are classified as "dry", he will modify the "typical" plan for "dry" conditions (see years 2 and 3).

The number of cows the case farmer takes through the summer is based on his rough estimate of the weeks grazing he has from his various options. He wants to feed the herd to the point where production will be maintained around 12 litres/cow/day (1.04 kg MS/cow/day). He makes an estimate of the number of cows the farm in its current state is likely to carry. He notes that this is a fairly subjective assessment, but in effect it is a form of feed budget. In a "dry" year, he will reduce the target to 10 litres/cow/day (0.5 kg MS/cow/day). This reduces feed demand, and allows him to carry more cows through the summer to the period of the autumn rains. He noted that the climate tends to even itself out over a season, and if it is dry in early summer, the farm will often receive good autumn rains and above average autumn pasture growth rates. Reducing the milk production target allows the case farmer to carry additional cows through the summer to take advantage of this feed if it does occur.

The case farmer also pointed out that his feed position around Christmas normally reflects the conditions over the late spring (late November - December). If growing conditions have been good, then the herd will be in good condition and producing at a high level, average pasture cover and pasture growth rates will be above average, the forage crops will be above average and he will have harvested above average levels of supplement. In a dry late spring, the opposite will have occurred.

In early March, the case farmer did use calculations to determine how much silage he could use once the crop was grazed off. A feed budget (monthly periods) for the period from March 9 through to calving was calculated. However, this was an abnormal planning exercise because the case farmer used it to analyse a strategic decision to change from feeding summer silage to using this in the spring to cope with the cold, wet conditions the farm had been experiencing over the last few seasons.

Table 2. Decision rules for the summer plan.

Activity	Decision Rule	Reason
Selection of summer stocking rate	Select sufficient cows given the current feed position (pasture, summer silage, forage crop), and the state of the herd (milk production, condition, culls) such that they can be fed to produce 12 - 13 litres/cow/day (1.04 kg MS/cow/day) until at least mid-March under typical conditions.	A herd producing at a higher level of milk production converts feed into pasture more efficiently than a herd producing at a low level of milk production. However, if feed demand is too high, the herd may have to be dried off in early summer and fail to take advantage of the autumn flush.
Specification of production levels	Aim to produce 12 - 13 litres/cow/day (1.04 kg MS/cow/day) until at least mid-March under typical conditions.	A herd producing at a higher level of milk production converts feed into pasture more efficiently than a herd producing at a low level of milk production. However, if feed demand is too high, the herd may have to be dried off in early summer and fail to take advantage of the autumn flush. At his level, the farmer knows that the herd is maintaining body condition.
Specification of intake levels	Feed the cows sufficient to produce 12 - 13 litres/cow/day (1.04 kg MS/cow/day) until at least mid-March under typical conditions.	A herd producing at a higher level of milk production converts feed into pasture more efficiently than a herd producing at a low level of milk production. However, if feed demand is too high, the herd may have to be dried off in early summer and fail to take advantage of the autumn flush.
Specification of condition score targets	Aim to maintain herd condition above 3.5 - 4.0 condition score units.	The herd must calve at condition score 4.5. In order to reach this target, the herd cannot be at too low a condition score at drying off.
Selection of rotation length	Use a 30 day rotation through the summer period. Maintain the herd on a 30 day rotation until the crop is ready to graze or milk production falls to 13litres/cow/day (1.13 kg MS/cow/day). Maintain the herd on a 30 day round post-silage until drying off. At drying off, double the rotation length to 60 days.	A faster round (< 25 days) would reduce pasture growth rates and reduces the level of pasture cover on the farm which protects the sward in hot, dry conditions. A longer round (approx. 40 days) would restrict cow intakes, resulting in a decline in milk production and body condition, and over summer, the feed that is pushed ahead of the herd would burn off. Also, pragmatically, such a rotation length suits the level of subdivision on the farm. The rotation length is doubled at drying off to halve cow intakes and to reduce the area the herd grazes to take advantage of the autumn flush.
Specification of timing and quantity of forage crop fed.	Feed the forage crop when it is mature or milk production falls to 13 l/cow/day (1.13 kg MS/cow/day) or the date/crop yield is such that the crop can be grazed off no later than March 15th. Feed sufficient crop to maintain milk production at 12 l/cow/day (1.04 kg MS/cow/day). The forage crop component should make up roughly 1/3 of the herd's diet.	The forage crop is fed at a stage when it is mature and has reached its highest yield and quality, or milk production falls to 13 litres/cow/day (1.13 kg MS/cow/day), with the latter over-riding the former. Normally crop quality declines after it has reached maturation and crop growth rates are poor. The forage crop is fed to maintain milk production at 12 - 13 litres/cow/day (1.04 kg MS/cow/day) because the case farmer believes it is more efficient to feed the crop for a shorter period at a higher level of production than for a longer period at a lower level of production. Therefore, although the case farmer recommends 1/3 of the herd's diet be fed as crop, the actual amount depends on the level of pasture the herd is being fed. The case

Activity	Decision Rule	Reason
		farmer recommends 1/3 of the diet in order to make an impact on feed supply. The crop is fed when production falls to 13 litres/cow/day (1.13 kg MS/cow/day) to allow for a fall in milk production as a result of a change in diet. The crop must also be harvested before the mid March to ensure the new grass is sown on time. One third of the herd's diet is fed because much less than this has little impact on the system. The crop is fed at this stage because normally the farm is in a feed deficit situation.
Specification of timing and quantity of summer silage fed	Feed the silage crop after the forage crop when milk production declines to 12 litres/cow/day (1.04 kg MS/cow/day) at the rate that maintains milk production at this level (approx. 1/3 of the herd's diet).	The silage is fed after the crop to ensure the herd continue to produce at high levels. Silage does not deteriorate in terms of quality, hence silage is fed after the crop. One third of the herd's diet is fed because much less than this has little impact on the system.

In contrast to the summer planning process, the autumn planning process was based around a formal feed budget that was estimated for the period April 1 to planned start of calving (15th July). The autumn period *per se*, starts at mid March, and at that point, the case farmer uses an informal qualitative approach, identical to that used for the summer plan to set out the events from mid March until calving. However, once April 1st arrives, the case farmer assesses whether the autumn is going to be late and dry, or early with good pasture growth, he initiates a formal planning process that quantifies his qualitative plan from April 1st until calving. The case farmer did not plan through to the point where pasture growth exceeds feed demand in early lactation because the planning process is overly complicated and time consuming. Given the level of uncertainty at this time of year, he prefers to specify an average pasture cover target for planned start of calving that he thinks will provided sufficient pasture to fully feed the herd in early lactation. This, in effect, simplifies the planning problem.

The reason for the change-over in planning technique is partly because the accuracy of the falling plate meter is much higher during the autumn than the summer, and therefore it is possible to use a formal planning technique. However, it is primarily due to the imminence of a critical decision, drying off. The case farmer does not initiate formal planning until April 1st, so that he obtains an idea of the nature of the autumn in relation to the timing and quantity of autumn rain that has occurred and the pasture response. The case farmer also mentioned that pasture growth rates over the summer period are much more variable than at other times of the year which makes it more difficult to use formal planning techniques. That is, a significant rainfall event, can have a much greater impact on feed supply than through the late autumn and winter.

As the case farmer had used up most of his options, the feed budget was used essentially to calculate a nominal drying off date. The sequence of activities within the plan were based on the case farmer's mental plan for the autumn-winter period. The autumn rains occur around mid April and induce a "pulse" of pasture growth. In order to take advantage of this, the case farmer dries off the herd, reducing the area they are grazing by half.

The first step in the formal planning process was to establish the state of the farm in terms of average pasture cover, cow condition and level of milk production. This information was formally assessed. The goals were already pre-defined and did not need to be formulated or clarified. The schedule of events in the plan were specified from the case farmer's mental model. The case farmer then quantified the scarce feed resources available for the period. These included average pasture cover, pasture growth rates and supplements. A feed profile was estimated for the herd based on current condition score and milk production, expected milk production levels, calving date, required condition at calving, cow numbers and nominal drying off date. Constraints were then defined, which in this case, were the terminating conditions for the plan at calving. As previously mentioned, the case farmer changed his target average pasture cover for calving to accommodate an increase in feed demand in response to synchronizing the mating of his rising two year old heifers. The case farmer then completed a monthly feed budget form April 1 to calving. The feed budget was used to estimate the required drying off date to achieve spring average pasture cover and cow condition targets. The case farmer also estimated intermediate average pasture cover targets for the autumn and winter.

The animal feed requirements and pasture growth rates used in the feed budget were based on the case farmer's experience, including his previous use of feed tables. He uses average pasture growth rates in his feed budget and did not adjust these for conditions specific to a particular season. However, because the case farmer had recently adopted a practice of on-off grazing over the winter which improved pasture growth by 20 - 30%, the average pasture growth rates used for planning were somewhat underestimated. This provided the case farmer with some flexibility in the case of a cold winter.

The autumn planning process *per se* in effect quantified the case farmer's mental plan and was then used to calculate a nominal drying off date that would ensure terminating conditions at calving were achieved. The plan also specified intermediate targets for average pasture cover that were used for control purposes in determining the actual drying off date. The case farmer did not generate and analyse alternative options during the planning process as these were already defined in the plan. He did however, use a partial budget to investigate the use of nitrogen to extend the lactation, but decided against the option on the basis of risk and timeliness. Only one option was investigated, although the case farmer had previously mentioned alternate options such as grazing and buying in hay. Nitrogen had not been used by the case farmer before to extend the lactation, and was only analysed because conditions were so good at the start of April.

Once the plan was developed on April 1st, the case farmer did not update it after each monitoring cycle, but rather, used the average pasture cover targets generated from the feed budget to decide when to dry off, i.e. he knew that to achieve his targets at calving, he had to have 1400 kg DM/ha by May 1st. Therefore, he dried off when the actual average pasture cover fell below 1400 kg DM/ha in late April. This saved him undertaking several time consuming planning exercises. The farmer did not own a computer, so all formal planning exercises were completed on paper with the aid of a calculator. The case farmer used a simple feed budget form developed by the dairy extension service to estimate his drying off date and quantify his autumn winter plan.

The Plan

The case farmer's plan comprised goals, a schedule of events or activities, a set of contingencies that could be used when actual performance deviated from planned, and a set of intermediate targets against which actual performance could be compared for control purposes. These latter two aspects of the plan will be discussed under control to avoid repetition. The schedule of events in the case farmer's plan is summarised in Table 3. He planned to carry 140 cows through the summer-autumn and these were expected to produce at around 12 - 13 litres/cow/day (1.04 kg MS/cow/day) for as long as possible into the autumn. The herd was to be kept on a 30 day round through until April 1st. In early February, the crop was expected to be mature and fed to the herd when production fell to 13 litres/cow/day (1.13 kg MS/cow/day) for a period of 2-3 weeks. The forage crop was to comprise roughly one third of the herd's diet, but the amount is dictated by the need to hold production at 12 litres/cow/day (1.04 kg MS/cow/day) hence it may vary depending on how much pasture is available. At the same time the herd were to remain on a 30 day round.

Silage (12,500 kg DM) was to be fed to the herd after the crop if required to maintain production at around 12 - 13 litres/cow/day. Again this was to be fed at around one third of the herd's diet and last two weeks. However, the amount fed was dictated by the need to hold production at 12 litres/cow/day (1.04 kg MS/cow/day) hence it may vary depending on how much pasture is available. After the silage had been fed, the herd was to continue on a 30 day round. The drying off date was to be dictated by the level of pasture cover on the farm and cow condition. Culls (10 - 15) were to be sold at drying off. The case farmer intended to increase herd numbers and winter 160 -165 cows, therefore he planned to limit his culling to the minimum. Cows were culled on the basis of production, somatic cell count and pregnancy status. The case farmer aimed to dry off the herd when the autumn rains occurred (normally mid April), and planned to place the herd on a sixty day rotation to take advantage of the "pulse" of high pasture growth rates that follow the autumn rains. Other activities undertaken by the case farmer during this period included: the removal of the bull from the herd on the 20th January, herd testing in mid February, pregnancy testing early March and the sowing of the new grass in mid March

Table 3. The case farmer's plan.

Feed related activities	Other activities
Carry 140 cows through the summer-autumn	
Maintain a 30 day rotation	Remove the bull on the 26th January
Feed the crop in early February when milk production falls to 13 litres/cow/day (1.13 kg MS/cow/day). Feed one third of the herd's diet and maintain production at 12 -13 litres/cow/day (1.04 kg MS/cow/day). Feed the crop for 2 - 3 weeks.	Herd test mid February
Feed silage (12,500 kg DM) after the crop to maintain milk production at 12 -13 litres/cow/day (1.04 kg MS/cow/day)	Pregnancy test the herd early March Sow the new grass mid March
Maintain a 30 day rotation	
Sell the cull cows at or near drying off	
Dry off the herd when the autumn rains arrive around mid April and increase the rotation length to 60 days.	

Implementation of the plan

Table 4 shows the case farmers plan and the actual outcome along with the reasons for any difference between the two. Some differences were due to biological variation in the herd. Two culls were sold in late January because they were producing minimal milk, and six rising three year old cows were put on once-a-day milking because they could not compete with the rest of the herd on the forage crop and lost condition. Similarly, the bull was kept with the herd for an extra two days because a valuable rising three year old cow was cycling, and in late April, all the rising three year old cows were put on once-a-day milking because they were not competing with the older cows and losing condition. Other differences were a result of a temporary shortage of labour that delayed an activity e.g. herd testing, pregnancy testing, resowing the new grass.

The major cause of differences between the plan and the actual outcome was the weather, and in particular rainfall. The forage crop was grazed for a month as opposed to

2 - 3 weeks due to exceptional summer rainfall. This meant the herd could not graze the forage crop for 5 days due to muddy conditions. The forage crop only comprised 25% of the herd's diet because pasture supply was greater as a result of the rain. The rain also caused the forage crop to increase in yield extending its grazing duration. The forage crop was also fed to the herd at 40 % of their diet to take advantage of a significant rainfall event. The grazing rotation varied between 24 and 30 days in response to rainfall events. The rotation was either shortened when the forage crop was not grazeable, or extended when additional forage crop was fed to take advantage of a rainfall event.

The exceptional rainfall meant that the silage was not required post-forage crop. This was retained for use at drying off. The culls were grazed on waste ground, an opportunity taken by the case farmer, and then sold a day prior to drying off. Eleven culls were sold, which was within the target of 10 - 15 specified by the case farmer. The herd was dried off eight days later than planned. This was because of the exceptional season. The herd was at least 0.5 condition score units above that expected in a typical year.

Table 4. A comparison of the plan with the actual outcome.

The plan	The outcome	Reason for difference
Carry 140 cows through the summer-autumn.	138 cows carried through the summer-autumn.	Two culled mid January due to low production (< 2.0 litres/cow/day).
Maintain a 30 day rotation.	Rotation reduced to 29 days.	The case farmer fed the herd additional feed during a wet day.
Remove the bull on the 26th January.	Bull removed on the 26th January and then returned on the 28th January for one day.	A good R.3yr cow was cycling. The bull was reintroduced to mate her.
Feed the crop in early February when milk production falls to 13 litres/cow/day (1.13 kg MS/cow/day).	The herd went onto the forage crop when milk production fell to 13 litres/cow/day (1.13 kg MS/cow/day).	
	Six thin heifers were placed on once-a-day milking.	These heifers would not eat the crop and lost condition. At c.s. 3.5 they were put on once-a-day milking to hold condition. They remained on once-a-day milking until drying off.
Feed one third of the herd's diet and maintain production at 12 -13 litres/cow/day (1.04 kg MS/cow/day).	The crop constituted about 25% of the herd's diet. For a period of 2 -3 days this was increased to 50%.	The ratio reflected the higher than average level of pasture on the farm. The crop intake was increased to 50% of the herd's diet to take advantage of a significant rainfall event and increase pasture cover. The case farmer increased cow intakes when the herd was on the forage crop because pasture growth rates were high for February, and he wanted to take advantage of the additional pasture growth, but also graze the forage crop by the end of the month. He increased the milk production target to 1.13 kg MS/cow/day to do this.
Feed the crop for 2 - 3 weeks.	The crop was grazed from 31st January to 1st March.	The herd were off the crop for 5 days, available pasture levels were higher than average, and the crop yield continued to increase throughout the month which was unusual.
While on the crop, maintain a 30 day round.	While on the crop the rotation length was reduced to 24 days.	The case farmer had to use pasture during periods when the crop was too muddy to graze due to significant rainfall events.

The plan	The outcome	Reason for difference
Herd test mid February	Herd test 20th February	Labour unavailable that week
Feed silage (12,500 kg DM) after the crop to maintain milk production at 12 -13 litres/cow/day (1.04 kg MS/cow/day).	The silage was not fed to the herd after the crop was grazed.	Sufficient rain fell while the crop was being grazed to allow the herd to maintain production on pasture alone. The silage was retained for use at drying off.
Maintain a 30 day rotation post-silage.	The rotation was extended out to 29 days post crop and held at 28 - 29 days through until drying off.	Silage was not required post-crop, and there was sufficient feed on the farm to extend the rotation out to 28 - 29 days from the 24 days the herd was on when grazing the crop.
Pregnancy test the herd early March	Herd pregnancy tested late March.	No reason was given, but the case farmer did not appear to need this information until April1 when he did a formal feed budget. Pressure of work may have delayed the pregnancy test.
Sow the new grass mid March	Sown April 2.	Pressure of work delayed the sowing date.
Sell the 10 - 15 cull cows at or near drying off.	Nine cull cows put on waste ground (but continued to milk them) on 5th April, then sold on the 22nd April. Two low producing culls were sold in January, to make a total of 11 culls sold.	The feed budget on April 1 suggested that Jim needed to sell the culls as APC was near his target of 1400 kg DM/ha. However, waste ground was available, so they were grazed on this until it ran out. On the 18th April, the APC had not improved, so the decision was made to sell the culls. It took a week to get them into the works. Only 9 were sold because the rest were kept to make up the herd numbers for the winter. Three high PI R.3yr heifers were carried over.
Dry off the herd when the autumn rains arrive around mid April and increase the rotation length to 60 days. The herd should be dried off at a condition score of between 3.5 - 4.0 and at an APC that is sufficient to ensure a target APC of 2200 kg DM/ha is achieved at calving.	The herd were placed on a 60 day round and fed 3 kg DM/cow/day of silage and 4 kg DM/cow/day of pasture. On the 18th April, the R.3yr cows were put on once-a-day milking. The herd was dried off on the 23rd April at condition score 4.5. This took a week and a half to complete and the rotation length was doubled to around 60 days.	The silage was not used earlier in the summer, and could thus be used to build up pasture cover at drying off. This was done to prevent the R.3yr heifers from losing condition. These animals struggle to compete with the older cows in the herd. Pasture growth this season was above average, and this allowed the case farmer to milk the herd for longer than normal and feed them better than normal so that they were in much better condition than in a typical year at drying off. The herd dried off at an APC of 1342 kg DM/ha. This is below the target of 1400 kg DM/ha, because even though the case farmer reacted quickly, pasture cover fell rapidly in the 5 days between monitoring. However, this level of APC was not seen as a problem.

The control process

The control process used by the case farmer consisted of monitoring key performance measures, comparing these to standards or intermediate targets to identify significant deviations, and if a deviation existed, using decision rules to select the most appropriate contingency plan for the conditions. Although problem detection was undertaken, it was not apparent that any form of conscious problem definition or diagnosis was undertaken in most instances. The case farmer did evaluate a range of areas in relation to his tactical management, and examples of learning were recorded.

The monitoring process

The most interesting finding was that the case farmer used quite different indicators for decision making during the summer versus the autumn planning period. During early summer, milk production (litres/cow/day) was the most important indicator from a management perspective (Table 5. As the autumn (mid March) approached, milk production became a less important indicator and pasture cover and cow condition replaced this measure. In this particular year, cow condition did not play a critical role in the drying off decision because the condition of the herd was very good (≥ 4.5 condition score units) during the autumn due to exceptional summer conditions.

The case farmer did not objectively monitor average pasture cover through the summer because the falling plate meter is inaccurate (± 30 - 40%) at this time of the year. Inaccuracies occur due to sward conditions in relation to variable dry matter content, dead matter content, sward density, clover content, and the impact of significant rainfall events on available dry matter. Sward conditions improve into the autumn and objective measures become more accurate and reliable. On March 9, the case study farmer used an objective measure for a feed budgeting exercise to determine whether or not he should feed silage, and the amount he should feed. This was a one-off measurement and it was not repeated until April 1 when a formal feed budget for the late autumn, winter was completed. However, the case farmer measured average pasture cover indirectly, by objectively measuring pre- and post-grazing residuals. This information was then compared to the targets set in the March feed budget to monitor the progress of the case farmer's plan.

The role of milk production as an indicator over the summer is shown in Figure 7. This measure is ideal because it is objective and is measured daily. Most importantly, the farmer uses it as an indicator of other key variables (average pasture cover, pasture growth, cow intakes, cow condition, pasture quality, crop yield). Because the herd is on a fixed round, daily milk production will reflect the level of intake the herd receives, which in turn will reflect the level of average pasture cover on the farm and the recent pasture growth rates. Similarly, milk yield and composition provides an indicator of the quality of the feed the herd is fed each day. Milk production also indicates when the herd is losing condition. The case farmer believed that the herd would maintain condition provided they were producing at or above 12 - 13 l/cow/day (1.04 kg MS/cow/day), but would lose it if production fell to around 0.87 - 0.96 kg MS/cow/day. Similarly, the case farmer used milk production when the forage crop was being grazed to indirectly estimate crop yield. The area of crop offered per day was adjusted on the basis of milk production, not some objective measure of crop yield.

Average herd condition was not monitored formally during summer because it tends not to be a problem until late summer, early autumn. Because cow condition has a critical influence on the subsequent springs production, and this in part is influenced by the condition of the herd at drying off, the case farmer begins to formally monitor cow condition at April 1. The case farmer does however formally monitor the condition of cows in poor condition. The case farmer also uses decision rules over the summer (and into the autumn) to place thin (3.5 condition score) cows on once-a-day milking or dry them off if condition continues to fall. These decision rules protect the herd's condition, and allows the case farmer to only monitor the thinner animals in the herd, as opposed to the whole herd.

Average pasture cover and cow condition are the key indicators for tactical management through the autumn because their level at drying off strongly influences the state the herd will be in at calving. To ensure the subsequent spring targets are met, these two factors are monitored intensively at 5 - 7 day intervals, with the frequency increasing when the drying off date is imminent.

The case farmer monitored a wide range of factors during the summer-autumn period for the tactical management of his herd (Table 5). These factors could be classified as either, livestock or climatic factors. Financial information was not relevant to the case farmer's production management except that the milk price had an influence on the type of options the case farmer might consider in extreme situations (buying in feed). The case farmer monitored some 21 factors over the summer-autumn period (Figure 8). The monitoring methods used by the case farmer ranged could be classified as objective (uses some form of instrument) or subjective (just uses his five senses), and under the category subjective, quantitative (uses some form of score, e.g. pasture or condition scoring) or qualitative (no scoring technique used, rather mental picture) (Table 5). An objective method is one in which an instrument is used such as a falling plate meter or the site glass on a vat. No instrument is used in the case of a subjective method, but instead, one or more of the five senses are used. In this instance, the case farmer used visual assessment as his primary means of monitoring information subjectively.

Table 5. Classification of the methods used by the case farmer to monitor the farm and environment over the summer-autumn.[5]

Factor	Summer				Autumn	
	Early summer		Late summer & early autumn			
	Method	Classification	Method	Classification	Method	Classification
Feed Factors						
Average pasture cover	Pasture scoring Visual assessment	Subjective, quantitative, Subjective, qualitative	Falling plate meter Pasture scoring Visual assessment	Objective Subjective, quantitative Subjective qualitative	Falling plate meter Pasture scoring Visual assessment	Objective Subjective, quantitative Subjective qualitative
Pasture growth rates	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative	Falling plate meter Visual assessment	Objective Subjective, qualitative
Pre- and post-grazing residuals	Pasture scoring Visual assessment	Subjective, quantitative, Subjective, qualitative	Falling plate meter Pasture scoring Visual assessment	Objective Subjective, quantitative Subjective qualitative	Falling plate meter Pasture scoring Visual assessment	Objective Subjective, quantitative Subjective qualitative
Pasture quality	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative
Crop yield	Visual assessment	Subjective, quantitative & qualitative				
Crop quality	Visual assessment	Subjective, qualitative				
Silage yield			Visual assessment	Subjective, quantitative & qualitative	Visual assessment	Subjective, quantitative & qualitative
Silage quality			Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative

[5] Where more than one method is used for monitoring a particular factor, the more important method from a decision making perspective is placed first.

Factor	Summer				Autumn	
	Early summer		Late summer & early autumn			
	Method	Classification	Method	Classification	Method	Classification
Livestock factors						
Cow numbers	Visual assessment	Subjective, quantitative	Visual assessment	Subjective, quantitative	Visual assessment	Subjective, quantitative
Milk yield	Vat sight glass	Objective	Vat sight glass	Objective	Vat sight glass	Objective
Individual cow milk yield	Milking time	Subjective, quantitative	Milking time	Subjective, quantitative	Milking time	Subjective, quantitative
Milk quality of herd	Laboratory test at factory	Objective	Laboratory test at factory	Objective	Laboratory test at factory	Objective
Production index	Herd test	Objective				
Individual cow somatic cell count	Herd test	Objective				
Average herd condition	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, quantitative
Individual cow condition	Visual assessment	Subjective, quantitative	Visual assessment	Subjective, quantitative	Visual assessment	Subjective, quantitative
Cow intakes	Pasture scoring Visual assessment	Subjective, quantitative Subjective qualitative	Falling plate meter Pasture scoring Visual assessment	Objective Subjective, quantitative Subjective, qualitative	Falling plate meter Pasture scoring Visual assessment	Objective Subjective, quantitative Subjective, qualitative
Reproductive status	Visual assessment of behaviour	Subjective, qualitative	Pregnancy testing Visual assessment of behaviour	Subjective, qualitative Subjective, qualitative		
Climatic factors						
Rainfall	Visual assessment	Subjective, quantitative	Visual assessment	Subjective, quantitative	Visual assessment	Subjective, quantitative
Temperature	Tactile and visual assessment	Subjective, qualitative	Tactile and visual assessment	Subjective, qualitative	Tactile and visual assessment	Subjective, qualitative
Wind run	Tactile and visual assessment	Subjective, qualitative	Tactile and visual assessment	Subjective, qualitative	Tactile and visual assessment	Subjective, qualitative
Cloud cover	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative
Market factors						
Output prices						
Cull cow schedule	Newspaper & stock agent	Subjective, quantitative	Newspaper & stock agent	Subjective, quantitative	Newspaper & stock agent	Subjective, quantitative
In-calf cow store price	Newspaper & stock agent	Subjective, quantitative	Newspaper & stock agent	Subjective, quantitative	Newspaper & stock agent	Subjective, quantitative
Milk price	Dairy company newsletter	Subjective, quantitative	Dairy company newsletter	Subjective, quantitative	Dairy company newsletter	Subjective, quantitative
Input prices						
Urea price	NA	NA	Stock agent	Subjective, quantitative	NA	NA

Subjective methods can be separated into two types, quantitative and qualitative. Quantitative methods are those where a subjective measure is placed on some form of quantitative scale, for example, assessing cow body condition on a scale of 1 - 5, or placing an estimate of pasture mass in kilograms of dry matter per hectare from a visual assessment of a paddock. Qualitative subjective methods do not convert a visual image of the factor into a scalar measure. Instead, the visual image would be compared to a other images in memory to classify the state of the factor, e.g. the herd looks in good condition.

Analysis of the monitoring methods (Table 5) shows that the majority of the methods used by the case farmer were subjective in nature. Of the subjective methods, the majority were qualitative, i.e. no quantitative scale was used to define the measure. Table 5 also shows that the use of objective measures increased from summer through to autumn. During summer, the only objective methods used by the case farmer were those used for measuring milk yield and quality (Table 5). Of the four methods employed, two related to a one-off herd test. In late summer, additional objective methods were used to measure the average pasture cover on the farm so that a feed budget could be used to estimate the amount of silage to be fed post-forage crop. After this, the case farmer continued to use the falling plate meter to objectively measure pre- and post-grazing residuals. From this data he could objectively estimate cow intakes and the average pasture cover[6] on the milking area. During autumn, the case farmer continued to use the objective methods used in the late summer. However, average pasture cover and pasture growth rates were now assessed on a regular basis by objectively measuring each paddock.

The subjective methods used by the case farmer were primarily qualitative. These methods normally involved some form of visual assessment, and some factors such as temperature and wind run were also measured through the tactile senses. The number of subjective measures used by the case farmer declined through the summer autumn. This was primarily because some factors did not need to be monitored in certain periods such as the forage crop once fed, the bulling behaviour of the herd once pregnancy tested and so on. Important subjective quantitative measures included cow condition and rainfall.

The methods used by the case farmer to monitor the farm are all relatively low cost in terms of capital and time. The only monitoring that require significant additional time above that spent in normal farm operations is that of average pasture cover and pasture growth rates in the autumn. Even here, the case farmer minimises his time input by visually selecting a small number (4) of representative sites within a paddock to measure. Capital outlay is also minimal. The only piece of measuring equipment the case farmer had to purchase was a falling plate meter, and in this case, it was made from waste material on the farm.

The measures monitored by the case farmer performed a number of roles in relation to his tactical management process. The primary role was to act as leading indicators for when a decision point was reached or a deviation from the plan occurred. In this case, the measures performed a decision point or problem recognition role. Table 6 summarises the indicators and associated targets used by the case farmer to identify a deviation from the plan. The measures are used primarily to indicate when there is an increase or decrease in feed supply. Another measure is used to identify primarily younger cows that are losing condition because they cannot compete with the older animals in the herd. Four other measures are used to identify potential culls. Few lagging indicators (those used for historical control - this is when you use an indicator like empty rate to assess how your mating management has gone for the season) were identified. The case farmer compared the number of empty cows identified through the pregnancy test with his own estimates from his observations and mating records. In this case the pregnancy test identified one more cow than the case farmer. He then reviewed his mating management in relation to that animal to assess why the discrepancy had occurred.

[6] The case farmer considered that the paddock the herd were about to graze, and the one they had just grazed represented the longest and shortest paddocks on the farm, and midway between these two measures would be an estimate of the average pasture cover.

Table 6. The role of key indicators in the decision point or problem recognition phase of the control process over the summer-autumn period.

Key Indicators	Target	Indicator Type (Leading/lagging)	Role in decision point or problem recognition
Early Summer			
Average milk production (l/cow/day)	≥ 13 l/cow/day (1.13 kg MS/cow/day) ≥ 12 l/cow/day (1.04 kg MS/cow/day)	Leading	Determines when to feed the forage crop. Determines how much forage crop to feed.
Crop maturity (and milk production)	Visual image of mature forage crop	Leading	May determine initiation of grazing of forage crop.
Rainfall Average milk production	≥ 25 mm of rain ≥ 12 l/cow/day (1.04 kg MS/cow/day)	Leading	Determine when to feed additional supplements and change grazing rotation.
Pre- and post-grazing residuals, cow intake, pasture growth rates, climatic conditions		Leading	Used to indicate need to increase supplement level in the short-term. Used to predict likely cow intakes in 25 – 30 days time and the need for additional supplement.
Forage crop utilisation	Visual image of poor forage crop utilisation	Leading	Influences crop grazing (muddy conditions)
Individual cow condition	≥ 3. 5 condition score units	Leading	Determines which cows to put on once-a-day or dry off.
Production index Somatic cell count Bulling behaviour	Relative ranking in the herd Above minimum target Bulling behaviour is observed	Leading Leading Leading	Used to identify potential cull. Used to identify potential cull. Used to identify a non-pregnant cow and potential cull.
Milking time	Milking time relative to herd average	Leading	Determines which cows to cull on production.
Late Summer			
Average pasture cover (and feed budget)	≥ 1400 kg DM/ha for the year one season	Leading	Determine how much silage to feed over late summer.
Average milk production (l/cow/day)	≥ 12 l/cow/day (1.04 kg MS/cow/day)	Leading	Determines when to feed the silage. Determines how much silage to feed.
Rainfall Average milk production	≥ 25 mm of rain ≥ 12 l/cow/day (1.04 kg MS/cow/day)	Leading	Determine when to feed additional supplements and change grazing rotation.
Pre- and post-grazing residuals, cow intake, pasture growth rates, climatic conditions		Leading	Used to indicate need to increase supplement level in the short-term. Used to predict likely cow intakes in 25 – 30 days time and the need for additional supplement.
Average pasture cover assessed using pre and post-grazing residuals.	≥ 1400 kg DM/ha for the year one season	Leading	Determines if target milk production level should be adjusted.
Individual cow condition	≥ 3. 5 condition score units	Leading	Determines which cows to put on once-a-day or dry off.
Production index Somatic cell count Bulling behaviour Pregnancy test	Relative ranking in the herd Above minimum target Bulling behaviour is observed No evidence of growing foetus found	Leading	Used to identify potential cull cows.
Milking time	Milking time relative to herd average	Leading	Determines which cows to cull on production.
Autumn			
Average pasture cover	≥ 1400 kg DM/ha for the year one season	Leading	Determines drying off date and when to feed silage.
Pasture growth	Rapid increase in pasture growth	Leading	Determines drying off date and when to feed silage.
Average herd condition	≥ 3. 5 - 4.0 condition score units	Leading	Determines drying off date and when to feed silage.
Individual cow condition	≥ 3. 5 condition score units	Leading	Determine which cows to put on once-a-day or dry off.
Average pasture cover (and feed budget)	≥ 1400 kg DM/ha for the year one season	Leading	Determine sale date for culls.

The measures used by the case farmer performed a number of other roles. These were in terms of planning, diagnosis/evaluation, contingency plan selection, and triangulation (confirmed that your main measures were accurate). Information was required for formal planning in terms of average pasture cover in early March to assess the amount of silage to be fed, and again at April 1 when a feed budget was completed for the autumn-winter. Other basic information such as current cow numbers, milk production, intakes and supplement levels were also used in the planning process. Data collected through the monitoring process was also used for diagnosis and evaluation purposes, however little detailed information was obtained in relation to these sub-processes. The case farmer used decision rules to decide which contingency plan to implement when a deviation from the plan occurred. The decision rules specified the distinct conditions under which a particular option would be implemented. This information was obtained through the monitoring process (Table 7).

Table 7. Information collected through the monitoring process that is used to determine option selection.

Contingency Plan	Factors used in option selection[7]
Feed forage crop (amount and timing)	Milk production Forage crop yield (weeks grazing) Date Rainfall Forage crop state (ungrazed, being grazed, grazed) Muddy conditions/utilisation
Feed silage	Forage crop state (ungrazed, being grazed, grazed) Milk production Silage availability Rainfall Average pasture cover Pasture growth rates Month Cow condition
Apply nitrogenous fertiliser	Average pasture cover
Once-a-day milking	Individual cow condition Lactation state (milked twice- or once-a-day)
Shorten rotation	Milk production Supplement availability Rainfall Forage crop state (ungrazed, being grazed, grazed) Crop utilisation
Extend rotation	Milk production Forage crop state (ungrazed, being grazed, grazed) Rainfall Silage availability Month Pasture growth rates Average pasture cover Average herd condition
Cull cows on low production	Milking time
Cull cows	Average pasture cover prediction Cull cows on milking area Feed on waste ground available
Dry off individual cows	Individual cow condition Lactation state (milked twice- or once-a-day)
Dry off the herd	Rainfall Pasture growth rates Average pasture cover Average herd condition Month Milk production Availability of supplements (forage crop/silage)

[7] Includes the problem recognition indicator.

A number of indicators that were monitored by the case farmer were used for triangulation purposes, i.e. to confirm that an indicator used for problem recognition was correct (Tables 8, 9 & 10). A similar role was played by a wide range of indirect measures used by the case farmer. These were measures the case farmer used to indirectly monitor another measure. These indirect measures appeared to play a triangulation role. The indirect measures fulfilled one of three roles (Figure 1). They either acted as a predictor for a change in the indicator, they identified a change in the indicator before it was measured directly, providing an early warning of a change, or they were used in a confirmatory role to confirm that the measure had been correct. An example of a predictive indirect measure is a significant rainfall event which heralds a short-term decline in both cow intakes and milk production, and an increase in subsequent pasture growth rates. Examples of early warning indicators include the use of milk production, and behaviour to identify a decline in cow condition before it can be visually measured in terms of condition scoring. An example of the use of a confirmatory indirect indicator would be where a decline in the condition of the herd would confirm that cow intakes, grazing residuals, average pasture cover and pasture growth rates had been declining.

Table 8. A summary of the direct and indirect measures used by the case farmer over early summer.

Factor	**Measurement Method**			**Fre-quency**	**Role**	**Classification of Role**[8]
	Direct Method	**Indirect Method**				
Production Factors						
Feed Factors		**Indicator**	**Method**			
Average pasture cover (APC)	Falling plate meter				Not used	**Not used**
	Visual assessment			Daily	Used to verify changes in other measures	**Confirmatory**
	Pre- and post grazing residuals[9]			Daily	Used to verify changes in other measures	**Confirmatory**
		Milk production	Milk docket	Daily	Used to indicate a change in APC	**Short-term predictor**
		Cow condition	Visual assessment	Daily	Confirms change in APC	**Confirmatory**
		Climate Rainfall (≥ 25 mm)	Rain gauge	Daily	Indicates an increase in APC within 2 weeks	**Long-term predictor**
		Rainfall (< 25 mm) Wind run Temperature Cloud cover	Visual assessment	Daily	Indicates change in APC	**Short-term predictor**
Pasture growth	Falling plate meter			Not used	Not used	
	Visual assessment			Daily	Used to confirm changes in other measures	**Confirmatory**
		Pre- & post grazing residuals	Visual assessment	Daily	Indicates a change in pasture growth	**Short-term predictor**
			Pasture scoring and visual assessment	2 – 5 days	Indicates a change in pasture growth	**Short-term predictor**
		Intake	Falling plate meter or pasture scoring	2 – 5 days	Indicates a change in pasture growth	**Short-term predictor**
		Milk production	Milk docket	Daily	Indicates a change in pasture growth	**Short-term predictor**

[8] This shows the role of the direct measures in decision point recognition and triangulation, and the role of the indirect measures in relation to the direct measures (predictive, early warning, confirmatory).

[9] Farmer A visually scores these and calculates the mean. As these are normally the shortest and longest paddocks on the farm, they provide an estimate of APC.

Factor	Measurement Method			Fre-quency	Role	Classification of Role[8]
	Direct Method	Indirect Method				
		Condition	Visual assessment	Daily	Confirms change in pasture growth	**Confirmatory**
		Climate Rainfall (≥ 25 mm)	Rain gauge	Daily	Predicts increase in pasture growth within two weeks	**Long-term predictor**
		Rainfall (< 25 mm) Wind run Temperature Cloud cover	Visual assessment		Indicates change before primary measure	**Short-term predictor**
Pasture quality	Visual assessment			Daily	Used to identify problems with pasture quality	**Decision point recognition**
		Milk production	Milk docket, composition	Daily	Confirms change in pasture quality	**Confirmatory**
Crop yield	Yield score & visual assessment			Daily	Used to estimate the amount of feed available	**Decision point recognition**
		Milk production	Milk docket	Daily	Used to confirm break size is adequate and yield estimate is correct	**Confirmatory**
Crop growth	Yield score & visual assessment			Daily	Used to verify other measures	**Confirmatory**
Crop quality and maturity	Visual assessment			Daily	Used to determine when crop maturity is reached	**Decision point recognition**
Livestock factors						
Cow numbers	Visual assessment				Used to predict feed demand	**Long-term predictor**
Average milk yield	Milk docket (l/cow/day)			Daily[10]	Used to identify when cow intakes and/or condition fall below target	**Decision point recognition**
		Intake	Falling plate meter or pasture scoring	2 - 5 days	Used to indicate change in milk production	**Short-term predictor**
		Post-grazing residual	Visual assessment Falling plate meter or pasture scoring	Daily 2 - 5 days	Used to indicate change in milk production	**Short-term predictor**
Individual cow milk yields	Herd test (PI)	Milking time	Visual assessment	Once Daily	)Used to identify potential)culls)	**Decision point recognition**
Average milk quality	Milk docket (fat/protein)			Daily	Used to verify feed quality assessment	**Confirmatory**
	Bulk count (somatic cell)			Daily	Used to identify milk quality problem	**Decision point recognition**
Individual cow milk quality	Fat/protein Somatic cell count			Once (Herd test)	Used to identify potential culls	**Decision point recognition**
Average herd condition	Condition scoring			Daily	Used to verify other measures	**Confirmatory**
	Visual assessment			Daily	Used to verify other measures	**Confirmatory**
		Milk production	Milk docket	Daily	Used to indicate when the herd is losing condition	**Short-term predictor**
		Residual dry matter levels	Visual assessment Falling plate meter or pasture scoring	Daily 2 – 5 days	Used to indicate when the herd is losing condition	**Short-term predictor**
		Behaviour	Visual assessment	Daily	Used to indicate when the herd is losing condition	**Short-term predictor**

[10] Milk volume is monitored daily, but milk production as litres/cow/day is only calculated when there is a significant change in milk volume.

Factor	Measurement Method			Fre-quency	Role	Classification of Role[8]
	Direct Method	Indirect Method				
Individual cow condition	Condition scoring			Daily	Used to identify cows that are below target condition	**Decision point recognition**
		Behaviour	Visual assessment	Daily	Used to indicate when the herd is losing condition	**Short-term predictor**
Intake	Falling plate meter or pasture scoring			2 - 5 daily	Used to identify when intakes fall below target	**Decision point recognition**
	Visual assessment			Daily	)Indicates changes in)milk production and)condition	**Short-term predictor**
		Post-grazing residual	Falling plate meter or pasture scoring	2 - 5 daily	It is used to predict if intakes will fall below target at the next grazing in 25 - 30 days	**Long-term predictor Decision point recognition**
			Visual assessment	Daily	Used to indicate a change in intake	**Short-term predictor**
		Milk production	Milk docket	Daily	Used to verify intake estimate	**Confirmatory**
		Condition	Visual assessment	Daily	Used to verify change in intake	**Confirmatory**
		Behaviour	Visual assessment	Daily	Used to indicate a change in intake	**Short-term predictor**
		Rainfall	Rain gauge	Daily	Significant rainfall events are used to predict (a) a short-term decline in intake and (b) a long term increase in pasture growth rates	**Decision point recognition Long-term predictor**
		Wind run) Temperature) Cloud cover) Rainfall) (< 25 mm) Weather forecast		Daily	Short-term prediction of cow intakes	**Short-term predictor**
Reproductive status of the herd	Pregnancy test			Once	)Used to identify potential)culls)	**Decision point recognition**
		Bulling behaviour	Visual assessment	Daily		
External Environment Factors						
Climatic factors						
Climate Rainfall (≥ 25 mm)	Rain gauge			Daily	Significant rainfall events are used to predict (a) a short-term decline in intake and (b) a long term increase in pasture growth rates.	**Decision point recognition Long-term predictor**
Wind run) Temperature) Cloud cover) Rainfall) (< 25 mm) Weather forecast)	Visual assessment			Daily	This is used as an early indicator of changes in pasture growth, average pasture cover, intake, milk production and condition	**Short-term predictor**
Market factors						
Output Price Factors						
Cull cow schedule	Newspaper & stock agent			Intermit-tent	Used for selling decisions	**Decision point recognition**
In-calf cow store price	Newspaper & stock agent			Intermit-tent	Used for selling decisions	**Decision point recognition**
Milk price	Dairy company newsletter			Monthly	Used in option selection decisions	

Table 9. A summary of the direct and indirect measures used by the case farmer over late summer, early autumn.

Factor	Measurement Method			Frequency	Role	Classification of Role[11]
	Direct Method	Indirect Method				
Production Factors						
Feed Factors		**Indicator**	**Method**			
Average pasture cover (APC)	Falling plate meter			10 daily[13]	Used to confirm other measures	**Triangulation**
	Visual assessment			Daily	Used to indicate a change in APC	**Early warning**
	Pre- and post grazing residuals[12]			Every 2-5 days	Used to indicate when APC falling below target in year one	**Decision point recognition**
		Milk production	Milk docket	Daily	Used to indicate a change in APC	**Short-term predictor**
		Cow condition	Visual assessment	Daily	Confirms change in APC	**Confirmatory**
		Rainfall	Rain gauge	Daily	≥ 25 mm indicates (a) a decrease in available pasture and (b) an increase in APC within 2 weeks.	**Long-term predictor**
Pasture growth	Falling plate meter			10 daily	Used to identify trends for planning purposes[14]	**Planning**
	Visual assessment			Daily	Used to indicate a change in pasture growth	**Early warning**
		Pre- & post grazing residuals	Visual assessment	Daily	Used to indicate a change in pasture growth	**Short-term predictor**
			Falling plate meter or pasture scoring	2 – 5 days		
		Intake	Falling plate meter or pasture scoring	2 - 5 days	Used to indicate a change in pasture growth	**Short-term predictor**
			Visual assessment	Daily	Used to indicate a change in pasture growth	**Short-term predictor**
		Milk production	Milk docket	Daily	Used to indicate a change in pasture growth	**Short-term predictor**
		Cow condition	Visual assessment	Daily	Used to verify a change in pasture growth	**Confirmatory**
		Climate Rainfall (≥ 25 mm)	Rain gauge	Daily	Useful for predicting pasture growth two weeks out	**Long-term predictor**
		Rainfall (< 25 mm) Wind run Temperature Cloud cover	Visual assessment	Daily	Useful for predicting short-term pasture growth	**Short-term predictor**
Pasture quality	Visual assessment			Daily	Used to decide if action must be taken to control pasture quality	**Decision point recognition**
		Milk production	Milk docket, composition	Daily	Confirms assessment of pasture quality	**Confirmatory**

[11] This shows the role of the direct measures in the decision point recognition and triangulation, and the role of the indirect measures in relation to the direct measures (predictive, early warning, confirmatory).
[12] Farmer A measures these with a falling plate meter and then calculates the mean. As these are normally the shortest and longest paddocks on the farm, it provides an estimate of APC.
[13] The use of objective pasture monitoring and the frequency of its use is dependent on the season.
[14] Pasture growth is measured objectively if conditions are poor during March, and Farmer A wants to analyse the trend in pasture growth.

Factor	Measurement Method			Fre-quency	Role	Classification of Role[11]
	Direct Method	Indirect Method				
Silage quantity & quality	Yield score and visual assessment			As and when necessary	Used to estimate available silage	**Decision point recognition**
		Milk production	Milk docket	Daily	Used to confirm silage yield estimates	**Confirmatory**
Livestock factors						
Cow numbers	Visual assessment				Used to predict feed demand	**Long-term predictor**
Average milk yield	Milk docket (l/cow/day)			Daily[15]	Used to identify when cow intakes and/or condition fall below target	**Decision point recognition**
		Intake	Falling plate meter or pasture scoring	2 - 5 days	Used to indicate change in milk production	**Short-term predictor**
		Post-grazing residual	Visual assessment Falling plate meter or pasture scoring	Daily 2 - 5 days	Used to indicate change in milk production	**Short-term predictor**
Individual cow milk yields	Herd test (PI)	Milking time	Visual assessment	Once Daily	)Used to identify)potential culls)	**Decision point recognition**
Average milk quality	Milk docket (fat/protein)			Daily	Used to verify feed quality assessment	**Confirmation**
	Bulk count (somatic cell)			Daily	Used to identify milk quality problem	**Decision point recognition**
Individual cow milk quality	Fat/protein Somatic cell count			Once (Herd test)	Used to identify potential culls	**Decision point recognition**
Average herd condition	Condition scoring Visual assessment			Daily[16]	Used to identify if average herd condition is at or below target Used to confirm other measures	**Decision point recognition** **Confirmatory**
		Milk production	Milk docket	Daily	Used to indicate when the herd is losing condition	**Short-term predictor**
		Intake	Falling plate meter, pasture scoring	2 - 5 days	Used to indicate when the herd is losing condition	**Short-term predictor**
		Residual dry matter levels	Falling plate meter, pasture scoring Visual assessment	2 - 5 days Daily	Used to indicate when the herd is losing condition	**Short-term predictor**
		Behaviour	Visual assessment	Daily	Used to indicate when the herd is losing condition	**Short-term predictor**
Individual cow condition	Condition scoring			Daily	Used to identify cows whose condition is at or below target	**Decision point recognition**
		Behaviour	Visual assessment	Daily	Used to indicate when individual cows are losing condition	**Short-term predictor**
Intake	Falling plate meter, pasture scoring			2 - 5 daily	Used to indicate when intake is below target Used to indicate a change in milk production and condition	**Decision point recognition** **Short-term predictor**
		Milk production	Milk docket (l/cow/day)	Daily	Used to verify intake estimate	**Confirmatory**

[15] Milk volume is monitored daily, but milk production as litres/cow/day is only calculated when there is a significant change in milk volume.

[16] Use dependent on herd condition. If herd condition falls below 4.5 condition score units, it is formally monitored by Farmer A.

Factor	Measurement Method			Fre-quency	Role	Classification of Role[11]
	Direct Method	Indirect Method				
		Residual dry matter	Visual assessment	Daily	Used to indicate a change in intake	**Short-term predictor**
			Falling plate, pasture score	2 - 5 daily	It is used to predict intake at the next grazing in 25 - 30 days	**Long-term predictor Problem recognition**
		Cow condition	Visual assessment	Daily	Used to verify change in intake	**Confirmatory**
		Behaviour	Visual assessment	Daily	Used to indicate a change in intake	**Short-term predictor**
		Rainfall & climate	Rain gauge	Daily	Used to predict change in intake. Also used to predict longer-term change in intake	**Short-term predictor Decision point recognition Long-term predictor**
Reproductive status of the herd	Pregnancy test			Once	Used to identify potential culls	**Decision point recognition**
		Bulling behaviour	Visual assessment	Daily	Used to identify potential culls	**Decision point recognition**
External Environment Factors						
Climatic Factors						
Climate						
Rainfall (≥ 25 mm)	Rain gauge			Daily	Significant rainfall events are used to predict a short-term decline in available dry matter and an increase in pasture growth rates.	**Decision point recognition Long-term predictor**
Wind run) Temperature) Cloud cover) Rainfall) (< 25 mm) Weather) forecast)	Visual assessment			Daily	This is used as an early indicator of changes in pasture growth, average pasture cover, intake, milk production and condition	**Short-term predictor**
Market Factors						
Output Price Factors						
Cull cow schedule	Newspaper & stock agent			Intermit-tent	Used for selling decisions	**Decision point recognition**
In-calf cow store price	Newspaper & stock agent			Intermit-tent	Used for selling decisions	**Decision point recognition**
Milk price	Dairy company newsletter			Monthly	Used in option selection decisions	
Input Price Factors						
Urea price	Stock agent			Once	Used for option analysis	

Table 10. Important factors monitored by the case farmer over the autumn[17].

Factor	Measurement Method			Frequency	Role	Classification of Role[18]
	Direct Method	Indirect Method				
Production Factors						
Feed factors		**Indicator**	**Method**			
Average pasture cover	Falling plate meter			5 - 13 daily	Used to identify when APC fell below targets.	**Decision point recognition**
		Milk production	Milk docket	Daily	Used to indicate a change in APC	**Short-term predictor**
		Pre- and post-grazing residuals	Falling plate meter	2 - 5 daily	Used to indicate a change in APC	**Short-term predictor**
Pasture growth rate	Falling plate meter[19]			5 - 13 daily	Used to indicate the start of the autumn flush	**Decision point recognition**
					Used to verify other measures	**Confirmatory**
Livestock Factors						
Cow numbers	Visual assessment				Used to predict feed demand	**Long-term predictor**
Average milk yield	Milk docket (l/cow/day)			Daily[20]	Used to identify when cow intakes and/or condition fall below target	**Decision point recognition**
		Intake	Falling plate meter or pasture scoring	2 - 5 days	Used to indicate change in milk production	**Short-term predictor**
		Post-grazing residual	Visual assessment	Daily	Used to indicate change in milk production	**Short-term predictor**
			Falling plate meter or pasture scoring	2 - 5 days	Used to indicate change in milk production	**Short-term predictor**
Individual cow milk yields	Herd test (PI)			Once	)Used to identify)potential culls)	**Decision point recognition**
		Milking time	Visual assessment	Daily		
Average herd condition[21]	Condition scoring			Daily	Used, in conjunction with APC and pasture growth rate information to decide when to dry off the herd	**Decision point recognition**
		Milk production	Milk docket	Daily	Used to indicate a change in condition score	**Short-term predictor**
		Average pasture cover	Falling plate meter	5-13 daily	Used to indicate a change in condition score	**Short-term predictor**
		Behaviour	Visual Assessment	Daily	Used to indicate a change in condition score	**Short-term predictor**
Individual cow condition	Condition scoring			Daily	Used to identify cows whose condition is below target	**Decision point recognition**
		Behaviour	Visual assessment	Daily	Indicates cows that are thin and losing condition.	**Short-term predictor**
Intake	Falling plate meter, pasture scoring			2 - 5 daily	Used to indicate when intake is below target	**Decision point recognition**
					Used to indicate a change in milk production and condition	**Short-term predictor**
		Milk production	Milk docket	Daily	Used to verify intake estimate	**Confirmatory**

[17] Subjective, qualitative measures used in late summer were also used in the autumn, but are not repeated in this figure to avoid repetition.
[18] This shows the role of the direct measures in decision point recognition and triangulation, and the role of the indirect measures in relation to the direct measures (predictive, early warning, confirmatory).
[19] Uses ungrazed paddocks to calculate pasture growth rates.
[20] Milk volume is monitored daily, but milk production as litres/cow/day was only calculated when there was a significant change in milk volume.
[21] Farmer A monitors both the average and the distribution or level of variation.

Factor	Measurement Method			Frequency	Role	Classification of Role[18]
	Direct Method	Indirect Method				
		Residual dry matter	Visual assessment Falling plate, pasture score	Daily 2 - 5 daily	Used to indicate a change in intake It is used to predict intake at the next grazing in 25 - 30 days	**Short-term predictor** **Long-term predictor** **Problem recognition**
		Condition	Visual assessment	Daily	Used to verify change in intake	**Confirmatory**
		Behaviour	Visual assessment	Daily	Used to indicate a change in intake	**Short-term predictor**
		Rainfall	Rain gauge	Daily	Used to predict change in intake	**Short-term predictor** **Decision point recognition**
External Environment Factors						
Climatic Factors						
Climate Rainfall (≥ 25 mm)	Rain gauge			Daily	Significant rainfall events are used to predict a short-term decline in available dry matter and an increase in pasture growth rates.	**Decision point recognition** **Long-term predictor**
Wind run) Temperature) Cloud cover) Rainfall) (< 25 mm) Weather) forecast)	Visual assessment			Daily	This is used as an early indicator of changes in pasture growth, average pasture cover, intake, milk production and condition	**Short-term predictor**
Market Factors						
Output Price Factors						
Cull cow schedule	Newspaper & stock agent			Intermit-tent	Used for selling decisions	**Decision point recognition**
In-calf cow store price	Newspaper & stock agent			Intermit-tent	Used for selling decisions	**Decision point recognition**
Milk price	Dairy company newsletter			Monthly	Used in option selection decisions	

As the results show, many of the measures used by the case farmer either, predict a likely change in another indicator, provide an early warning of an impending change, or confirm that the indicator was accurately measured. Such measures keep the case farmer attuned to changes in his system and test the validity of his indicators to ensure he does not respond to an inaccurate or false measure. This approach is only possible because of the case farmer's detailed understanding of his production system. Figure 2 shows the causal chains the case farmer appears to use in the application of his monitoring system. The indirect measures were used to not only determine trends in other measures, but also absolute values, e.g. the case farmer can estimate cow intakes from milk production.

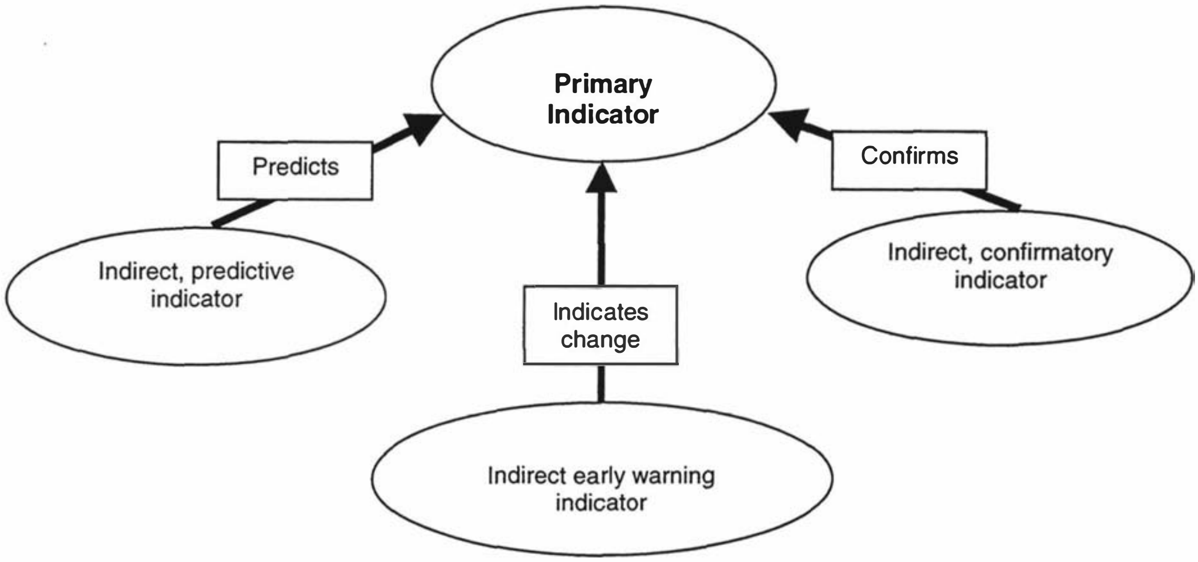

Figure 1. The role of indirect measures in the monitoring process.

One of the cornerstones of measuring a valid and accurate monitoring system is the role the objective measures play in terms of triangulation. Milk production plays a critical role in triangulation, particularly over the summer when objective pasture measurement systems are inaccurate. In autumn, when pasture monitoring is more accurate, this takes over the dominant role in the control system. The importance of this cross-referencing came through when the case farmer identified that on the basis of his milk production, he was underestimating cow intakes and other pasture measures (pre- and post-grazing residuals). This forced him to reassess his monitoring system. As such, this "networked" monitoring system may be important for learning.

Frequency of monitoring

Analysis of Tables 8, 9 and 10 show that the majority of the measures the case farmer uses for control are monitored on a daily basis. Other than one-off measures such as herd and pregnancy testing, the other measures are monitored on a 2 - 7 day interval. For example, pre- and post-grazing residuals are monitored at 2 - 5 day intervals, and average pasture cover and pasture growth rates are monitored at 5 - 7 day intervals, with the interval reduced to 5 days if the case farmer thinks the drying off date is imminent. Thus, the longest interval between monitoring is seven days. The case farmer stated that a measurement interval of less than 5 days created problems in terms of measurement errors for average pasture cover and pasture growth rates. The use of indirect measures also means that the case farmer will often know the state of the farm before it is measured objectively using the falling plate meter.

Recording

The case farmer used a very simple recording system. Milk production data provided by the company (ten daily) was stored in a folder as were herd and pregnancy test results. The bulk of the information was stored either in a large farm diary or the case farmer's memory. In the diary, the case farmer recorded information in relation to key event (sale of culls, date crop fed, drying off), pasture cover and pasture growth rate data, and mating information. The diary acted as a historical record of the season and could be referred back to for diagnostic or evaluation purposes, or to check what had been done in previous seasons. (Check later text for more on this information).

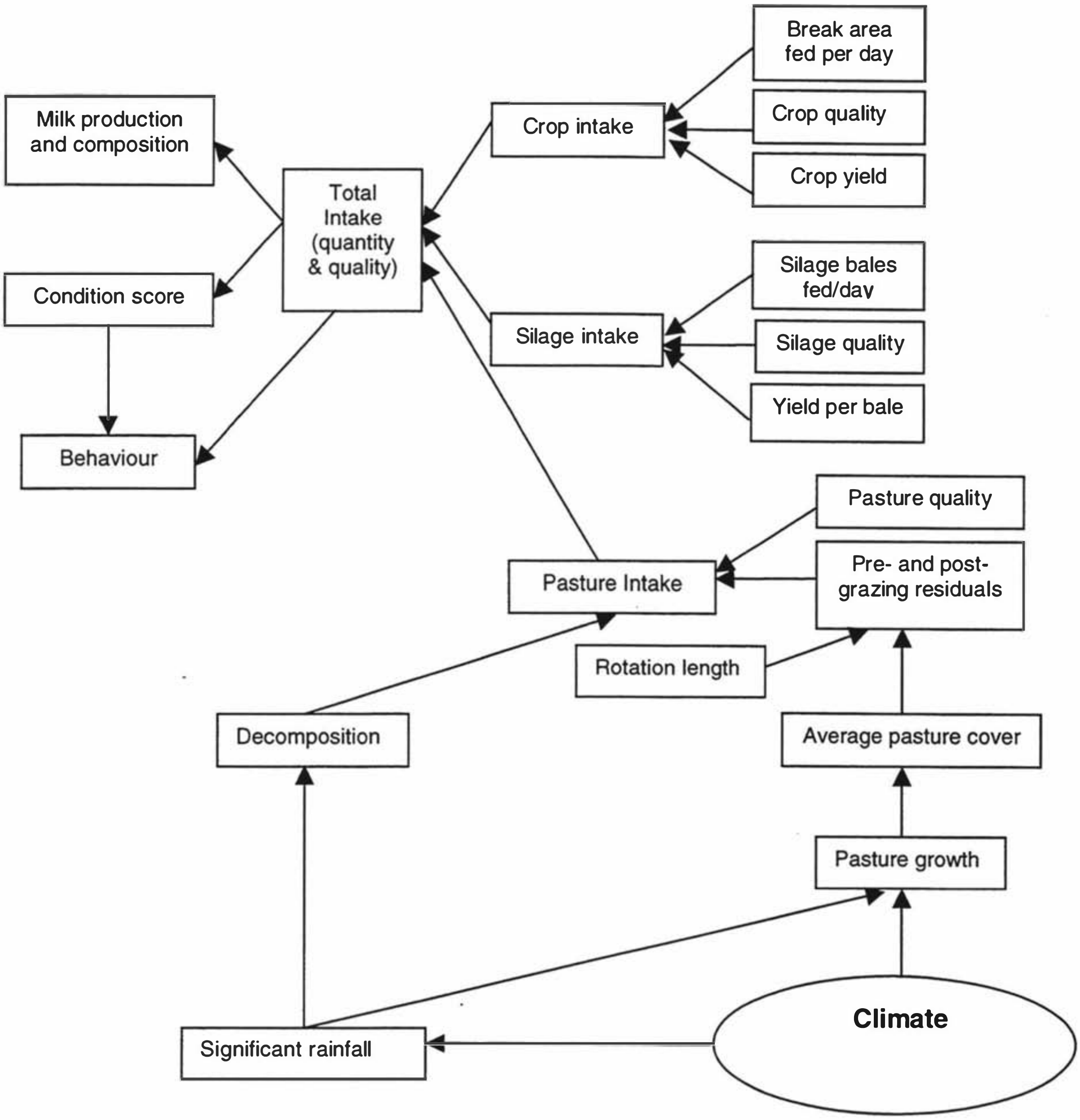

Figure 2. Causal relationships used in the case farmer's monitoring system.

Data processing

Limited processing was undertaken on the data collected by the case farmer. In most cases the most complex calculations involved the estimation of means (average pasture cover, pasture growth rates, milk production per cow per day). The farmer did not own a computer , and most calculations were performed mentally or with a calculator.

Problem identification for control purposes

The case farmer identified problems when an indicator of actual performance fell outside, or approached a target specified in the plan. Key indicators and targets are identified in Table 11. To avoid identifying the wrong problem, the case farmer triangulates these indicators with a range of other indicators (See Tables 8, 9 & 10). Milk production is the primary indicator used by the case farmer in problem recognition over the summer. This measure is used because it is objective, accurate, and measured on a daily basis. Alternative measures such as average pasture cover are inaccurate at this time of the year. Cow condition can be accurately measured, but is not as timely as milk production in identifying changes in the feed situation on the farm, and at that time of year it is not normally important (the herd is normally in good condition). Milk production is used in effect as an indirect measure of several key variables (average pasture cover, pasture growth, intake and cow condition). The case farmer can use milk production in this manner because of his thorough understanding of cause and effect relationships (Figure 2). The case farmer had a target for rotation length of between 25 - 30 days throughout the summer autumn period.

In late summer, the case farmer continued to use milk production and condition score as targets, but because he had completed a feed budget to assess the impact of using half his silage post-forage crop, he also used a target for average pasture cover derived from the feed budget. The feed budget predicted that he needed to maintain average pasture cover at or above 1400 kg DM/ha through March.

During autumn, the case farmer relies primarily on average pasture cover, pasture growth and cow condition for problem recognition. Milk production plays no role in problem recognition. This change is a result of a change in sward conditions that allow accurate estimates of pasture cover and pasture growth. At the same time, cow condition and pasture cover are critical factors in ensuring the case farmer's targets for calving are met. In contrast, milk production is treated as a variable that is adjusted to ensure these targets are met. Rainfall was an important target during the autumn, and the case farmer would dry off the herd if sufficient rain fell to initiate the autumn flush.

Table 11. Indicators and targets used in the control process.

Indicator	Targets
Summer	
Milk production	≤ 12 - 13 litres/cow/day ≤ 1.13 kg MS/cow/day[22] ≤1.04 kg MS/cow/day
Rotation length	25 - 30 days
Individual cow condition	≤ 3.5 condition score units
Late Summer	
Average pasture cover	≤ 1400 kg DM/ha[23]
Milk production	≤ 12 litres/cow/day ≤1.04kg MS/cow/day
Rotation length	25 - 30 days
Individual cow condition	≤ 3.5 condition score units
Autumn	
Individual cow condition	≤ 3.5 condition score units
Average herd condition score	≤ 3.5 - 4.0 condition score units
Average pasture cover	≤ 1400 kg DM/ha[24]
Rainfall	≥ 25 mm
Rotation length	25 - 30 days

[22] This higher target is used to initiate crop feeding. The case farmer introduces the crop at a higher production level because production declines in response to a change in diet.

[23] This is the target for this year, but it will depend on conditions in the particular year. The level is assessed using a formal feed budget.

[24] This is the target for this particular year, but it will depend on conditions in the particular year. The level is assessed using a formal feed budget.

Problem definition and diagnosis

The most interesting point to come out of the study in relation to problem definition and diagnosis is that the case farmer rarely consciously defined or diagnosed a problem. It appears that he uses indicators to identify feed problems (in most cases a feed deficit), and then implements an option from his set of contingency plans without undertaking any form of conscious problem definition or diagnosis. Problem definition may not be an issue because at this time of the year, the primary problem the farmer expects to face is a feed deficit. Diagnosis may occur at a subconscious level, and may explain the case farmer's use of a range of indicators that do not appear to be used specifically for decision making. For instance, although declining milk production may indicate a feed deficit, the case farmer is also monitoring climatic data, residuals, average pasture cover, pre- and post-grazing levels, cow intakes and condition score. Therefore, he will know that the weather has not been conducive for growth, and that average pasture cover, pre- and post-grazing residuals, intake and condition are declining. As such, the diagnosis is probably completed before the indicator signals that a threshold has been broken.

The case farmer however, did consciously diagnose two problems over the study period. The first was a monitoring system problem where he was underestimating cow intakes on the basis of his pasture monitoring. Milk production data suggested the herd was eating 20% more dry matter than the case farmer's estimate. The case farmer explored a range of reasons for this (dry matter content, warmer conditions, dry matter content, clover content, plant survival and density) and discussed it with a peer. The reason for the discrepancy was attributed to the nature of the season (wet) and its influence on sward structure (more clover, higher density due to higher plant survival). The second area of evaluation was in relation to a system performance problem, the herd's reproductive performance. The pregnancy test results differed from the case farmer's own estimates and he attempted to diagnose why this might be by working back through what he knew about the animal in question in relation to mating management. Factors he considered included age and difficulty at insemination. Although limited data was obtained on the diagnosis process used by the case farmer, the evidence suggests he uses his knowledge of cause and effect relationships to develop hypotheses about possible causes (e.g. infertility increases with age, sward density affects pasture estimates) and then tests these by obtaining values for the attribute of interest.

The contingency plans

The contingency plans of the case farmer could be classified under four headings in relation to their impact on feed supply and feed demand (Table 12). The case farmer had seven options which he used to increase feed supply: feed forage crop early, increase forage crop break by increasing milk production target, feed silage early, increase the level of silage fed, decrease rotation length, apply nitrogenous fertiliser, and use winter, early spring silage over the summer-autumn and replace later. The nitrogenous fertiliser was applied post-drying off, but this feed allowed the case farmer to extend the lactation. Feed supply was reduced by extending the rotation, delaying the grazing of the forage crop, and retaining the summer silage for the spring. Options for increasing feed demand included increasing cow intakes through increasing the milk production target and extending the lactation. Feed demand could be reduced through selling the cull cows early, putting the thin cows on once-a-day milking, drying off the thin cows, and drying off the herd.

Table 12. The case farmer's contingency plans.

Category	Option
Increase feed supply	Feed the forage crop early[a] Increase forage crop break by increasing the milk production target Feed silage early[a] Increase the level of silage fed[a] Reduce rotation length Apply nitrogenous fertiliser[a] Use winter, early spring silage over the summer-autumn and replace later[a]
Decrease feed supply	Increase rotation length Delay grazing of forage crop[a] Retain silage for the spring
Increase feed demand	Increase cow intakes by increasing the milk production target Extend the lactation[25]
Decrease feed demand	Sell culls early[26a] Place thin cows on once-a-day milking[27][28] Dry off thin cows and graze on runoff[a] Dry off the herd early[29]

Contingency plan selection

The selection of a contingency plan is triggered when a key indicator crosses the target threshold (Figure 3) set by the case farmer. The process the farmer uses to select the most appropriate contingency plan to minimise the impact of the deviation can best be represented by decision rules. The decision rules take the form of an "IF" statement that specifies the conditions that indicate a problem exists, then normally several "AND" statements that specify important characteristics that define the problem situation, followed by a "THEN" statement which specifies the contingency plan that should be instigated (Figure 3). The problem situation characteristics are important, because they are used to distinguish between alternative courses of action in most instances. In other words, the problem situation characteristics are matched to a problem solution.

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[a] These options were mentioned by Farmer A, but not implemented.

[25] The feed budget in early April estimated a drying off date of 30th April. This is 15 days later than the typical date of mid April.

[26] Farmer A stated that if culls were to be sold early to reduce feed demand, then at least 20 cows should be sold to make some impact on feed demand.

[27] This was undertaken to protect condition.

[28] Although this option is in the plan, the timing and number of cows placed on once-a-day milking is dependent on conditions.

[29] The herd was actually dried off a day earlier than initially predicted in the feed budget because average pasture cover fell below target.

IF milk production is $\leq$ 13 l/cow/day		Indicates the problem exists
AND the crop is mature,	)	Specifies the characteristics that
AND the ground is dry,	)	define the problem situation
THEN feed sufficient crop to the herd to maintain milk production at 12 l/cow/day.		Specifies the contingency plan that should be implemented to match the characteristics of the problem situation.

Figure 3. Structure of a decision rule.

The contingency plans used by the case farmer are presented in Appendix VIII (Volume II).

Control responses

The majority of the case farmer's responses to a deviation in the plan were to select a contingency plan that minimised the impact of the deviation. There was no evidence during the study period that the case farmer undertook to develop a new plan or change his goals in response to deviations from the plan. However, in one instance, the case farmer responded to a deviation from his plan by changing his targets for milk production over the late summer. This was because pasture growth rates were so high that the case farmer decided that the best way to take advantage of these was to feed the herd at a higher level and hence set a milk production target that was 0.09 kg MS/cow/day higher than in his original plan. In this instance, the case farmer admitted the conditions were outside his experience.

Evaluation

Despite the case farmer being a recognised expert, he still undertook a reasonable amount of evaluation during the study period. The areas of evaluation could be classified as: monitoring system, choice of targets, choice of inputs, management practices, overall management of the autumn. As previously mentioned, the case farmer evaluated why his monitoring system appeared to be under-estimating cow intakes. The case farmer changed his milk production target from 1.04 kg MS/cow/day to 1.22 kg MS/cow/day because feed conditions were so good. He considered that this was a good decision, and would use this higher target in years when summer feed supply was extremely good. The farmer had changed his forage crop to a leafier variety to improve utilisation and evaluated it after the crop was grazed. He thought the change was worthwhile. In relation to management practices, the case farmer evaluated his mating management in the light of his pregnancy test results to identify why a particular animal had not conceived when he thought it was in-calf. He also evaluated his decision to dry off the herd on April 23rd at the end of the month. The criteria he used for this was to assess the state of the farm (cow condition and average pasture cover) relative to his targets and a projection of the likely state of the farm if he had not dried off. The main aim of these evaluations is to assess areas where the case farmer might improve his practice. The final evaluation the case farmer undertook was to reflect on his management through the autumn. In this case he compared the actual outcome against his expectations. He thought that the pattern of pasture growth was as he had predicted, but that the herd had continued to produce at a higher level than he would have expected for this time of the year. As with all these evaluations, they were undertaken mentally, quickly and relatively simply. The main criterion was whether the action met the case farmer's objectives or expectations.

Learning

Evaluation and learning are inextricably linked. Six areas of learning were identified from the study. The case farmer undertook learning in relation to his: monitoring system, targets, decision rules, production system, management practices and planning. He learnt that in wet summers his monitoring system may need to be adjusted to more accurately assess pasture cover levels due to changes in sward density. The case farmer also learnt that in a wet summer where feed is abundant, he could change his milk production target and associated decision rules to operate at a higher level of production, and also use the forage crop rather than silage to take advantage of significant rainfall events. Similarly, he learnt that his production system, and his herd in particular, can produce at a higher level over the summer-autumn than he believed possible, provided feed is available. The data also identified learning that had occurred in the past. The case farmer admitted that in the past he had monitored a wide range of factors, but over time he had learnt which factors were critical for management purposes and therefore reduced the his monitoring input. Several years ago, the case farmer developed the target level for milk production over the summer, and associated decision rules based on his experience. Similarly, the condition score targets and decision rules for managing thin cows were learnt two years ago. The management practice of on-off grazing over winter was tested two years ago and then introduced as standard practice. Planning, and the plan the case farmer adopts is influenced by learning in relation to targets, decision rules and management practices. New targets and associated decision rules will change the plan, as will the introduction of new management practices.

Appendix XXI. Farmer A – Summary of Year Two

Description of year two

At the start of the planning period, the farm had a higher level of pasture cover and the herd was in better condition than the previous year (Table 1). Milk production was the same as last season (1.39 kg MS/cow/day), and the case farmer had a similar level of silage on hand (103 versus 100 bales). An additional 1.0 ha of forage crop had been planted, but the farmer had about 900 less bales of hay on-hand. The silage and hay had been cut later than last year and this would result in reduced pasture growth rates if the season turned dry. The case farmer was carrying an extra four cows, but had an additional 4.0 ha in the milking area. January was cool and wet like the previous year, but pasture growth was higher and the farm had a higher pasture cover on February first than the previous year (1800 versus 1350 - 1400 kg DM/ha). Conditions started to turn dry at the end of January. Pasture growth rates were very low during February and gradually declined through the month as conditions remained dry with the farm only receiving some 21 mm of rainfall. In contrast, the farm experienced good growing conditions over February in the previous year. The difference in growing conditions is reflected in the change in average pasture cover. In the first season, the average pasture cover remained constant throughout February, whereas this year, it fell some 500 kg DM/ha over the month.

March was cooler than normal, and rainfall was about average. In contrast, pasture growth rates had been above average during the previous March. Pasture cover declined slightly through March, whereas last season, it increased by almost 100 kg DM/ha. During April, pasture growth rates were about average and pasture cover increased slightly during the month. In the previous season, pasture growth rates were above average during the first half of April, but declined rapidly as conditions became cold and dry.

Table 1. Comparison of years one and two.

Factor	Year 2	Year 1
25th December		
Average pasture cover (Kg DM/ha)	1800	1700
Cow condition	4.8 (+)	4.5 (+)
Milk production (kg MS/cow/day)	1.39	1.39
Cow numbers	150	140
Rotation length (days)	30	30
Effective area (ha)	52	48?
January 1st		
Average pasture cover (Kg DM/ha)	1800	1650
Cow condition	4.8	4.5+
Milk production (kg MS/cow/day)	1.39	1.39
Cow numbers	144	140
Forage crop area (ha)	3.0	2.0
Silage (bales)	103	100
Hay (bales)	1488	2400
Rotation length (days)	30	30
February 1st		
Average pasture cover (Kg DM/ha)	1800	1400
Cow condition	4.8	4.5
Milk production (kg MS/cow/day)	1.39	1.39
Cow numbers	144	138
Rotation length (days)	28 - 30 (30)	29 - 30

Factor	Year 2	Year 1
March 1st[e]		
Average pasture cover (Kg DM/ha)	1300	1350 - 1400
Cow condition	4.8[h]	4.5
Milk production (kg MS/cow/day)	1.04[i]	1.13 – 1.22
Cow numbers	142	138
Rotation length (days)[a]	25 - 28 (25)	24 - 29 (25)
Date forage crop started	10/2/xx[f]	31/1/xx
Date forage crop terminated	23/3/xx	1/3/xx[c]
Date silage started	15/3/xx	NA[d]
Date silage terminated	29/3/xx	
Amount fed	17 bales	
April 1st		
Average pasture cover (Kg DM/ha)	1280	1445
Cow condition	4.5	4.5 (+)
Milk production (kg MS/cow/day)	1.04	1.13 – 1.17
Cow numbers	126	138
Rotation length (days)[a]	24 - 25 (25)	25 - 29 (28)
Drying off date	28/4/xx	29/4/xx
Cow numbers at drying off	119	129[g]
Milk production (kg MS/cow/day)	0.84	1.13
Condition score	4.5 (-)	4.5
Average pasture cover (Kg DM/ha)	1332	1392
Date herd on once-a-day	13/4/xx	24/4/xx[b]
Rotation length at drying off (days)	25	28
Urea planned for winter	1.5 tonnes	0.0 tonnes

[e] The young stock were given 3.0 ha because they were short of feed as a result of late hay and silage crops.
[h] Average herd condition increased to 5.0 condition score units on the 24th March, and then declined to 4.8 condition score units.
[i] Milk production held at 1.22 kg MS/cow/day through most of February. When the herd went onto the second forage crop on the 28th February, the case farmer reduced milk production to 1.04 kg MS/cow/day.
[a] The rotation length is the range over the previous month, and the figure in brackets is the rotation length at the end of the month.
[f] Second forage crop of 1.5 ha fed on the 28th February.
[c] The crop was not grazed for 5 days during this period due to muddy conditions.
[d] Not fed until the herd were dried off.
[g] The case farmer put 9 cull cows on waste ground on the 5th April and milked them until the 18th April when they were sold to the works.
[b] R. 3yr cows on once-a-day on 18 April.

The plan

Planning horizon

The data from year two confirms that the summer planning period starts at Xmas and goes through to mid March when the autumn rains are expected. This planning horizon is chosen because it is a period when the farm is in feed deficit. It moves from a feed surplus position in late spring to a feed deficit situation in early summer. Termination of the planning horizon occurs when the autumn rains arrive in mid March. The rains cause a flush of growth and the farm experiences a period of feed surplus conditions. Mid March is also near a critical decision, drying off, which has a major influence on next season's production.

Hierarchies of plans

There were two plans that dominated the period of the study, one over the summer (Xmas - April 1st), and another from April 1st to calving. Shorter planning periods were encapsulated within these two plans and related to events, e.g. pre-forage crop, forage crop, post-forage crop to April 1st, April 1st to drying off.

Values, goals and targets

As with last season, the case farmer's goal over the summer-autumn was to maximise the number of milking cows on-hand at mid March. To achieve this goal, the farmer had several important intermediate targets. He aimed to maintain the herd on a 25 - 30 day rotation. The case farmer's milk production target in early January (pre-forage crop) was to maintain milk production at the post-Xmas level (1.39 kg MS/cow/day in this year) for as long as possible. This goal was not identified last year. It appears the case farmer tries to hold milk production at a particular level for as long as possible. The case farmer has no absolute level in mind, but the aim is to prevent a downward trend in milk production. This is achieved through reducing the rotation length. Normally, the case farmer then introduces a target of 1.13 kg MS/cow/day which is used to signal that it is time to introduce the forage crop. Once introduced to the forage crop, the milk production target for the herd is 1.04 kg MS/cow/day. Post-forage crop, the case farmer's targets are to maintain the herd on a 25 - 30 day rotation and ensure the condition of individual cows does not fall below 3.5 condition score units.

This year, the case farmer changed the forage crop milk production target to 1.13 kg MS/cow/day with an introduction target of 1.22 kg MS/cow/day. The herd went onto the forage crop at 1.22 kg MS/cow/day, but the case farmer then increased the forage crop milk production target from 1.13 kg MS/cow/day to 1.22 kg MS/cow/day because of the good feed situation and the state of the herd. Conditions deteriorated through February, and the case farmer revised the forage crop milk production target downwards to 1.04 kg MS/cow/day when he placed the herd on the second forage crop in early March.

In early April, the primary goal of the case farmer for the autumn period was to maintain herd condition at 4.5 condition score units. The case farmer prefers to maintain the condition of the herd at the level he will calve at rather than take condition off the herd in late lactation and put it back on during the winter. This is because it is more difficult to increase herd condition over the winter months. The case farmers other goal was to maintain milk production at 1.04 kg MS/cow/day. This target was used because the case farmer knew that if milk production fell below this level, the herd would be losing condition.

The case farmer also used the average pasture cover targets he had calculated from his feed budget. He analysed six scenarios which comprise three drying off dates and for each of these scenarios, with and without winter nitrogen options. The case farmer developed a 3 x 2 matrix (Table 2) which showed the average pasture cover target required at drying off for each of the six options. The case farmer used the same average pasture cover (2200 kg DM/ha) and cow condition targets (4.5 condition score units) for calving as last year.

Table 2. Pasture cover targets the case farmer must dry off at for different dates, with and without urea.

Drying Off Date	With Urea	Without Urea
15th April	1250	1450
20th April	1287	1487
30th April	1325	1525

The case farmer had an annual production target of 26,000 kg MF. In early March he had produced 22,500 kg MF and believed that if he could maintain milk production at 1.04 kg MS/cow/day through March, he would produce 25,000 kg MF by the end of the month and would only need to produce 1000 kg MF in April to meet target. This target did not influence decision making.

Planning method

At the start of summer, the case farmer assessed the state of the farm (average pasture cover, pasture growth rates, forage crop, silage yield, cow intake, condition and milk production). He then used this information to undertake a mental simulation (rough feed budget) from Xmas to mid March to assess whether his typical plan would work. Importantly, the case farmer believed a climatic shift had occurred and that wet summers had become the norm. He therefore used higher than average pasture growth rates in his mental simulation. This and the good feed position suggested his "typical" plan was too conservative. Therefore he modified the planning heuristics and increased his milk production targets by 0.085 kg MS/cow/day. This in effect increased cow intakes, and initiated forage crop grazing at an earlier date. The "typical" plan was modified in two other ways. First, because a strategic decision had been made to replace the summer silage with 1.0 ha of forage crop, this second crop replaced the silage in the plan. This also meant the plan included a second paddock of new grass that was to be sown before mid April. The other modification was because of a tactical problem with reproductive performance in the previous spring (very cold and wet). As such the case farmer planned to delay removing the bull for two weeks to allow later cycling cows to be mated. This in turn meant he had to shift pregnancy testing two weeks later. These modifications were pre-set before the case farmer tested the feasibility of this modified "typical" plan. The case farmer did not undertake a formal feed budget once the forage crop was grazed to assess the amount of silage to be fed as was undertaken last year. This was because the initially the case farmer did not intend to use silage.

As with last year, once the pregnancy test information was obtained, the case farmer completed a formal feed budget with monthly time intervals for the period April 1st to calving. The first step was to estimate the average pasture cover he required on the farm at May 1st to achieve his average pasture cover and cow condition targets at calving. His targets at calving (20th July) were 2200 kg DM/ha and an average herd condition of 4.5 condition score units. After entering cow numbers, feed requirements, supplements and average pasture growth rates into the equation, the case farmer estimated that he needed an average pasture cover of 1600 kg DM/ha on May 1st. The case farmer then estimated the extra average pasture cover he could grow if he applied 1.5 tonnes of urea during autumn-winter. This allowed him to reduce his May 1st target to 1400 kg DM/ha. Average pasture cover was 1300 kg DM/ha in early April. The case farmer then estimated the pasture cover targets he needed to achieve for different drying off dates, with and without urea (Table 2). The plan the case farmer developed had no allowance in it for increasing cow condition. Therefore, his main concern at that point in time was the condition of the herd.

The case farmer used a partial budget to estimate the costs of the urea, and the income generated from extending the lactation. This analysis showed nitrogen was economic to use. Although the case farmer had previously mentioned bought-in hay as another option for extending the lactation, this was not analysed.

The case farmer stated that he would not use nitrogen if the autumn flush occurred because he did not believe he would get a response under these conditions. This argument was based on his experience with spring nitrogen. He believed that if he used urea at the same time, it would upset the nutrient balance, and this would lead to reduced pasture growth later in the winter. He has experienced a lag effect in spring after applying urea. Pasture growth rates used in the planning process come from previous experience.

The case farmer only completed one feed budget before drying off. Rather than recalculate another feed budget after each farm walk, he just compared his actual average pasture cover to the targets he had calculated that are shown in Table 2. This reduced the amount of effort the case farmer had to put into the planning process.

Planning rules

Analysis of the data identified several planning rules used by the case farmer to develop his plan (Table 3). The reasons given by the farmer for these rules is also specified.

Table 3. Decision rules for the summer plan.

Activity	Decision Rule	Reason
Selection of summer-autumn stocking rate	IF date = Xmas, THEN identify cull cows not considered suitable for milking through the summer-autumn and sell them and milk the remainder through the period.	At Xmas the case farmer aims to take as many cows as possible through the summer-autumn period. He identifies culls that he thinks are not suitable to take through this period, and sells them at, or soon after Xmas. These culls are cows with mastitis or a dangerous temperament.
Drying off the herd or part of the herd	Do not dry off part of the herd and continue to milk the remainder.	The case farmer has a policy of keeping the herd together as a unit. Therefore he does not dry off part of the herd and continue milking the remainder.
Culling empty cows	IF a cow is empty, THEN retain the cow until near drying off.	The case farmer prefers to continue milking empty cows rather than cull them immediately because they are the best producing animals. Without a developing fetus, empty cows produce more milk than pregnant cows.
Milk production target for supplement feeding	Do not use a milk production target that will result in poor utilisation of supplements or pasture.	The case farmer has used a milk production target when feeding supplements (forage crop, silage) that has ensured a high level of utilisation. This target also ensures the level of pasture utilisation is high and pasture

Activity	Decision Rule	Reason
		quality is maintained. The case farmer believes that if he used a milk production target of 1.39 kg MS/cow/day when feeding supplements, both supplement and pasture utilisation would be poor. Therefore, supplement and pasture utilisation determine the upper limit of the milk production target over the summer period.
Forage crop grazing	Introduce the forage crop when milk production falls to 1.22 kg MS/cow/day.	The forage crop is introduced to the herd relatively early so that the change in diet is relatively gradual. This also allows the forage crop to last for longer than if it was introduced later and made up a larger proportion of the herd's diet. Data from this season suggests that if the proportion of pasture in the diet is too low, metabolic problems can occur when feeding the forage crop. The case farmer thought year two was going to be a wet summer and increased the milk production target by 0.085 kg MS/cow/day to take advantage of the expected above average pasture growth rates.
The amount of forage crop fed to the herd	Feed sufficient forage crop to maintain milk production at 1.13 kg MS/cow/day.	The case farmer thought that year two was going to be another wet summer, and so he increased the milk production target 0.085 kg MS/cow/day in order to take advantage of the expected higher then average pasture growth rates. He had leamt in the previous wet summer that the herd could produce at high levels over the summer provided they had sufficient feed.
Forage crop nutrition		The case farmer admits that one of the problems with the forage crop is that unlike maize, it does not put condition on his herd. Instead, it is used to produce milk. However, if the level of pasture the herd is consuming reaches low levels while feeding the forage crop, the herd will lose condition.
Forage crop maturity	Feed the forage crop at its maturity date.	Forage crop quality tends to decline after its maturity date is reached. The case farmer attempts to minimise this effect by planting the forage crop at a date that ensures maturity coincides with the period when the forage crop is likely to be grazed. However, forage crop maturity has little effect on the case farmer's decision making at the actual time of grazing.
Forage crop removal and new grass sowing date	Graze the forage crop such that the new grass can be sown by mid April.	The date by which the new grass must be sown is reasonably flexible. For example, the first crop was sown in late March, while the second crop was sown in mid April. In year one, the impression was gained that the new grass had to be sown by mid March.
Rotation length	Maintain rotation length between 25 - 30 day round.	The case farmer's choice of maximum rotation length relates to the impact of the stocking rate/cow concentration effect. Above a thirty day round, cow density per hectare is such that there is insufficient pre-grazing mass to fully feed the herd. The rate of pasture regrowth is also

Activity	Decision Rule	Reason
		insufficient to achieve the pre-grazing residuals the case farmer needs to fully feed the herd at the next grazing. On a longer rotation, pasture cover can get too long (> 2000 kg DM/ha) and reduce pasture growth rates. At the other extreme, the case farmer does not want a rotation length of less than 25 days because at this rate, average pasture cover declines too quickly, and pasture regrowth is reduced.

Plan

The case farmer's plan for year two is summarised in Table 4. At Xmas he planned to carry 144 cows through the summer-autumn. The case farmer planned to maintain a rotation of 25 - 30 days and hold production at some level for as long as possible. The forage crop was to be fed when milk production fell to 1.22 kg MS/cow/day in late January, early February. The area planted in forage crop had been increased by 50 % this year (3.0 ha versus 2.0 ha) because the case farmer believed that the climatic patterns were changing to a colder wetter spring and that he needed all his silage for the early part of this period. Therefore, he replaced the silage with another 1.0 ha of forage crop. The second forage crop was planted three weeks later to allow him to stagger the grazing of the forage. The herd was to be fed sufficient forage crop to maintain milk production at 1.13 kg MS/cow/day. The first forage crop was expected to last three weeks, and then the second crop was to be fed for a further three weeks. After the forage crops, the herd would be fed a diet of pasture and continue on a 25 - 30 day round until drying off. Culls were to be sold at or near to drying off.

The case farmer has changed his reproductive management. The bull was to be left out two weeks longer than last year to pick up later cycling cows. This change was introduced because the reproductive performance had been affected by the cold, wet spring. As a result, pregnancy test had to be shifted two weeks later. The case farmer planned to pregnancy test the whole herd in late March this year. Last year he only tested a group of 20 - 30 animals, but because he is testing 20 "lease cows" he decided to test the whole herd.

Table 4. The case farmer's plan from Xmas until drying off.

Feed related activities	Other activities
Carry 144 cows through the summer-autumn.	
Maintain a 25 - 30 day rotation.	
Feed the first forage crop in late January, early February when milk production falls to 14 litres/cow/day (1.22 kg MS/cow/day). Feed the first forage crop for 3 weeks and maintain milk production at 13 litres/cow/day (1.13 kg MS/cow/day).	Remove the bull on the 9th February.
Feed the second forage crop three weeks after the first and maintain milk production at 13 litres/cow/day (1.13 kg MS/cow/day).	Herd test early March.
Maintain a 25 - 30 day rotation post-forage crop.	Sow the first paddock of new grass mid March.
Sell the cull cows at or near drying off.	Pregnancy test the herd in late March.
Dry off the herd when the autumn rains arrive around mid April and increase the rotation length to 50 - 60 days.	Sow the second paddock of new grass mid April.

Pre-plan conditions

The case farmer noted that if silage and hay crops are not taken off early, these paddocks are vulnerable to dry conditions, which will reduce pasture regrowth. He also noted that he planted the second forage crop three weeks later than the first so that he could stagger the grazing. This allowed the second crop to mature three weeks later and avoided problems of over-maturity. The conditions through the late spring suggested to the case farmer that the farm was likely to experience another wet summer like in year one. His response to this was to increase the milk production targets for forage crop feeding by 0.085 kg MS/cow/day. He had learnt that the herd could produce at high levels over the summer provided they were well fed, and the case farmer wanted to take advantage of the expected higher than average pasture growth rates.

Implementation of the plan

The case farmer's plan, its implementation, and the reasons for any discrepancies between the two are summarised in Table 5. At Xmas the case farmer had 152 cows on hand at condition score 4.8 producing 1.39 kg MS/cow/day. Average pasture cover was around 1800 kg DM/ha and the herd was on a 30 day round. Six cows were culled soon after Xmas because they were not suitable for taking through the summer-autumn (mastitis, temperament). To maintain milk production at 0.8 kg DM/ha/day, the rotation length was reduced from a 30 to a 28 day round in late January as conditions became dry. Prior to this, it was cool and had rained most days. In late January, average pasture cover was around 1800 kg DM/ha. Pasture growth over January had been good, but had declined over the last week of January due to dry conditions. Milk production and cow condition had held over the month and in late January, the herd was being fed 10 - 11 kg DM/cow/day of high quality pasture.

During February, one cow died of metabolic disease and one was culled due to cancerous eye. Milk production declined from 1.39 kg MS/cow/day in late January to 1.22 kg MS/cow/day on the 10th February. At that point, the herd were placed on the first forage crop. Production held at 1.22 kg MS/cow/day (14.0 litres/cow/day) through until the first forage crop was grazed on the 27th February. The case farmer estimated pasture growth over February to be about 10 kg DM/ha/day. This was relatively constant through February with the majority of the 21 mm of rainfall occurring around the 17th of the month. This freshened things up, but did not result in a "pulse" of pasture growth. During this period, the herd returned to paddocks grazed at the start of the round. However, the combination of low post-grazing residuals at the last grazing and poor subsequent pasture growth rates resulted in low pre-grazing residuals in late February and hence low cow intakes from pasture. The herd was foraging, or grazing into the sward profile to obtain sufficient intake. During the period, the case farmer shortened the rotation length from a 27 - 28 day round, to a 25 day round when rain fell.

The conditions at the end of February forced the case farmer reduced the milk production target to 1.04 kg MS/cow/day when the herd went onto the second forage crop on the 28th February because conditions were so dry. Cow intakes declined through the latter part of February and by early March, the herd was receiving 6 - 7 kg DM/cow/day of pasture and 2 - 4 kg DM of forage crop. Cow condition improved from 4.8 in late January to 5.0 around the 24th February, but as conditions became dry, condition declined back to 4.8 condition score units. Average pasture cover declined from 1800 kg DM/ha in late January to 1300 - 1400 kg DM/ha in early March. At that stage, the case farmer was milking 142 cows producing 1.04 kg MS/cow/day on a 25 day rotation. The tight feed situation was further compounded because the case farmer had to transfer a 3.0 ha paddock to the young stock because they were short of feed. This was primarily because the regrowth from the late cut hay paddock had been poor in the dry conditions. The case farmer could have fed the young stock silage, but feed utilisation is poor with young stock. The case farmer's preference was to give a paddock to the young stock and if required, feed the silage to the herd because utilisation is much higher.

The herd was herd tested on the 5th March, and 14 thin and/or low producing cows were dried off on the 10th March to free up feed for the remainder of the herd. They were put on the dry stock block with the rising two year old heifers. On the 15th of March, silage was fed to the herd because of metabolic problems. This occurred because the herd were obtaining insufficient pasture intake with the forage crop. The crop was finished 8 days later on the 23rd March. The case farmer continued to feed silage (17 bales in total) until the 29th of March. By this stage, there was sufficient average pasture cover on hand to fully feed the 126 cows on pasture alone, and silage feeding ceased. By early April, both forage crop paddocks had been planted in new grass.

Pasture cover increased slightly over the latter half of March. On the 25th March it was 1279 kg DM/ha and on April 5th it was 1295 kg DM/ha. The case farmer estimated pasture growth rates were 20 kg DM/ha/day in the second half of March, and he measured 30 kg DM/ha/day between April 3rd and April 8th, and 25 kg DM/ha/day for the 10 days prior to that. The pattern of pasture growth was a reflection of the rainfall over March. The farm was dry at the start of March and then received 18 mm on March 4th, 18 mm on March 10th, 12 mm on March 18th, 8mm on March 21st, 8mm April 4th, and 10 mm April 8th[30].This was enough rain to keep the pasture growing, but not enough to induce an autumn flush. The case farmer described the climate in March as cooler than normal with about average rainfall. The first period of April was fairly typical.

Milk production was held at around 1.04 kg MS/cow/day through March, but average herd condition declined from 4.8 to 4.5 condition score units. Cow intakes were held at around the 9 - 10 kg DM/cow/day. While on silage, the herd received receiving 7.5 kg DM/hd/day of pasture, and 2 kg DM/hd/day of silage. At the start of April, cow intakes were around 9.5 kg DM/cow/day, but only 126 cows were being milked[31] on a 25 day round. During March, the herd got down to a 24 day round. This was because two paddocks were out, one with the cows the case farmer dried off, and the other was used when the herd was grazing the forage crop. These paddocks were returned to the round in late March. The pasture that was generated by the rain through March had "hardened up" by late March and pasture quality improved through the month.

On April 1st, two thin rising three year old cows were dried off on condition. On the same date, the herd was pregnancy tested and 8 empty cows and one heifer were identified. Once the pregnancy test results were obtained, the case farmer decided to winter 176 cows. This was an increase in cow numbers on previous years, and to run this number of stock, the case farmer decided incorporate the beef unit into the milking area for next season. Around this time, the case farmer decided to use urea applied post-drying off to extend the lactation.

On the 13th April, the case farmer put the herd of 126 cows on once-a-day milking. Milk production had declined from 1.04 kg MS/cow/day to 9.5 litres/cow/day or 0.96 kg MS/cow/day. The case farmer knew that once milk production fell below 1.04 kg MS/cow/day, then the herd was losing condition. The average condition of the herd had dropped below 4.5 condition score units and they were consuming 9.0 kg DM/cow/day of

[30] The rain fall data was recorded for the benefit of the researchers, as the case farmer does not normally record it.
[31] The removal of the 14 cows equates to another 1.0 kg DM/hd/day intake for the remaining cows.

pasture. The case farmer's aim at that stage was to milk the cows on once-a-day until the average pasture cover dropped to target, and then dry off the herd.

The case farmer sent seven empty cows to the works on the 18th April primarily because the drying off date was imminent. By the 20th April, the herd was only producing 8.5 litres/cow/day or 0.87 kg MS/cow/day. At this stage only 119 cows were being milked. The cows remained on a 25 day rotation through until drying off on the 28th April. At that stage, he was milking 119 cows, producing 0.84 kg MS/cow/day and the herd was losing condition. The average pasture cover on the 10th April was 1284 kg DM/ha with a growth rate of 21 kg DM/ha/day, on the 20th April, it was 1330 kg DM/ha with a growth rate of 28 kg DM/ha/day, and on the 28th April, 1332 kg DM/ha with a growth rate of 24 kg DM/ha/day. The average pasture cover target for the 30th of April was 1325 kg DM/ha.

When the case farmer dried off the herd, he reduced cow intakes to maintenance providing half their rations as hay. He then skipped one milking and then two. The herd was then given dry cow treatment and was shut up in a paddock. The rotation was extended from a 25 to a 50 day rotation.

Table 5. A comparison of the plan with the actual outcome.

The plan	The outcome	Reason for difference
Carry 144 cows through the summer-autumn.	119 lactating cows were on-hand at drying off.	During February, one cow died of a metabolic disease and another cow was culled with cancerous eye. Fourteen R. 3yr cows were dried off on the 10th March to free up feed for the remainder of the herd. These cows were either thin or low producing. Two R. 3yr cows were dried off on the 1st April due to condition. All the dry cows that were retained were placed on the young stock block. Seven empty cows were culled on the 18th April.
Maintain a 25 - 30 day rotation pre-forage crop.	Rotation reduced to 28 days in late January.	Conditions became dry in late January, and the case farmer had to shorten the rotation to maintain milk production at 1.39 kg MS/cow/day.
Remove the bull on the 9th February.	Bull removed on the 9th February.	
Feed the forage crop in late January, early February when milk production falls to 14 litres/cow/day (1.22 kg MS/cow/day).	The herd went onto the forage crop on the 10th February when they were producing 1.22 kg MS/cow/day.	Feed conditions were such that the forage crop was grazed later than planned.
Maintain milk production at 13 litres/cow/day (1.13 kg MS/cow/day) while the herd was on the two forage crops.	Milk production was maintained at 1.22 kg MS/cow/day while the herd was on the first forage crop.	Feed conditions were that good, that the case farmer decided to increase the milk production target to 1.22 kg MS/cow/day.
	Milk production was maintained at 1.04 kg MS/cow/day while the herd was on the second crop.	Feed conditions deteriorated during February, and the case farmer decided to revert back to his original milk production target to conserve forage. He also transferred a 3.0 ha paddock to the young stock.
Feed each forage crop for 3 weeks.	The first forage crop was fed from the 10th February until the 27th February.	This was a bit less than three weeks, but the first forage crop was fed at a greater rate than initially planned.

The plan	The outcome	Reason for difference
	The second forage crop was fed from the 28th February until the 23rd March.	This was a bit longer than three weeks, but the forage crop was supplemented with silage because of metabolic problems.
While on the crop, maintain a 25 - 30 day round.	The rotation length was reduced from 28 days to 25 days during the feeding of the first crop, and remained at 25 days during the second crop except for a period when it was reduced to 24 days.	When rain fell, the rotation length was shortened to maintain cow intakes and production at target. The rotation was briefly reduced to 24 days when a paddock was used during the day with the forage crop, and another was used briefly to dry off the 14 thin low producing R. 3yr old cows.
	On the 15th of March, silage was fed to the herd because of metabolic problems. The crop was finished 8 days later on the 23rd March. The case farmer continued to feed silage (17 bales in total) until the 29th of March.	This occurred because the herd were obtaining insufficient pasture intake with the forage crop. By this stage, there was sufficient average pasture cover on hand to fully feed the 126 cows on pasture alone, and silage feeding ceased.
	Provide 3.0 ha of the milking area to the young stock.	The young stock were short of feed. Regrowth from the late cut hay paddocks was poor and conditions were dry. The case farmer did not want to feed them silage because utilisation is poor with young stock.
Herd test early March.	Herd test 5th March.	
Conserve silage for the early spring.	The case farmer fed 17 bales of silage between the 15th March until the 29th March.	The farmer had to feed silage on the15th March because of a metabolic problem due to the ratio of pasture to forage crop. The case farmer continued to feed silage because feed conditions were improving as a result of frequent rain. This meant the herd did not need to be dried off once the forage crop was fed. The case farmer decided to feed the silage and use urea to replace the lost supplement.
Maintain a 25 - 30 day rotation post-forage crop.	The rotation remained at 25 days through until drying off.	
Pregnancy test the herd in late March.	The herd was pregnancy tested on April 1st.	
Sow the new grass by mid April.	First paddock sown mid March Second paddock sown mid April.	
Sell the cull cows at or near drying off .	Seven culls sold on the 18th April.	
Dry off the herd when the autumn rains arrive around mid April, or when cow condition and average pasture cover targets are met.	On the 13th April, the herd was put on once-a-day milking. On the 28th April, the herd was dried off.	The herd was put on once-a-day milking to maintain condition. Pasture was still actively growing, but the herd was still losing condition. The herd was losing condition, milk production had fallen to 0.84 kg MS/cow/day and intakes were only 8.0 kg DM/cow/day. Pasture growth was about equal to feed demand and average pasture cover was static. The average pasture cover level was at the same level as the target for the 30th April. The planned use of urea post-drying off allowed the case farmer to extend the lactation beyond the normal drying off date of mid April.

Control

The control process used by the case farmer consisted of monitoring key performance measures, comparing these to standards or intermediate targets to identify significant deviations, and if a deviation existed, using decision rules to select the most appropriate contingency plan for the conditions. Although problem detection was undertaken, it was not apparent that any form of conscious problem definition or diagnosis was undertaken in most instances. The case farmer did evaluate a range of areas in relation to his tactical management, and examples of learning were recorded.

The monitoring process

An important parameter not identified in year one is that the case farmer visually estimates the residual dry matter (e.g. 1200 kg DM/ha) left behind by the herd when he shifts them. He then estimates the likely pasture cover in the paddock at the next grazing in 25 - 30 days time given his estimate of current pasture growth rates. In this case, he estimated that the pasture was growing at 10 kg DM/ha/day, and therefore in 25 days time, the pasture cover would be 1350 kg DM/ha. He then worked out how much feed would be available to the herd on the 2.0 ha per day they are roughly fed. For example, if they grazed down to 1200 kg DM/ha, then the 142 cows would obtain about 3.5 kg DM/cow/day[32] from the pasture or about one third of their requirements. From this, the case farmer inferred that he would be in a serious feed deficit situation if it did not rain before the herd finished grazing the forage crop. This process allows the case farmer to consider his likely feed position in 3 - 4 weeks time (this depends on rotation length - 25 - 30 days). It is a simple, but effective feed prediction process, that is updated every 3 - 4 days and provides an early warning on likely feed deficit problems almost a month in advance. It is a powerful, yet simple, early warning tool. With this, the case farmer can also work out how much pasture will need to grow to fully feed the herd in 25 -30 days time. In March, the pasture had to grow at around 30 kg DM/ha/day for a paddock to fully feed the herd at the next grazing. Key factors are obviously the post-grazing residual, pasture growth, and the post-grazing residual required at the next round to feed the herd to target. A mathematical representation of the above process is provided in Table 6.

Table 6. Simple mathematical representation of the system.

Post-grazing residual now	Post-grazing residual in 25 days	Pasture growth rates	Estimated cow intakes (125 cows on 2.0 ha)	Percentage of target (12 kg DM/hd/d))
1200	1200	10	4	33%
		20	8	67%
		30	12	100%
		40	16	125%
1300	1200	10	5.6	47%
		20	9.6	80%
		30	13.6	113%
		40	17.6	147%
	1300	10	4	33%
		20	8	67%
		30	12	100%
		40	16	125%
1400	1200	10	7.2	60%
		20	11.2	93%
		30	15.2	127%
		40	19.2	160%

32 (250 kg DM/ha × 2.0 ha/day = 500 kg DM/ha/day)/142 cows

Post-grazing residual now	Post-grazing residual in 25 days	Pasture growth rates	Estimated cow intakes (125 cows on 2.0 ha)	Percentage of target (12 kg DM/hd/d))
	1300	10	5.6	47%
		20	9.6	80%
		30	13.6	113%
		40	17.6	147%
	1400	10	4	33%
		20	8	67%
		30	12	100%
		40	16	125%

The case farmer also uses the pre - and post-grazing residual to work out what the cows are being fed, and compares this to standard requirements, i.e. what he thinks they should be getting. He then considers if he can meet requirements by shortening the rotation length. If this cannot be done, he then considers if he has enough supplement to make up a difference if one exists. If he has, he will make up the difference with supplement, otherwise if he has no other feed options available, he may reduce cow numbers to ensure the remaining cows have sufficient feed (Check year one when he put the culls on waste ground). The case farmer delays the decision for 4 - 5 days to see if there is any improvement, but if there is not, then he will act.

This approach demonstrates the benefits of a relatively fixed rotation length. The case farmer noted that he can verify his intake estimate using the vat, and therefore he does not need to do another estimate for four days as the milk vat will tell him if intakes have held or are continuing to decline further. This is another example of the case farmer using his knowledge of cause and effect relationships to reduce his monitoring "effort". The case farmer noted that the post-grazing residual only changes slowly, so few subsequent estimates are required once an initial estimate has been made. This data also shows the role of early warning indicators and how they link into the main indicators for decision making. This information suggests some meta rules for monitoring:

IF post-grazing residuals and expected pasture growth rates suggest cow intake targets will not be met at the paddocks next grazing,
THEN begin to consider options and monitor the situation closely.

IF pre- and post-grazing residuals suggest cow intakes are below target,
THEN monitor feeding levels closely over the next 3 - 4 days using milk production and consider options.

The case farmer also uses the behaviour of indicator cows that he observes around three hours after they have gone into a paddock. If these animals are still grazing and there is not much left in the paddock, he knows that the herd is not being fed to requirement.

IF after three hours of entering a paddock, the indicator cows are still grazing,
AND the amount of feed remaining in the paddock is minimal,
THEN the herd is not being fed to requirements.

The year two study, as shown above, highlighted the importance the case farmer ascribes to monitoring pre- and post-grazing residuals and cow intakes. This information was not identified in year one. The interaction between milk production (litres/cow/day) and cow intakes is emphasised by the case farmer. Both factors are monitored every 3 - 4 days to determine what the herd was eating and whether that level of intake was maintaining milk production. He noted that he uses litres per cow per day because this indicates a change in cow intake more quickly than milk fat and protein. This is because the fat and protein test will often increase when volume declines. This information suggests that the case farmer has target intake levels as mentioned in the literature by Mathieu (1989). The case farmer also reiterated the difficulty of accurately measuring pasture cover during summer and the importance of the milk vat as an indirect measure that quickly identifies changes in feed supply.

During summer, the case farmer's primary concern in relation to cow condition is the condition of thin rising three year old cows. The case farmer attempts to identify cows that are at or near condition score 3.5 so that he can take action to prevent them losing further condition. If the herd is in good condition (≥ 4.5 condition score units) and feed is plentiful, then the condition of these animals is not a problem. The case farmer may sub-consciously[33] monitor cow condition under such conditions, but he does not actively monitor this information except to occasionally check what is happening.. It appears that other factors such as a rapid decline in milk production, or the feeding of the forage crop[34] may trigger the case farmer to begin actively monitoring the condition score of his thinner cows. The case farmer did not monitor the condition of his thin heifers in January, but initiated this practice when milk production fell from 1.22 kg MS/cow/day to 1.04 kg MS/cow/day. The case farmer then identified two cows that were around 3.5 condition score units and these were put on once-a-day milking. He also identified four other cows that were almost at this condition score.

IF milk production falls to 1.04 kg MS/cow/day,
AND the herd has been introduced to the forage crop,
THEN begin monitoring the condition of the younger cows in the herd.

The case farmer subconsciously monitored average pasture cover when he consciously monitored pre- and post-grazing residuals. The case farmer identified a decline in pasture growth rates through informal visual assessment such as the lawn not growing and regrowth on paddocks, but he was not monitoring this factor through January and February. He could however, estimate likely pasture growth rates if asked. This appeared to be based on what the herd was eating, the level of supplementation and his estimated change in average pasture cover. The factors that are monitored subconsciously appear to be used for triangulation.

The case farmer did not respond to rainfall events during January because it rained most days and there has not been a "dry spell" as such. However, once such dry conditions occurred, the case farmer then expected a pulse of pasture growth as a result of a significant rainfall event (≥ 25 mm). The case farmer mentioned that clumpy pasture that was not cleaned out in the previous two rotations tended to be the feed that decays in response to a significant rainfall event.

The case farmer did not monitor average pasture cover up until March. He intended to start this process in mid March, but did not see much point in formally measuring average pasture cover while there was little growth and the change in conditions was very slow. The case farmer began formal pasture monitoring on the 25th March. This information was used to estimate average pasture cover, pasture growth rates and the trend in pasture growth rates. Formal pasture monitoring was initiated because it was getting close to April 1st. The cows were also losing condition, and average pasture cover was relatively stable - no autumn flush had occurred. The case farmer said the decision was based on 80% time of year and the need to prepare a feed plan through the year, and

[33] By this, the author means that the case farmer was not consciously looking at cow condition when he moved the herd. However, if asked what condition the herd was in, the case farmer could provide an estimate of the average condition score and what had happened to condition score over the previous period.
[34] Rising three year old cows can have problems adjusting to the grazing of forage crops due to their teeth.

20% that the cows were losing condition. As with last year, the case farmer could not initiate formal planning until pregnancy testing was completed to identify the number of cows that would be wintered.

IF the date is ≥ mid March,
AND the date is ≤ April 1st,
AND the farm is in a poor feed position,
AND herd condition is declining,
THEN initiate objective pasture monitoring,
ELSE delay this until April 1st.

When monitoring average pasture cover, the case farmer uses 10 day intervals initially because it makes it relatively easy to work out pasture growth rates. He reduced the interval to five days in early April because of the imminence of the drying off decision and his poor feed situation. He believes that 10 days is the maximum monitoring period at this time of year because things change quickly. The case farmer reduced his monitoring interval down to 7 - 8 days this year which he thought was adequate for the conditions.

The case farmer is trying to pick up the pattern of what is happening over the autumn so that he can make the right decision. To establish a pattern, he requires more than two monitoring points and will normally not make a drying off decision without establishing the trend. This shows that the farmer does not want to make an irrevocable decision without adequate information. The case farmer calculates pasture growth rates by estimating what the herd has eaten, the level of supplementation, the change in average pasture cover, and then the pasture growth rates that are required to bring about this change in pasture cover. The case farmer stressed the importance of validating his pasture scoring against other measures.

The case farmer monitored the forage crop to estimate how much was left (grazing days).

Many of the factors used for option or contingency plan selection are simple things such as crop maturity, whether the herd is grazing the forage crop, or the rotation length. These factors are monitored, but probably at a subconscious level. In effect, they are "known" without the case farmer having to formally monitor them.

Prior to herd testing on March 5th the case farmer stated that he would use this information for culling decisions. He said that cows producing less than 0.52 kg MS/cow/day would be culled. Animals that were light, and young or had teeth or animal health problems would be retained. However, low producing cows that were fat would be culled. The cows that were to be retained would be dried off and fed sufficient feed to put on condition. Interestingly, when the herd was herd tested cows producing below 5 litres/cow/day were dried off. The case farmer decided he did not have time to wait for the milk solids data and used volume (litres/cow/day) as the basis for his drying off decision. He also noted that milk volume was a better indicator than milkfat or milksolids. The cutoff was an arbitrary figure, and the aim of the exercise was to reduce stocking rate to a level where the remaining cows could be fed to target.

The main indicators the case farmer measured through April were milk production, cow intakes, cow condition, average pasture cover, and pasture growth rates. Milk production was an important indirect measure of cow condition. Once the herd dropped below 1.04 kg MS/cow/day the case farmer knew it was losing condition and he therefore had to put the herd on once-a-day milking.

In the latter part of the lactation, because the case farmer was concerned about maintaining the condition of the herd, he used milk production as an indirect measure of this factor. Cow condition was important because no allowance had been made in the feed budget for increasing cow condition, and the condition of the herd was at target at that point. At drying off, it was the decline in milk production that triggered the drying off decision, not average pasture cover or pasture growth rates. The case farmer noted that he would have had to wait several days to pick this up through his plate meter.

The case farmer stated that he can identify empty cows at this time of year on the basis of milking time with 90% accuracy.

Financial data was not used for decision making over the summer-autumn.

Monitoring decision rules

The data suggests that there is a meta-level process occurring in relation to monitoring in which the case farmer consciously monitors key factors when they start to approach important thresholds or dates. Prior to that, these factors are monitored subconsciously, i.e. they do not have the case farmer's "attention". However, if asked about, the case farmer can often give a value for the particular factor. Other indicators appear to play a role in identifying when a "threshold" is reached which then activates the case farmer's "attention". In particular, milk production plays a dominant role in this process. An example of this process was given by the case farmer who said that when monitoring milk production, he does not estimate litres per cow per day until the volume in the vat changes significantly. Therefore, if total volume is between 2250 and 2300 litres each day, he will note this and continue to implement the current plan. However, if it drops significantly, then the case farmer will calculate the production in terms of litres per cow per day. He noted that milk production can change by up to half a litre per cow per day. Similarly, the case farmer did not begin monitoring the condition of his rising three year old cows until milk production declined from 1.22 kg MS/cow/day to 1.04 kg MS/cow/day.

IF milk volume changes significantly,
THEN recalculate milk production in litres per cow per day,
ELSE continue to monitor milk volume.

IF indirect measures suggest a factor is trending towards a threshold,
THEN begin formal monitoring of that factor.

This suggests that indirect measures play another role in terms of drawing "attention" to particular factors that need to be monitored. Dates and other events can also have the same effect e.g.

IF the date is April 1st,
THEN begin to objectively monitor pasture cover and pasture growth rates.

IF the autumn rains occur before April 1st,
THEN begin to objectively monitor pasture cover and pasture growth rates.

This ties in with the data where the case farmer moves from monitoring milk production to cow condition, to average pasture cover.

Frequency of monitoring

The data confirmed the monitoring frequencies identified in year one. In most cases, data was monitored on a daily basis. However, the data shows that milk production and cow intakes were monitored at about four day intervals, and that this frequency was adequate because the factors do not change that quickly. The case farmer did not change to 5 day monitoring for average pasture cover in April this year because he thought weekly monitoring was adequate.

Data processing

Formal calculation of such factors as milk production in litres/cow/day are not undertaken except if a change in total milk production occurs. The case farmer developed a matrix when he drew up the feed budget on April 1st that showed the target average pasture cover required for different drying off dates, with and without urea. This matrix meant the case farmer did not have to draw up a new feed budget each time he obtained new average pasture cover information, but rather he could compare the figure to the target for the nearest drying off date in the matrix.

Recording

No new material was identified on the case farmer's recording system.

Problem identification for control purposes

The case farmer identified problems when an indicator of actual performance fell outside, or approached a target specified in the plan. Key indicators and targets are identified in Table 7. Milk production is the primary indicator used by the case farmer in problem recognition over the early summer. This measure is used because it is objective, accurate, and can be measured on a daily basis. Alternative measures such as average pasture cover are inaccurate at this time of the year. Cow condition can be accurately measured, but is not as timely as milk production in identifying changes in the feed situation on the farm, and at that time of year it is not normally important (the herd is normally in good condition). Milk production is used in effect as an indirect measure of several key variables (average pasture cover, pasture growth, intake and cow condition). An important point identified in year two that was not reported in year one was that the pre-forage crop milk production target is not an absolute figure. Rather, the case farmers objective at this point in time is to maintain production at some level the herd and prevent a decline in production. This season, that "level" was 1.39 kg MS/cow/day. The case farmer also had a target for rotation length for the entire summer-autumn period, which was between 25 and 30 days.

In late summer, milk production is the still the primary measure, but because condition tends to decline at this time of year due to the dry conditions and some rising three year old cows have "teeth" problems on the forage crop and lose condition, individual cow condition is an important measure. The most interesting point, in relation to the summer targets was that the milk production target was adjusted in response to the feed conditions at the time. The case farmer did not complete a feed budget in early March, as was the case in year one, and therefore he did not have average pasture cover targets for the late summer period.

During autumn, the case farmer relies primarily on average pasture cover, pasture growth and cow condition for problem recognition. However, unlike year one, milk production played an important role in problem recognition. The case farmer used milk production to identify when the herd was losing condition. This measure will identify a change in herd condition more quickly than eye appraisal. Rainfall was important because if more than 25 mm fell, this would result in an autumn flush of growth and this would trigger the drying off decision.

Table 7. Indicators and targets used in the control process.

Indicator	Targets used in Year 2
Summer	
Milk production	
Pre-forage crop .	≤ 16 litres/cow/day or 1.39kg MS/cow/day
Forage crop one.	
Introduction	≤ 14 litres/cow/day or 1.22kg MS/cow/day[35]
Maintenance	≤ 14 litres/cow/day or 1.22kg MS/cow/day[36]
Forage crop two	≤ 12 litres/cow/day or 1.04kg MS/cow/day
Post-forage crop	≤ 12 litres/cow/day or 1.04kg MS/cow/day
Rotation length	25 - 30 days
Individual cow condition	≤ 3.5 condition score units
Autumn	
Rotation length	25 - 30 days
Individual cow condition	≤ 3.5 condition score units
Average herd condition score	≤ 4.5 condition score units
Average pasture cover	≤ target average pasture cover level in matrix
Rainfall	≥ 25 mm
Milk production	≤1.04kg MS/cow/day[37] ≤0.87kg MS/cow/day[38]

Problem definition and diagnosis

The previous comments on the subconscious-conscious monitoring process suggest that indirect measures may indicate the emergence of a feed "problem" and that given the case farmers knowledge of cause and effect relationships, diagnosis is not required, as the cause of the problem has been established sub-consciously before it is identified consciously. For example, hot, dry windy conditions would have been noted subconsciously noted the impact of such conditions, a decline in milk production, average pasture cover and or cow condition was identified.

The contingency plans

As with year one, the contingency plans of the case farmer could be classified under four headings in relation to their impact on feed supply and feed demand (Table 8). The case farmer had four options which he used to increase feed supply: feed forage crop early, increase forage crop break by increasing the milk production target, reduce rotation length, apply nitrogenous fertiliser, and use winter, early spring silage over the summer-autumn and replace later. The nitrogenous fertiliser was applied post-drying off, but this feed allowed the case farmer to extend the lactation. Feed supply could be reduced by increasing the rotation length and providing part of the milking area to the young stock.

35 The case farmer originally had a target of 1.13 kg MS/cow/day, but changed this to 1.22 kg MS/cow/day because the feed situation improved.

36 The case farmer changed this value twice. Initially, the target was 1.04 kg MS/cow/day, but when feed conditions improved it was increased to 1.13 kg MS/cow/day. However, when the herd went onto the forage crop, feed conditions were so good that the case farmer increased the target a second time to 1.22 kg MS/cow/day.

37 Used to determine when to put the herd onto once-a-day milking. If milk production fell below this level, it indicated the herd was losing condition.

38 It appears the case farmer used this second and lower milk production target to indicate that the herd was losing condition while on once-a-day milking.

Options for increasing feed demand included increasing cow intakes by increasing the milk production target and extending the lactation. Feed demand was reduced through, reducing cow intakes by reducing the milk production target, placing the herd on once-a-day milking, drying off individual cows, or the entire herd.

Table 8. The case farmer's contingency plans.

Category	Option
Increase feed supply	Feed forage crop early[a] Increase forage crop break by increasing the milk production target Reduce rotation length Apply nitrogenous fertiliser[39] Use winter, early spring silage over the summer-autumn and replace later
Decrease feed supply	Increase rotation length[a] Provide part of the milking area to the young stock
Increase feed demand	Increase cow intakes by increasing the milk production target Extend the lactation
Decrease feed demand	Reduce cow intakes by reducing the milk production target Dry off thin cows and place on runoff[40] Place the herd on once-a-day milking Dry off the herd early[41]

Although the contingency plans can fit under these four quadrants, the primary purpose of some of these contingency plans is not to influence feed supply or feed demand. For example, several contingency plans are used to protect cow condition. These include the decisions to dry off thin rising three year old cows, the decision to put the herd on once-a-day milking and to dry off the herd.

Contingency plan selection

The selection of a contingency plan is triggered when a key indicator crosses the target threshold (Figure 1) set by the case farmer. The process the farmer uses to select the most appropriate contingency plan to minimise the impact of the deviation can best be represented by decision rules. The decision rules take the form of an "IF" statement that specifies the conditions that indicate a problem exists, then normally several "AND" statements that specify important characteristics that define the problem situation, followed by a "THEN" statement which specifies the contingency plan that should be instigated (Figure 17). The problem situation characteristics are important, because they are used to distinguish between alternative courses of action in most instances. In other words, the problem situation characteristics are matched to a problem solution.

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[39] In year two, nitrogenous fertiliser was included in the plan, but Farmer A also had a plan that did not include it. The decision to use it or not depended on pasture growth through April and the average pasture cover on the farm at drying off. As such, it was a contingency of sorts.

[40] Although this option is in the plan, the timing and number of cows dried off is dependent on conditions at the time.

[41] The herd was dried off two days earlier than planned in the feed budget primarily because the herd was losing condition and average pasture cover was at target.

IF milk production is ≤ 13 l/cow/day	Indicates the problem exists
AND the crop is mature,	) Specifies the characteristics that
AND the ground is dry,	) define the problem situation
THEN feed sufficient crop to the herd to maintain milk production at 12 l/cow/day.	Specifies the contingency plan that should be implemented to match the characteristics of the problem situation.

Figure 1. Structure of a decision rule.

The contingency plans used by the case farmer are presented in Appendix VIII (Volume II).

Control responses

During early summer, the case farmer's control responses included the normal implementation of contingency plans, the adjustment of milk production targets, and the revision of an existing plan. The milk production target was increased because the case farmer believed there had been a change in the underlying climatic conditions, i.e. there had been a shift to cooler, wetter summer conditions such as had been experienced in year one. Under such conditions, above average pasture growth rates occur. Therefore, the case farmer increased his milk production target which meant that the herd went onto the forage crop earlier and consumed the forage crop at a faster rate than normal. By late February, the case farmer realised that this shift in climatic conditions had not occurred and changed the milk production target back to the normal value. The case farmer had originally planned not to use silage over the summer, and instead use it during early spring. However, he changed the plan and decided to use some silage during March because conditions had become so dry.

Evaluation

The areas of evaluation identified in year one were classified as: monitoring system, choice of targets, choice of inputs, management practices, overall management of the autumn. The areas of evaluation identified in year two could be classified under: monitoring system, choice of targets, choice of inputs, and key decisions. In relation to the monitoring system, every 3 - 4 days the case farmer measures milk production and cow intakes. He then uses the milk production data to validate his estimate of cow intakes. Because the objective measure of milk production is accurate, this process is important for validating less accurate measures, whether they are objective or subjective. For example, the case farmer found that as conditions became drier in early summer, he had to adjust his estimates of pasture cover based on milk production information. He adjusted his visual estimate of pasture cover based on height upwards by of 300 - 400 kg DM/ha. If he had not made this change, he would have under-estimated the amount he was feeding the herd. The milk production data appears to play an important role in terms of triangulation and validation in relation to the case farmer's monitoring system.

Milk production is also used to triangulate the case farmer's estimate of crop yield in relation to setting a daily break for the herd. He estimates how much feed the herd needs, estimates the crop yield, allocates an area of forage crop to meet the herd's needs, feeds it, monitors milk production, and uses this to confirm his estimate of crop yield. If his estimate is wrong, he adjusts it and the break size and repeats the process. The level of pasture the herd is receiving may change over time, so the case farmer may be adjusting the break size every 4 - 5 days.

In early April, the case farmer evaluated his decision to start formal monitoring on the 25th March. His concern was that he should have started a bit earlier so that he would have had more data points to pick up a trend for his drying off decision.

In relation to the choice of targets, the case farmer decided to increase his milk production targets when grazing the first forage crop. He evaluated this change in relation to this season and decided that the targets were too high. As such, he reduced his milk production target back to the norm when he shifted the herd onto the second forage crop. A higher milk production target meant the forage crop was grazed earlier and at a faster rate than if a lower target was used. In a typical or dry year, this would normally result in the herd being dried off before the autumn rains arrived in mid March. As a result of his evaluation, the case farmer has decided to use the lower milk production target in future years.

In relation to the choice of inputs, the case farmer reevaluated his plan to only use silage in the early spring. The case farmer decided it was preferable to use some of the silage in March to maintain milk production and cow condition rather than have the herd produce at a lower rate and lose condition, which would have to be made up during the winter. The case farmer also believed that if he did not use the silage, the herd would be dried off before the autumn rains. Alternatively, he decided the silage could be used to hold milk production in the event that significant rain fell in March. Any silage used in March would be replaced with urea or bough-in hay.

Immediately after drying off, the case farmer made a cursory evaluation of the decision. He thought he had made the right decision, and the data showed that the average condition of the herd and average pasture cover were at the targets specified for the end of April. This may explain why the evaluation was cursory.

Learning

Evaluation and learning are inextricably linked. Six areas of learning were identified in year one of the study and these were in relation to: the monitoring system, targets, decision rules, the production system, management practices and planning. Less "learning" was identified this season, and this may be because last season was an unusual year, while this season was more "typical". The learning undertaken by the case farmer in year two could be classified under: the environment, and targets, monitoring systems. The case farmer has developed a new plan for the summer-autumn because he believed there had been a fundamental shift in climatic conditions, and "environmental" aspect. During the last two years the farm had experienced cool, wet springs and summers. On this basis the case farmer decided to retain all the silage for use in the early spring rather than feed part of it during the summer-autumn. He planted an additional 1.0 ha of forage crop to replace the summer-autumn silage.

Also in relation to the environment, the case farmer also thought that the conditions in January indicated another cool, wet summer and a fundamental shift in climatic pattern. In late January, the case farmer thought that the current season was going to be similar to the last because the weather patterns in January were similar to the previous two years in which cool, wet summers had occurred. As a result, the case farmer decided to increase the milk production targets he used to determine the timing and level of supplement feeding. The season was not cool and wet, and therefore the case farmer changed back to his normal milk production targets. He learnt that it is difficult to predict climate shifts and that he was better to use a more conservative milk production target over the summer to ensure he could milk the herd through to the autumn rains. The use of a higher milk production target meant that he went into the forage crop earlier and used the feed at a faster rate. This demonstrates one of the important problems in relation to monitoring which is the ability to distinguish between an aberration and a fundamental change in the environment.

Appendix XXII. Farmer A – Summary of Year Three

Description of year three

The case farmer had increased the milking area in the previous year (a non-study year) from 52 to 63 ha effective. As such, he was running 174 cows, 24 more than in year two, at a slightly lower stocking rate than normal of 2.8 cows/ha at 25th December (Table 1). The farm state at Xmas was affected by climatic conditions during the spring. In late November, the farm was flooded and two thirds of the area went under water. To hold production, all the silage paddocks that had been shut up had to be grazed by the milking herd. The farmer could not implement his normal practices to manage pasture quality. After the flood, conditions changed from very wet to hot and dry. As such, the case farmer did not top paddocks through December because he believed he would need the additional cover if it remained dry. This meant that pasture quality on the farm at the start of summer was a lot lower than in normal years.

As a result of the flood, much less hay (2.4 ha) and silage (2.0 ha) was made this year compared to the past. The case farmer only made 16 round bales of hay and bought-in the remainder. He only made 25 bales of silage which is just under 25% of his normal requirements. The case farmer planted 3.0 ha of forage crop in November. These crops were poor because the wet conditions delayed sowing until late November. The case farmer decided to plant another 1.5 ha of forage crop in December because his supplement position was so poor. This gave a total area of forage crop of 4.5 ha which comprised 3.0 ha of Emerald rape and 1.5 ha of Barkant turnips. The dry December limited germination and growth. Two of the forage crops were only at about 25% of their normal yield by mid January and the other was just beginning to germinate. The case farmer noted that this was the worst feed position he had been in, in early January in his experience.

The case farmer had hoped that the hay paddocks on the runoff would have recovered by Xmas and provide grazing for his dry cows. However, because conditions were so dry, this did not eventuate. This meant that his only option was to run dry cows on the milking area and feed them hay. The case farmer stated that the season appeared to be a month earlier than normal. Therefore, at the start of the planning period, the farm was in a worse state than in the other two years of the study (Table1). Average pasture cover was lower than the two previous years (1650 kg DM/ha) and crop yield and the amount of silage on-hand was about 25% of that in the previous two years. The area in forage crop was 1.5 ha more than in year two, and 2.5 ha more than was grown in year one. The hay had to be bought-in because it could not be made on the place. Conditions were dry and pasture quality was poor relative to other years. In contrast to the feed position, the herd was in good condition (4.8 condition score units), but production per cow per day was below that achieved in the previous two seasons (1.22 versus 1.39 kg MS/cow/day).

Conditions through January were drier than either of the two previous years with average pasture cover falling to 1200 kg DM/ha at the end of January. This is reflected in the milk production and cow condition of the herd at February 1st. The herd was producing 0.87 kg MS/cow/day at a condition score of 4.4. The farm only received 20 mm of rain through January. Conditions remained very dry through until mid February and then around the 22 - 24th February, 40 mm of rain fell and pasture growth rates improved. However, conditions had become so dry that the case farmer had placed the herd on once-a-day milking on the 23rd February to maintain condition. Average pasture cover (1150 kg DM/ha), milk production (0.70 kg MS/cow/day) and cow condition (4.0 condition score units) at March 1st were the lowest for the three years of the study (Table 1) and this reflected the dry season and poor forage crop yields. The forage crop was fed from the 28th January until the 18th March. It was fed out earlier than the previous two years because of the dry conditions. The forage crop lasted longer than the previous two years because it was fed at a lower rate and supplemented with hay and silage (Table 1).

During March, good rain fell through the first half of the month. As a result, pasture growth rates increased, and average pasture cover rose to 1360 kg DM/ha by the end of the month. During April, ideal growing conditions occurred and pasture growth was in excess of 40 kg DM/ha/day. This allowed the case farmer to milk through until mid May. Thus although growing conditions were drier through December, January and February than in year one and year two, and March was similar to the previous two years, growing conditions in April and early May were much better and this allowed the case farmer to milk through until mid May.

Table 1. Comparison of the three years.

Factor	Year 3	Year 2	Year 1
25th December			
Average pasture cover (Kg DM/ha)[42]	1650	1800	1700
Cow condition	4.8	4.8 (+)	4.5 (+)
Milk production (kg MS/cow/day)	1.22	1.39	1.39
Milking cow numbers	174	150	140
Rotation length (days)	24	30	30
Effective area (ha)	63	52	48?
Stocking rate (cows/ha)	2.8	2.9	2.9?
January 1st			
Average pasture cover (Kg DM/ha)	1600	1800	16 50
Cow condition	4.8	4.8	4.5+
Milk production (kg MS/cow/day)	1.13-1.22	1.39	1.39
Milking cow numbers	174	144	140
Forage crop area (ha)	4.5	3.0	2.0
Silage (bales)	25	103	100
Hay (bales)[43]	2592[44]	1488	2400
Rotation length (days)	24	30	30
February 1st			
Average pasture cover (Kg DM/ha)	1200	1800	1400
Cow condition	4.4	4.8	4.5
Milk production (kg MS/cow/day)	0.87	1.39	1.25
Milking cow numbers	160	144	138
Rotation length (days)	24	28 - 30 (30)	29 - 30
March 1st[e]			
Average pasture cover (Kg DM/ha)	1150	1300	1350 - 1400
Cow condition	4.0	4.8[h]	4.5
Milk production (kg MS/cow/day)	0.70	1.04[i]	1.13 –1.22
Milking cow numbers	141[45]	142	138
Rotation length (days)[a]	24	25 - 28 (25)	24 - 29 (25)

[42] During summer, the figures given for average pasture cover are estimates because the case farmer was not formally monitoring this information.
[43] In standard bale equivalents. One round bale is equivalent to 12 standard bales.
[44] There were 2040 bales bought prior to Xmas, 192 were made in January on the runoff, and 360 bales were purchased in January.
[e] The young stock were given 3.0 ha because they were short of feed as a result of late hay and silage crops.
[h] Average herd condition increased to 5.0 condition score units on the 24th March, and then declined to 4.8 condition score units.
[i] Milk production held at 1.22 kg MS/cow/day through most of February. When the herd went onto the second forage crop on the 28th February, the case farmer reduced milk production to 1.04 kg MS/cow/day.
[45] The herd was put on once-a-day on the 23 February and remained on once-a-day milking until drying off.
[a] The rotation length is the range over the previous month, and the figure in brackets is the rotation length at the end of the month.

Factor	Year 3	Year 2	Year 1
Date forage crop started	28/1/xx	10/2/xx[f]	31/1/xx
Date forage crop terminated	18/3/xx	23/3/xx	1/3/xx[c]
Date silage started	28/1/xx	15/3/xx	NA[d]
Date silage terminated	19/2/xx	29/3/xx	
Amount fed	25 bales	17 bales	
April 1st			
Average pasture cover (Kg DM/ha)	1360	1280	1445
Cow condition	4.3	4.5	4.5 (+)
Milk production (kg MS/cow/day)	0.78	1.04	1.13 – 1.17
Milking cow numbers	140	126	138
Rotation length (days)[a]	24	24 - 25 (25)	25 - 29 (28)
May 1st			
Average pasture cover (Kg DM/ha)	1685	NA	NA
Cow condition	4.7	NA	NA
Milk production (kg MS/cow/day)	0.80	NA	NA
Milking cow numbers	138	NA	NA
Rotation length (days)[a]	24	NA	NA
Drying off date	15/5/xx	28/4/xx	29/4/xx
Cow numbers at drying off	138	119	129[9]
Milk production (kg MS/cow/day)	0.70	0.84	1.13
Condition score	4.7	4.5 (-)	4.5
Average pasture cover (Kg DM/ha)	1570	1332	1392
Date herd on once-a-day	23/2/xx	13/4/xx	24/4/xx[b]
Rotation length at drying off (days)	24	25	28
Urea planned for winter	2.5 tonnes	1.5 tonnes	0.0 tonnes

The plan

Planning horizon

The data from year two confirms that the summer planning period starts at Xmas and goes through to mid March when the autumn rains normally occur. The case farmer initiated the development of a formal feed budget on April 1st, in much the same manner as he had in the two previous years.

He stated that he did not see any benefit in undertaking a formal feed budget before April 1st and the two week period between mid March and April 1st allowed him to establish the nature of the autumn (dry, normal, wet). The case farmer initiated formal pasture monitoring on the 28th March. He did not initiate it any earlier than this because conditions (cow condition and average pasture cover) on the farm were improving. He noted that if conditions had been declining in mid March, he would have initiated formal monitoring earlier in order to obtain three data points and identify a trend. Once the formal monitoring had been undertaken, the case farmer then developed a formal feed budget. The data also confirmed that the case farmer has sub-plans that relate to key

[f] Second forage crop of 1.5 ha fed on the 28th February.
[c] The crop was not grazed for 5 days during this period due to muddy conditions.
[d] Not fed until the herd were dried off.
[9] The case farmer put 9 cull cows on waste ground on the 5th April and milked them until the 18th April when they were sold to the works.
[b] R. 3yr cows on once-a-day on 18 April.

activities or periods, e.g. pre-forage crop, forage crop, post forage crop to April 1st, April 1st to drying off.

Hierarchies of plans

There were two plans that dominated the period of the study, one over the summer (Xmas – mid March), and another from mid March to calving. Shorter planning periods were encapsulated within these two plans and related to events, e.g. pre-forage crop, forage crop, post-forage crop to mid March, mid March to drying off.

Values, goals and targets

As with last season, the case farmer's goal over the summer-autumn was to maximise milk production without jeopardising next seasons production. The aim through summer was to milk as many cows as possible through to mid March. To achieve this goal, the farmer had several important intermediate targets. Because conditions were so dry, the herd was already on a 24 day rotation at the start of summer. Therefore, the case farmer's aim was to maintain the herd on a minimum 24 day round. The case farmer wanted to delay the grazing of the forage crop until the end of January so that it would provide more feed and increase the chance of supplementing the herd through until mid March. The case farmer reduced his milk production target to 0.87 kg MS/cow/day in order to ensure as many cows as possible were in a lactating state by mid March when he expected the herd to finish the forage crop. This delayed the grazing of the forage crop and then extended its use. This demonstrated that in a dry year, the case farmer would lower his milk production target to ensure as many lactating cows as possible are on hand when the autumn rains occurred. The case farmer admitted that by accepting this lower milk production goal, he would have to accept a lower average herd cow condition target (4.0 condition score units) for the summer period. During February and March the case farmer wanted to maintain average herd condition at or above 4.0 condition score units. The case farmer still put cows that were at condition score 3.5 onto once-a-day milking to protect condition. After the forage crop was grazed, the case farmer's target was to maintain the herd on a 24 day rotation and maintain average herd condition at 4.0 condition score units.

The case farmer had an average pasture cover target at calving of 2300 kg DM/ha. This was 100 kg DM/ha higher than normal because the case farmer did not have his normal quota of silage on-hand for early lactation. Average pasture cover targets were set at April 1st using a feed budget. The feed budget suggested that to achieve his target at calving the case farmer would have to apply 3.0 tonnes of urea. The case farmer was concerned about extending the lactation because milk production had been poor through the summer and there were financial advantages in producing milk on the shoulder. However, the amount of nitrogen the case farmer would actually use was not specified as was the case in year two. Under once-a-day milking, the herd was improving in condition over the autumn and the case farmer considered attempting to calve at condition score 5.0. However, declining pasture growth rates and average pasture cover dictated the drying off data. A feed budget completed just prior to drying off suggested that the case farmer would have to apply 2.5 tonnes of urea to reach his average pasture cover target at calving.

Although not stated directly in the transcript, it appears that the poor season and resultant low production through summer, and the newly introduced premium for "shoulder milk[46]" influenced the case farmer's drying off decision during the autumn. This may be why the case farmer delayed the drying off decision for as long as possible and did not commit himself to a definite amount of nitrogen in the initial plan. Although the case farmer's use of autumn nitrogen had been increasing throughout the period of the study, his values still tended to constrain how much nitrogen he used.

Planning method

The planning method was similar to the previous two years. The "typical" plan was modified in response to strategic decisions. Since year one, the case farmer had replaced his autumn silage with additional forage crop. One strategic decision did influence the summer plan. The case farmer wanted to increase herd size for the following season. As such he wanted to retain high producing cows. Therefore, rather than cull the herd pre-Xmas as was his normal policy, he wanted to delay culling until the next herd test in early January. As a result, the "typical" plan was modified. The case farmer had also made a strategic decision to grow an extra paddock of forage crop, a new crop for the district, Barkant turnips. This also modified the plan, and under normal conditions, would have provided feed further into March. This also meant the new grass would have to be sown later.

At the start of summer the case farmer assessed the state of the farm (cow condition, cow intake, milk production per cow, average pasture cover, pasture growth rates, forage crop yield, and other supplements on-hand (hay and silage). He then simulated a rough mental feed budget to test whether, given the poor state of the farm, his modified "typical" plan was feasible. In this case it was not. The case farmer then postulated some changes to the typical plan to ensure as many lactating cows as possible made it through to the autumn rains. Once these changes were postulated, they were simulated to test their feasibility. This was an iterative process and further changes were postulated and simulated until a suitable plan was developed. In effect, the case farmer substituted his "typical" planning heuristics for what were normally contingency plans for coping with feed deficit conditions. As such he reduced his milk production and associated cow condition and intake targets. This also meant the younger cows would go onto once-a-day milking or be dried off earlier than normal. He also planned to introduce once-a-day milking to limit loss of condition score over the summer. He also changed the method (and timing) of pregnancy diagnosis allowing him to cull the herd a month earlier. He also decided to use his spring silage and buy additional hay to ensure the forage crop lasted for longer (see the section on planning rules). Once a suitable plan had been developed, it was implemented.

As in year two, the case farmer developed a formal feed budget around April 1st. The method was the same as that used in previous years. However, the case farmer did not make allowances for an increase in cow condition of 0.2 condition score units to ensure the average herd condition target was met when he developed the feed budget. The case farmer also estimated how much nitrogen he had to apply to meet his average pasture cover target at calving. However, he did not develop a 3 x 2 matrix of drying off date versus nitrogen application as he had in year two. This was because in the previous year, he had learnt that nitrogen was a profitable feed source and he had incorporated it directly into his plan.

[46] The dairy company paid a premium for milk produced either side of the peak production months of October and November.

The other interesting point was that the case farmer used pasture growth rates for April, that were 5 kg Dm/ha/day above average. He did this because he believed that with the growing conditions at the time, pasture growth through April would be above average. This proved to be the case and growth rates of over 40 kg DM/ha/day were recorded. This decision was based on the magnitude of the "dry period" and the advent of reasonable rains. The case farmer stated previously that after a prolonged dry spell, there was a large "flush" of autumn growth when the autumn rains arrived.

Unlike other years, the case farmer completed a second formal feed budget prior to drying off on the 15th May. This feed budget showed that in order to meet targets at calving, the case farmer had to dry off immediately and then apply 2.5 tonnes of urea over the winter. With pasture cover declining rapidly, the case farmer dried off.

An important point made by the case farmer was that he did not perceive any additional benefits from formal planning over the summer relative to his current planning method. He viewed the summer as too variable to justify formal planning because one significant rainfall event could change the feed situation dramatically over the summer. He noted, however, that he would incur additional time costs in terms of the planning process and subsequent associated formal monitoring.

Planning rules

Analysis of the data identified several planning rules used by the case farmer to develop his plan that were different from previous years (Table 2). The reasons given by the farmer for these rules is also specified. In some cases the rules are almost a reverse of those identified in previous years. These new rules apply to a year in which conditions were very dry at the start of the planning period, the herd was already on the shortest rotation the case farmer would allow, and the farm had limited silage and poor forage crops. The case farmer was also considering increasing cow numbers and increasing the milking area next season. He therefore did not want to sell too many culls until he knew exactly which cows were pregnant. He had also intended to dry off some cows and retain them on the runoff. However, because regrowth on the runoff was poor after the hay crops, and as a result of the dry conditions, the beef cattle on the runoff had not been sold because they had not reached target weights, there was insufficient feed for the dry cows. This meant that the case farmer would have to run any cows he dried of and did not cull on the milking area.

Table 2. Decision rules for the summer plan in year three.

Activity	Decision Rule	Reason
Selection of summer-autumn stocking rate	IF increasing herd size next winter, AND date = Xmas, AND conditions are very dry, THEN delay stocking rate decision until the next herd test and identify cows not considered suitable for milking through the summer-autumn.	The case farmer wanted to increase herd size next winter. However, he did not want to dry off animals without some objective production data. He therefore decided to delay the decision until the herd test on January 11th.
Drying off the herd or part of the herd	IF conditions are dry, AND a herd test has been completed, THEN dry off low producing cows, high somatic cell count cows and older cows	Removing poorer producing cows from the herd will free up feed for the remainder of the herd in dry conditions. The removal of high somatic cell count cows is important in dry conditions because these cows create milk quality problems if placed on once-a-day milking which is likely to occur in a dry year.

Activity	Decision Rule	Reason
Using ultrasound to diagnose empty cows	IF conditions are dry. THEN use ultrasound to diagnose empty cows.	Normally, the empty cows are retained until near drying off because they are the best milk producers. Therefore, in a normal year there is little point identifying these cows until mid- late March. However, in a dry year when feed is short, it is better to cull these cows early and use their feed to better feed the remaining cows and extend the lactation. Ultrasound allows the case farmer to diagnose empty cows at least a month earlier than normal.
Culling empty cows	IF a cow is empty, THEN cull the cow once it is identified	In a dry year, it is more important to feed capital stock than carry empty cows that produce well.
Milk production target for supplement feeding	If the year is dry, THEN reduce the milk production target for supplement feeding to 0.87 kg MS/cow/day.	A lower milk production target has a number of effects. Firstly, it reduces cow intakes so feed demand is reduced and therefore what feed is on the farm lasts for longer. Secondly, it delays the first grazing of the forage crop so it is grazed later in the season. Thirdly, it reduces the rate at which the forage crop is grazed extending its use into the later part of the summer. This increases the likelihood that the herd will still be lactation when the autumn rains arrive.
The use of silage	IF it is dry, AND the forage crop yield is poor, Then feed silage with the forage crop to extend its use.	This method allows the case farmer to extend the use of the forage crop.
The use of hay	IF it is dry, AND the forage crop yield is poor, AND limited silage is available, THEN feed good quality hay with the silage and forage crop.	This method allows the case farmer to extend the use of the forage crop.
Place the herd on once-a-day milking	IF it is dry, AND the milk production target has been reduced to 0.87 kg MS/cow/day, AND the herd is going onto the forage crop, Then place the herd on once-a-day and increase the forage crop ration briefly to hold milk production at target.	If the herd is producing at 0.87 kg MS/cow/day, it will be losing condition. In order to stop the herd losing condition, it must be placed on once-a-day milking. However, when a herd is placed on once-a-day milking, milk production will decline unless cow intakes are increased briefly to prevent this. A forage crop can be used to do this. In a dry year, once-a-day milking keeps more options open to the case farmer than drying off a large proportion of the herd.
Rotation length	IF conditions re dry, THEN maintain the rotation length at 24 days.	Under dry conditions, the case farmer cannot extend the rotation without reducing cow intake. This would result in lower milk production, a further reduction in condition and some cows will dry themselves off. The 24 day minimum rotation length for this season instead of 25 days was just a result of the farm circumstances (more area in crop, increased area and the paddock numbers).

Plan

The case farmer's plan for year three is summarised in Table 3. It was changed from that normally used by the case farmer because the forage crop had produced 25% of normal yield at the start of the planning period, only 25% of normal silage was on-hand, and the farm was in a dry state. The case farmer had two dry cows on the milking area that had had mastitis. He planned to sell these in early January along with any other culls. The case farmer planned to delay his normal Xmas cull until his herd test on January 11th because he wants to go up in cow numbers next season and did not want to cull animals until he had some more objective information. The plan was to dry off a number of low producing and high somatic cell count cows once the herd test results were in. These cows would either be culled or if suitable for next season, retained on the runoff and fed hay. The exact number would depend on the conditions, and the case farmer had not decided exactly how many he would dry off, but he was considering up to 20 animals. He noted that it was particularly important to dry off high somatic cell count cows if the herd is going onto once-a-day milking because this exacerbated the problem. As in previous years, thin cows would be placed on once-a-day milking if condition score fell to 3.5 condition score units.

Table 3. The case farmer's plan from Xmas until early to mid March.

Feed related activities	Other activities
Delay culling until herd testing on January 11th	
Maintain a 24 day rotation	Herd test on January 11th
Dry off up to 20 low producing and or high somatic cell count cows and place them on the runoff. Sell 2 dry cows that had mastitis.	
Put thin cows on once-a-day milking	
Put the herd of on once-a-day milking and feed the forage crop in late January, early February when milk production falls to 10 litres/cow/day (0.87 kg MS/cow/day). Feed the forage crop along with a bale of hay and a bale of silage until early to mid March and maintain milk production at 10 litres/cow/day (0.87 kg MS/cow/day).	Pregnancy test early February with ultrasound
Cull empty cows	
Put the herd on twice-a-day milking if conditions improve through March	
Maintain a 24 day rotation post-forage crop	Sow new grass late March
Dry off the herd	Sell remaining culls

If conditions remained dry, the case farmer was going to milk the herd until production fell to 0.87 kg MS/cow/day or 10 litres/cow/day and then put the herd on once-a-day. If conditions improved during March, then he would put the herd back onto twice-a-day. The case farmer noted that in a dry season, cow condition is the biggest concern, and he would prefer to put the herd onto once-a-day milking at 0.87 kg MS/cow/day and hold condition, rather than continue to milk them twice-a-day and take condition off the herd. The forage crop will be fed to the herd when production declines to 10 litres/cow/day or 0.87 kg MS/cow/day and hold production at this level. He will put the herd onto once-a-day milking at the same time or just after the herd has been introduced to the forage crop. The forage crop intake will be increased when the herd goes onto once-a-day to maintain milk production at 0.87 kg MS/cow/day. The case farmer expected to be only running 150 cows after culling in early January. He planned to feed silage with the forage crop and introduce high quality hay to make up for the limited silage. He would then replace his winter stocks with bought-in feed. The case farmer expected the forage crop and silage to last about a month or until the start of March.

The case farmer planned for the herd to remain on a 24 day round while grazing the forage crop. At that stage he was only planning through to mid March, the point when the forage crop would be completed, because conditions were so dry. The case farmer also planned to pregnancy test on February 10th using ultra-sound. This method allowed the case farmer to identify empty cows a month earlier than if the more conventional method had been used. This will allow the case farmer to cull empty cows if conditions are still dry. Empty cows may graze waste areas prior to sale.

The case farmer also planned to allow cow condition to fall to a lower level (4.0 condition score units) than in a normal year (4.5 condition score units). His plan was to sow the forage crop areas into new grass in late March. The case farmer's plan was to milk for as long as possible into March and then dry off the herd and sell the remaining culls if conditions remained dry. He did note that if conditions improved through February - March, he would place the herd back onto twice-a day milking.

Implementation of the plan

The case farmer's plan, its implementation, and the reasons for any discrepancies between the two are summarised in Table 4. Between Xmas and New Year, there was no rain and hot dry winds. On January 1st, the case farmer was running 174 cows on 63 ha and two of these were dry cows that had a persistent mastitis problem and were to be sent to the works. The herd were producing 1.13 – 1.22 kg MS/cow/day at a condition score of 4.8 and consuming around 12 kg DM/cow/day on a 24 day rotation. The herd was on a 24 day round, rather than a 25 day round because a extra paddock was sown into forage crop in December. The feed situation was good and the average pasture cover was estimated at around 1650 kg DM/ha, but conditions were becoming dry very rapidly and average pasture cover was declining. Pasture growth rates were similar to cow requirements, but declining. The herd was going into 1700 - 2000 kg DM/ha and coming out of 1100 - 1300 kg DM/ha. At that stage the herd were just starting to "work", i.e. eat into the poorer quality level of the sward. Pasture quality was poorer than in the previous two years, but typical for a dry summer.

The case farmer had bought-in 170 round bales of hay which was enough for his wintering requirements. He had only made 25 bales of silage, which was just under 25% of normal requirements. The case farmer had 4.5 ha of forage crop (3 paddocks), 3.0 ha of Emerald rape and 1.5 ha of Barkant turnips. The yields of the first two forage crops were poor (25% of normal) because wet conditions delayed sowing until late November. The third crop, which was sown in December, had only just germinated because of the dry conditions in December. The case farmer noted that this was the worst feed position he had been in, in early January in his experience.

During the previous year, the case farmer had purchased a new runoff and on this he ran beef cattle. However, because the profitability of beef cattle had declined, he was considering milking on the runoff next season. To do this he would have to retain cows he would normally cull to build up numbers for the additional area. As such, he did not want to cull cows at Xmas as he normally did, preferring to delay culling until he had more objective herd test data in early January.

The herd continued on a 24 day rotation through January. On January 11th the herd was herd tested. However, the case farmer did not receive the results of the herd test until the 21st January due to a bureaucratic error. By mid January, the case farmer was running 170 milking cows. Two more cows had been dried off because of persistent mastitis problems, bringing the total number of dry cows on the milking area to four. The cows were producing 0.96 kg MS/cow/day or 11 litres/cow/day and at condition 4.6 consuming

11.0 kg DM/cow/day of pasture. Pre-grazing pasture cover was 1800 kg DM/ha and post-grazing residuals of 1100 kg DM/ha. Average pasture cover was estimated at 1450 kg DM/ha and pasture quality was poor and declining. Due to the dry conditions, the crop had not grown much over the first half of January. The weather was hot, dry and windy, and virtually no rain had fallen.

Table 4. A comparison of the plan with the actual outcome.

The plan	The outcome	Reason for difference
Delay culling until herd testing on the 11th January.	Culling was delayed until the 11th January.	
Maintain 24 day rotation.	The 24 day rotation was maintained.	
Herd test on the 11th January.	Herd test undertaken on the 11th January.	
Dry off up to 20 cows on the basis of milk production and somatic cell count after the herd test. Sell definite culls and place any cows that need to be retained for next season on the runoff.	Two cows with mastitis were dried off in early January. Fourteen culls were sold on the 27th January. They comprised 10 cows from the milking herd which were old or low producers, and the 4 dry cows with mastitis.	Although the herd test was completed on the 11th January, the results were not available until the 21st January due to a bureaucratic error at the herd testing station. It then took a further six days to identify and sell the cull cows. The case farmer decided to only cull 14 cows because he wanted to increase herd numbers next season and therefore he did not want to cull any cows other than those that were definite culls until after pregnancy testing. The case farmer did not see much point in drying off further cows because they would still have to be run on the milking area. Therefore, the net impact of drying another six cows off would be marginal.
	On the 20th February, 9 thin cows were dried off because they continued to lose condition. These were retained on the milking area. In early March, a cow was dried off because it had mastitis and retained on the milking area.	When cows were dried off during February and early March, they were grazed on the milking area because feed was short on the runoff.
	Nine dry cows were placed on the runoff in late March.	The case farmer decided he would make more money converting pasture into milk rather than beef. Therefore he sent the dry cows to the runoff to free up feed for the other cows and sacrificed liveweight gain on his beef cattle.
	A cow dried itself off in early April.	
	In early April, the case farmer brought the 9 dry cows from the runoff and put them back on the milking area.	Pasture growth had been so high that the herd was leaving behind clumps that needed to be cleaned up by the dry cows to prevent future pasture quality problems.
	In late April the case farmer dried off a cow with mastitis.	

The plan	The outcome	Reason for difference
Put thin cows on once-a-day milking.	On the 27th January, two thin cows were placed on once-a-day milking. On the 6th February, 8 thin cows were placed on once-a-day milking.	The case farmer had expected to have the whole herd on once-a-day milking by early February and this would have held cow condition. However, because the condition of the herd was being maintained by the while on the forage crop, the case farmer continued to milk twice-a-day.
Put the herd of on once-a-day milking and feed the forage crop in late January, early February when milk production falls to 10 litres/cow/day (0.87 kg MS/cow/day).	On the 28th January when milk production fell to 0.87 kg MS/cow/day, the herd was placed on the forage crop. However, the herd was not put on once-a-day milking. The herd was placed on once-a-day milking on the 23rd February.	The herd was not placed on once-a-day milking because cow condition was holding on the diet of pasture and supplements. The case farmer had expected condition to decline, and was therefore planning to introduce once-a-day milking to hold condition. The herd was placed on once-a-day milking because it had lost condition over February and was at the case farmers limit of 4.0 condition score units. The case farmer also noted that he had to change to once-a-day milking while he still had forage crop because he has to increase cow intakes with the forage crop during the transition period to ensure cows do not dry themselves off.
Feed the forage crop along with a bale of hay and a bale of silage from late January/early February until early to mid March and maintain milk production at 10 litres/cow/day (0.87 kg MS/cow/day).	The herd was fed a break of forage crop, a bale of silage and a bale of hay along with pasture each day. The silage ration was doubled a few times during the first half of February. The milk production target was reduced to 7.5 litres/cow/day or 0.70 kg MS/cow/day in late February. The forage crop ration was doubled from 23rd -28th February.	The case farmer doubled the silage ration because of rainfall events in order to maintain cow intakes and milk production. Conditions became so dry through mid February, that the case farmer allowed milk production and cow intakes to decline to conserve the forage crop. Alternatively, he could have increased the forage crop, but wanted to extend its use through into early March. The forage crop ration was doubled because the a) the herd went onto once-a-day milking, and b) 40 mm of rain fell over the period. If cow intakes are not kept high when a herd goes onto once-a-day milking, many of the cows in the herd will dry themselves off.
Maintain a 24 day rotation while on the forage crop.	The herd was maintained on a 24 day rotation while on the forage crop.	
Pregnancy test the herd in early February using ultrasound.	The herd was pregnancy tested on the 10th February.	
Cull empty cows once diagnosed.	Ten empty cows were sold on February 13th.	The case farmer did not cull any more cows because an in-calf cow was worth $700 more if sold store later in the year than if sold to the works over the summer.

The plan	The outcome	Reason for difference
Complete forage crop early - mid March.	Forage crop completed by 18th March.	The forage crop improved through time with the rain and the case farmer did not increase intakes when the pasture component of the herd's diet declined. In early March, the forage crop was not grazed for a number of days due to the wet muddy conditions.
Put the herd on twice-a- day milking if conditions improve through March.	The her remained on once-a-day milking until it was dried off.	Conditions did not improve sufficiently through March to allow the case farmer to put the herd back onto twice-a-day milking. Conditions were suitable in April, but time of year prevented the farmer from putting the herd back onto twice-a-day milking.
Maintain a 24 day rotation post-forage crop.	The herd remained on a 24 day rotation until drying off.	
Dry off the herd in late March if conditions remained dry.	The herd was dried off on the 15th May.	Conditions improved through March due to good rains and pasture growth rates in April were above 40 kg DM/ha/day. Pasture growth rates in early May were over 30 kg DM/ha/day. These conditions allowed the case farmer to milk until mid May.
Sell culls at or near drying off.	Three culls were sold before drying off and four culls were sold after drying off.	
Sow the new grass late March.		

Once the herd test results were obtained on the 21st January, the case farmer used this information to identify 14 cull cows. These were sold on the 27th January. Ten of these cows were from the milking herd, and the remaining four were dry cows that had had persistent mastitis. The culls were a mixture of low producing, high somatic cell count and older cows. The case farmer could have culled up to 20 cows, but decided that with the need to increase numbers next season, he had to delay further culling until he had information about the pregnancy status of the remainder of the herd. He argued that six cows made little impact on feed demand. Rather than use his own hay and replace it, the case farmer directly purchased 30 bales of high quality hay in late January to feed with the silage.

During late January, the herd continued on a 24 day round and conditions continued to decline. On the 26th January, the case farmer had visually measured pre- and post-grazing residuals to estimate cow intakes. This indicated that cow intake was barely sufficient to maintain milk production. This observation was supported by observations of a slight decline in cow condition and milk production (Triangulation). On the 27th January, two cows were put on once-a-day because they had fallen below 3.5 condition score units. Prior to this, the case farmer was not concerned about cow condition. The two cows were his indicators for cow condition for the whole herd. The condition of the indicator cows had dropped rapidly during the preceding week and this told the case farmer that the herd was declining in condition at a faster rate than the previous week. On the 28th January, milk production declined to 0.87 kg MS/cow/day or 10 litres/cow/day and the case farmer started feeding the herd supplements. He was surprised at how well the herd maintained production and condition on the supplement mix. As such, he did not put them onto once-a-day milking to hold condition.

On February 1st, the case farmer was milking 160 cows producing 0.87 kg MS/cow/day or 10 litres/cow/day at 4.4 condition score units. Cow intakes were estimated at 10.0 kg DM/cow/day and the herd is being fed a break of turnips, a bale of silage and a bale of hay with pasture. About a third of the diet was supplement and two thirds pasture. Within the supplement mix they were getting a third of each feed type. The case farmer had maintained the herd on a 24 day round.

The feed position on February 1st was poor, conditions had remained dry over January with limited (15 mm on the 15th and 5 mm on the 27th January, plus 15mm on the 3rd February) rainfall. The bulbs in the turnip crop had doubled in size as a result of the rainfall in mid January. Average pasture cover had declined gradually over January and was estimated at 1200 kg DM/ha on February 1st. Pasture quality was poor and the herd was going into 1400 kg DM/ha and grazing down to 1000 kg DM/ha. There was 15 mm of rain on the 3rd February. Condition were dry from then until mid February. It was so dry, that the case farmer thought that without the rain he would have lost pasture plants. On the 6th February, the case farmer put 8 thin cows on once-day-milking.

On the 10th February, the herd was pregnancy tested. Ten empty cows were identified and drafted out of the herd onto waste ground, but still milked twice-a-day. They were booked into the works and sold on the 13th February. The case farmer decided not to cull any more cows. His argument was that ten extra cows would make little difference in terms of feed demand (0.5 kg DM/cow/day), but as in-calf cows, they were a valuable commodity. The case farmer could sell them for $1000 in the winter, or $300 at the works in February.

On the 14th February, the case farmer was milking 150 cows of which nine were on once-a-day milking due to poor condition. The cows were producing at 9 litres/cow/day or just below 0.87 kg MS/cow/day at 4.0 condition score units. They had lost almost 0.4 condition score units since the start of February. The herd was eating 9.0 kg DM/cow/day with 2 kg DM/cow/day from forage crop, a similar amount from hay and silage, and 5.0 kg DM/cow/day from pasture. The case farmer had not increased the supplement level despite a decline in the pasture component of the diet because of the extremely dry conditions. The herd was on a 24 day rotation going into 1300 kg DM/ha and grazing down to 950 kg DM/ha. Pasture growth rates had continued to decline gradually through the first half of the month and average pasture cover was estimated at 1125 kg DM/ha. Pasture quality was still poor. Rain had caused the case farmer to double his ration of silage a couple of times during the first half of February. At the 14th February, the last break of the turnip crop was being fed. The 3.0 ha of Emerald rape had improved with the rain.

On the 20th February, nine thin cows that had been on once-a-day milking were dried off because they continued to lose condition. These were retained on the milking area and fed a diet of 100% hay for several days before being placed on waste areas. On the 23rd February, the case farmer put the herd onto once-a-day milking to hold condition. The case farmer took this option rather than dry off a large number of cows and milk the remainder because it gave him more options. The reason the decision was made was because the herd had lost condition rapidly over February and had reached the case farmers minimum target of 4.0 condition score units. The case farmer believed that there was still the possibility of taking advantage of pasture growth later in the autumn.

On the 22 - 24th February, 40 mm of rain fell which improved subsequent pasture growth rates considerably (e.g. "*we had a tremendous boost of growth*"). At the same time, the case farmer had to double the amount of forage crop fed to the herd for five days to minimise the impact of dead matter decomposition and going onto once-a-day milking. Milk volume fell from 9.0 litres/cow/day to 7.5 litres/cow/day. The case farmer noted that the decision to go onto once-a-day milking had to be undertaken while he still had some forage crop. If he had gone to once-a-day without having supplement available to increase intake, many of the cows in the herd would have dried themselves off. Milk production increased slowly to reach 8.0 litres/cow/day at the end of February. Prior to the rain, conditions were very dry.

At the 28th February, the case farmer was milking 141 cows on once-a-day and running 9 dry cows on the milking area. The herd are producing 0.70 kg MS/cow/day or 7.5 litres/cow/day. The condition of the herd had held at 4.0 condition score units. The herd is consuming 10 kg DM/cow/day, 7.0 kg DM/cow/day of pasture and 2 - 3 kg DM/cow/day of forage crop. The surplus hay and silage has been consumed. The herd was still on a 24 day round and going into 1350 kg DM/ha and coming out of 950 kg DM/ha. Conditions had improved considerably in the last 4 - 5 days of February due to the 40 mm of rain with very high pasture growth rates being observed. However, average pasture cover was estimated at only 1150 kg Dm/ha.

In early March, one cow was dried off because it had mastitis. Nine cows were also sent to the runoff because the case farmer decided that it was more profitable turning pasture into milk fat rather than beef. Therefore, he sacrificed the weight gains on the beef cattle to run the dry cows on the runoff and free up this feed for the milking cows.

By mid March, the case farmer was milking 140 cows on once-a-day. Ten dry cows were on the farm, but only one of these was on the milking area and the rest were on the runoff. The herd is producing 9.5 litres/cow/day and production was declining. The herd was at 4.2 condition score units and condition had increased 0.2 condition score units since the start of the month. The herd are eating 10 kg DM/cow/day of which 2 - 3 kg DM/cow/day was forage crop and the remainder pasture. Intakes and pasture growth had increased through the first half of the month due to the rain. The herd was going into 1500 kg DM/ha and coming out of 1050 kg DM/ha. Average pasture cover had increased to about 1300 kg DM/ha.

The forage crop was finished on the 18th March. It lasted past mid March because there had been a lot of rain through the first half of March and the case farmer did not graze the crop when conditions were muddy. When the forage crop was finished, cow intakes declined from 10.0 kg DM/cow/day to 9.0 kg DM/cow/day. Milk production declined by about 0.5 litres/cow/day. Growing conditions were good through the first half of March with 5 - 10 mm of rain falling during each rainfall event.

At the end of March the case farmer was still milking 140 cows on once-a-day. Ten dry cows were on the farm, nine on the runoff and one on the milking area. Although milk production declined to 8.5 - 9.0 litres/cow/day or around 0.78 kg MS/cow/day. Cow condition improved to 4.3 condition score units. The cows were eating 9.0 kg DM/cow/day of pasture on a 24 day rotation. The pre- and post-grazing residuals were 1150 and 1500 kg DM/ha respectively. Average pasture cover gradually improved and was formally measured at 1360 kg DM/ha on the 28th March. Pasture quality was excellent and clover content had improved. The forage crop paddocks were sown into new grass on the 20 - 25th March. The weather over the second half of March was warm and moist and ideal for pasture growth.

Although conditions improved dramatically over the second half of March, the case farmer decided not to put the herd onto twice-a-day milking because the average pasture cover had not increased to the level where he could feed the herd 11.0 kg DM/cow/day, his target for changing over to twice-a-day milking.

In early April, a cow dried itself off and the case farmer bought the nine dry cows back to the milking area from the runoff to increase the total number of dry cows to 11. These cows were returned to the milking area because the residuals left behind by the milking herd were too high (clumps) and there was limited feed on the runoff. The dry cows were used to clean up the poorer quality pasture. On the 15th April the case farmer was milking 139 cows once-a-day, producing 9 litres/cow/day or 0.85 kg MS/cow/day. Cow condition had improved 0.2 condition score units to 4.5 condition score units and condition was more evenly distributed across the herd. The herd was still on a 24 day rotation and cow intakes had increased to 12 kg DM/cow/day. The case farmer had stated that he would put the herd onto twice-a-day milking if intake increased to 11 kg DM/cow/day. However, this only applied for the months of February and March. Once into April, the case farmer did not see the point of putting the herd onto twice-a-day milking with drying off imminent. Average pasture cover was 1550 kg DM/ha on the 15th April. Pasture growth rates were 42 kg DM/ha/day, which was above the estimate of 30 kg DM/ha/day used in the plan, and the long term average of 25 kg DM/ha/day. Pre- and post-grazing residuals were 1950 kg DM/ha and 1250 kg DM/ha. The weather was warm and moist with excellent growing conditions. The case farmer ranked this April as the best he had experienced.

In late April, one further cow had been dried off due to persistent mastitis and by May 1st the case farmer was milking 138 cows once-a-day and 12 dry cows were running on the milking area. Milk production was 0.80 kg MS/cow/day or 8.0 litres/cow/day and condition was 4.7 condition score units. The cows were eating 13.5 kg DM/cow/day on a 24 day round. Pasture quality was good, but the case farmer thought residuals were too high with the herd going into 2150 kg DM/ha and coming out at 1400 kg DM/ha. However, he noted that if he tightened them up, milk production would decline. Pasture cover on the 2nd of May was 1685 kg DM/ha and pasture growth rates for the second half of the month were 45 kg DM/ha/day. The weather was milder than normal for April, but conditions gradually became cooler and wetter as the month progressed.

During the first half of May, the weather turned cooler and this had influenced pasture growth rates which declined to 33 kg DM/ha/day and as a results, pasture cover fell 115 kg DM/ha to 1570 kg DM/ha by May 15th. Three cull cows were sold during this period. On the 15th May the case farmer was milking 138 cows on once-a-day producing 7 litres/cow/day or around 0.70 kg MS/cow/day at a condition score of 4.7 condition score units. There were only nine dry cows left on the farm. Cow intakes were 13 kg DM/cow/day and the herd was on a 24 day round. Pre- and post-grazing residuals were 2050 kg DM/ha and 1250 kg DM/ha. At this point, the case farmer completed another feed budget. This showed that if he dried off the herd, he could calve onto an average pasture cover of 1972 kg DM/ha. This was 300 kg DM/ha below target. The case farmer worked out that if he put on 2.5 tonnes of urea, he would achieve his target of 2300 kg DM/ha at calving. The alternative was to use more nitrogen and extend the lactation. The case farmer decided to dry off because pasture cover and pasture growth rates had fallen sharply over the first half of May. He believed that if this trend continued, then the average pasture cover would be at 1300 kg DM/ha by the end of May.

Control

The control process used by the case farmer consisted of monitoring key performance measures, comparing these to standards or intermediate targets to identify significant deviations, and if a deviation existed, using decision rules to select the most appropriate contingency plan for the conditions. Although problem detection was undertaken, it was not apparent that any form of conscious problem definition or diagnosis was undertaken in most instances. The case farmer did evaluate a range of areas in relation to his tactical management, and examples of learning were recorded.

The monitoring process

The monitoring process used by the case farmer in year three was pretty much the same as that used in the previous two years. Milk production data was monitored daily through the milk vat, and cow intakes were measured every 3 - 4 days using pre- and post-grazing residuals in combination with the milk vat. The case farmer was also monitoring the forage crops and climatic data, particularly rainfall. Triangulation of other factors was used to confirm changes in a factor used for decision making, e.g. when the case farmer found intakes were declining, this was supported by his observations that cow condition and milk production were declining.

This year the case farmer used a different method (ultrasound) to monitor the reproductive status of the herd. This method allowed the case farmer to identify empty cows a month ahead of normal. This is important in a dry year when the cows can be culled to free up feed for the rest of the herd. However, in a normal year, where feed is plentiful, the case farmer retains empty cows through until drying off because they produce more milk than in-calf cows (no energy demand for pregnancy).

IF the year is a dry year,
THEN use ultrasound to pregnancy test the herd early,
ELSE use conventional methods in late March.

When the case farmer does the plate metering he also spends 10 minutes formally assessing cow condition when he walks through the paddock the herd is in. Cow condition is also assessed on a daily basis when he milks the herd.

This season, the case farmer monitored pasture quality in relation to the post-grazing residual left behind by the herd (clumpiness) which had not been important in the past because in the previous two years, pasture quality had not been a problem. This was monitored visually by observing the "clumpiness" of the post-grazing residual left behind after grazing (subjective, informal monitoring approach).

Rainfall information was collected and the main influence this has on decision making is in terms of fine tuning the supplement feeding. On a wet day the herd does not harvest as much pasture or crop as on a dry day, so the case farmer will give the herd more crop.

The case farmer stated that in previous years he identified when the herd was being fed below target by observing the post-grazing residuals. This method identified when cow intakes dropped below target before he could pick this up through the milk vat. The information from the vat then confirms that the residuals are too low to maintain milk production at 1.04 kg MS/cow/day and this information was then used for decision making. To identify when cow intakes fell below target, the case farmer observed how far into the sward horizon the cows grazed. Problems occurred when the herd was forced to "*work*" which was when they grazed into the stalky low quality feed at the base of the sward.

Monitoring decision rules

The data indicated that the case farmer used knowledge of the farm and its history to focus attention on particular factors in relation to monitoring. He mentioned that if there was some area he was not comfortable with, he would measure that area. For example, if a paddock ahead of the herd was one that was pugged earlier in the year, he would check it because it was likely to provide less feed than other paddocks. He then adjusted the amount of forage crop fed to the herd so that milk production did not fall. The case farmer knew that his farm had some areas that were drier than others and he checked these paddocks. The advantage of a fixed round was that he knew the sequence of paddocks and this never changed over the summer-autumn. The case farmer was grouping paddocks as "dry" and "not as dry" on the basis of how well they grow over the summer. These rules are useful for fine tuning the management of the farm.

IF a paddock is likely to grow less grass than others due to a previous problem,
AND the paddock is soon to be grazed,
AND the herd is being fed supplements,
THEN assess the feed on the paddock before grazing and adjust the supplement level to maintain intakes at target as required.

IF a paddock classification = dry,
AND the paddock is soon to be grazed,
AND the herd is being fed supplements,
THEN assess the feed on the paddock before grazing and adjust the supplement level to maintain intakes at target if required.

Much of the time, the case farmer was not monitoring many factors "actively", but rather he would observe things as he moved around the farm as part of his normal dairy farm activities. If asked about the state of a particular factor the case farmer could recall the factor and estimate its value. However, if one of these factors fell outside the case farmer's "comfort zone", then he would begin actively monitoring that factor. For example, the case farmer was not "actively" monitoring cow condition until his indicator cows identified that cow condition was declining rapidly.

IF informal monitoring suggests the state of some variable is outside the comfort zone for that parameter,
THEN measure the parameter more formally.

On the 6th February, the case farmer began to formally assess cow condition through visual assessment. This was because in late January, the condition of two indicator cows fell to 3.5 condition score units indicating the herd's condition was declining quite rapidly. Throughout February, cow condition has been the main determinant of decision making. The indicators cows triggered the case farmer to pay more attention to cow condition.

IF indicator cows ≤ 3.5 condition score units,
AND cow condition is not being formally monitored,
THEN begin to monitor cow condition formally.

The case farmer was not formally monitoring pasture cover during the first half of March. Formal pasture monitoring began on the 28th March. The case farmer noted that it would be mid April before he could get sufficient information to identify a pasture growth rate trend (three data points, two pasture growth rate calculations). However, because cow condition had been improving, this was not a concern to the case farmer. If cow condition had been trending down he would have begun formal monitoring earlier and identified the "trend". The following are activation and non-activation rules for formal pasture monitoring:

IF the date is ≥ mid March,
AND the date is ≤ April 1st,
AND cow condition is improving,

AND other indicators suggest the feed situation is improving,
THEN delay objective pasture monitoring until around April 1st.

IF the date is ≥ mid March,
AND the date is ≤ April 1st,
AND cow condition is declining,
AND other indicators suggest the feed situation is declining,
THEN begin objective pasture monitoring and identify the trend in pasture growth rates.

The case farmer changed from using the traditional pregnancy diagnosis to an ultrasound method because it could be used in early February rather than late March. This meant that he could identify and cull empty cows at least a three weeks earlier than normal. In a normal year, the case farmer's policy is to milk his empty cows through to near drying off because they produce more efficiently than in-calf cows, hence the timing of the pregnancy diagnosis is tied to the need to identify the number of cows the farmer will winter for the winter feed budgeting process completed on April 1st. When feed is short, the case farmer changes this policy.

IF the conditions appear to be indicating a dry summer,
THEN adopt the ultrasound method and undertake the pregnancy diagnosis in early February,
Else use the conventional method and undertake the pregnancy diagnosis in late March.

Frequency of monitoring

The data confirmed the monitoring frequencies identified in year one. In most cases, data was monitored on a daily basis. However, the data shows that milk production and cow intakes were monitored at about four day intervals, and that this frequency was adequate because the factors do not change that quickly. Milk production was monitored "actively" when the milk docket changed significantly.

Formal average pasture cover and pasture growth rate data was collected every 8 - 13 days during the autumn. The case farmer did not monitor the feed situation with the normal intensity because feed conditions were very good. This demonstrates another rule that determines the frequency of pasture monitoring. When feed conditions are deteriorating, the case farmer increases his monitoring frequency to around 5 days, whereas when feed conditions are improving, he reduces his monitoring frequency to 7 - 14 days.

IF feed conditions are good and/or improving,
AND objective pasture monitoring is being used,
THEN use a monitoring frequency of between 7 - 14 days, but reduce the frequency if conditions deteriorate.

IF feed conditions are poor and/or deteriorating,
AND objective pasture monitoring is being used,
AND the monitoring frequency > 5 days,
THEN reduce monitoring frequency to 5 days,
ELSE maintain monitoring frequency at 5 days.

The case farmer monitored average pasture cover on the 2nd and 15th of May. He believed that he should have been monitoring more frequently given the rate at which pasture cover declined. He picked this trend up informally on the 12th May, but took three days to get a farm walk done due to other work commitments. Milk production, the residuals and the fact that the cows were working a bit harder each day suggested average pasture cover was declining. This suggests that the case farmer had not followed his own decision rules in terms of frequency of monitoring due to work pressure.

Data processing

Formal calculation of such factors as milk production in litres/cow/day are not undertaken except if a change in total milk production occurs. Intake calculations are completed every 3 - 4 days.

Recording

No new material was identified on the case farmer's recording system.

Problem identification for control purposes

The case farmer identified problems when an indicator of actual performance fell outside, or approached a target specified in the plan. Key indicators and targets are identified in Table 5. As in previous years, milk production was the primary indicator used by the case farmer in problem recognition over the early summer. However, this year, the case farmer made some changes to his typical milk production targets. In the past he has attempted to hold milk production through January at the level at which the herd is producing at the start of the period. This year, the aim was not to hold milk production, but to delay the grazing of the forage crop until late January. Therefore, the target was to hold milk production above 0.87 kg MS/cow/day until late January when the herd would go onto the forage crop. In effect, this reduced cow intakes, reduced the rate of feed consumption, delayed forage crop grazing and used body condition as a supplement.

The case farmer introduced the herd to the forage crop when milk production fell to 0.87 kg MS/cow/day, not the traditional value of 0.65 kg DM/cow/day. In the past, the case farmer has used an introduction target of 0.085 kg MS/cow/day above the maintenance target to allow for the drop in milk production that normally occurs when the herd is introduced to the forage crop. In this instance, the introduction and maintenance targets were the same and the case farmer just increased forage crop intake over the introduction period to maintain milk production at 0.085 kg MS/cow/day.

The case farmer also had a target for rotation length for the entire summer-autumn period, which was between 24 and 30 days. The minimum rotation length was a day shorter than in previous years because an extra paddock was in forage crop and out of the rotation. Normally milk production is the primary target over the summer and cow condition remains unimportant in terms of decision making until the autumn. However, under the extremely dry conditions the herd lost condition rapidly and the case farmer placed the herd on once-a-day milking when average herd condition fell to 4.0 condition score units. Therefore, the average herd condition target rather than the milk production target dictated decision making in late summer. The case farmer used the same target of 3.5 condition score units to dry off thin cows. Rainfall was important because if more than 25 mm fell, this would result in the decomposition of dead matter and a reduction in cow intakes. The case farmer used this target to dictate when to increase supplement intake to counteract the impact of the rain. Interestingly, adjustments to intake were made in response to rainfall levels that were less than the target of 25 mm. In most cases this was around 15 mm of rainfall. This was attributed to the impact of rainfall in a very dry year.

During autumn, as conditions improved, cow condition increased through until drying off because the herd was on once-a-day milking. Thus, although the case farmer had a minimum condition score target, it was not relevant because of the conditions. Similarly, milk production targets were not used because the herd was on once-a-day milking. The herd was maintained on the minimum rotation length. The most important target was average pasture cover which was specified in the feed budget. There was some flexibility in the average pasture cover target because the case farmer was comfortable using nitrogen to extend the lactation. However, he did not specify how much nitrogen he would use. The decision to dry off was based on the level of average pasture cover and its rate of decline during early May. When average pasture cover fell 100 kg DM/ha in two weeks, the case farmer decided to dry off. Rainfall was not important during the autumn. Sufficient rain had fallen prior to April to trigger an autumn flush, but rather than dry off in response to this flush of growth, the case farmer used it to extend the lactation.

One target not identified from the previous two years was the degree of clumpiness in relation to the post-grazing residuals. This measure could not be specified objectively, but occurred at residuals of around 1400 kg DM/ha.

The case farmer measures cow intakes every 3 - 4 days, and compared these to target intake figures. In previous years this target has been around 12 kg DM/cow/day, but this year it was about 10 kg DM/cow/day. The intake information provides an early warning as to when performance would drop below these targets. Similarly, the case farmer looked ahead and predicted future intakes either in terms of what intake the herd would have, based on the current post-grazing residual when it returns to the paddock after the next round, or in terms of what intake the herd would have when he stopped feeding supplement.

Table 5. Indicators and targets used in the control process.

Indicator	Targets used in Year 3
Summer	
Milk production Pre-forage crop .	≥ 10 litres/cow/day or 0.87 kg MS/cow/day
Forage crop one. Introduction Maintenance	 ≥ 10 litres/cow/day or 0.87 MS/cow/day ≥ 10 litres/cow/day or 0.87 kg MS/cow/day
Post-forage crop	No milk production target - condition score was the determinant
Rotation length	24 - 30 days
Average herd condition score	≥ 4.0 condition score units
Individual cow condition	≥ 3.5 condition score units
Rainfall	≥ 25 mm, ≥ 15 mm in some cases
Target intake	Reflected in other factors
Autumn	
Rotation length	24 - 30 days
Individual cow condition	≥ 3.5 condition score units
Average herd condition score	≥ 4.0 condition score units
Average pasture cover	≥ target average pasture cover level in feed budget
Rate of decline in average pasture cover	≥ 100 kg DM/ha over two weeks ?
Milk production	No milk production target
The level of "clumpiness" in post-grazing residuals	
Target intake	Reflected in other factors

Problem definition and diagnosis

Indirect measures may indicate the emergence of a feed "problem" and given the case farmers knowledge of cause and effect relationships, diagnosis is not required, as the cause of the problem has been established sub-consciously before it is identified consciously. For example, hot, dry windy conditions would have been noted subconsciously before the impact of such conditions, a decline in milk production, average pasture cover and or cow condition was identified.

The contingency plans

As with years one and two, the contingency plans of the case farmer could be classified under four headings in relation to their impact on feed supply and feed demand (Table 6). The case farmer had six options which he used to increase feed supply: increase the level of forage crop fed, increase the level of silage fed, reduce rotation length, apply additional nitrogenous fertiliser, use winter, early spring silage over the summer-autumn and replace later, and feed 100% hay to dry cows on the milking area. The only contingency plan specified by the case farmer that would reduce feed supply in year three was reducing the rotation.

Table 6. The case farmer's contingency plans.

Category	Option
Increase feed supply	Increase the level of forage crop fed Increase the level of silage fed Reduce rotation length Apply additional nitrogenous fertiliser Use winter, early spring silage over the summer-autumn and replace later Feed 100% hay to dry cows on the milking area
Decrease feed supply	Increase rotation length [a]
Increase feed demand	Increase cow intakes by maintaining current rotation length[47] Delay placing herd on once-a-day milking Sell less culls than planned Dry off less cows than planned Retain dry cows on milking area[48] Return dry cows from the runoff to the milking area Extend the lactation[49]
Decrease feed demand	Reduce cow intakes by further reducing the milk production target[50] Feed cull cows on waste ground until sold Place thin cows on once-a-day milking[51] Dry off thin cows and place on runoff[52] Do not place the herd back onto twice-a-day milking Place dry cows currently run on the milking area onto the runoff Place the herd on once-a-day milking Dry off the herd early

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[47] Farmer A could have extended the rotation to reduce cow intakes during late April, because they had increased to 13.5 kg DM/cow/day. However, he chose not to in order to maintain cow condition.

[48] They were retained on the milking area and fed 100% hay because there was no feed for them on the runoff.

[49] The feed budget undertaken on March 28th set a date of May 1st. The herd was actually dried off on May 20th.

[50] Farmer A had reduced the milk production target to 10 litres/cow/day or 0.87 kg MS/cow/day in the summer plan. As a contingency to reduce cow intakes further, he reduced this target to7.5 litres/cow/day or 0.70 kg MS/cow/day in February.

[51] Although this option is in the plan, the timing and number of cows placed on once-a-day milking is dependent on conditions.

[52] Although this option is in the plan, the timing and number of cows dried off is dependent on conditions at the time.

Options for increasing feed demand included: increasing cow intakes by maintaining current rotation length, delaying placing the herd on once-a-day milking, selling less culls than planned, drying off less cows than planned, retaining dry cows on milking area, returning dry cows from the runoff to the milking area, and extending the lactation. Feed demand was reduced through, reducing cow intakes by further reducing the milk production target, feeding cull cows on waste ground until sold, placing thin cows on once-a-day milking, drying off thin cows and placing them on the runoff, not placing the herd back onto twice-a-day milking, placing dry cows currently run on the milking area onto the runoff, placing the herd on once-a-day milking and drying off the herd early.

Although the contingency plans can fit under these four quadrants, the primary purpose of some of these contingency plans was not to influence feed supply or feed demand. For example, several contingency plans were used to protect cow condition. These include the decisions to dry off thin rising three year old cows, and the decision to put individual cows and the herd on once-a-day milking.

Contingency plan selection

The selection of a contingency plan is triggered when a key indicator crosses the target threshold (Figure 1) set by the case farmer. The process the farmer uses to select the most appropriate contingency plan to minimise the impact of the deviation can best be represented by decision rules. The decision rules take the form of an "IF" statement that specifies the conditions that indicate a problem exists, then normally several "AND" statements that specify important characteristics that define the problem situation, followed by a "THEN" statement which specifies the contingency plan that should be instigated (Figure 1). The problem situation characteristics are important, because they are used to distinguish between alternative courses of action in most instances. In other words, the problem situation characteristics are matched to a problem solution.

IF milk production is ≤ 13 l/cow/day	Indicates the problem exists
AND the crop is mature,	) Specifies the characteristics that
AND the ground is dry,	) define the problem situation
THEN feed sufficient crop to the herd to maintain milk production at 12 l/cow/day.	Specifies the contingency plan that should be implemented to match the characteristics of the problem situation.

Figure 1. Structure of a decision rule.

The contingency plans used by the case farmer are presented in Appendix VIII (Volume II).

Control responses

A broader range of control responses were used in year three of the study than in the other two years. At the start of the season, after assessing the situation, the case farmer revised his basic plan. The majority of these changes were made in response to the dry conditions and poor supplement situation. However, the case farmer's strategic decision to increase cow numbers next season and use the runoff which runs beef cattle for milking also influenced the case farmers plan. The latter decision meant that the case farmer could undertake limited culling over the summer. As such, he did not want to make culling decisions without full information. Therefore, he delayed his normal Xmas cull until herd testing in early January when he had more objective information on the herd.

The other changes in the case farmer's plan related to the dry conditions and poor supplement situation. The case farmer tends to use a pre-defined plan most years provided his simulation suggests the plan is feasible. The plan is modified if conditions are different from the norm at the start of the planning period. The major changes to the plan were that: the milk production target was reduced from 1.04 kg MS/cow/day to 0.87 kg MS/cow/day, hay and silage would be fed with the forage crop to extend its use, once-a-day milking would be used to maintain cow condition and extend the lactation, and pregnancy testing would be completed a month early and empty cows culled rather than retained until drying off.

A major change to the plan was the reduction in the milk production target. This indicates that the milk production target is one of the mechanisms the case farmer uses to cope with either above or below average pasture growth rates. The case farmer also used a range of contingency plans to cope with variation in feed supply once the plan was implemented (Table 6).

Diagnosis, evaluation and learning

Few examples of diagnosis were identified during the third year of the study for case study one. The case farmer attributed the reason for the poor forage crop yields to a combination of wet conditions at sowing, followed by dry conditions through December that limited germination and subsequent yields. He found, through the diagnosis of pregnancy test data, in conjunction with discussions with his veterinarian, that cows he had thought conceived during artificial insemination, had in fact stopped cycling due to the poor feed conditions during the wet spring, and had then exhibited a "quiet heat" in December that he had not identified and were then mated by the bull.

Several examples of evaluation were identified during the third year of the study. These were in relation to management practices and the monitoring process used by the case farmer. The management practices the case farmer evaluated were: the planting of an additional paddock of forage crop, the use of ultrasound for pregnancy diagnosis, and the use of once-a-day milking. He briefly evaluated his decision to plant an extra paddock in forage crop in early December, and decided that given the dry conditions, he would have been better to keep it in pasture. The basis of this evaluation was that given the poor forage crop yield, he would have obtained more feed off the paddock by retaining it in pasture.

The case farmer evaluated the use of the ultrasound pregnancy diagnosis by comparing meat processing data on the pregnancy status of the cows identified as empty with the ultrasound results. The ultrasound was 100% accurate and the case farmer decided that this new management practice was a good option in a dry year when he needed to reduce stocking rate early. The case farmer also evaluated his decision to put the herd onto once-a-day milking on the 23rd February. The criteria he used to assess this was to compare the number of milking cows he had on hand in early March compared to what he would have had, had he kept the herd on twice-a-day milking and dried off a proportion of the herd to ensure the lactating cows were fed sufficient feed to maintain condition. He believed that the herd could return to a reasonable level of milk production if the feed situation improved.

The case farmer evaluated the monitoring interval he used when monitoring average pasture cover and pasture growth rates over autumn. He thought he should have used a five day monitoring interval rather than a thirteen day monitoring interval. The criteria he used to assess this was to estimate the additional average pasture cover he would have had on the farm if he had dried off earlier as a result of more frequent monitoring. In hindsight, he thought that he would have dried off ten days earlier which would have resulted in another 100 kg DM/ha of average pasture cover being on hand at the end of the month.

A number of areas of learning were identified in the third year of the study. Some of these areas were related to events outside of the study period, but are provided as examples. The areas of learning identified in year three of the study were in mainly in relation to management practices and the production system and their interaction with the environment. However, the case farmer also mentioned learning in relation to production targets. Learning was reported in relation to the management practices of harvesting early supplements (hay and silage), the feeding of Barkant turnips, the use of ultrasound, and autumn nitrogen.

The case farmer mentioned that he had learnt from the previous season that he needed to ensure the hay and silage paddocks were harvested early and back into the rotation before the dry conditions arrived. If they were not back into the round early, and dry conditions occurred, then subsequent regrowth was limited. Therefore, this season he only made hay and silage that could be harvested early. In the past, the case farmer has preferred to be self-sufficient and make all his own hay and silage. However, he decided that this comes at a cost in a dry summer and has changed his practice. This shows the influence of the case farmer's "self-sufficiency" on his management practices, but also how pragmatism has over-ruled these values. This is learning in relation to management practice and in terms of how the farming system responds to such practices under different environmental conditions.

The case farmer had not fed Barkant turnips before and learnt that the herd would not graze the bulbs until they had been uprooted for 2 days. This appeared to soften the bulbs and the herd would then ingest them. This meant a change in the case farmer's forage crop feeding practice because he now had to ensure the herd could back-graze the turnip crop. The case farmer also learnt that ultrasound could be used to accurately diagnose empty cows a month earlier than conventional methods. This provided management flexibility in a dry year.

The case farmer was asked why he did not use nitrogen in the autumn when conditions were warm. He made the comment that he might have learnt something[53]. He has tended to only use nitrogen as a tactical option in the winter and late spring rather than in the autumn. Prior to the study, he also believed that there was little point applying nitrogen in the autumn because the natural "flush" of growth limited any response. He also has an attitude that one should not develop systems that rely on nitrogen. He admits that he has a lot to learn about the use of nitrogen, but his attitude towards nitrogen has tended to limit the amount he puts on. This again indicates that the case farmer's "self sufficiency" values have dictated many of his management practices, but that these values are gradually being challenged.

The other main area of learning recorded during the third year of the study was in relation to the production system and its interaction with the environment. The main areas of learning were in relation to: crop establishment, and heat detection. The case farmer learnt that in a year in which very wet conditions are followed by very dry conditions during late spring, forage crop germination rates and subsequent yields can be very poor. The

[53] This is one example, of where the study may have influenced farmer behaviour. In this case, by asking the case farmer about the reasons behind his management practices, this forces him to reflect on and challenge what he does. This may not have happened, or happened at a less accelerated rate without the stimulus of the study.

case farmer also learnt that during a wet spring, cows can stop cycling if under nutritional stress. This behaviour can be misinterpreted to mean that such cows are in-calf. These cows can then exhibit a "quiet heat" when conditions improve that is difficult to detect. This can results in a higher proportion of the herd being mated to a bull than the farmer thinks on the basis of behavioural observation.

The case farmer also described why he uses 1.04 kg MS/cow/day as an important target over the summer. He had learnt that if he allowed milk production to drop below this level, it was difficult to lift production later if feed supply improved. The case farmer also learnt that the herd would lose condition quickly once milk production fell below this level. The case farmer had also found that the herd began to "*work*" just prior to milk production falling below 1.04 kg MS/cow/day. By "*work*" he meant that the herd begins to graze at a level lower than that the case farmer would be happy grazing the herd at. At this level, they are grazing into the sward and eating dead material and stem.

The case farmer mentioned an aspect of learning that could be classified at a higher level than the other factors mentioned in this study. He stated that on the basis of this year, he had learnt to methodically work through his options and then ensure those decisions were implemented rather than panic or over-react. This related to his decision to go onto once-a-day milking. It suggests that at a higher level, he is evaluating his management process and the validity of his decision rules.

Appendix XXIII. Farmer B – Summary of Year One

Description of year one

The summer of year one was cool and wet, providing good growing conditions for pasture. As such, pasture growth rates and the resultant levels of pasture cover were above average. Conditions through April were dry and frosty, but pasture growth rates were also above average (44 kg DM/ha c.f. 35 kg DM/ha/day). The case farmer believed that this may be because of the high average pasture cover and long rotation length at the time. Pasture growth rates declined rapidly in early May, falling from 44 kg DM/ha/day to 18 kg DM/ha/day. Overall, the season could be described as a wet summer where above average growth rates were experienced from January until April.

The plan

Planning horizons

The case farmer operated at two planning levels during the study period. At a higher level, he separated the summer-autumn into two periods. The first was from early January until mid March, when his primary focus was to optimise milk production in the current season and ensure as many cows as possible were in a lactating state when the autumn rains arrived around mid March. The second was from mid March through to the point when pasture growth rates exceeded feed demand (balance date) at the end of September. The objective of the second period was primarily to ensure production in the next season was not jeopardised whilst optimising milk production through until drying off.

The case farmer viewed the summer as the period that encompassed forage crop and grass silage feeding. However, this period was seen as separate from the autumn when the case farmer fed out maize silage and dried off the herd. The initiation of the summer period related to a change in seasons where the farm moved from a period where pasture growth exceeded feed demand, and the focus of the case farmer's management was to control pasture quality, to a period when feed demand exceeded feed supply, and the focus of the case farmer's management was to optimise milk production from his available feed source. In mid March, the case farmer's focus shifted from the current season to the next season with the approach of drying off. Mid March was the date at which the autumn rains normally arrived. These were followed by a period of high pasture growth rates known as the "autumn flush". Around mid March, the case farmer undertook a gross feed budget to determine his likely drying off date. Drying off was seen as a critical decision as it has a major influence on next season's production. As the change in planning horizon occurred, the case farmer also shifted from an informal planning mode to a more formal, quantitative approach.

The drying off decision was seen as critical by the case farmer because it was important in determining the level of average pasture cover and the condition of the herd going into the winter. These two factors were critical for setting the farm up for the coming season. The drying off decision is also irrevocable, and if made too early can result in lost production for the current season. The second critical point mentioned in the second planning horizon was calving. Milk production in early lactation, and subsequent reproductive performance is determined to a large extent by the condition of the herd and the level of feed on-hand at calving. As such, this was viewed as a critical point in the planning horizon.

The termination date for the second planning period was the end of September at "balance date", the point at which pasture growth exceeded feed demand. The objective for the second planning period was to (i) ensure optimum milk production during early lactation and ii) ensure the herd was well set up in terms of cow body condition and nutrition for mating. Within these constraints, the case farmer aimed to optimise autumn milk production. The terminating date for the second planning period related to another seasonal change where the farm moved from a period where feed demand exceeded feed supply, to a period where feed supply exceeded feed demand.

At a lower level, the case farmer used shorter planning horizons of approximately four weeks duration. These were event-driven and related to important activities within the longer planning time-frame. During summer, this included a pre-forage crop period, the period during which the herd was fed the forage crop, and then the period in which the herd was fed grass silage. During autumn, two periods were involved, the first encompassed the feeding of maize silage to the herd, culling, and drying off thin rising three year old cows whilst the second related to the drying off process. Unlike the other activities, the drying off process only encompassed a period of a week.

Values, and goals

There was little evidence that values influenced the tactical management of the case farmer. However, the case farmer did actively seek opportunities in relation to external sources of feed that could be used to extend the lactation. This suggested the case farmer was not constrained by values relating to "low input" farming or "self-sufficiency". Little evidence of the case farmer's use of a goal formulation process was found during the study and the goals appeared to have been formulated at an earlier date. High level goals were identified for the two planning periods. During the summer, the case farmer's goal was to optimise milk production from his available feed supply and to ensure the maximum number of lactating cows were on-hand when the autumn rains arrived. The summer goal was subservient to the goal of the second planning period. The goal for the second planning period was to optimise milk production in early lactation and ensure the herd was in good condition with suitable feed on hand for mating. Optimising autumn milk production was secondary to this goal.

To ensure the summer goal was met, the case farmer used a set of targets that were designed to optimise milk production from the available feed supply while protecting average pasture cover and cow condition (See later section). Similarly, the terminating conditions specified in the second planning period dictated the average pasture cover and cow condition score targets required at planned start of calving. These in turn dictated the respective targets at drying off, therefore constraining autumn milk production.

Planning process

The case farmer used a qualitative planning process for the first planning period, and then changed to a quantitative planning process for the second planning period. At the start of summer the case farmer assessed the state of the farm in terms of average pasture cover, pasture growth rates, climatic conditions, supplements on-hand, forage crop state, cow condition, milk production and cow intakes, cow numbers and stocking rate. He also assessed per hectare feed demand (kg DM/ha/day) and used his pre- and post-grazing residuals to estimate the feed situation on the farm in 3-4 weeks time. This information was then used to test the feasibility of the case farmer's "typical" plan. In effect a mental feed budget was developed from January 1st to mid March. If the mental simulation demonstrated that the "typical" plan was feasible, it was implemented. Otherwise it was modified to suit the conditions. The "typical" plan was based on experience and had been developed by the case farmer over time. It was however, modified in response to strategic decisions and/or learning (historical control). In year one the case farmer modified the typical plan because he had made several important strategic decisions (Table 1).

Table 1. Farmer B's plan[1] for the summer-autumn for year one of the study.

Typical year	Year 1
Maintain the herd on a 21 - 22 day rotation until late January or milk production falls to 1.13 kg MS/cow/day	Maintain the herd on a 21 - 22 day rotation until late January or milk production falls to 1.13 kg MS/cow/day
When milk production falls to 1.13 kg MS/cow/day in early February, feed the forage crop for 3 weeks and maintain milk production at or above 1.04 kg MS/cow/day.	When milk production falls to 1.13 kg MS/cow/day in early February, feed the forage crop for 3 weeks and maintain milk production at or above 1.04 kg MS/cow/day.
Remove the bull in early February.	Remove the bull in early February.
Herd test on the 20th February.	Herd test on the 20th February.
When the forage crop is finished, feed grass silage for four weeks and use the grass silage to extend the rotation out to 35 - 42 days while holding milk production at 1.04 kg MS/cow/day.	When the forage crop is finished, feed grass silage for four weeks and use the grass silage to extend the rotation out to 35 - 42 days while holding milk production at 1.04 kg MS/cow/day.
	Regraze the forage crop for a week in late February and then continue to feed the grass silage. A third grazing may be obtained from the forage crop in March.
Sow the new grass by mid March.	Sow the new grass by mid March.
Pregnancy test the herd 6 - 8 weeks after the bull is removed in late March.	Pregnancy test the herd 6 - 8 weeks after the bull is removed in late March.
Undertake a herd test in early April.	Undertake a herd test in early April.
Sell cull cows in early April after pregnancy diagnosis.	Sell cull cows in early April after pregnancy diagnosis.
Dry off the thin induction and rising three year old cows in early April.	Dry off the thin induction and rising three year old cows in early April.
Extend the rotation as the cull and dry cows are removed from the milking platform.	Extend the rotation as the cull and dry cows are removed from the milking platform.
	Feed 100 tonnes of maize silage through April.
	Production will decline to 0.87 kg MS/cow/day in the last month of lactation and the herd will hold condition on the maize silage.
Dry off the herd in late April, early May.	Dry off the herd in May. The feed budget estimated the herd could be milked until May 20th provided average pasture cover remained above 2100 kg DM/ha.

Two important strategic changes were made in year one. First, the traditional forage crop was replaced by Japanese millet. This forage crop, unlike the brassica that had been used previously, could be regrazed, and allowance had to be made for this in the plan. Second, the case farmer incorporated 100 tonnes of maize silage into the autumn plan. This allowed him to extend the lactation further into the autumn.

Heuristics or decision rules were used to determine the sequencing, and timing (activation and termination) of events, and the type and level of inputs (Table 2). Sequencing rules determine the sequence of events e.g. the feeding of silage after the forage crop. Activation rules initiate the introduction of a management practice or input e.g. grass silage feeding. Termination rules stop a management practice or input, e.g. termination of lactation - the drying off decision. The input type and level rules determine what input and

[1] This is Farmer B's plan as at 1/1/xx. In the last row, the drying off date estimated through the feed budget undertaken in early autumn is given.

how much of an input to use e.g. feed sufficient grass silage to maintain production at, or above 1.04 kg MS/cow/day.

Table 2. Planning rules used by the case farmer.

Planned event	Decision rule	Reasons behind the rules
Select summer stocking rate. **Input type and level rule**	Select the stocking rate at which the herd can be fed such that production can be maintained at, or above 1.04 kg MS/cow/day through until mid March. Assess the average pasture cover, climatic conditions, pasture growth rates and supplements on-hand, around late December. Estimate the likely forage crop yield. From this decide on the number of cows that can be taken through the summer.	The case farmer wants to take as many cows as possible through the summer to take advantage of the autumn rains. He believes that the most efficient use of feed is to run enough cows to produce at 1.04 kg MS/cow/day. Cull cows are sold prior to the start of the summer period.
Maintain the herd on a 21 - 22 day rotation until milk production falls to 0.65 kg DM/ha/day. **Sequencing rule** **Input type and level rule** **Termination rule**	Graze pasture before feeding the forage crop IF date ≥ January 1st, AND the forage crop is ungrazed, AND milk production > 1.13 kg MS/cow/day, THEN maintain the rotation length at 21 - 22 days.	The case farmer used pasture before the forage crop so that the forage crop could reach optimum yield. IF the case farmer used a faster rotation, the herd would overgraze the sward, limiting pasture regrowth, particularly after rain. The farm is susceptible to over-grazing because of the high stocking rate. This method also stops the sward opening up allowing weed species to invade. The majority of the farm is in 4.0 ha paddocks which suits a 21 - 22 day rotation.
Feed the forage crop when milk production falls to 1.13 kg MS/cow/day. Feeding should occur from early February for four weeks. When grazing the forage crop, maintain milk production at 1.04 kg MS/cow/day. **Activation rule** **Input type and level rule**	Feed the forage crop in late January, early February IF milk production ≤ 1.13 kg MS/cow/day, AND the forage crop is ungrazed, THEN feed sufficient forage cop to maintain milk production at 1.04 kg MS/cow/day.	The forage crop must be grazed at this point in time or it loses quality as it matures. The case farmer used Japanese millet because it is more flexible than turnips. It can be fed over a longer period, regrazed, or made into silage if not required. The forage crop is fed during a period when feed demand normally exceeds pasture growth due to dry summer conditions. The forage crop is used to maintain milk production at target and ensure the post-grazing residual is maintained above a minimum level. This prevents over-grazing, increases pasture growth rates and ensures pastures respond quickly to rain. The forage crop allows the case farmer to increase post-grazing residuals.
Maintain milk production at 1.04 kg MS/cow/day on the supplement. **Input type and level rule**	IF the herd is being fed supplements, AND it is summer, THEN feed sufficient supplement to maintain milk production at 1.04 kg MS/cow/day.	The case farmer believes that if milk production falls below 1.04 kg MS/cow/day, the herd is being underfed and will lose condition rapidly. This does depend to some extent on the stage of lactation. At this level of milk production, the herd leave behind a post-grazing residual that enhances pasture growth and prevents over-grazing.
Feed grass silage after the forage crop at the start of March for four weeks. **Sequencing rule** **Activation rule** **Input type and level rule**	Feed the grass silage after the forage crop. IF the forage crop is grazed off, AND the pre-grazing pasture cover is insufficient to maintain milk production at 1.04 kg MS/cow/day, THEN feed sufficient grass silage to	Grass silage does not deteriorate over time, but the forage crop does. Quality declines as the crop matures. The grass silage is fed during a period when feed demand normally exceeds pasture growth due to dry summer conditions. The forage crop is used to maintain milk production at target and

Planned event	Decision rule	Reasons behind the rules
	maintain milk production at 1.04 kg MS/cow/day.	ensure the post-grazing residual is maintained above a minimum level..
Use the grass silage to extend the rotation out to 35 - 42 days. **Input type and level rule**	IF grass silage is being fed to the herd, AND the rotation length is < 35 - 42 days, AND the pre-grazing pasture cover is such that the rotation can be extended without dropping milk production below target, THEN extend the rotation ELSE increase the ration of grass silage so that the rotation can be extended out to 35 - 42 days.	The case farmer used the grass silage to extend the rotation out to 35 - 40 days. This is possible in a wet year, but the case farmer finds that in a dry year, the rotation may only be extended out to a 25 - 28 day round. The case farmer believed that a longer round, in combination with adequate post-grazing residuals, at this time of year increased pasture growth rates.
Regraze the forage crop for a week when it is ready, then continue to feed the grass silage. **Sequencing rule** **Termination rule** (of silage) **Activation rule** **Input type and level rule**	IF the forage crop is ready to be regrazed, AND the herd is being fed silage, THEN substitute the silage for forage crop and maintain milk production at or above 1.04 kg MS/cow/day.	The forage crop Japanese millet regrows after grazing and the case farmer expects one or two additional grazings off the crop.
Pregnancy test the herd 6 - 8 weeks after the bull is removed. **Activation rule**	IF the bull is removed on date = X, THEN pregnancy test the herd 6 - 8 weeks after this date.	To accurately diagnose pregnancy status, the herd should not be examined for at least six weeks after the bull has been removed.
Sell cull cows in early April after pregnancy diagnosis. **Sequencing rule** **Activation rule**	Sell the cull cows after pregnancy diagnosis. IF it is early April, AND the cull cows have been identified. THEN sell the cull cows.	The case farmer does not want to cull in-calf cows, so he delays culling until he knows exactly which cows are in-calf. The case farmer stated that culling is a form of supplement, and by culling, he can increase the feed supply to the rest of the herd.
Dry off thin rising three year old and induction cows **Termination rule**	Dry off the thin induction and rising three year old cows in late March, early April. IF the condition of a cow is ≤ threshold, AND the cow is to be induced, OR the cow is a rising three year old, THEN dry off the cow.	To ensure the induced cows are in good condition at calving, the thin ones are dried off. Similarly, thin rising three year old cows are dried off in late lactation to ensure they calve in good condition. The date at which the case farmer expects to undertake this management practice depends upon the season. In a wet summer, it will be in late March, early April, but in a dry year, it may start as early as January.
Feed maize silage after the grass silage and prior to drying off. **Sequencing rule** **Activation rule** **Input type and level rule** **Termination rule**	Feed the maize silage after the grass silage has been fed. IF milk production is ≤ 1.04 kg MS/cow/day, AND the forage crop is grazed, AND the grass silage is fed out, THEN feed the maize silage at such a rate that milk production is held at 1.04 kg MS/cow/day. Stop feeding maize silage once the drying off process is initiated. IF the drying off process is to be initiated, AND the herd is being fed maize silage, THEN stop feeding maize silage.	The maize silage is used to increase average pasture cover and cow condition pre-winter. It is a good feed for holding or increasing cow condition in late lactation. To effectively dry off the herd, cow intakes must be reduced rapidly. This is achieved through the cessation of maize silage and increasing the rotation length.
Dry off the herd **Sequencing rule** **Termination rule**	Dry off the herd after all other options are exhausted. Dry off the herd on the date estimated through the feed budget analysis.	The herd is dried off to ensure sufficient average pasture cover is on-hand to meet targets at calving and at balance date. The drying off date is also used to ensure the herd calve at target condition score.

During mid March, the case farmer's focus changed from the current season to next season. At this point, he used a feed budget with monthly time periods to quantify his plan through to balance date when pasture growth exceeded feed demand at the end of September. The feed budget was developed by the local extension service. It was used to estimate the likely drying off date given the current state of the farm, pasture cover and cow condition targets for calving and balance date, and the expected pattern of feed supply and feed demand throughout the planning period. The analysis suggested that with his current feed resources, he could dry off on the 20th May. The data confirmed that he was in a good feed position. Pasture growth rate data had originally been obtained from the local university and had been validated through the years. Cow intake data was based on experience and information from the local extension service. The case farmer planned to use 200 (100 t in autumn and 100 t in spring) of the 300 tonnes of maize silage he had on-hand and retain 100 tonnes in reserve.

The case farmer, in conjunction with his consultant, undertook a more detailed feed budget with weekly time periods, in early April. He stated that at this point in time, the planning process was relatively simple because most of his options for the summer-autumn had been used up. The case farmer provided the inputs, events and targets for the plan, along with several scenarios and the consultant entered these into a feed budget spreadsheet and calculated the various outcomes. The case farmer then discussed these with the consultant. The first scenario was to milk all the herd (319 cows) through until drying off. The case farmer then looked at a range of options such as drying off the thin induction and rising three year old cows in early April, selling the 38 culls in early April, and drying off another mob of thin rising three year old cows in late April. By culling and drying off the thin cows, the case farmer could milk the remaining 230 cows for longer. The criteria for selecting amongst these options was that the thin cows must be at target condition score by early to mid June. The cull cows are normally sold at this stage so they were to go anyway. The risk was that the schedule would fall. The analysis showed that the 230 cows could be milked through until the 14th May which was 9 - 10 days longer than if the whole herd had been milked right through. The case farmer decided to adopt his current plan rather than milk the whole herd through. This was because of the risk of not getting the thinner cows back up to target condition score at calving and the likelihood of obtaining a lower price for cull cows if they were milked for longer into the autumn. The plan included the use of 100 tonnes of maize silage in autumn and spring with 100 tonnes in reserve. Two hundred cows were to be grazed off for six weeks, 2250 bales of hay were to be fed over the winter, and 4 tonnes of urea were to be applied in August.

Because the case farmer did not have a computer, he could not update his feed budget as it was implemented. Instead he compared his actual pasture cover levels to the weekly targets in the feed budget and adjusted his management accordingly. He did however, arrange for the consultant to return two weeks before the expected drying off date to revise the feed budget and adjust the plan if required. In early May, the feed budget was revised with the consultant. The only important deviation from the initial plan was that the grazing for the 200 cows for six weeks was re-estimated and reduced to five weeks. This meant that the feed budget showed that the herd would need to be dried off a few days earlier than predicted in the initial plan.

The case farmer undertook limited analyses of alternatives during the formal planning process. The only "what-if" analysis related to whether or not he should sell his culls and dry off the thin heifers in April or at drying off. No financial analysis was undertaken, and because these decisions had limited impact on the drying off date (± 9 - 10 days), the case farmer elected to implement his original plan rather than milk these cows for longer. No other alternatives were investigated such as the use of additional grazing or nitrogen. This is interesting because the case farmer was an opportunity seeker, yet he did not evaluate further opportunities during the formal planning process. Interestingly, the case farmer obtained additional grazing for the 51 dry heifers from a neighbour soon after they were dried off. He made a comment, that he was willing to utilise grazing provided he could obtain it for less than $5.00/cow/week. This was the price at which he thought it was economic to purchase grazing to extend the lactation. This was an historical figure based on previous analysis. The case farmer did not calculate the marginal cost and marginal benefit of additional grazing for his property during year one.

An important point made by the case farmer was that he did not perceive any additional benefits from formal planning over the summer relative to his current planning method. He noted, however, that he would incur additional time costs in terms of the planning process and subsequent associated formal monitoring (2-3 hours per farm walk).

The plan and its implementation

The outcome from each planning process comprised a schedule of events, a set of targets for controlling the implementation of the plan and a set of contingency plans. The schedule of events specified in the case farmer's plan for the study period[2] for year one is summarised in Table 3. The case farmers plan was to milk the cows on the farm at January 1st for as long as possible into the autumn. He stated that the worst cows were culled prior to the start of the summer and that the remaining cows were to be culled on the basis of pregnancy status, somatic cell count and milk production. The case farmer's plan for the summer-autumn was relatively simple. The herd was to be maintained on a 21 -22 day rotation until milk production fell to 1.13 kg MS/cow/day. It was then to be fed the 5.2 ha of forage crop at a level that maintained milk production at, or above 1.04 kg MS/cow/day. Once the forage crop was grazed, the herd was to be fed grass silage (120 tonnes) at a rate that maintained milk production at 1.04 kg MS/cow/day. Additional grass silage was to be fed and the area of pasture reduced so that the rotation could be extended out to a 35 - 42 day round. The forage crop was expected to regrow after grazing and provide another weeks grazing in the middle of the silage feeding with a third possible grazing after this. After the grass silage had been fed, the case farmer planned to cull forty cows and dry off the thin induction and rising three year old cows. He then planned to feed 100 tonnes of the maize silage and then dry off the herd in May.

Table 3. A comparison of the plan to the actual outcome for year one.

The plan	The actual outcome	Reason for deviation
Keep the 323 cows on a 21 - 22 day rotation until Late January or milk production falls to 1.13 kg MS/cow/day.	Pre-forage crop, the rotation ranged between 21 and 24 days, but was around 21 - 22 days just prior to grazing the forage crop.	Some of the paddocks had higher pre-grazing residuals than others which meant the case farmer could keep the herd in some paddocks for half a day longer than others while achieving the same intake and post-grazing residual.
When milk production falls to 1.13 kg MS/cow/day in early February, feed the forage crop for 3 - 4 weeks and maintain milk production at or above 1.04 kg MS/cow/day.	The case farmer began grazing the forage crop on February 1st. Milk production was at 1.17 kg MS/cow/day. The forage crop was grazed from February 1st to 18th. Milk production held at 1.17 - 1.18 kg MS/cow/day.	The case farmer grazed the forage crop earlier than he expected because the forage crop was approaching maturity. With the good growing conditions, the forage crop reached maturity a week earlier than expected. Because pasture growth rates were above average, the case farmer used the forage crop to increase the post-grazing residuals. This meant the herd produced above target during this period and the forage crop did not last the 3 - 4 weeks originally predicted.

[2] The schedule of events comprises those for the period of the study (January 1st - drying off). This schedule of events covers the summer period and the early part of the plan developed at mid March. Events beyond drying off are not incorporated, although this would include the return of the in-calf rising two year heifers to the milking area, the feeding of supplements over the winter and the grazing rotation of the herd over winter.

The plan	The actual outcome	Reason for deviation
Remove the bull in early February.	The bull was removed on the 1st February.	
	Two cows were culled because of lameness.	
Herd test on the 20th February.	The herd test was undertaken on the 20th February.	
	Two culls were identified with high somatic cell counts and dried off.	
When the forage crop is finished, feed grass silage for four weeks and use the grass silage to extend the rotation out to 35 - 42 days while holding milk production at 1.04 kg MS/cow/day.	The grass silage was fed from the 19th February until the 29th February. The forage crop was regrazed from the 1st to 5th March. The silage was then fed again from the 6th March to April 7th. The silage was used to extend the rotation. By the 24th February, the rotation had been extended out to 32 days and it was further extended to 36 days by the 11th March. By the 2 April, the rotation had been extended out to 42 days. While on the grass silage, milk production was held at around 1.06 - 1.07 kg MS/cow/day through much of the period. It declined briefly to 0.96 kg MS/cow/day in mid March.	The farm experienced cold, windy conditions in March, and the case farmer under-estimated the impact of the wind chill effect on the herd's nutritional requirements. As such, milk production fell to 0.96 kg MS/cow/day. The case farmer realised the problem, and increased the level of silage feeding, after which milk production increased to 1.04 - 1.08 kg MS/cow/day.
Regraze the forage crop for a week in late February and then continue to feed the grass silage. A third grazing may be obtained from the forage crop in March.	The forage crop was regrazed from March 1st - 5th. A third grazing was not undertaken.	The forage crop did not regrow as fast as was expected and then turned to seed. This meant it could not be grazed a third time.
Pregnancy test the herd in mid - late March.	The herd was pregnancy tested in late March.	
Sow the new grass in March.	The new grass was sown on March 31st.	
Sell approximately forty cull cows in early April.	The case farmer sold 38 cull cows on the 5th April.	
Herd test in early April	A herd test was undertaken on April 15th.	
Dry off the thin induction and rising three year old cows in early April.	A mob of 24 thin heifers were dried off on April 10th and another mob of 27 on April 23rd.	Twenty seven of the rising three year old cows were above target condition in early April. These were milked until their condition fell to target in late April.
Extend the rotation as the cull and dry cows are removed from the milking platform.	As the cull and dry cows were removed from the milking platform, the case farmer continued to feed the same total amount of silage and extended the rotation length from 42 to 60 days.	
Feed 100 tonnes of maize silage.	One hundred tonnes of maize silage was fed from the 8th April until the case farmer initiated the drying off process on May 6th.	
Production will decline to 0.87 kg MS/cow/day in the last month of lactation and the herd will hold condition on the maize silage.	Milk production declined to 0.96 kg MS/cow/day in mid April but then increased to 1.01 - 1.04 kg MS/cow/day. At drying off the herd was still producing 1.01 kg MS/cow/day and had put on 0.1 condition score units over the last month..	The herd was well fed through April as a result of above average pasture growth rates and the input of maize silage that is high in energy. Production fell in mid April because the farm worker mis-interpreted the case farmer's instructions and gave the herd less area than was specified.
January plan = dry off the herd in May. Feed budget plan = dry off the herd on the 20th, 14th May [3] and 13th[4] May.	The herd was dry by the 13th May. The case farmer began the drying off process on the 6th May.	A revised feed budget in early May suggested the case farmer dry the herd off a few days earlier than the previous feed budget. This was because the case farmer found that he had a week's less grazing than expected for the 200 cows he was to graze off.

[3] The second estimate is for the detailed feed budget undertaken in early April.
[4] This is the date predicted by a revised detailed feed budget in early May.

At the start of January, the case farmer was carrying 323 Friesian, Jersey cross cows that were producing 1.31 kg MS/cow/day and were between condition score 4.5 - 5.0. The herd was consuming around 13.0 - 14.0 kg DM/ha of pasture on a 22 day rotation (4.0 ha/day). The average pasture cover was around 2000 kg DM/ha and 5.2 hectares was planted in Japanese millet which was growing at 100 kg DM/ha/day and had an average yield of 1500 kg DM/ha. There was 120 tonnes of grass silage and 300 tonnes of maize silage on-hand. The case farmer maintained the herd on a 21 - 22 day rotation through January. In some paddocks that had higher pre-grazing residuals, the case farmer obtained an extra half days grazing, but this was compensated for by other paddocks that had less feed in them. Pasture cover declined slowly through January and was measured at 1990 kg DM/ha on the 22nd January and 1974 kg DM/ha on February 8th.

The case farmer began grazing the forage crop with the herd on February 1st when milk production (1.17 kg MS/cow/day) was still above the target of 1.13 kg MS/cow/day. This was because the forage crop (yield = 7000 kg DM/ha) had matured a week earlier than the case farmer had expected as a result of good growing conditions and he had to graze it to prevent quality deteriorating. The forage crop was grazed through until the 18th February, a few days less than the three weeks specified in the original plan. The herd produced at a higher level (1.17 - 1.18 kg MS/cow/day versus 1.04 kg MS/cow/day) than was originally planned because of the good growing conditions. The case farmer took advantage of the good growing conditions by increasing the milk production target to increase the post-grazing residuals. This increased cow intakes and the case farmer hoped to increase pasture growth rates through the higher post-grazing residual. Cow intakes were therefore higher, reducing the time it took the herd to graze the forage crop. On the same date that the forage crop was fed, the case farmer removed the bull from the herd. Two lame cows were culled in early February, reducing the number of milking cows to 321.

Cow condition declined from around 4.75 at the start of January to 4.25 when the herd went onto the forage crop. While on the forage crop, the herd was fed 13 kg DM/cow/day, of which 4.0 kg DM/cow/day came from the forage crop and the remainder from pasture. The level of forage crop in the herd's diet was increased through time to 8.0 kg DM/cow/day with only 4.0 kg DM/cow/day of pasture which allowed the post-grazing residuals to increase. Once the forage crop was grazed, the herd was fed grass silage from the 19th until the 29th February. Milk production fell from 1.17 - 1.18 kg MS/cow day when the herd was on the forage crop, to 1.06 - 1.08 kg MS/cow/day when it went onto grass silage, and then held at this level. Milk production was slightly above target and reflected the good growing conditions. The herd was fed 10.0 - 10.87 kg DM/cow/day of pasture and 2.0 kg DM/cow/day of grass silage. The condition of the herd declined from 4.25 to 4.00 condition score units over February. The herd was herd tested on the 20th February. The case farmer fed additional silage through this period and reduced the area of pasture fed to the herd per day to extend the rotation length out to 32 days by the 24th February. Pasture cover increased slowly through February and was 2000 kg DM/ha on the 11th March. Pasture growth rates for February were estimated at 32 kg DM/ha/day. In late February, two cows were culled due to high somatic cell counts. This reduced the number of milking cows to 319.

The forage crop was regrazed from the 1st to the 5th March. It had gone to seed rapidly and as such, the case farmer did not get a third grazing off it. The case farmer then continued to feed grass silage through until April 7th. The rotation was further extended to 36 days by March 11th. During March, cold, windy conditions created a wind chill effect and the silage ration was insufficient to meet cow requirements. Milk production fell to 0.96 kg MS/cow/day until the case farmer reacted and fed additional silage, after which, milk production increased to 1.06 - 1.08 kg MS/cow/day. Cow intakes were at that stage around 12.0 - 13.0 kg DM/cow/day comprising 8.0 - 9.0 kg DM/cow/day of pasture and 4.0

- 5.0 kg DM/cow/day of silage. The pasture ration was further reduced and the silage ration increased so that the rotation could be extended out to 42 days (2.0 ha/day) in late March. Pasture cover declined from 2000 kg DM/ha on March 11th to 1825 kg DM/ha on April 2nd. During this period, pasture growth was measured at 37 kg DM/ha/day. The new grass was sown on March 31st.

The herd was pregnancy tested in late March, and the case farmer found he had 64 empty cows. This was an empty rate of 20% and much higher than the case farmer expected (8%). This meant the case farmer could not cull on production and would have to milk some cows through the winter on a neighbouring farm and buy-in replacement in-calf cows during the winter. On the 5th April, the case farmer culled 38 cows, the majority of which were empty (38 empty, 2 high somatic cell count, 2 lame). On the 10th April, 24 thin rising three year old cows were dried off at an average condition score of 3.5 condition score units. On the 23rd April, another 27 thin rising three year old cows were culled at an average condition score of 3.75 condition score units reducing the milking herd numbers to 230 cows. With the removal of the thin younger cows, the average condition score of the herd was 4.5 condition score units. The grass silage was finished on April 7th and the case farmer began feeding the maize silage on the 8th April.

The culling and drying off of thin cows allowed the case farmer to further extend the rotation over April from 42 days to 60 days (1.5 ha per day). As cow numbers were reduced, he maintained the total silage ration and reduced the pasture ration and area such that milk production was maintained around 1.04 kg MS/cow/day. The silage ration increased from 4.0 - 5.0 kg DM/cow/day to 6.0 kg DM/cow/day, and the pasture ration has been reduced from 8.0 - 9.0 kg DM/cow/day to 7.0 - 8.0 kg DM/cow/day.

Milk production fell briefly to 0.96 kg MS/cow/day in mid April because the farm worker had mis-interpreted the case farmer's instructions and gave the herd too little area for a few days. This problem was rectified once detected and the production increased to 1.01 - 1.04 kg MS/cow/day for the remainder of April. During April, average pasture cover increased from 1825 kg DM/ha to 2014 kg DM/ha. Pasture growth rates were 44 kg DM/ha/day, 9.0 kg DM/ha/day above average. A herd test was completed on April 15th, but because the case farmer had already made his culling decisions, and this information was not used.

The case farmer milked the 230 cows through until May 6th and then initiated drying off. The herd was dried off a few days earlier than planned because the case farmer found that the available grazing would provide five rather than six weeks feed for 200 cows over the winter. As a result, the feed budget analysis suggested he dry off the herd a few days earlier than planned. The herd was dry by the 13th May. It was still producing 1.01 kg MS/cow/day up until May 6th and was 4.6 condition score units having gained 0.1 condition score units over the previous two weeks. Intakes were rapidly reduced from around 12.0 kg DM/cow/day to 7.0 kg DM/cow/day during the drying off process. Maize silage feeding was stopped and the rotation was extended out from 60 (1.5 ha per day) to 100 days (0.8 ha per day). Despite reduced feeding levels during drying off, average pasture cover declined from 2014 kg DM/ha on May 1st to 1926 kg DM/ha on May 14th. This occurred because pasture growth rates declined dramatically from 44 kg DM/ha/day in April to 18 kg DM/ha/day in the first two weeks of May.

The targets

In order to control the implementation of the plan, the case farmer had a set of targets (Table 4) and associated contingency plans. The targets can be separated into two types, those that act as terminating conditions at the end of the second planning, and those that are used to control the implementation of the plan through time. The terminating conditions act as constraints to the second plan and ensure systems performance is "optimised" during this period. Interestingly, there were no terminating targets for the summer plan. This may be because there was no firm termination date for the summer plan as it appears to merge into the "autumn" plan and the other targets may ensure the system is constrained sufficiently that performance in the second planning period is not affected.

Table 4. Targets specified in the plan that are used in the control process.

Targets	Year 1
Summer	
Milk production	
Pre-forage crop .	
kg MS/cow/day	> 1.13
Forage crop.	
Introduction	
kg MS/cow/day	1.13
Maintenance	
kg MS/cow/day	≥ 1.04
Grass silage	
kg MS/cow/day	≥ 1.04
Rotation length (days)	
Pre-forage crop	21 - 22
Forage crop	21 - 22
Grass silage	35 - 42[5]
Cow intakes	
kg DM/cow/day	≥12.0
Individual cow condition	
condition score units	≥ 3.50
Average herd condition	
Condition score units	NA
Average pasture cover (kg DM/ha)	NA
Post grazing residuals (kg DM/ha)	≥ 1400
Autumn	
Rotation length (days)	
Pre-culling	35 - 42
Post culling & destocking	60
Drying off	100
Thin cows condition score	
Early April	≥ 3.50
Late April	≥ 3.75
Average herd condition	
Calving	4.75[6]
Average pasture cover	
Drying off (May 14th)	2000 kg DM/ha
Maximum winter APC	2300 kg DM/ha
Planned start of calving	2000 kg DM/ha
Balance date (September 30th)	1700 kg DM/ha
Milk production	
MS/cow/day	1.04 kg MS/cow/day

[5] If conditions are dry, the target is only 25 - 28 days.

[6] The target condition score for the herd at planned start of calving was 4.5 condition score units. When the case farmer found he had a high empty rate, he decided to increase this target to 4.75 condition score units to enhance reproductive performance next season.

The case farmer wanted to maintain the average condition of the herd at or above 4.0 condition score units through the summer. However, he relied on the drying off of the thin cows (≤ 3.5 condition score units) rather than reacting to average herd condition score. The terminating conditions for the summer plan were to be to have the herd in a lactating state producing a minimum of 1.04 kg MS/cow/day at an minimum condition of 4.0 condition score units on a minimum rotation length of 35 days.

The second plan terminates at the end of September when pasture growth exceeds feed demand ("balance date") and the terminating condition specified by the case farmer was that the average pasture cover on the farm was at least 1700 kg DM/ha (Table 4). The case farmer did not specify a terminating condition for the average condition of the herd, but he did specify an intermediate condition score target (Table 4) at planned start of calving. The terminating average pasture cover target of 1700 kg DM/ha determines the target average pasture cover at planned start of calving, and at drying off through the feed budget analysis. Similarly, the condition score target at calving determines the condition at drying off. The average pasture cover target of 1700 kg DM/ha at balance date was chosen by the case farmer because he believed that if he had a higher level of pasture cover at this time of year, it would create pasture quality problems. It would also require him to take a lot more feed into the winter, shortening the herd's lactation length. In contrast, if he had a lower level of average pasture cover at balance date (e.g. 1500 kg DM/ha), milk production in early lactation would be depressed due to underfeeding. The herd would lose additional condition over early lactation and this would create problems in terms of reproductive performance, increasing the empty rate and extending the calving spread.

The case farmer had a maximum average pasture cover target over winter of 2300 kg DM/ha. If average pasture cover exceeds this level, shading in the base of the sward occurs and pasture regrowth is reduced post-grazing in the spring. This has the effect of reducing the pasture growth during the second round after calving, and will result in the herd being underfed.

The condition of the herd at planned start of calving is an important determinant of reproductive performance. The case farmer originally planned to calve the herd at an average condition of 4.5 condition score units. However, given his problem with empty cows this season, the case farmer decided to increase this target to 4.75 condition score units.

The case farmer used several targets to control the implementation of his plans through the summer-autumn period. During the summer, the most important target was milk production. This target was used instead of cow intakes because it was easier to measure accurately. In the early summer, the case farmer aimed to feed the herd pasture until milk production fell to 1.13 kg MS/cow/day. When this level of milk production was reached, the case farmer introduced the forage crop. He aimed to hold milk production at or above 1.04 kg MS/cow/day through the summer. His reasons for doing this was because at this level of milk production, the herd began to lose condition. This level of milk production also represented a minimum level of intake the case farmer wanted to achieve through the summer of around 12.0 kg DM/cow/day. At this level of intake, the risk of over-grazing was minimised. The residuals(1400 kg DM/ha) left behind by the herd at this level of production also ensured high rates of pasture regrowth, particularly after rain. The case farmer also stated that there was no point increasing cow intakes much above 12 kg DM/cow/day in late summer because there would be minimal increase in milk production with the majority of the feed being diverted to improve body condition.

The case farmer used the milk production/intake targets in combination with several rotation length targets. In early summer, pre-forage crop, the case farmer aimed to maintain a 21 - 22 day rotation. The objective of this rotation length was to minimise over-grazing and enhance pasture regrowth. Once the herd has been placed on the forage crop, the case farmer aimed to maintain a 21 - 22 day rotation. The effect of feeding the forage crop while on this rotation length was to increase the post-grazing residual left behind the herd during the driest month of February. This enhanced pasture regrowth and minimised over-grazing. When the herd finished the forage crop and went onto grass silage, the case farmer aimed to extend the rotation out to 35 - 42 days whilst maintaining milk production at 1.04 kg MS/cow/day. This improved pasture growth rates and increased average pasture cover. The case farmer aimed for a minimum rotation length of 35 days by early March, but admitted that in a dry year he may not be able to increase the rotation length beyond 25 - 28 days.

During the summer, the case farmer did not have minimum average pasture cover targets. However, he did try to maintain the average condition of the herd at or above 4.0 condition score units. He used the milk production target to ensure the herd was well enough fed through the summer to maintain condition at or above this level. He also used his individual cow condition target to ensure average herd condition remained above 4.0 condition score units.

During autumn, condition score targets became important. The case farmer used targets for his thin induction and rising three year old cows (Table 4). These targets increased with time. The reason for this was that the case farmer did not want to put condition on cows after early June because at this time conditions were cold and feed was limiting. He therefore set his condition score targets on the basis of the time it would take to put one condition score unit on a cow. Thus, in early April, because he had more time to increase cow condition, the target he used to dry off thin cows was 3.5 condition score units. In late April, this target was increased 0.25 condition score units because the case farmer had 15 days less to increase condition score. These targets were designed to protect the condition of the younger and induction cows in the herd and ensure they calved at target in the spring. During year one, the average condition of the older cows was 4.5 condition score units in April. As such, cow condition was not a major concern to the case farmer in relation to drying off. Importantly, he used individual cow condition score targets rather than average herd condition score targets to protect the condition of the herd.

The other important target used during the autumn was average pasture cover. The case farmer used a feed budget to estimated the target average pasture cover and date for drying off. Weekly average pasture cover targets were estimated for the weeks preceding this critical decision point. The case farmer also had target rotation lengths for the autumn. He aimed to extend the rotation out to 35 - 42 days prior to culling. This was increased to 60 days during the period when the farm was destocked through culling and drying off the thin induction and rising three year old cows. Finally, during the drying off process, the case farmer aimed to extend the rotation out to 100 days. His objective was to maintain milk production at 1.04 kg MS/cow/day with intakes of 12 kg DM/cow/day. However, the case farmer noted that milk production can decline through this period to around 0.96 kg MS/cow/day due to the stage of lactation.

The case farmer has monthly total milk production targets which are part of his cashflow budget. He compares his actual production to these targets to see how the season is progressing. However, they have no influence on the decisions made over the summer-autumn.

The control process

The control process used by the case farmer comprised monitoring farm performance, comparing this information to his targets. If a target was met or exceeded, the next activity in the plan was implemented unless conditions deviated from those predicted in the plan. If conditions deviated from those predicted in the plan, a suitable control response was selected. The following section describes the control process used by the case farmer in more detail.

Monitoring

The monitoring process used by the case farmer was a relatively complex process. Some 25 factors were monitored over the summer-autumn, and these can be separated into "*feed*", "*livestock*", "*climatic*" and "*market*" factors (Table 5). The methods by which the various factors are monitored can be classified into two categories: objective or subjective (Table 5). An objective method uses some form of measuring device such as the falling plate meter to measure average pasture cover. A subjective method does not use any form of measuring device, but instead one or more of the case farmer's five senses are used to measure a factor. For example, the case farmer may visually assess the residual dry matter the herd left behind. The subjective methods used by the case farmer can be separated into two types: quantitative and qualitative. A subjective quantitative method is one where the case farmer applies some form of quantitative scale to his visual image of the factor. For example, pasture or condition scoring. A qualitative subjective method does not apply a quantitative scale to the visual image of the factor. The majority of the monitoring methods used by the case farmer were subjective and qualitative in nature. Only milk production, average pasture cover, pasture growth rates, pre- and post-grazing residuals and cow intakes were monitored objectively, and the latter two only occasionally. Several subjective quantitative methods were used and these related primarily to some form of pasture, feed, or condition scoring.

Table 5. Classification of the methods used by the case farmer to monitor the farm over the summer-autumn.[7]

Factor	Early summer		Late summer		Autumn	
	Method	**Classification**	**Method**	**Classification**	**Method**	**Classification**
Feed Factors						
Average pasture cover	Falling plate meter	Objective	Falling plate meter	Objective	Falling plate meter	Objective
	Pasture scoring	Subjective, quantitative	Pasture scoring	Subjective, quantitative	Pasture scoring	Subjective, quantitative
	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative
Pasture growth rates	Falling plate meter	Objective	Falling plate meter	Objective	Falling plate meter	Objective
	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative
Pre- and post-grazing residuals	Falling plate meter	Objective	Falling plate meter	Objective	Falling plate meter	Objective
	Pasture scoring	Subjective, quantitative	Pasture scoring	Subjective, quantitative	Pasture scoring	Subjective, quantitative
	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative

[7] Where more than one method is used for monitoring a particular factor, the more important method from a decision making perspective is placed first.

Factor	Early summer		Late summer		Autumn	
	Method	Classification	Method	Classification	Method	Classification
Pasture quality	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative
Crop yield	Visual assessment	Subjective, quantitative/ qualitative	NA	NA	NA	NA
Crop quality	Visual assessment	Subjective, qualitative	NA	NA	NA	NA
Silage yield	NA	NA	Visual assessment	Subjective, quantitative	Visual assessment	Subjective, qualitative/quantitative
Silage quality	NA	NA	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative
Rotation length	Visual assessment	Subjective, quantitative	Visual assessment	Subjective, quantitative	Visual assessment	Subjective, quantitative
Livestock factors						
Cow numbers	Visual assessment	Subjective, quantitative	Visual assessment	Subjective, quantitative	Visual assessment	Subjective, quantitative
Milk yield	Factory docket	Objective	Factory docket	Objective	Factory docket	Objective
Individual cow milk yield	Herd test	Objective	Herd test	Objective	Herd test	Objective
Average herd condition	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative	Condition scoring	Subjective, quantitative
Individual cow condition	Visual assessment	Subjective, qualitative	Condition scoring	Subjective, quantitative	Condition scoring	Subjective, quantitative
Cow intakes	Pasture scoring Visual assessment Falling plate meter	Subjective, quantitative Subjective, qualitative Objective	Pasture scoring Visual assessment Falling plate meter	Subjective, quantitative Subjective, qualitative Objective	Pasture scoring Visual assessment Falling plate meter	Subjective, quantitative Subjective qualitative Objective
Reproductive status	Visual assessment of behaviour	Subjective, qualitative	Pregnancy testing Visual assessment of behaviour	Subjective, qualitative Subjective, qualitative		
Climatic factors						
Rainfall	Rain gauge	Objective	Rain gauge	Objective	Rain gauge	Objective
Weather forecast	Weather map	Objective	Weather map	Objective	Weather map	Objective
Temperature	Tactile and visual assessment	Subjective, qualitative	Tactile and visual assessment	Subjective, qualitative	Tactile and visual assessment	Subjective, qualitative
Wind run	Tactile and visual assessment	Subjective, qualitative	Tactile and visual assessment	Subjective, qualitative	Tactile and visual assessment	Subjective, qualitative
Cloud cover	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative
Market factors						
Output prices						
Cull cow schedule	Newspaper & stock agent	Subjective, quantitative	Newspaper & stock agent	Subjective, quantitative	Newspaper & stock agent	Subjective, quantitative
In-calf cow store price	Newspaper & stock agent	Subjective, quantitative	Newspaper & stock agent	Subjective, quantitative	Newspaper & stock agent	Subjective, quantitative
Milk price	Dairy company newsletter	Subjective, quantitative	Dairy company newsletter	Subjective, quantitative	Dairy company newsletter	Subjective, quantitative
Input prices						
External feed sources	Newspaper, local farmers	Subjective, quantitative	Newspaper, local farmers	Subjective, quantitative	Newspaper, local farmers	Subjective, quantitative

An interesting point that came out of the study was that the case farmer measures factors indirectly. This process is possible because of the case farmer's detailed knowledge of the cause-effect relationships within his farming system (Figure 1).

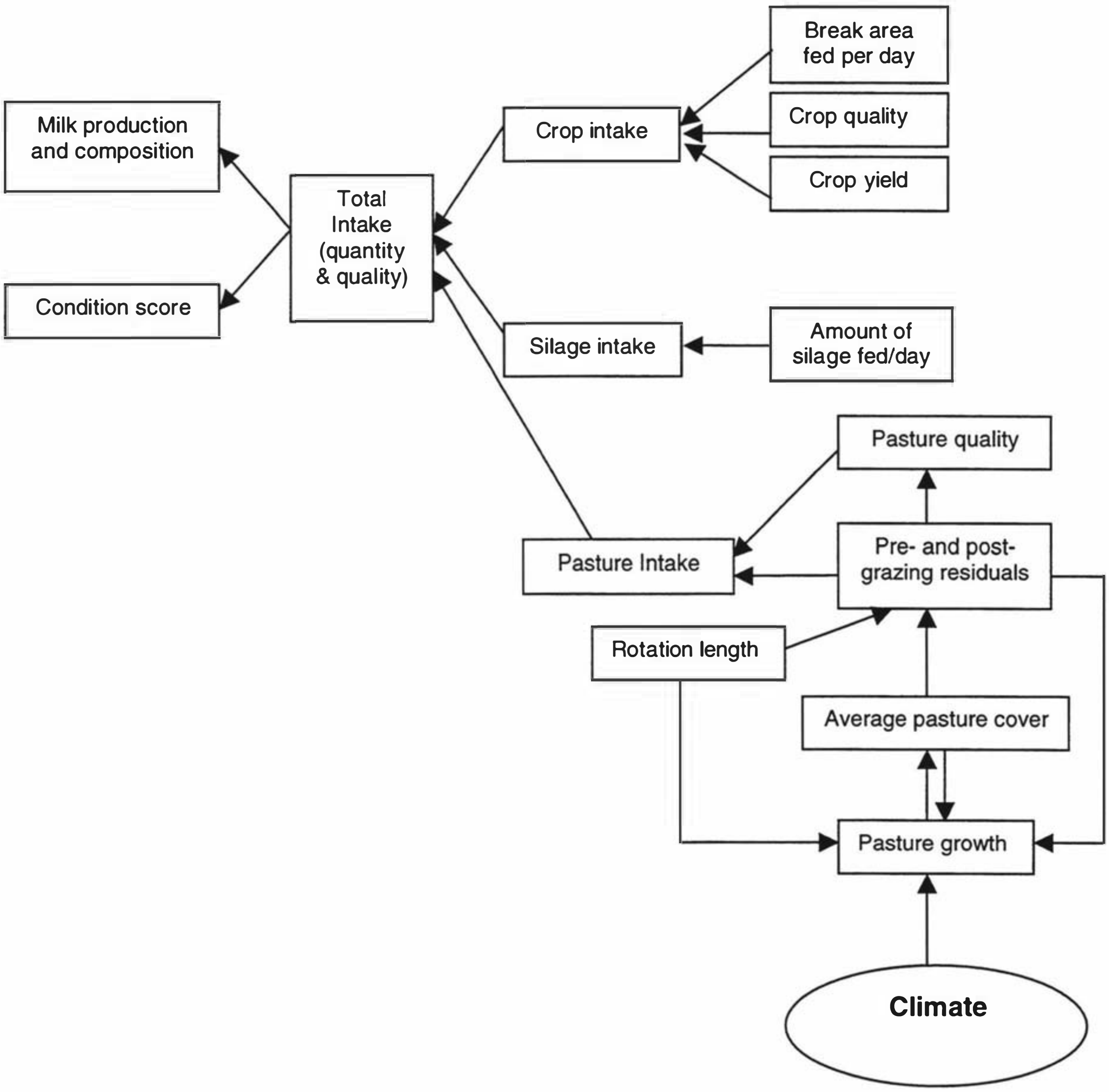

Figure 1. Causal relationships used in the case farmer's monitoring system.

The indirect methods used by the case farmer to measure various factors are summarised in Tables 7 & 8. An example of this process is where the case farmer uses milk production (kilograms of milkfat/cow/day) to indirectly monitor cow intakes, cow condition, average pasture cover and pasture growth rates. Milk production is influenced by the dry matter intake of the herd. The case farmer knows that if milk production is declining, then cow intakes will be declining. The decline in cow intakes will be due to a decline in pre- and post-grazing residuals. Pre- and post-grazing residuals in any particular paddock are a function of pasture growth since the previous grazing. A decline in milk production will also indicate that pasture growth rates are declining. Pre- and post-grazing residuals tend to reflect the average pasture cover on the farm, and if these are declining, then the case farmer knows the average pasture cover is declining. Similarly, the case farmer knows that when milk production falls below a certain point, normally 1.04 kg MS/cow/day, the herd is beginning to lose condition rapidly.

The ability to indirectly measure factors provides the case farmer with the ability to select the most suitable, accurate and efficient methods of monitoring his production system. For example, monitoring average pasture cover over the summer with a falling plate meter is inaccurate due to sward conditions during that period. Therefore, the case farmer uses milk production as an indirect measure because it is accurate, requires little time to monitor and is provided on a daily basis.

The information monitored by the case farmer plays different roles in the control process. The most important role played by the information is in relation to problem recognition or identifying when a deviation from the plan occurs. The case farmer identified problems when an indicator of actual performance fell outside, or approached a target specified in the plan. Key indicators are identified in Table 6. To avoid identifying the wrong problem, the case farmer triangulates these indicators with a range of other indicators. Table 6 shows the factors monitored by the case farmer through the summer-autumn that are used for problem recognition. All these indicators can be classified as leading indicators and are used for concurrent control (Table 6). Few lagging indicators were identified. An example was the pregnancy status of cows within the herd or the empty rate. This information was used to evaluate the case farmer's reproductive management and on the basis of this, refine the subsequent season's reproductive management providing a form of historical control. Other short-term lagging indicators were used to validate short-term feed estimates, e.g. confirm that the case farmer had fed the correct amount of supplement.

Table 6. The role of key indicators in the problem recognition phase of the control process over the summer-autumn period.

Key Indicators	Indicator Type (Leading/lagging)	Role in decision point recognition
Early Summer		
Average milk production (MS/cow/day). Rainfall prior to January 1st.	Leading	Used to predict likely level of milk production in early summer.
Average milk production (MS/cow/day).	Leading	Determines when to feed the forage crop. Determines how much forage crop to feed.
Pre-grazing pasture cover.	Leading	Used to determine when to extend rotation length. Used to indicate whether or not supplements need to be fed and on a daily basis, how much.
Post-grazing residual and cow intakes.	Leading	Indicates when milk production and intakes are about to fall below target and therefore the need to feed supplements or the amount of supplement.
Forage crop maturity .	Leading	May determine initiation of grazing of forage crop.
Forage crop yield.	Leading	Used to assess area required to feed the herd to target.
Average pasture growth rates, post-grazing residual, feed demand. Climatic data.	Leading	Used to predict future pasture growth rates over the next two weeks and the supplements that are likely to be required.
Production index. Somatic cell count. Milking time. Bulling behaviour.	Leading	Used to identify potential culls.
Weather forecast	Leading	Used to predict weather for hay making.
External feed sources	Leading	Used to identify external feed sources that can be introduced into the system.
Late Summer		
Date and/or the quantity of forage crop on-hand.	Leading	Indicates when to feed grass silage
Forage crop yield and quality[8].	Leading	Indicates when to regraze the forage crop.
Pre-grazing pasture cover.	Leading	Used to determine when to extend rotation length. Used to indicate whether or not supplements need to be fed and on a daily basis, how much.
Post-grazing residual and cow intakes.	Leading	Indicates when milk production and intakes are about to fall below target and therefore the need to feed supplements or the amount of supplement.

[8] Only used in year one when the case farmer used a forage crop he could regraze.

Key Indicators	Indicator Type (Leading/lagging)	Role in decision point recognition
Average pasture growth rates, post-grazing residuals, feed demand. Climatic data.	Leading	Used to predict future pasture growth rates over the next two weeks and the supplements that are likely to be required.
Individual cow condition.	Leading	Determines which cows to dry off.
Production index. Somatic cell count. Milking time. Bulling behaviour. Pregnancy status.	Leading	Used to identify potential cull cows.
External feed sources.	Leading	Used to identify external feed sources that can be introduced into the system.
Autumn		
The quantity of grass silage on-hand.	Leading	Indicates when to feed the maize silage.
Average milk production (MS/cow/day).	Leading	Determines how much silage (maize or grass) to feed.
Pre-grazing pasture cover.	Leading	Used to determine when to extend rotation length. Used to indicate whether or not supplements need to be fed and on a daily basis, how much.
Post-grazing residual and cow intakes.	Leading	Indicates when milk production and intakes are about to fall below target and therefore the need to feed supplements or the amount of supplement.
Average pasture growth rates. Climatic data.	Leading	Used to predict future pasture growth rates over the next two weeks and the supplements that are likely to be required.
Date.	Leading	Determines when to sell culls.
Individual cow condition.	Leading	Determine which cows to dry off.
The quantity of maize silage on-hand.	Leading	Used in the assessment of the drying off date.
Average pasture cover.	Leading	Determines drying off date.
Pasture growth.	Leading	Determines drying off date.
Average herd condition.	Leading	Determines drying off date.
External feed sources.	Leading	Used to identify external feed sources that can be introduced into the system.

The importance of the various factors changed with time over the summer-autumn period. The primary indicator used for problem recognition over the early summer was milk production obtained from a dairy factory docket provided to the case farmer on a daily basis. This measure was used because it was objective, accurate, and measured on a daily basis. Alternative measures such as average pasture cover are inaccurate at this time of the year. Cow condition is also difficult to measure because its rate of change is gradual. It is also not normally important at this time of year (the herd is normally in good condition). Milk production is used in effect as an indirect measure of several key variables (average pasture cover, pasture growth, intake and cow condition). The case farmer can use milk production in this manner because of his thorough understanding of cause and effect relationships.

Average pasture cover is not used to identify deviations from the plan over summer because it is too difficult to accurately measure with a falling plate meter at that time of year due to the sward conditions. It also takes several hours to collect average pasture cover data, hence the case farmer only undertakes this process once a fortnight. As such, the data is unsuitable for making day to day feeding decisions. Instead, the case farmer scores the pre-grazing pasture cover level of the next paddock to be grazed and the post-grazing residual of the last paddock the herd has grazed. He then determines if there is enough feed in the paddock for the herd to be fed to target. If there is not enough feed to meet the case farmer's target feeding level, he then initiates supplement feeding, or if it is currently being fed, supplies additional supplement. This process is also used when the case farmer is extending the rotation in late summer, autumn except that in this case he adjusts the grazing area. The case farmer noted that he did monitor trends in average pasture cover over the summer as an indicator of when he was likely to need to feed supplements.

During autumn, the case farmer relied primarily on average pasture cover, pasture growth and cow condition for problem recognition. Milk production was used to identify when cow intakes fell below target, but the case farmer noted that because he feeds maize silage through this period, the supplement "masks" any change in average pasture cover. At the same time, cow condition and average pasture cover were critical factors in ensuring the case farmer's targets for planned start of calving and balance date were met.

An important aspect of problem recognition is to ensure that any deviation from the plan is accurately measured. The case farmer used many of the factors he monitored to triangulate the measures he used for problem recognition (Tables 7 & 8). To do this, he used his knowledge of cause and effect relationships within the system (Figure 1). For example, he knew that climate drove pasture growth, which in turn, affected average pasture cover. Average pasture cover in turn influenced pre- and post grazing residuals and therefore cow intakes. Cow intake in turn influences the level of milk production and changes in body condition. Using this chain of cause and effect relationships, the case farmer can (i) predict effects further along the chain, and (ii) use effects that occur later in the chain to confirm changes in antecedent factors. The other important factor the case farmer knew was that changes in some factors along the causal chain are more quickly identified than others. For example, the measurement of a change in average pasture cover or average pasture growth rates using a falling plate meter had a monitoring interval of two weeks. Similarly, the identification of a change in herd condition may take up to a week to identify visually. The case farmer knew that the measurement of intakes, pre-and post-grazing residuals, and milk production would provide an indication of any change in pasture growth or average pasture cover before it could be measured objectively with the falling plate meter. Similarly, milk production was used to indicate when cow condition was changing.

Table 7. A summary of the direct and indirect measures used by the case farmer over early summer.

Factor	**Measurement Method**			**Fre-quency**	**Role**	**Classification of Role**[9]
Production Factors	**Direct Method**	**Indirect Method**				
Feed Factors[10]		**Indicator**	**Method**			
Average pasture cover (APC)	Falling plate meter			Fort-nightly	Used to verify changes in other measures	**Triangulation**
	Visual assessment			Daily	Used to verify changes in other measures	**Early warning**
	Pre- and post grazing residuals[11]			Daily	Used to indicate change in APC	**Early warning**
		Milk production	Milk docket	Daily	Used to indicate a change in APC	**Short-term predictor**
		Cow condition	Condition scoring	Daily	Used to confirm change in APC	**Confirmatory**
		Climate	Rain gauge, visual assessment	Daily	)Used to predict likely)change in APC over the)next fortnight	**Longer-term predictor**
		& Pasture growth data	Falling plate meter	Fort-nightly	)	

[9] This shows the measures used for decision point and triangulation, and the role of the indirect measures in relation to the direct measures (predictive, early warning, confirmatory).

[10] The falling plate meter was only used over the early summer in year one.

[11] The case farmer visually scores these and calculates the mean. As these are normally the shortest and longest paddocks on the farm, they provide an estimate of APC.

Factor	Measurement Method			Fre-quency	Role	Classification of Role[9]
Production Factors	**Direct Method**	**Indirect Method**				
Pasture growth	Falling plate meter			Fort-nightly	Used to verify changes in other measures and predict pasture growth over the next two weeks	**Triangulation Longer-term predictor**
	Visual assessment			Daily	Used to confirm changes in other measures	**Early warning**
		Pre- and post-grazing residuals	Pasture scoring and visual assessment	Intermit-tent	Used to indicate changes in pasture growth rates	**Short-term predictor**
		Milk production	Milk docket	Daily	Indicates a change in pasture growth	**Short-term predictor**
		Intake	Pasture scoring	Daily	Indicates change in pasture growth rates	**Short-term predictor**
		Cow condition	Condition scoring	Daily	Confirms change in pasture growth	**Confirmatory**
		Climate	Rain gauge Visual assessment	Daily	Predicts increase in pasture growth within two weeks	**Longer-term predictor**
Pasture quality	Visual assessment			Daily	Used to identify problems with pasture quality	**Decision point recognition**
		Milk production	Milk docket	Daily	Used to confirm change in pasture quality	**Confirmatory**
Crop yield	Yield score & visual assessment			Daily	Used to estimate the number of weeks grazing for the herd	**Decision point recognition**
		Milk production	Milk docket	Daily	Used to confirm break size is adequate and yield estimate is correct	**Confirmatory**
Crop growth	Yield score & visual assessment			Daily	Used to verify other measures and determine when to graze along with maturity information	**Triangulation Decision point recognition**
Crop quality and maturity	Visual assessment			Daily	Used to determine when crop maturity is reached	**Decision point recognition**
Silage quantity & quality[12]	Yield scoring & visual assessment			Daily	Used for planning purposes and decisions in relation to supplements	**Planning Decision point recognition**
		Milk production	Milk docket	Daily	Used to confirm estimates of silage yield and quality	**Confirmatory**
Livestock factors						
Cow numbers	Visual assessment				Used to predict feed demand	**Long-term predictor**
Average milk yield	Milk docket (l/cow/day)			Daily	Used to identify when cow intakes and/or condition fall below target	**Decision point recognition**
		Intake	Pasture scoring	When it changes	Used to indicate change in milk production	**Short-term predictor**
		Post-grazing residual	Visual assessment	Daily	Used to indicate change in milk production	**Short-term predictor**
Individual cow milk yields	Herd test			Twice	)Used to identify potential)culls	**Decision point recognition**
Average milk quality	Milk docket (fat/protein)			Daily	Used to verify feed quality assessment	**Confirmatory**
	Bulk count (somatic cell)			Daily	Used to identify milk quality problem	**Decision point recognition**
Individual cow milk quality	Fat/protein Somatic cell count			Once (Herd test)	Used to identify potential culls	**Decision point recognition**
Average herd condition	Condition scoring			Daily	Used to identify when condition was approaching target	**Decision point recognition**
	Visual assessment			Daily	Used to identify when condition was approaching target	**Early warning**
		Milk production	Milk docket	Daily	Used to indicate when the herd is losing condition	**Short-term predictor**
Individual cow condition	Condition scoring			Daily	Used to identify cows that are below target condition	**Decision point recognition**

[12] Includes both pasture and maize silage.

Factor	Measurement Method			Fre-quency	Role	Classification of Role[9]
Production Factors	**Direct Method**	**Indirect Method**				
Intake	Pasture scoring			When it changes	Used to identify when intakes fall below target and to verify other measures	**Decision point recognition Triangulation**
	Visual assessment			Daily	Indicates change in intake	**Early warning**
		Post-grazing residual	Pasture scoring	Daily	)Used to indicate a)change in intake	**Short-term predictor**
			Visual assessment	Daily	)Used to predict cow)intakes in 3 – 4 weeks	**Long-term predictor**
		Milk production	Milk docket	Daily	Used to verify intake estimates and indicate change in intake	**Confirmatory Short-term predictor**
		Cow condition	Condition scoring	Daily	Used to confirm change in intake	**Confirmatory**
		Pasture growth data	Falling plate meter	Fort-nightly	Used to predict likely intakes in two weeks time	**Longer-term predictor**
		Climatic data	Rain gauge Visual assessment	Daily	Used with pasture growth rate data to predict intakes in two weeks time	**Longer-term predictor**
Per hectare feed demand (kg DM/ha/day)[13]	Pasture scoring Falling plate meter			When it changed	Used to predict future feed deficits	**Longer-term predictor**
Reproductive status of the herd	Pregnancy test			Once	)Used to identify)potential culls and late)calving cows	**Decision point recognition**
		Bulling behaviour	Visual assessment	Daily		
External Environment Factors						
Climatic factors						
Climate Wind run) Temperature) Cloud cover) Rainfall) Weather forecast)	Rain gauge Visual assessment			Daily	Used to predict changes in average pasture cover, pasture growth and cow intakes two weeks in advance	**Longer-term predictor**
Market factors						
Output Price Factors						
Cull cow schedule	Newspaper & stock agent			Intermit-tent	Used for selling decisions	**Decision point recognition**
In-calf cow store price	Newspaper & stock agent			Intermit-tent	Used for selling decisions	**Decision point recognition**
Milk price	Dairy company newsletter			Monthly	Used in option selection decisions	
Input Price Factors						
External feed sources	Newspaper, local farmers			Intermit-tent	Used to identify feed sources to fill feed deficits or extend lactation	**Decision point recognition**

[13] This figure was calculated by multiplying cow intake by stocking rate.

Table 8. Important factors monitored by the case farmer over the autumn[14].

Factor	Measurement Method			Frequency	Role	Classification of Role[15]
Production Factors	**Direct Method**	**Indirect Method**				
Feed factors		**Indicator**	**Method**			
Average pasture cover	Falling plate meter			Fortnightly	Used to identify when APC fell below targets.	**Decision point recognition**
		Milk production	Milk docket	Daily	Used to indicate a change in APC	**Short-term predictor**
		Pre- and post-grazing residuals	Pasture scoring	Daily	Used to indicate a change in APC	**Short-term predictor**
Pasture growth rate	Falling plate meter[16]			Fortnightly	Used in the drying off decision	**Decision point recognition**
Silage quantity & quality[17]	Yield scoring & visual assessment			Daily	Used for planning purposes and decisions in relation to supplements	**Planning Decision point recognition**
		Milk production	Milk docket	Daily	Used to confirm estimates of silage yield and quality	**Confirmatory**
Livestock factors						
Cow numbers	Visual assessment				Used to predict feed demand	**Long-term predictor**
Average milk yield	Milk docket (l/cow/day)			Daily	Used to identify when cow intakes and/or condition fall below target	**Decision point recognition**
		Intake	Pasture scoring	When it changes	Used to indicate change in milk production	**Short-term predictor**
		Post-grazing residual	Visual assessment	Daily	Used to indicate change in milk production	**Short-term predictor**
Individual cow milk yields	Herd test			Twice	)Used to identify)potential culls	**Decision point recognition**
		Milking time	Visual assessment	Daily		
Average herd condition	Condition scoring			Daily	Used to identify when condition was approaching target	**Decision point recognition**
	Visual assessment			Daily	Used to identify when condition was approaching target	**Early warning**
		Milk production	Milk docket	Daily	Used to indicate when the herd is losing condition	**Short-term predictor**
		Post-grazing residuals	Visual assessment	Daily	Indicates change in cow condition	**Short-term predictor**
Individual cow condition	Condition scoring			Daily	Used to identify cows that are below target condition	**Decision point recognition**
Intake	Pasture scoring			When it changes	Used to identify when intakes fall below target and to verify other measures	**Decision point recognition Triangulation**
	Visual assessment			Daily	Indicates change in intake	**Early warning**
		Post-grazing residual	Pasture scoring	Daily	)Used to indicate a)change in intake)Used to predict cow)intakes in 3 – 4 weeks	**Short-term predictor Long-term predictor Confirmatory**
			Visual assessment	Daily	Used to verify intake estimates and indicate change in intake	**Short-term predictor Confirmatory**
		Milk production	Milk docket	Daily	Used to confirm change in intake	**Longer-term predictor**
		Cow condition		Daily		

[14] Subjective, qualitative measures used in late summer were also used in the autumn, but are not repeated in this figure to avoid too much repetition.
[15] This shows the role of the direct measures in the control process (Planning, problem recognition, triangulation), and the role of the indirect measures in relation to the direct measures (predictive, early warning, confirmatory).
[16] Uses ungrazed paddocks to calculate pasture growth rates.
[17] Includes both pasture and maize silage.

Factor	Measurement Method			Frequency	Role	Classification of Role[15]
Production Factors	**Direct Method**	**Indirect Method**				
		Pasture growth data Climatic data	Condition scoring Falling plate meter Rain gauge Visual assessment	Fort-nightly Daily	Used to predict likely intakes in two weeks time Used with pasture growth rate data to predict intakes in two weeks time	**Longer-term predictor**
External Environment Factors						
Climatic Factors						
Climate Wind run) Temperature) Cloud cover) Rainfall) Weather forecast)	Rain gauge Visual assessment			Daily	Used to predict changes in average pasture cover, pasture growth and cow intakes two weeks in advance	**Longer-term predictor**
Market Factors						
Output Price Factors						
Cull cow schedule	Newspaper & stock agent			Intermit-tent	Used for selling decisions	**Decision point recognition**
In-calf cow store price	Newspaper & stock agent			Intermit-tent	Used for selling decisions	**Decision point recognition**
Milk price	Dairy company newsletter			Monthly	Used in option selection decisions	
Input Price Factors						
External feed sources	Newspaper, local farmers			Intermit-tent	Used to identify feed sources to fill feed deficits or extend lactation	**Decision point recognition**

The case farmer, used three methods to triangulated the measures used in his monitoring system (Tables 7 & 8). Firstly, direct, subjective and qualitative measures were used to identify a change in a factor before it was monitored more formally, a form of "*early warning*" (Tables 7 & 8). For example, the case farmer would visually identify a change in average pasture cover before he monitored it using the falling plate meter. Second, the case farmer would monitor an indirect measure of the factor of interest and then use his knowledge of cause and effect relationships to predict the value of the factor of interest at the next monitoring, a "short-term predictor" (Tables 7 & 8). For example, the case farmer measured intake and used this to predict subsequent milk production and cow condition.

The third means by which problem recognition indicators were triangulated was through the use of other "*confirmatory*" measures (Tables 7 & 8). These measures were used to confirm the veracity of other measures used by the case farmer. For example, during the summer, the case farmer used pasture scoring and post-grazing residuals to subjectively assess cow intakes. To confirm the veracity of these two measures, the case farmer used milk production per cow per day and changes in cow condition. This process ensured the case farmer employed accurate information for problem recognition. This process also tested the veracity of the case farmer's monitoring system and his mental model of the production system. Central to this process is the role of objective measurement. With the case farmer using so many subjective measures, it is important that these are calibrated to ensure accuracy. It appears that case farmer employed the objective measures of milk production and average pasture cover to calibrate his subjective measures.

The case farmer used climate data and average pasture growth rate date to predict pasture growth rates two weeks in advance. This forecast was also used to estimate likely changes in average pasture cover and cow intakes. It provided the case farmer with an indication of the likely level of supplement feeding required by the herd in the following two weeks. The case farmer also used the level of milk production at January 1st and amount of rainfall received prior to this date to predict the level of milk production in early summer. Thus, some factors provided a "longer-term" prediction of the future state of the farm.

The information collected by the case farmer was also used for planning. Information was collected at the start of summer to assess the feasibility of his “typical” plan. He collected information in late summer and throughout the autumn for planning purposes. This included the average pasture cover and level of supplement on hand, pasture growth rate trends, and average herd condition (Tables 7 & 8). This information was used to develop feed plans for the period from mid March through to balance date. The case farmer also used information for diagnosis, but few examples of this were identified during the study. The most comprehensive example, the high empty rate, showed that the case farmer drew on a wide range of information to diagnose the likely cause of the problem. This included: the condition of the herd and sub-groups within the herd at calving and mating, the milk production and feeding levels of the herd in early lactation, the performance of the three artificial breeding technicians, the submission and conception rates of the herd, trace element usage, bull fertility, the types of cows that were empty, the number of cows cycling before mating, and his own heat detection capability.

An important use for much of the information collected by the case farmer was for determining which contingency plan to implement. The choice of a contingency plan depended on the conditions at the time. Table 9 shows the range of information used for contingency plan selection. Of particular interest in relation to the information that is monitored by the case farmer, is the fact that virtually all the information is internal in nature. Limited external information is used in the control of the production system over the summer-autumn. The case farmer noted that financial and cull cow price information was irrelevant to the summer-autumn tactical management. The case farmer was however, actively seeking external sources of feed, particularly grazing.

Table 9. Information collected through the monitoring process that is used to determine option selection.

Contingency Plan	Factors used in option selection[18]
Feed forage crop (amount and timing).	Milk production. Rate of forage crop growth. Forage crop maturity. Forage crop previously grazed. Physiological state - non-reproductive, reproductive. Grass silage state (available and unused, being fed, finished).
Feed grass silage (amount and timing).	Forage crop state (ungrazed, being grazed, finished, rate of growth, maturity, suitable yield and maturity for regrazing). Milk production. Grass silage state (available and unused, being fed, finished). Rotation length. Pre-grazing pasture cover level. Climatic conditions (cool, windy).

[18] Includes the problem recognition indicator.

Contingency Plan	Factors used in option selection[19]
Feed maize silage (amount and timing).	Grass silage state (available and unused, being fed, finished). Maize silage state (available and unused, being fed, finished). Culling date. Date thin cows dried off. Rotation length.
Harvest forage crop.	Crop maturity. Feed conditions.
Extend rotation.	Current rotation length. Milk production. Silage availability. Pre-grazing pasture cover level. Culling date. Date thin cows dried off. Type of summer (wet, dry).
Terminate grass silage feeding.	Grass silage state (being fed, finished). Forage crop state (ready for second grazing).
Terminate maize silage feeding.	Maize silage state (available and unused, being fed, finished). Amount used. Initiation of drying off decision.
Cull cows.	Date. Post-pregnancy testing.
Dry off individual cows.	Date. Individual cow condition.
Dry off the herd.	Average pasture cover. Average herd condition. Pasture growth rates.

Weather forecasts information played a limited role in his control system and was used mainly for day-to-day decisions such as hay making decisions. Otherwise, it was too unpredictable to be useful for tactical decision making. The case farmer monitored external factors, primarily to identify opportunities in relation to outside feed sources. The information the case farmer collected comprised the type, quality, quantity and cost of various feed sources along with their proximity to the farm.

Frequency of monitoring

Analysis of Tables 7 & 8 show that the majority of the measures used by the case farmer are monitored on a daily basis. Other than one-off measures such as herd and pregnancy testing, the other measures were monitored up to a maximum of a fortnightly interval. For example, average pasture cover and pasture growth rates were monitored at fortnightly intervals and cow intakes were monitored when a change occurred such as milk production declining, or the introduction or removal of a supplement (Figure 2).

IF milk production per cow changes,
OR a supplement is added to, or removed from the herd's diet,
THEN monitor cow intakes.

Figure 2. Decision rule used by Farmer B to activate the monitoring of cow intake.

Although the case farmer monitored a wide range of information, much of this was monitored subconsciously or at a pre-attentive level. For example, if the author asked the case farmer about a particular piece of information that fell into a specific category, he could recall it and place a value on the measure. However, the case farmer would often

[19] Includes the problem recognition indicator.

state that he was not consciously or actively monitoring that factor. The evidence suggested that the case farmer had decision rules (Figure 3) that determined when particular factors had to be monitored. Normally, the monitoring of a factor changed when some threshold was exceeded or there was some change in the factor. For example, the case farmer only actively monitored cow intakes when some change occurred such as the feeding of supplements or a change in milk production or post-grazing residuals. In relation to thresholds, the case farmer began formally monitoring the condition of the herd when it fell to 4.0 condition score units in early March. He stopped formally monitoring the condition of the herd when it improved to 4.5 condition score units after the thin rising three year old cows had been dried off in late April. Alternatively, the decision to actively monitor a factor may be triggered by another measure that the case farmer used to indirectly monitor the factor. For example, the case farmer stated that he would begin formally monitoring cow condition if milk production fell below 1.04 kg MS/cow/day, or it declined at a rate of 0.061 kg MS/cow/day. This information indicated to the case farmer that the herd was losing condition. These rules had developed through time as the case farmer learnt what factors needed to be monitored at particular points in time and under particular conditions to ensure his goals were met. They minimised the effort the case farmer had to put into the monitoring process at any one point in time. There was little evidence of the case farmer increasing the frequency of monitoring at key times of the year. Exceptions were average pasture cover and pasture growth rates, which were monitored on a monthly basis prior to the start of the summer. However, at the start of the summer period, the case farmer increased the monitoring frequency to fortnightly. However, this information was only used to help confirm his other measures and was not used for decision making.

IF the condition of the herd is ≤ 4.0 condition score units,
AND it is March,
THEN begin monitoring cow condition formally.

IF milk production is < 1.04 kg MS/cow/day,
OR milk production declines at ≥ 0.061 kg MS/cow/day,
THEN begin formally monitoring condition score.

IF the condition of the herd is ≥ 4.5 condition score units,
AND it is late lactation,
AND the thin cows rising three year old cows have been dried off,
AND the herd is being fed to target,
THEN cease monitoring cow condition formally.

Figure 3. Examples of decision rules used by the farmer to initiate or terminate the active monitoring of a particular factor.

The case farmer also used historical information to initiate the monitoring of particular paddocks. For example, he knew which paddocks had heavy treading damage during the winter and which were in old pastures. These factors can effect the rate of regrowth on these paddocks, and the case farmer monitored them prior to their next grazing to assess whether the herd would need additional feed when grazing these paddocks. In this manner, the case farmer used grouping rules to place paddocks with similar characteristics into the same group. The case farmer also differentiated between the rising three year old cows and the older cows. This was because the younger cows can not compete with the older cows and tend to lose condition. The case farmer monitors the condition of this group and takes action (dries them off) to ensure they reach target condition by next calving.

Recording and data processing

The case farmer used a relatively simple recording system. Milk production data provided by the company was stored in a folder. The case farmer uses a computer program "Dairyman" to record his herd records in relation to milk production and reproductive performance. This information could be retrieved and analysed to identify potential culls and to rank individual cows. The bulk of his information was stored either in a large farm diary or the case farmer's memory. In the diary, the case farmer recorded information in relation to key event (sale of culls, date crop fed, drying off), pasture cover and pasture growth rate data, mating information and rainfall data. The diary acted as a historical record of the season and could be referred back to for diagnostic or evaluation purposes, or to check what had been done in previous seasons. As with the recording, limited processing was undertaken by the case farmer on the data he collected. Most of the data required no processing. The case farmer calculated means to estimate milk production per cow and average pasture cover. Pasture growth rates, cow intakes, and per hectare feed demand were also calculated. More advanced processing was used for predicting pasture growth rates and cow intakes two weeks ahead.

Control responses and their selection

Examples of the three types of control were found during the study of the case farmer in year one. By far the most common type of control used by the case farmer was concurrent control. The case farmer had a large number of contingency plans which he implemented should a deviation from the plan occur. Some examples of preventative control were found. For example, the case farmer uses a preventative animal health programme and grows forage crops and harvests silage to provide feed during a period when pasture growth is highly variable. Some examples of historical control were also identified. The case farmer increased his average herd condition score target for planned start of calving from 4.5 to 4.75 condition score units because his reproductive performance was poor in the current season and he decided increasing cow condition at the next calving would enhance performance.

A range of control responses were used by the case farmer during year one (Appendix XVII, Volume II). The primary control response was the use of contingency plans to minimise the impact of a deviation from the plan. The case farmer also changed his condition score target at planned start of calving to enhance reproductive performance. The case farmer also changed his basic autumn plan to cope with deviations from the norm when a 20% empty rate was identified. During year one, the case farmer however, did not change his goals in response to a deviation from the plan.

Contingency plans

The contingency plans used by the case farmer (Appendix XVII, Volume II) can be classified under four headings in relation to their impact on feed supply and feed demand (Table 10). The case farmer mentioned five options for increasing feed supply: feed forage crop early, increase the silage ration, feed grass silage before the forage crop, reduce the rotation length target, and use winter grazing to extend the lactation. Only two of these options were implemented: feeding forage crop early, and increasing the silage ration. Feed supply could be reduced by harvesting the forage crop as silage, but this option was not used. The only options the case farmer mentioned for increasing feed demand was to increase the milk production target, and hence cow intakes while on the forage crop and extending the lactation. Only the former was implemented. Feed demand was reduced through activating options such as drying off thin cows, culling, and drying off earlier than planned. Only the latter option was implemented in year one.

Table 10. The case farmer's contingency plans.

Category	Option
Increase feed supply	Feed forage crop early Increase silage ration Feed silage before the forage crop[20] Reduce rotation length target[20] Use winter grazing to extend the lactation[20]
Decrease feed supply	Harvest forage crop as silage[20]
Increase feed demand	Increase milk production target in order to increase cow intakes while on the forage crop Extend lactation[20]
Decrease feed demand	Dry off the thin cows earlier than planned[20] Cull earlier than planned[20] Dry off the herd earlier than planned

Although the contingency plans can fit under these four quadrants, the primary purpose of some of these contingency plans was not to influence feed supply or feed demand. For example, several contingency plans were used to either maintain milk production or protect cow condition. Supplements were fed to ensure the herd produced around 1.04 kg MS/cow/day over most of the summer, target intakes were met, condition was maintained above 4.0 condition score units and post-grazing residuals were maintained at a high level. Similarly, the decision to dry off thin rising three year old cows was designed to protect the condition of the herd.

Contingency plan selection

The selection of a contingency plan is triggered when a key indicator crosses the target threshold (Figure 4) set by the case farmer (Appendix XVII, Volume II). The process the farmer used to select the most appropriate contingency plan to minimise the impact of the deviation can best be represented by decision rules. The decision rules take the form of an "IF" statement that specifies the conditions that indicate a problem exists, then normally several "AND" and/or "OR" statements that specify important characteristics that define the problem situation, followed by a "THEN" statement which specifies the contingency plan that should be instigated. The problem situation characteristics are important, because they are used to distinguish between alternative courses of action in most instances. In other words, the problem situation characteristics are matched to a problem solution.

IF milk production is ≤ 1.13 kg MS/cow/day,	) Indicates a problem exists.
AND the forage crop is not mature and growing actively,	) Specifies the characteristics that define
AND surplus grass silage is available,	) the problem situation.
THEN begin feed the silage at a level that	) Specifies the contingency plan that
maintains milk production at or above	) should be implemented to match the
1.04 kg MS/cow/day until the forage crop is ready.	) the characteristics of the problem situation.

Figure 4. The structure of a contingency plan selection decision rule.

Factors used in option selection are summarised in Table 9.

[20] Mentioned by case farmer, but not used.

Changing intermediate targets

The case farmer made two changes to intermediate targets in year one. One was a form of concurrent control, while the other was a form of historical control. In February, he increased the milk production target while the herd were on the forage crop to take advantage of the good growing conditions. This allowed him to increase both cow intakes and post-grazing residuals. The aim was to improve pasture growth rates through the higher post-grazing residuals. The case farmer also changed the condition score target at calving. This change was made because he had identified a 20% empty rate when the herd was pregnancy tested in late March. Although the case farmer and veterinarian could not identify the cause of the high empty rate, the case farmer decided to increase his condition score target at calving to enhance reproductive performance and minimise the chances of a repeat of this season's poor reproductive performance.

Changing plans

A more significant control response is the changing of a plan. During year one, the case farmer made some changes to his plan because 20% of the herd were empty. These changes were mainly outside the scope of the study period and related to ensuring the case farmer had the correct number of cows on-hand for the next season. In this instance, the case farmer wintered 15 empty cows on a neighbouring town milk farm. These cows were milked through the winter, then returned to the farm the following spring. The case farmer also had to buy in additional cows because of the high number of empty cows he had to sell. Within the study period, the main impact of the high empty rate was on the case farmer's culling decision. He had planned to cull 40 cows in early April, and had expected that 26 of these would be empty. Instead, he culled 38 cows and all except 4 were empty.

Diagnosis, evaluation and learning

The most interesting point to come out of the study in relation to evaluation was that the case farmer rarely consciously defined or diagnosed the reason for a short-term deviation from the plan (problem) (Table 11). He used indicators to identify feed problems (in most cases a feed deficit), and then implemented an option from his set of contingency plans without undertaking any form of conscious problem definition or diagnosis. Problem definition may not be an issue because at this time of the year, the primary problem the case farmer expects to face is a feed deficit.

Table 11. The evaluations carried out by the case farmer.

Category and instance	Initiated by	Method of evaluation	Criteria	Criteria met	Diagnosis undertaken	Unusual Situations
Monitoring systems						
Calibrate pasture scoring against falling plate measures	On-going	Comparison	Match	± 50 kg DM/ha	No	No
Calibrate condition scoring	On-going	Comparison	Match	Yes	No	No
Calibrate average pasture cover, intake and pre- and post-grazing residuals against milk production date	On-going	Comparison	Match	Yes	No	No

Category and instance	Initiated by	Method of evaluation	Criteria	Criteria met	Diagnosis undertaken	Unusual Situations
Choice of targets						
Condition score at calving	High empty rate	Comparison of empty rate of heifers to rest of herd	Match	Yes	Yes	Yes
Use of inputs						
The timing of feeding Japanese millet	Utilisation of Japanese millet at grazing	Comparison to expectations	Match	No	No	Yes
The use of maize silage	Several weeks feeding of maize silage	Comparison of herd performance to expectations	Match	Yes	No	Yes
Level of supplement feeding	On-going	Compare actual milk production to expectations	Match	Yes No	No Yes	No Yes
Management practices						
Selling 38 culls	The decision	Comparison of actual and expected increase in average pasture cover	Match	Yes	No	No
Dry off thin rising three year old cows	The decision	Comparison of actual and expected increase in average pasture cover. Estimation of the impact of the decision on the condition of the thin cows at calving.	Match	Yes	No	No
Systems performance						
Reproductive performance	Identification of 20% empty rate	Comparison to expectations	8% empty rate	No	Yes	Yes
Milk production in mid March	Production fell below target	Comparison to target	1.04 kg MS/cow/day	No	Yes	Yes
Milk production in mid April	Production fell below target	Comparison to target	1.04 kg MS/cow/day	No	Yes	No
Pasture growth rates in May	Fall in average pasture cover despite drying off	Comparison to expectations	Expected average pasture cover to hold or increase	No	Yes	No
Overall plan						
Autumn plan	On-going process	Re-evaluated likely drying off date	Comparison of inputs and predicted drying off date	No	No	No
Planning assumptions						
Assess the validity of the pasture growth rate assumptions	On-going evaluation	Comparison of actual to expected	Match, given conditions	Yes	No	Second year on the farm

The holistic nature of his monitoring system also verifies the existence of a feed problem, making the need for diagnosis redundant. For example, before the case farmer's primary indicator, milk production, has indicated a feed problem, he knows from climatic data that the season has become drier. He will also identify a decline in intakes, pre- and post-grazing residuals, and milk production before the threshold is reached.

Diagnosis was primarily used where the case farmer's expectations or targets were not met and in extreme situations that were beyond the experience of the case farmer. For example, the case farmer undertook a detailed diagnosis of the reasons for his high empty rate. The case farmer had expected an empty rate of 8 %, but the actual rate was 20%. Although limited data was obtained on the diagnosis process used by the case farmer, the evidence suggested that he used his knowledge of cause and effect relationships to develop hypotheses about possible causes and then tested these by obtaining values for the attributes of interest. The factors reviewed by the case farmer included: condition score at calving and mating, milk production and nutrition in early lactation, the number of cows cycling before mating, the effectiveness of the AB technicians, the case farmer's heat detection capability, the fertility of the bull, the types of cows that were empty and trace element deficiencies. Despite a detailed diagnostic process, neither the case farmer nor the veterinarian could identify the cause of the high empty rate.

The other diagnoses undertaken by the case farmer were relatively minor in comparison to the empty rate. The case farmer identified that the herd was being underfed in mid April because milk production was 0.09 kg MS/cow/day below what the case farmer thought they should be producing. The cause of the problem was quickly identified by the case farmer. He found that the farm worker had not implemented his grazing instructions correctly, and had given the herd less area than the case farmer had specified. The case farmer also thought that the farm should have grown more grass in early May because he had reduced feed demand and extended the rotation length during the drying off process. However, the case farmer could not explain this discrepancy. The case farmer also found that milk production fell below expectations in March. This occurred because the farm experienced unusual climatic conditions, high wind run and cool temperatures that created a wind chill effect on the herd. Intake was insufficient to meet cow requirements under these conditions and milk production fell. The case farmer diagnosed this as the reason for the decline in milk production. In the other instances of evaluation, the outcomes either met the expectations of the case farmer, and he had no need to undertake a diagnosis, or if the outcome did not meet his expectations, the case farmer already knew the reason for the discrepancy from his monitoring of the situation. For example, the case farmer realised he had grazed the forage crop a week too late because quality and utilisation were not as high as expected. However, the case farmer knew that the forage crop had been growing extremely rapidly and that he should have grazed it earlier. The remaining evaluations undertaken by the case farmer met his farmer's expectations.

The evaluations undertaken by the case farmer can be classified into seven categories: monitoring system, choice of targets, use of physical inputs, management practices, systems performance, overall plan, and planning assumptions (Table 11). During the study, the case farmer evaluated the accuracy of his monitoring system. He used a consultant and the veterinarian to calibrate his estimates of average herd condition. He also used his objective pasture cover data to calibrate his pasture scoring which he used to estimate cow intakes, and pre- and post-grazing residuals. Finally, milk production data was used to calibrate his estimates of average pasture cover, cow intakes and pre- and post-grazing residuals. This form of evaluation was on-going and used to ensure the accuracy of the case farmer's monitoring system.

The case farmer evaluated his choice of targets in relation to cow condition at calving. This action was initiated after he found that 20% of the herd was empty. He evaluated whether condition at calving could have contributed to the problem, but found no data to support this. However, he decided to increase the condition score target for the herd at calving to enhance reproductive performance. This appears to be a form of risk management.

The case farmer used two inputs that he had no previous experience with, Japanese millet and maize silage. The case farmer sought information from other farmers that had used both these inputs to help with his management. He evaluated the date at which he initiated grazing of the forage crop and decided on the basis of the utilisation of the crop that he could have grazed it a week earlier, i.e. it had become too long to utilise efficiently. He attributed the problem to the rapid growth of the crop due to good growing conditions. He thought that under normal conditions, the date of grazing would have been correct. The case farmer also evaluated the use of the maize silage against his expectations. He believed that the supplement would maintain the body condition of the herd over late lactation. He found that it met his expectations. In relation to inputs, the case farmer also constantly evaluated whether he was feeding the correct amount of supplement to the herd. He did this by comparing actual milk production to target. In most cases this was correct, or minor modifications were made to feeding levels. However, in two instances milk production fell below target. In one instance this was due to abnormal cool windy conditions, and in the other, the farm worker failed to implement the case farmer's grazing plan correctly.

During year one, the case farmer only evaluated two management practices. These related to his decisions to sell the culls in early April, and to dry off the thin rising three year old cows in mid and late April. The evaluations were relatively simple. The case farmer compared the actual outcome to his expectations in terms of impact on average pasture cover. The case farmer also compared a projection of the likely condition of the thin cows if he had, and had not dried them off at that point.

Four examples of systems performance evaluation were identified: reproductive performance, milk production in mid March and mid April, and pasture growth rates in early May. These were all triggered when the case farmer found performance to be below his expectations. These examples been discussed above under diagnoses.

The case farmer also evaluated his formal plan with a consultant, a month after its implementation. In effect, he reassessed the input variables and re-estimated the predicted drying off date. Although the drying off date predicted by the new plan was different from the original plan, the difference was small, and the reason for the deviation was known to the case farmer.

The final area evaluated by the case farmer was in relation to his planning assumptions. He informally evaluated his pasture growth rate assumptions over the summer, and also did this more formally during the winter months.

A range of factors initiated the evaluation process. In some instances, it was because the outcome deviated from some standard or target. In other cases, there were extreme, or a rapid changes in conditions. Alternatively, the case farmer initiated the evaluation after the decision had been implemented and the outcome of the decision was known. Finally, some evaluations were undertaken on an on-going basis, such as those used to ensure the accuracy of the case farmer's monitoring system.

The means by which the case farmer evaluated each of the six areas could be classified into two main areas. The simplest method was to compare the outcome to some target, standard, norm or ideal, and the criteria used to evaluate the decision or factor was the degree of match between the two. If the criteria were not met, and the case farmer did not know the reason for the deviation, then diagnosis was undertaken. The second approach, an ex-poste evaluation, was to undertake an historical simulation of what would have happened if the decision of interest had not been made, or a different decision had been made, and compare this to the actual outcome. The criteria used to evaluate the decision of interest was whether the outcome was better than the alternative. This was normally measured in terms of feed on hand, or cow condition. In these cases no diagnosis was undertaken because the case farmer had a full understanding of the situation.

Learning

One of the products of the evaluation process is learning. Limited examples of learning were identified during year one (Table 12). Primarily, the learning the case farmer mentioned related to the use of two supplements he had no previous experience with, a forage crop, Japanese millet, and a supplement, maize silage, and the effect of abnormal climatic conditions on milk production in March. The case farmer had done some research before adopting two new inputs (Japanese millet and maize silage), and had drawn on local farmer knowledge. The Japanese millet performed as expected except that under the good growing conditions over the summer, it grew faster than the case farmer had expected. This meant that he grazed it when it was too tall and had problems with utilisation. He learnt that in such years, he should graze it about a week earlier. The case farmer also learnt that Japanese millet goes to seed quite rapidly after the first grazing. He had expected to obtain two additional grazings off the forage crop, but only obtained one. The learning undertaken by the case farmer in this instance could be classified as input use and environment interaction.

The case farmer also confirmed that maize silage is a suitable supplement for maintaining the condition of the herd in late lactation. The learning undertaken in this instance can be classified under input use and production systems. The final area of learning identified in year one related to a period of extreme weather in March. The case farmer learnt that conditions over summer could be cool and windy enough to create a wind chill effect. This increased the maintenance requirements of the herd and caused a decline in milk production. Once the case farmer had identified the cause of the problem, he responded by increasing cow intakes through feeding additional silage. This area of learning could be classified under environment-production system interaction, and input use.

Table 12. Instances of learning undertaken by the case farmer.

Instances of learning	Areas of learning	Outcome of learning
Year one		
The case farmer learnt about the use of Japanese millet as a forage crop. He also learnt that the utilisation of the forage crop was a function of height, and that he had to graze it before it became too tall. He learnt that in seasons where growing conditions were good, the forage crop would reach a grazeable height earlier than in a normal season.	Input use, environment.	The case farmer learnt that the utilisation of Japanese millet declined as crop height increased. He learnt that in a good growing season, the forage crop reached a suitable height more quickly. He also learnt that the forage crop could turn to seed quite quickly after its first grazing.
The case farmer learnt that maize silage did maintain the condition of the herd in late lactation.	Production system, input use.	The case farmer confirmed that maize silage was a suitable supplement for use in late lactation where he wanted a feed that would maintain the condition of the herd.
The case farmer also learnt that conditions could become cool and windy enough in March to create a wind chill effect, increasing the maintenance requirements of the herd.	Production system, input use, environment.	The case farmer learnt that a wind chill effect was possible over summer, and that if it was experienced, he had to increase the feed intake of the herd to ensure target milk production was met.

The outcome from the learning process depended on the learning areas. In most cases, the information was added to the case farmer's general understanding of the production system. In other cases it resulted in a change in the case farmer's decision rules in relation to contingency plan selection (e.g. timing of forage crop feeding in good growing seasons, or the use of additional supplements in cool, windy summers). In the case of the maize silage, its use was confirmed, and this reinforced the case farmer's planning rules for its use in late lactation.

Appendix XXIV. Farmer B – Summary of Year Two

Description of year two

Prior to the first of January, the farm had experienced a very wet spring. For example, rainfall in December was 200 mm compared to 70 mm the previous year. Conditions were such that peak milk production was only 1.39 kg MS/cow/day and the condition of the herd declined from 4.75 condition score units at calving to around 3.8 condition score units at mating. The cool, wet conditions also limited the amount of supplements that were made on the farm. As such, the farm was in a poor state in terms of feed and cow condition at the start of the summer period (Table 1). Average pasture cover was around 300 kg DM/ha lower than the previous year, and the case farmer had 37.5% less grass silage, 46% less hay, and no maize silage on-hand (300 tonnes in year one). He also had 38.5% less area in forage crop and because 4.0 hectares was in maize for maize silage, he also had 2.0 ha less area in pasture. The 4.0 ha of maize would however, supply him with 300 wet tonnes of maize silage, equivalent to what he had in the stack at the start of the year one summer. However, unlike year one, the case farmer planned to use the maize silage solely in the spring, rather than use a proportion in the autumn. Although cow numbers were similar to year one (320 versus 323 cows), the case farmer had decided to retain 84 replacement calves on the farm over the summer-autumn. These animals were grazed off in year one. The condition of the herd was much lower in year two (4.1 versus 4.75 condition score units, as was milk production (1.04 versus 1.31 kg MS/cow/day).

Table 1. Comparison of years one and two[21].

Factor	Year 2	Year 1
January 1st		
Area	94	94
Average pasture cover (Kg DM/ha)	1700	2000
Cow condition	4.1	4.5 - 5.0
Milk production (kg MS/cow/day)	1.04	1.31
Cow intake (kg DM/cow/day)	12.0	14.0
Cow numbers	320	323
Forage crop area (ha)	3.2	5.2
Maize silage crop area (ha)	4.0	0
Grass silage (wet tonnes)	75	120
Maize silage (wet tonnes)	0[22]	300
Hay (bales)	1210	2250[23]
Rotation length (days)	23 - 24	21 - 22
Calf numbers	84	0
February 1st		
Average pasture cover (Kg DM/ha)	1600	1980
Cow condition	3.8	4.4
Milk production (kg MS/cow/day)	1.04	1.17 - 1.18
Cow intakes (kg DM/cow/day)	12.0	13.0
Cow numbers	320	323
Rotation length (days)	23 - 24	21 - 22
Calf numbers	84	0

[21] Because data could not always be collected on the first of the month, these figures are extrapolated from the data.
[22] The case farmer later purchased 420 wet tonnes of maize silage off the neighbour in April.
[23] Purchased in January.

Factor	Year 2	Year 1
March 1st		
Average pasture cover (Kg DM/ha)	1530	1990
Cow condition	3.8	4.0
Milk production (kg MS/cow/day)	0.96 - 1.04	1.06 - 1.08
Cow intakes (kg DM/cow/day)	11.0	12.5
Cow numbers	270	319
Rotation length (days)	23 - 24	32
Periods when the forage crop was fed	28th January to 8th March	1 - 18th February 1 - 5th March
Area (ha)	3.2	5.2
Yield/ha (kgDM/ha)	10,000	7,000[24] 3,500[25]
Periods when grass silage fed	10 - 27th January	19 - 29th February 6th March to 7th April
Amount fed (wet tonnes)	75	120
Date urea applied	5th March	NA
Amount applied (tonnes)	4.0	0
April 1st		
Average pasture cover (Kg DM/ha)	1480	1840
Cow condition	4.2	4.0
Milk production (kg MS/cow/day)	0.99 - 1.01	1.06 - 1.08
Cow intakes (kg DM/cow/day)	11.0	12
Cow numbers	242	319
Rotation length (days)	23 - 24	42
Period of Maize silage feeding	NA	8th April to 5th May
Amount (wet tonnes)	0	100
Period of green feed maize feeding	11th April to 5th May	NA
Amount (wet tonnes)	125	0
Period cut grass fed	6 - 20th May	NA
Amount fed (kg DM)	10,000	0
May 1st		
Average pasture cover (Kg DM/ha)	1650	2014
Cow condition	4.6	4.5
Milk production (kg MS/cow/day)	1.01 - 1.08	1.01 - 1.04
Cow intakes (kg DM/cow/day)	15.0	14.0
Cow numbers	233	230
Rotation length (days)	30 - 34 [26]	60
Drying off date	26th May	13th May
Cow numbers at drying off	172	230
Milk production (kg MS/cow/day)	1.01 - 1.04	1.01
Condition score	5.0	4.6
Average pasture cover (Kg DM/ha)	1800	1926
Date herd on once-a-day	20th May	6th May
Rotation length at drying off (days)	100	100
Winter supplements		
Nitrogen planned for early spring	9.4 tonnes DAP[27]	4.0 tonnes of urea
Winter grazing	7 - 8 weeks for the herd	6 weeks for 200 cows
Maize silage on-hand (wet tonnes)	420[28]	200
Hay on hand (bales)	1100[29]	2250

[24] At first grazing.
[25] At second grazing.
[26] The rotation was extended out to 50 days as culls and thinner cows were dried off and removed from the property in early May.
[27] When the additional maize silage was bought-in, this was removed from the plan because it was not needed.
[28] Only 220 wet tonnes was planned to be fed over early spring, with 200 wet tonnes kept in reserve.
[29] About 110 bales fed out during drying off.

The month of January was dry and windy with the farm only receiving 32 mm of rain, which was less than half that received in the previous year. The conditions resulted in poor pasture growth rates and this was reflected in the lower average pasture cover (1600 versus 1980 kg DM/ha), intakes (12.0 versus 13.0 kg DM/cow/day), milk production (1.04 versus 1.17 - 1.18 kg MS/cow/day), and cow condition (3.8 versus 4.4 condition score units) at the start of February. It was also reflected in the supplement feeding where in year two, the case farmer had fed all his grass silage and a portion of his forage crop (12.5%) by the end of January. In contrast, neither of these had been used by this date in year one.

February was also dry and the farm received 39 mm of rain (53 mm in year one) compared to the average of 86 mm. Pasture growth rates were estimated at 25 kg DM/ha/day for February (32 kg DM/ha/day in year one). These were reflected in the lower average pasture cover (1530 versus 1990 kg DM/ha), intakes (11.0 versus 12.5 kg DM/cow/day), milk production (0.96 - 1.04 versus 1.06 - 1.08), cow condition (3.8 versus 4.0 condition score units), rotation lengths (23 - 24 versus 32 days), and cow numbers (270 versus 319 cows) at the end of February.

The farm received 72 mm of rain through March compared to 113 mm in year one. Pasture growth rates were estimated at 25 kg DM/ha/day (36 kg DM/cow/day in year one) compared to the average of 36 kg DM/cow/day. The difference between pasture growth rates in year two and year one is mainly reflected in the rotation length (23 - 24 versus 42 days) and cow numbers (242 versus 319 cows) at April 1st. Average pasture cover (1480 versus 1840 kg DM/ha), and cow intakes (11.0 versus 13.0 kg DM/cow/day) are also lower. However cow condition was higher (4.2 versus 4.0 condition score units) because the case farmer had dried off 90[30] thin cows between January 1st and April 1st.

Conditions through April were fairly typical, with pasture growth rates of 30 kg DM/ha/day (44 DM/ha/day in year one). The case farmer attributed his high pasture growth rates in year one to his high average pasture cover (1840 - 2014 kg DM/ha) and long rotation (42 - 60 days). In contrast, average pasture cover was lower (1480 - 1650 kg DM/ha) and the rotation length was shorter (23 - 34 days) in year two. However, because the case farmer had less cows on-hand at the start of April (242 versus 319) he was able to feed them better through most of April in year two (15.0 versus 14.0 kg DM/cow/day). However, the lower average pasture cover through this period prevented the case farmer from extending the rotation to the extent that was undertaken in year one (23 to 34 days versus 42 to 60 days).

The only month in year one in which pasture growth rates were higher in year two than year one was May (25 versus 18 kg DM/ha/day). This partly explains why the case farmer dried off the herd later in year two (26th versus 13th May). However, the case farmer had to dry off the herd because of grazing commitments[31] rather than feed constraints in year two. Theoretically, given his feed situation, he could have milked through until June 10th. The difference is also explained by the amount of winter supplements (Table 1) the case farmer had available for the two years. Although he planned to use a similar amount of nitrogen in both years, he had 1150 less bales of hay on-hand in year two. However, this was more than compensated for by the extra grazing (8 weeks for the herd versus 6 weeks for 200 cows) and maize silage (420 versus 200 wet tonnes) he had available.

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[30] Note: 17 in-milk lease cows were returned to the case farmer on March 9th because the farmer leasing them did not have the feed to continue to milk them.

[31] The herd had to be dried off because the case farmer had contracted eight weeks grazing from the ehnd of May.

Overall, the case farmer started the year two season in a much worse state in terms of average pasture cover, supplements on-hand, cow condition and milk production than in year one. This problem was further compounded when all the months through the summer-autumn period with the exception of May, produced less pasture growth than in year one. The only positive aspect of the season was that the case farmer went into the winter with more supplements than year one and the condition of the herd was slightly better.

Planning horizons

The planning horizons used in year two were the same as specified in year one. On March 13th, the case farmer undertook a gross feed budget to determine his likely drying off date. As in year one, the case farmer used shorter planning horizons of approximately two to four weeks duration. These included such activities as the pre-grass silage period, the period during which the herd was fed the grass silage, and so on. During autumn, five important events were involved, the first encompassed a continuation of the feeding of pasture after the forage crop, which was then followed by a period when the farmer fed the herd greenfeed maize bought off a neighbour. In early May, the culls were sold, and another mob of thin cows dried off. After the greenfeed maize was fed, the herd were fed cut grass purchased from another neighbour, and then the herd was dried off over a six day period.

The case farmer sometimes thought in terms of intermediate targets between the two extremes mentioned above. For example, in early January, his main focus was to ensure he did not graze the forage crop until the end of January. This planning horizon encompassed two activities, the maintenance of the herd on a purely pasture diet, followed by a period of three weeks in which the herd was supplemented with grass silage. The selection of this planning horizon was goal-driven. The case farmer knew that to optimise the use of his forage crop he had to delay grazing it until the end of January. Given his poor feed position at the start of January, he had to tailor his plan to achieving this. The case farmer was also planning out to the end of February, the point to which he wanted his forage crop to last. The reason for this was that if he could use the crop to ensure the maximum number of cows were in a lactating state at this point, he had a greater chance of taking advantage of the autumn rains. Similarly, in early March, the case farmer was planning through to early April. His concern at that point was that if pasture growth rates did not improve and/or he could not generate additional feed through some other means, he might have to dry off the herd in early April.

Values, and goals

The values and goals used by the case farmer over the summer-autumn in year two were the same as those in year one. In year two, the case farmer decided to run his replacement heifer calves on the milking area to ensure they were well grown out. His goal was to grow them as fast as possible through the summer. He used target liveweight profiles as a guide to how fast they should be growing.

Planning process

As in year one, the case farmer used a qualitative planning process for the first planning period, and then changed to a quantitative planning process for the second planning period. The same informal planning process was used in year two as in year one.

However, due to the poor state of the farm at the start of summer, and the case farmer's belief that pasture growth rates would be below average over summer due to the current dry conditions, the simulation (mental feed budget) suggested the "typical" plan would not be feasible. The case farmer then used an iterative process to modify and test various "modified" plans to develop a feasible plan for the summer. The heuristics (sequencing, activation and termination, input level and type and target selection) in the "typical" plan were modified to ensure the case farmer's summer goals were met. These included decisions on summer stocking rate, the sequencing of silage and forage crop use, and the selection of milk production targets. These heuristics are summarised in Table 2.

The case farmer also had to modify his "typical" plan in response to other changes. These were due to learning or historical control, strategic decisions and factors that occurred in the preceeding spring. The case farmer had evaluated his decision to use Japanese millet in year one and decided to replace it with a brassica (Emerald rape). This meant the forage crop would not be regrazed. The case farmer had also evaluated his decision to graze his young stock off the milking area and had decided not to do this in year two. As such, they had to be incorporated into the plan. During the previous spring, the 100 tonnes of maize silage in reserve had been used to counter the very wet, cold conditions. The case farmer had hoped to use this over the autumn and as such had to remove this option from his "typical" plan. The case farmer also made a strategic decision to plant 4.0 ha of maize silage for the following year.

Table 2. Planning rules used by the case farmer for the summer plan in year two.

Planned event	Decision rule	Reasons behind the rules
Set stock the calves across the entire farm over the summer-autumn. **Activation rule** **Input type and level rule**	IF calves are run on the milking area, AND it is summer, THEN setstock the calves over the entire farm.	To ensure high rates of liveweight gain, the calves were setstocked across the entire farm. Setstocking ensures high intakes and minimises stress.
Select summer stocking rate **Input type and level rule**	Select the stocking rate at which the herd can be fed such that production can be maintained at, or above 1.04 kg MS/cow/day through until mid March. Assess the average pasture cover, climatic conditions, pasture growth rates and supplements on-hand, around late December. Estimate the likely forage crop yield. From this decide on the number of cows that can be taken through the summer.	The case farmer wants to take as many cows as possible through the summer to take advantage of the autumn rains. He believes that the most efficient use of feed is to run enough cows to produce at 1.04 kg MS/cow/day. Cull cows are sold prior to the start of the summer period.
Maintain the herd on a 23 - 24 day rotation feeding solely pasture until three weeks before the end of the month.. **Sequencing rule** **Input type and level rule**	IF average pasture cover and expected pasture growth rates are insufficient to maintain the herd at target milk production until the end of January, AND grass silage is available, AND grass silage is insufficient to fully feed the herd until the end of January, AND no other supplements are available, THEN maintain the herd on their current rotation length allowing milk production to fall below target and begin feeding the silage at the point when it can be used to feed the herd to target until the end of January.	IF the case farmer used a faster rotation, the herd the farm would be in a worse position at the start of the next round because average pasture cover would have been reduced more quickly. Extending the rotation would reduce cow intakes and post-grazing residuals. Low post-grazing residuals limit pasture growth rates. The case farmer preferred to feed grass silage later rather than earlier, because if he fed it early, and then ran out, the drop in cow intakes and milk production would be much more dramatic than that which would occur if he delayed the silage feeding. The other risk of feeding the grass silage early is that the case farmer may have been tempted to then feed the forage crop early when the grass silage ran out.

Planned event	Decision rule	Reasons behind the rules
During this period, allow milk production to fall below 1.04 kg MS/cow/day. **Target setting rule** **Input type and level rule**	IF average pasture cover and expected pasture growth rates are insufficient to maintain the herd at target milk production until the end of January, AND grass silage is available, AND grass silage is insufficient to fully feed the herd until the end of January, AND no other supplements are available, THEN ignore the milk production target for the period when the herd is grazing solely pasture and draw on cow condition as an alternative supplement.	In a dry year, the case farmer knows he cannot feed the herd to target. Therefore, he uses cow condition as another form of supplement to ensure he can carry as many lactating cows as possible through the summer.
Feed grass silage before the forage crop. **Sequencing rule** Feed grass silage at the point when it can be used to feed the herd to target until the end of January. **Activation rule** **Input type and level rule**	IF average pasture cover and expected pasture growth rates are insufficient to maintain the herd at target milk production until the end of January, AND grass silage is available, AND grass silage is insufficient to fully feed the herd until the end of January, AND no other supplements are available, THEN maintain the herd on their current rotation length allowing milk production to fall below target and begin feeding the silage at the point when it can be used to feed the herd to target until the end of January.	The case farmer feeds grass silage in January before the forage crop in a dry year because the forage crop is still actively growing at this point in time whereas the grass silage yield will not change with time. Therefore the grass silage is fed to optimise the dry matter yield from the forage crop. The case farmer still wants to maintain milk production above 1.04 kg MS/cow/day when feeding supplements in order to minimise loss of body condition.
While feeding silage and the forage crop, maintain the herd on a 23 - 24 day rotation unless the feed situation improves. **Input type and level rule**	IF grass silage is being fed prior to the forage crop, AND conditions are dry, AND the current rotation length is 23 - 24 days, AND supplement is limited, AND post-grazing residuals are at, or below target, Then maintain the rotation length at 23 - 24 days until feed conditions improve.	The case farmer did not have sufficient feed on hand to extend the rotation while maintaining post-grazing residuals and cow intakes at target. If post-grazing residuals were reduced, then pasture regrowth would be inhibited. Any reduction in cow intakes would reduce milk production and cow condition.
Feed the forage crop at the end of January after the grass silage at a level that maintains milk production at 1.04 kg MS/cow/day. **Sequencing rule** **Activation rule** **Input type and level rule**	Feed the forage crop in late January, early February IF the grass silage has been fed, AND it is a dry year, AND it is late January, THEN feed the forage crop at such a rate that milk production is held at 1.04 kg MS/cow/day.	At this point in time, the case farmer has optimised yield given his other constraint that he must have the forage crop grazed by the end of the month to ensure the new grass is planted at the correct time. The forage crop is used to maintain milk production at target and ensure the post-grazing residual is maintained above a minimum level. This prevents over-grazing, increases pasture growth rates and ensures pastures respond quickly to rain. The forage crop allows the case farmer to increase post-grazing residuals.
In a dry year make the forage crop last until the end of February, and reduce cow numbers if necessary to maintain milk production at 1.04 kg MS/cow/day. **Termination rule**	IF it is a dry year, AND a forage crop is available, AND the grass silage has been used, AND the level of other supplement on the farm is limited, THEN ensure the forage crop lasts for the month of January and dry off cows to ensure milk production is held around 1.04 kg MS/cow/day.	IF the forage crop was fed at a faster rate, the case farmer believed that it would be used more quickly and then when it was finished there would be little feed available for the herd. The alternative approach forces the case farmer to dry off cows to ensure milk production is maintained at 1.04 kg MS/cow/day. As such, it increases the likelihood of having a proportion of the herd in a lactating state at the end of February.

Planned event	Decision rule	Reasons behind the rules
Input type and level rule		The milk production target ensures higher post-grazing residuals and therefore higher pasture growth rates. At this level of milk production, intakes are sufficient to limit the rate at which the herd loses condition.
Remove the bull in early February. **Termination rule**	IF date = early February, THEN remove the bull	The case farmer allows the bull to remain with the herd for a specified period to ensure later cycling cows are mated.
Dry off thin cows if there is insufficient feed to maintain milk production at 1.04 kg MS/cow/day. **Termination rule**	IF intakes are predicted to fall below target, AND it is a dry year, AND the herd is grazing the forage crop, AND no additional supplement is available, AND the condition of the herd is < 4.0, THEN dry off sufficient thin cows to ensure the remaining cows are fed to target, and graze them off the milking area.	If the case farmer did not dry off the thin cows through February, the forage crop would be used more quickly, and when it was finished there would be no further supplements with which to augment the herd's diet. In this situation, the case farmer would have to dry off the herd. As such, he would not have cows in a lactating state in March/April to take advantage of the autumn rains.
Complete the grazing of the forage crop by the end of February. **Termination rule**	Terminate forage crop grazing by the end of February.	To ensure the new grass is well established, it must be planted by mid March. Therefore, the forage crop must be grazed off by the end of February to allow time for cultivation and sowing.
Maintain the herd on a 23 -24 day rotation after the forage crop unless the feed situation improves. **Sequencing rule** **Input type and level rule**	IF average pasture cover is low, AND supplements are unavailable, THEN maintain rotation length at 23 - 24 days until the feed position improves.	The case farmer needs some form of supplement or high average pasture covers so that he can extend the rotation without reducing cow intakes and post-grazing residuals. In a dry year, with limited supplements, this is not possible until the autumn rains arrive and pasture growth rates increase rapidly.
Dry off thin cows if there is insufficient feed to maintain milk production at 1.04 kg MS/cow/day and graze them off the farm. **Termination rule**	IF intakes are predicted to fall below target, AND it is a dry year, AND the herd is grazing the forage crop, AND no additional supplement is available, AND the condition of the herd is < 4.0, THEN dry off sufficient thin cows to ensure the remaining cows are fed to target, and graze them off the milking area.	This practice achieves three end points. First, it removes thin cows from the herd so that their condition can be improved in time for calving. Second, it ensures the lactating cows are fed to target, minimising the loss of condition. Third, it ensures higher post-grazing residual's are maintained, which in turn results in higher pasture growth rates.
Pregnancy test the herd 6 - 8 weeks after the bull is removed (Normally mid - late March). **Sequencing rule** **Activation rule**	IF the bull is removed on date = X, THEN pregnancy test the herd 6 - 8 weeks after this date.	To accurately diagnose pregnancy status, the herd should not be examined for at least six weeks after the bull has been removed.
Sell cull cows in early April after pregnancy diagnosis. **Sequencing rule** **Termination rule**	Sell the cull cows after pregnancy diagnosis IF it is early April, AND the cull cows have been identified. THEN sell the cull cows.	The case farmer does not want to cull in-calf cows, so he delays culling until he knows exactly which cows are in-calf. The case farmer stated that culling is a form of supplement, and by culling, he can increase the feed supply to the rest of the herd.
Dry off the herd. Date unknown, but is very dependent on pasture growth over the summer-autumn and the acquisition of other feed sources. **Sequencing rule** **Termination rule**	Dry off the herd after all other options are exhausted. Dry off the herd on the date estimated through the feed budget analysis.	The herd is dried off to ensure sufficient average pasture cover is on-hand to meet targets at calving and at balance date. The drying off date is also used to ensure the herd calve at target condition score.

The case farmer also used a process that allowed him to predict likely cow intakes three to four weeks in advance which assisted with his prediction of a dry year. When he shifted the herd, he measured his post-grazing residual. He then took into account the recent weather, particularly rainfall, and his latest estimate for pasture growth rates to predict likely pasture growth rates over the period until the paddock was grazed again. In this case the herd was on a 23 - 24 day rotation. From this, the case farmer estimated the pre-grazing pasture cover on the paddock, estimated the likely residual at the next grazing, and calculated the average intake for the herd from the paddock. This information would provide the case farmer with an estimate of the proportion of the herd's diet, he was likely to obtain from pasture at the next grazing. By undertaking this exercise at regular intervals, the case farmer was continually predicting the likely proportion of the diet that his pasture feed source would provide in three to four weeks time or longer as the rotation was extended. This information was used to assess whether, with the current level of average pasture cover (and hence the resultant post-grazing residuals) and likely pasture growth rates, there would be sufficient feed to feed the herd solely on pasture through January. The case farmer's estimates suggested that even with the 75 tonnes of wet silage, the herd was unlikely to be fed to target through January.

During early to mid March, the case farmer's focus changed from the current season to next season. On march 13th, as in year one, he used a feed budget to quantify his plan from the March through to balance date when pasture growth exceeded feed demand at the end of September. It was used to estimate the likely drying off date given the current state of the farm, pasture cover and cow condition targets for calving and balance date, and the expected pattern of feed supply and feed demand throughout the planning period. The analysis suggested that with his current feed resources, he could dry off the herd on June 10th. The data confirmed that he was in a good feed position relative to the number of cows he was milking (242 cows versus 319 cows in year one). The case farmer used average pasture growth rates in his plan. Cow intake data was based on experience and information from the local extension service. The case farmer planned to graze the herd off the farm for eight weeks and feed 1200 bales of hay over the winter. He then planned to apply 20 units per hectare of nitrogen in the form of diammonium phosphate in early August and feed out a proportion of the maize silage harvested from the 4.0 hectare maize crop in early lactation. However, the case farmer thought that given current conditions, the feed budget was optimistic and he doubted the herd would actually milk through until June 10th.

The gross feed budget was re-evaluated on April 27th and confirmed the expected drying off date was still the 10th June. The case farmer did not incorporate additional maize silage (120 wet tonnes) he had purchased in April into the plan. This was retained as a buffer should another wet spring occur. However, this revised feed budget showed that the case farmer's previous belief that the farm would not grow sufficient grass to dry off on June 10th was correct because he had purchased and fed approximately 24000 kg DM of green feed maize during April, and had another 13500 kg DM to feed that was not in the plan. This was equivalent to increasing pasture growth rates by 7 kg DM/ha/day over March and April. The case farmer had also incorporated cut grass from the neighbours into the revised plan that was not in the original plan. This was equivalent to increasing pasture growth rates by 2 kg DM/ha/day over March and April. Therefore, the additional feed inputs had the equivalent effect of increasing pasture growth rates by 9 kg DM/ha/day over March and April. Analysis of the pasture growth rate data for March and April shows that pasture growth rates in March were only 25 kg DM/ha/day compared to the average of 37 kg DM/ha/day, and those in April were 28 kg DM/ha/day compared to an average of 35 kg DM/ha/day. Over the two months, pasture growth rates were 9.5 kg DM/ha/day below the average figures used in the case farmer's feed budget. The greenfeed maize and the cut grass effectively made up for the poor pasture growth rates over March and April. The revised feed budget also showed that with the additional maize silage on-hand (100 - 120 wet tonnes purchased), the case farmer would not need to apply nitrogen (diammonium phosphate) in the early spring.

The case farmer did not complete a detailed weekly feed budget with his consultant until after drying off[32] on June 8th. The case farmer stated that he could see no point in completing a detailed feed budget when he was in such a good feed position. He was also extremely busy building a winter feed pad and this limited the time he could devote to detailed planning.

The case farmer undertook limited formal or quantitative analyses of alternatives during the formal planning process. Rather, the case farmer uses decision rules to determine the optimum sequence of options within his plan.

The case farmer undertook one piece of risk analysis. When he completed his revised feed budget in April, he ran a second option where spring growth rates were reduced 30% to simulate a cold, wet spring similar to that experienced in the spring of year one. He then evaluated whether his reserves of maize silage could cope with this level of variation and his analysis showed that it could. This analysis reflected the case farmer's concern that climatic conditions in the region were changing and that wet, cold springs were becoming the norm.

The plan

The outcome from each planning process comprised a schedule of events, a set of targets for controlling the implementation of the plan and a set of contingency plans and associated decision rules that were used to select the most appropriate contingency plan for the conditions should a deviation occur. The schedule of events specified in the case farmer's plan for the study period[33] for year two and year one is summarised in Table 3. The plan used by the case farmer in year two was different from that used in year one. The reasons for these differences were due to the position the case farmer was in at the start of the summer planning period. Although cow numbers were slightly lower (320 versus 323 cows), the farmer was carrying 84 calves that in year one were grazed off. The herd was in much poorer condition (4.1 versus 4.5 - 5.0 condition score units) and the average pasture cover (1700 versus 2000 kg DM/ha), amount of grass silage (75 versus 120 wet tonnes), and area in forage crop (3.2 versus 5.2 ha) were all lower than in year one. The soils on the farm were also waterlogged due to the wet spring and conditions had turned hot and dry. Therefore pasture growth rates were also poor at this point in time. The other important factor was that at that point in time, the case farmer believed that with the dry, windy conditions the farm was experiencing, it was likely that it would be a dry summer. As such, the plan he devised for year two was different from that in year one where feed was plentiful, the herd was in good condition, and producing well, and the indications were that it was going to be a wet summer. One other difference between the year two and year one plan was that the case farmer had also decided to run his replacement heifer calves on the milking area because they had performed poorly on a grazier's property in year one. The case farmer planned to setstock these calves over the entire farm for the duration of the summer-autumn.

[32] The herd was dried off on the 26th May.

[33] The schedule of events comprises those for the period of the study (January 1st - drying off). This schedule of events covers the summer period and the early part of the plan developed at March 13th. Events beyond drying off are not incorporated, although this would include the grazing off and return of the herd to the milking area, the feeding of supplements and the grazing rotations of the herd over winter and early spring.

Table 3. A comparison of the plan for year two versus year one.

Year 2 Plan	Year 1 Plan
Set stock the calves across the entire farm over the summer-autumn.	
Maintain the herd on a 23 - 24 day rotation feeding solely pasture until three weeks before the end of the month. During this period, allow milk production to fall below 1.04 kg MS/cow/day.	Keep the 323 cows on a 21 - 22 day rotation until late January or milk production falls to 1.13 kg MS/cow/day
Feed grass silage before the forage crop. Feed grass silage at the point when it can be used to feed the herd to target until the end of January. While feeding silage and the forage crop, maintain the herd on a 23 - 24 day rotation unless the feed situation improves.	
Feed the forage crop at the end of January after the grass silage at a level that maintains milk production at 1.04 kg MS/cow/day. In a dry year make the forage crop last until the end of February, and reduce cow numbers if necessary to maintain milk production at 1.04 kg MS/cow/day.	When milk production falls to 1.13 kg MS/cow/day in early February, feed the forage crop for 3 weeks and maintain milk production at or above 1.04 kg MS/cow/day
Remove the bull in early February.	Remove the bull in early February
	Herd test on the 20th February
Dry off thin cows if there is insufficient feed to maintain milk production at 1.04 kg MS/cow/day.	
Complete the grazing of the forage crop by the end of February.	When the forage crop is finished, feed grass silage for four weeks and use the grass silage to extend the rotation out to 35 - 42 days while holding milk production at 1.04 kg MS/cow/day.
Maintain the herd on a 23 -24 day rotation after the forage crop unless the feed situation improves.	Regraze the forage crop for a week in late February and then continue to feed the grass silage. A third grazing may be obtained from the forage crop in March.
Sow the new grass by mid March	Sow the new grass in March
Dry off thin cows if there is insufficient feed to maintain milk production at 1.04 kg MS/cow/day and graze them off the farm.	
Pregnancy test the herd 6 - 8 weeks after the bull is removed (Normally mid - late March).	Pregnancy test the herd in mid - late March
Sell cull cows in early April after pregnancy diagnosis.	Sell approximately forty cull cows in early April
	Herd test in early April
	Dry off the thin induction and rising three year old cows in early April.
	Extend the rotation as the cull and dry cows are removed from the milking platform
	Feed 100 tonnes of maize silage
	Production will decline to 0.50 kg MS/cow/day in the last month of lactation and the herd will hold condition on the maize silage
Dry off the herd. Date unknown, but is very dependent on pasture growth over the summer-autumn and the acquisition of other feed sources.	Dry off the herd in May

As in year one, the case farmer's first planning event for the milking herd was to maintain the herd on a fixed round through January. The planned rotation length was slightly longer than year one (23 - 24 days versus 21 - 22 days), but this minor difference was because the case farmer had a second paddock out in a maize crop for maize silage. In year one, only one paddock was out in Japanese millet. The first change in the planning rules was that the case farmer planned to use grass silage before the forage crop. The reason for this change was that he had predicted that with his current average pasture cover and expected pasture growth rates, there would be insufficient pasture to feed the herd to target levels until the forage crop was ready to graze in late January. The case farmer had estimated that he had sufficient grass silage to provide the herd with about one third of their feed requirements for three weeks. His plan was therefore to maintain the herd on a 23 - 24 day rotation until three weeks from the end of the month, and then feed the grass silage for three weeks. The forage crop was to be grazed through February and cow numbers were to be reduced as dictated by cow condition and feed supply. In this plan, the case farmer assumed that the summer would remain dry. If he had thought that the dry period at the start of January was a short-term aberration and sufficient rain would fall in late January, he would have planned to feed the grass silage when milk production fell to 1.04 kg MS/cow/day. The year two plan was quite different from year one where at the start of the planning period the farm was in a very good feed position. In year one, the case farmer believed that he had sufficient average pasture cover to maintain the herd on pasture alone through January. The forage crop was to be fed in early February, and the grass silage was to be fed after the forage crop, not before.

Interestingly, the case farmer relaxed his summer milk production target for January. In year one, the case farmer aimed to maintain milk production at or above 1.04 kg MS/cow/day. However, in year two, because the case farmer knew he had insufficient feed on hand to maintain milk production above 1.04 kg MS/cow/day, the case farmer relaxed this target and allowed the milk production to fall below 1.04 kg MS/cow/day until the date at which the grass silage was to be grazed was reached. In effect, he used cow condition as a supplement during this period.

The case farmer did not plan to reduce his rotation length during the summer of year two, because, although this action might have allowed him to increase cow intakes and post-grazing residuals in the short-term, he believed that by doing this, he would place himself in a worse feed situation at the start of the next round because average pasture cover would have been reduced more quickly. However, the case farmer did not believe he had sufficient feed to extend the rotation length whilst maintaining post-grazing residuals and cow intakes as he had in year one. His post-grazing residuals were too low as it was, and extending the rotation would further reduce cow intakes and subsequent pasture growth rates.

As in year two, the case farmer planned to maintain milk production at or above 1.04 kg MS/cow/day while the herd was on supplements. This was to ensure post-grazing residuals were maintained at a reasonable level, and to minimise the loss of condition. In contrast to year one however, the case farmer also expected to have to dry off thin cows through the summer in order to protect their condition and ensure there was sufficient feed on hand for the remaining cows to produce to target. This again reflected the difference in the feed positions between the two plans. The case farmer's year two plan contained limited detail. This was because once the forage crop was finished, he had no other supplements available at that point in time[34] with which to extend the lactation should conditions remain dry. Therefore, his actions after this point in time were dependent on the climatic conditions over the summer-autumn (pasture growth rates) and whether he could secure additional feed in some form (nitrogen, grazing, forage crop, maize silage). His plan was therefore to remain on a 23 - 24 day round and dry off thin cows as condition and feed supply dictated. The case farmer planned to cull in early April after pregnancy testing in late March. The herd would then be dried off as average pasture cover and cow condition dictated.

In contrast to year two, the case farmer had access to 45 additional tonnes of grass silage and 100 tonnes of maize silage in year one which meant that he could plan to feed the herd supplements through March, April and into May, as well as extend the rotation

[34] The case farmer later purchased additional supplements in April, but in January, he did not know if he would be able to obtain these supplements.

length. Because the herd was in good condition at the start of January, year one, and the farm had a high average pasture cover and adequate supplements on-hand, the case farmer believed that he could feed the herd to target over the summer. He therefore expected that he would not have to dry off any thin cows until early April. The case farmer also had 100 tonnes of maize silage which he could feed through April to further extend the rotation length and ensure the herd milked into May. This option was not available to the case farmer when he put together his plan at the start of the summer in year two because he had made a tactical decision to use this to counter the effects of cold, wet conditions during the previous spring.

The case farmer had also made a strategic decision to grow 4.0 ha of maize for maize silage. The plan was to harvest this in mid April and then sow the paddock into new grass.

Implementation and comparison to the plan

Table 4 compares the year two plan to the actual outcome and identifies the reasons for any discrepancies. In year one, the case farmer grazed the replacement calves off the farm. However, he found that the grazier did not grow out the replacements to the standard he expected. Therefore, in year two, the case farmer planned to setstock the calves on the milking area, rather than graze them off, so that he could control their management and ensure that they reached target liveweights. In relation to the milking herd, the case farmer planned to maintain them on a 23 -24 day rotation and feed them a diet of pasture until the 10th January. He then planned to feed them silage for three weeks to allow the forage crop to reach optimum yield. Once the silage was fed, the herd were to graze the forage crop over the month of February. The case farmer aimed to maintain the herd on a 23 - 24 day rotation while they were being fed supplements and maintain milk production at 1.04 kg MS/cow/day. He believed he would have to dry off thin cows in February to ensure the remaining cows were fed to requirements. The case farmer's plan was somewhat vague after the end of February. This was because the duration over which the herd could be milked after this date depended on the climatic conditions over the summer-autumn and whether or not the case farmer could secure other sources of feed. The case farmer expected to cull the herd after pregnancy diagnosis in late March. Further thin cows would be dried off, but the timing and number would depend upon the season. Similarly, the actual drying off date would depend on the season and the feed situation. The case farmer also planned to harvest 4.0 ha of maize for maize silage in mid April and then resow the paddock into new grass.

Table 4. A comparison of the plan to the actual outcome for year two.

The plan	The actual outcome	Reason for deviation
Set stock the calves across the entire farm over the summer-autumn.	The calves were setstocked until 10th February and then sent away to grazing.	The feed situation on the milking area deteriorated through January and into February. The case farmer could not see this improving, and decided to graze off the calves to free up feed for the milking herd.
Maintain the herd on a 23 - 24 day rotation feeding solely pasture until three weeks before the end of the month. During this period, allow milk production to fall below 1.04 kg MS/cow/day.	The case farmer maintained the herd on a 23 - 24 day rotation feeding solely pasture until the 10th January. Milk production declined to 0.96 kg MS/cow/day prior to supplementation with grass silage.	

The plan	The actual outcome	Reason for deviation
Feed grass silage before the forage crop. Feed grass silage at the point when it can be used to feed the herd to target until the end of January. While feeding silage and the forage crop, maintain the herd on a 23 - 24 day rotation unless the feed situation improves.	The grass silage was fed before the forage crop. The grass silage was fed three weeks before the forage crop was ready to be grazed, but it only lasted 17 days. Milk production was held at 1.04 kg MS/cow/day. The herd was maintained the herd on a 23 - 24 day rotation and supplemented with grass silage from the 10th to the 27th January. The rotation length was also maintained at 23 - 24 days while the herd was on the forage crop.	 Pasture growth rates over January were slightly lower than the case farmer expected, and therefore the grass silage was used more quickly to maintain milk production at target.
Feed the forage crop at the end of January after the grass silage at a level that maintains milk production at 1.04 kg MS/cow/day. In a dry year make the forage crop last until the end of February, and reduce cow numbers if necessary to maintain milk production at 1.04 kg MS/cow/day	The forage crop was fed after the grass silage on the 28th January. The forage crop was fed from the 28th January until the 8th March. Milk production held at 1.04 kg MS/cow/day or more until mid February, and then declined to 0.96 kg MS/cow/day.	The grass silage did not last quite as long as the case farmer had originally planned. The forage crop lasted longer than the case farmer initially planned because he reduced the crop area offered to the herd in order to obtain another eight days grazing. To obtain the additional grazing, the case farmer accepted that he had to sacrifice milk production and cow condition as a result of a decline in cow intakes.
Remove the bull in early February	The bull was removed on the 3rd February.	
	The case farmer applied 4.0 tonnes of urea to the milking area.	This was an opportunistic decision. The farm had received a reasonable amount of rain, and the forecast indicated that further rain was likely as a tropical cyclone was passing over the north of the country.
Dry off thin cows if there is insufficient feed to maintain milk production at 1.04 kg MS/cow/day and graze them off the farm.	The case farmer dried off 45 thin cows on the 7th February and they left the milking area on the 15th February.	
	17 lease cows were returned to the milking area by a farmer who was leasing them on 9th March.	The farmer who was leasing the cows could not feed them due to the dry conditions. He sent them back and offered to pay grazing for them.
Complete the grazing of the forage crop by the end of February	Grazing of the forage crop was completed by 8th March.	The case farmer decided to obtain an additional eight days grazing from the forage crop to increase the likelihood of having the cows in a lactating state when the autumn rains arrived.
Maintain the herd on a 23 -24 day rotation after the forage crop unless the feed situation improves	The herd was maintained on a 23 - 24 day rotation.	
Sow the new grass by March 15th	The new grass was sown on March 20th.	The forage crop was grazed for an additional 8 days, and then wet weather and a tractor breakdown further delayed sowing.
Dry off thin cows if there is insufficient feed to maintain milk production at 1.04 kg MS/cow/day	The case farmer dried off 45 thin cows on the 9th March and these left the milking area on the 11th March. The case farmer dried off 22 thin cows on May 2nd.	A farmer returned 17 lease cows to the milking area, and offered to pay grazing for them. The case farmer kept the 15 best condition lease cows milking and grazed off 15 of the thinner cows plus the thinnest lease cows, along with 38 other thin cows.
Pregnancy test the herd 6 - 8 weeks after the bull is removed (Normally mid - late March).	The herd was pregnancy tested on April 1st.	
Sell cull cows in early April after pregnancy diagnosis	The case farmer sold nine empty cows from the milking herd and one dry empty cow on the 18th April.	The case farmer only sold 10 culls in April out of a total 69 - 70 possible culls. This was because firstly he wanted to

The plan	The actual outcome	Reason for deviation
		cany twenty of the thirty empty cows, over winter to get them in-calf next year. Of the other 39 - 40 cows, he decided that it would be more profitable to sell these as in-calf cows after drying off, rather than as cull cows to the works. The case farmer had also expected a higher proportion of empty cows due to the poor spring in year one.
	The case farmer sold 39 in-calf culls on the 11th May.	The in-calf culls were sold on the 11th May rather than after drying off because a buyer wanted them then, and the case farmer was concerned that cow prices were declining.
	In early April, the case farmer purchased 6.0 hectares of greenfeed maize.	The case farmer identified an opportunity to purchase greenfeed maize off a neighbour to use to extend the lactation.
	In early April, the case farmer purchased 4.5 hectares of maize for maize silage.	The case farmer identified an opportunity to purchase maize for maize silage off a neighbour to use to extend the lactation.
	The case farmer purchased 10,000 kg DM of standing pasture off a neighbour which he harvested and then fed out to the herd.	The case farmer identified an opportunity to purchase standing grass off a neighbour to use to extend the lactation.
Harvest 4.0 ha of maize for maize silage.	Harvested 4.0 ha of maize for maize silage.	
Sow new grass after maize crop.	New grass sown after the maize crop.	
January plan = dry off the herd. Date unknown, but is very dependent on pasture growth over the summer-autumn and the acquisition of other feed sources.	The herd was dried off on the 26th May.	In early January, the case farmer did not really know when he would dry off because it was dependent on pasture growth rates over the summer autumn and what other feed sources the case farmer could acquire. The reduction in cow numbers over the summer-autumn, and the purchase of additional greenfeed maize and cut grass allowed the case farmer to milk the herd for longer than he had initially expected in January.
Feed budget plan = dry off the herd on the 10th June[35].		The revised feed budget predicted the same drying off date as the initial feed budget because although the case farmer had purchased in additional greenfeed maize, maize silage and cut grass, actual pasture growth rates were 9.5 kg DM/ha/day below those used in the feed budget for the period March, April. The additional greenfeed maize and cut grass countered the impact of the below average pasture growth rates in March and April. The additional maize silage was sufficient for the farmer to remove early spring nitrogen (diammonium phosphate) from his plan.
		The case farmer dried off the herd earlier than the feed budget plan because he had to graze the herd off at the start of June. The grazing contract, rather than the feed position or cow condition determined the decision.

In early March, the case farmer calculated a gross feed budget and predicted that the herd would be dried off on the 10th June given the feed on-hand, average pasture growth

[35] Date predicted by the gross feed budget undertaken March 13th and a revised gross feed budget undertaken 27th April.

rates and the projected cow numbers. This feed budget was revised on the 27th April, and predicted the same drying off date. However, pasture growth rates through March, April were 9.0 kg DM/cow/day below average, but the case farmer had secured additional feed (greenfeed maize and cut grass) which were equivalent to the feed lost from the system because pasture growth rates were below average. The case farmer had also secured an additional 100 - 120 tonnes of maize silage, and because of this, the case farmer found that he could omit the spring application of 20 units of nitrogen per hectare from the plan.

There were only minor discrepancies between the case farmer's plan and its implementation through January. The calves were set stocked through January and were ahead of target at the end of the month. The herd remained on a 23 - 24 day rotation and was fed solely pasture until three weeks before the end of the month. The herd were fed below target during part of this period with milk production and cow condition falling from 1.04 kg MS/cow/day to 0.96 kg MS/cow/day, and from 4.1 to 4.0 condition score units, respectively. The grass silage was fed from the 10 to 27th January providing 17 rather 21 days feed for the herd as predicted in the plan. The herd remained on a 23 - 24 day rotation and milk production was maintained at 1.04 kg MS/cow/day whilst the grass silage was being fed. The forage crop was fed to the herd four days earlier than planned, primarily because the grass silage did not provide as many days feeding as first expected. The case farmer fed 0.1 hectares of forage crop per day to the herd. This provided them with 3.0 kg DM/cow/day of forage crop, and another 9 - 10 kg DM/cow/day was provided from pasture.

The bull was removed from the herd on the 3rd February and the case farmer pregnancy tested 15 cows that had been carried over as empty cows from the previous year. Three empty cows were identified and culled along with two lame cows. By March 5th, feed conditions had deteriorated to the point where the case farmer predicted he would not be able to fully feed the herd and his calves. Milk production had declined to 1.01 kg MS/cow/day, the average condition of the herd had declined to 3.8 condition score units and there was a mob of younger cows that were at, or below condition score 3.5. The case farmer decided to dry off a mob of 45 thin, younger cows and graze these and the calves off the farm. The calves were grazed off immediately, and the drying off process for the cows began on the 7th February, and these were grazed off on the 15th February. The drying off of the 45 thin cows increased both the condition (4.1 condition score units), and feed supply for the remaining 270 cows because the case farmer maintained the same rotation length and daily break of forage crop. As a result, milk production increased to 1.043 kg MS/cow/day by mid February.

On the 15th February, the case farmer decided that the herd was being too well fed for the dry conditions, and he reduced the forage crop area to 0.065 hectares per day. As a result, milk production declined to 0.96 kg MS/cow/day. Pasture growth through February remained low (25 kg DM/ha/day) and cow condition declined to 3.8 condition score units by early March. However, by rationing the forage crop, the case farmer obtained another eight days feeding from it and it was finished on March 8th. Prior to March 5th, the farm had received 14 mm of rain. The weather forecast predicted further rain within the next few days and on this basis, the case farmer decided to apply 4.0 tonnes of urea to increase pasture growth rates. However, although there was sufficient rain to wash in the urea, it was not sufficient to increase pasture growth rates to the extent the case farmer had expected.

On March 9th, a farmer who was leasing 17 of the case farmer's cows returned them to the milking area because he could not feed them. He did, however, offer to pay the case farmer grazing fees. Conditions were still poor at this point in time, and average pasture cover was below 1500 kg DM/ha. Analysis of post-grazing residuals indicated that the case farmer could not feed the 287 cows to target during March. At that point, the case farmer was feeding the 270 cows 10.0 kg DM/cow/day of pasture. The case farmer decided to dry off another 45 thin cows to free up feed for the herd. Because most of the lease cows were in better condition than his own, he only dried off two of these along with 43 cows from the herd. This increased the intake of the remaining 242 cows to 11.0 kg DM/cow/day and the removal of the thin cows increased the average condition of the herd to 4.0 - 4.1 condition score units.

On March 13th, the case farmer calculated his likely drying off date to be June 10th given average pasture growth rates. However, after the dry cows had been removed from the, milk production gradually declined to 0.96 kg MS/cow/day in the middle of March as conditions remained dry and the farm experienced below average pasture growth rates. Rain from mid March on increased pasture growth rates and average pasture cover. As a result, milk production increased to 1.01 kg MS/cow/day by the start of April.

The herd was pregnancy tested in late March. Only 30 empty cows were identified which was much lower than the case farmer had expected given conditions in the spring. This meant that he had 40 in-calf cows which he could cull on the basis of production. The case farmer decided to sell only 10 of the thirty empty cows (9 milking, 1 dry) to the works on the 18th April and carry over the other twenty to get in-calf next spring. He sold these cows on the 18th April because he believed the schedule was falling and he would get more for the cows if he sold them at that point. He also believed that the feed freed up through their sale would be converted into milk by the remaining cows, increasing their milk production per cow, and therefore he would not be subject to a decline in total milk production. The case farmer also decided to sell the other 40 in-calf cull cows on the store market after drying off rather than to the works in early April because he believed they would be worth more on the store market. He also believed that given the feed position on the farm as a result of buying in the greenfeed maize, he could milk the other cows through to drying off.

In early April, the case farmer negotiated to purchase 6.0 hectares of greenfeed maize for direct feeding to the herd and 4.5 hectares of greenfeed maize for maize silage from a neighbour. This was an opportunistic decision, and was not in the plan completed on March 13th. The herd was fed the greenfeed maize on April 11th, and it was used to extend the rotation from 23 - 24 days out to 30 - 34 days. During this period, the remaining 233 cows were fed 5.0 kg DM/cow/day of greenfeed maize and 10.0 kg DM/cow/day of pasture. Despite the increase in cow intakes, milk production remained at around 1.01 kg DM/cow/day. However, cow condition increased as a result of the greenfeed maize and was recorded at 4.5 condition score units at the 23rd April. This was an increase of 0.3 - 0.4 condition score units since early March. The case farmer harvested his 4.0 hectare crop of maize and a 4.5 hectare crop he bought-in on April 15th. His own crop yielded 300 wet tones of maize silage, and the bought-in crop 100 - 120 wet tonnes. Therefore, the case farmer had 100 - 120 wet tonnes more maize silage than he had planned for at the start of the planning period. While the herd was on the greenfeed maize, pasture growth rates increased from 25 kg DM/ha/day to 30 kg DM/ha/day through April. On the 23rd April, the average pasture cover had increased to 1600 kg DM/ha.

On May 2nd, the case farmer dried off 22 thin cows that were under condition score 4.0 and sent them away to grazing so that their condition could be increased to meet target by planned start of calving. The greenfeed maize crop was used to supplement the herd until the 5th May. The case farmer then purchased standing grass off a neighbour, harvested it, and fed it to the herd over the period 6th to 20th May. During this period the herd was fed 4.0 kg DM/cow/day of cut grass, and 11.0 kg DM/ha/day of pasture. Average pasture cover continued to increase in early May and it was 1695 kg DM/ha on May 8th. On May 11th, 39 in-calf cull cows were sold to a buyer. The case farmer decided to sell that culls at that stage rather than after drying off because he believed that cow prices were declining (a drop of $300/cow over the last two months) due to over-supply. The decision to sell the cows was made on May 2nd, but it took over a week to dry them off and organise their sale. Once the cows were culled, the case farmer extended the rotation out from 30 - 34 days to 50 days. The herd remained on this rotation and was fed pasture and cut grass until May 20th.

At May 20th, the case farmer was milking 172 cows producing 1.01 - 1.04 kg MS/cow/day and at 5.0 condition score units. On the 20th May, the case farmer initiated the drying off process and the herd was fed 2.0 kg DM/cow/day of hay, and 4.0 kg DM/cow/day of pasture on a rotation length of around 100 days. The herd was dried off on May 26th at an average pasture cover of 1800 kg DM/ha. The case farmer dried off at this stage because he had contracted to graze off the herd from the start of June for eight weeks. Neither the feed position, nor the condition of the herd dictated the drying off decision in this instance. Pasture growth rates through May were the same as that predicted in the case farmer's feed budget at 25 kg DM/ha/day.

The targets

In order to control the implementation of the plan, the case farmer had a set of targets (Table 5) and associated contingency plans. The targets can be separated into two types, those that act as terminating conditions at the end of the second planning, and those that are used to control the implementation of the plan through time. The terminating conditions act as constraints to the second plan and ensure systems performance is "optimised" during this period. Interestingly, there are no terminating targets for the summer plan. The aim is to have as many lactating cows on-hand as possible. The individual cow condition score targets and milk production targets ensure the herd and pastures are in a reasonable state at the start of autumn.

Table 5. Targets specified in the plan that are used in the control process for years one and two.

Targets	Year 2	Year 1
Summer		
Milk production		
Pre-supplement[36] crop .		
kg MS/cow/day	≥ 0.96	> 1.13
Forage crop.		
Introduction		
kg MS/cow/day	NA	1.13
Maintenance		
kg MS/cow/day	≥ 0.96	≥ 1.04
Grass silage		
kg MS/cow/day	≥ 1.04	≥ 1.04
Date at which forage crop grazing must be initiated by	End of January/early February	End of January,/early February
Date at which grass silage feeding must be initiated on	January 10th	NA
Rotation length (days)		
Pre-forage crop	23 - 24	21 - 22
Forage crop	23 - 24	21 - 22
Grass silage	23 - 24	35 - 42[37]

[36] The supplement may be silage or the forage crop.
[37] If conditions are dry, the target is only 25 - 28 days.

Targets	Year 2	Year 1
Cow intakes kg DM/cow/day	≥12.0	≥12.0
Individual cow condition condition score units February March	 ≥ 3.50 ≥ 3.50	 NA NA
Average herd condition condition score units	No target	NA
Average pasture cover (kg DM/ha)	NA	NA
Post grazing residuals (kg DM/ha)	≥ 1400	≥ 1400
Date forage crop must be grazed by	≤ February 28th	≤ February 28th
Date new grass must be sown by	March 1st	March 31st
Autumn		
Rotation length (days) pre-culling Post culling & destocking Drying off	 23 - 24 50 100	 35 - 42 60 100
Thin cows condition score Early April Late April Early May	 ≥ 3.50 ≥ 3.75 ≥ 4.0	 ≥ 3.50 ≥ 3.75 ≥ 4.0
Average herd condition Calving	4.75	4.75[38]
Average pasture cover (kg DM/ha) Drying of Winter maximum Planned start of calving Balance date	 1800 2300 2100 1800	 2000 2300 2000 1700
Milk production kg MS/cow/day	≥ 1.04	≥ 1.04
Date herd must be grazed off	June 1st	NA

Interestingly, there were some changes in targets and the rigidity to which targets were kept to as a result of the "dry year". Unlike year one, the case farmer did not attempt to maintain the average condition of the herd at or above 4.0 condition score units through the summer. Rather, his main aim was, given the dry conditions and poor state of the farm feed resources, to ensure as many cows as possible made it through to the autumn rains. As such, he was willing to sacrifice cow condition to a greater extent than in year one when feed was plentiful by comparison. As a result, cow condition fell to 3.8 condition score units on several occasions during the summer of year two. Therefore, unlike year one, in year two, the case farmer did not have definite terminating conditions for milk production or condition score for the summer plan. These constraints were relaxed so that his primary aim, "ensuring as many cows as possible were on hand in a lactating state was met

The second plan terminated at the end of September when pasture growth exceeds feed demand ("balance date") and the terminating condition specified by the case farmer was that the average pasture cover on the farm was at least 1800 kg DM/ha (Table 5). The

[38] The target condition score for the herd at planned start of calving was 4.5 condition score units. When the case farmer found he had a high empty rate, he decided to increase this target to 4.75 condition score units to enhance reproductive performance next season.

case farmer did not specify a terminating condition for the average condition of the herd, but he did specify an intermediate condition score target (Table 5) at planned start of calving. The terminating average pasture cover target of 1800 kg DM/ha determined the target average pasture cover at planned start of calving (2100 kg DM/ha), and at drying off (1800 kg DM/ha) through the feed budget analysis (Table 5). Similarly, the condition score target at calving determined the condition at drying off. The average pasture cover target of 1800 kg DM/ha at balance date was chosen by the case farmer because he believed that if he had a higher level of pasture cover at this time of year, it would create pasture quality problems. It would also require him to take a lot more feed into the winter, shortening the herd's lactation length. In contrast, if he had a lower level of average pasture cover at balance date (e.g. 1500 kg DM/ha), milk production in early lactation would be depressed due to underfeeding. The herd would lose additional condition over early lactation and this would create problems in terms of reproductive performance, increasing the empty rate and extending the calving spread.

The case farmer increased his average pasture cover target at balance date by 100 kg DM/ha because he wanted to increase his milk production per cow over the early spring and peak at 1.7 – 1.8 kg MS/cow/day. He believed that a higher average pasture cover at balance date, and therefore at calving, would result in higher milk production per cow. The difference in the drying off target between years one and two reflects the difference in feed resources used by the case farmer over the winter/early spring of the two years. The case farmer used more non-pasture feed resources in year two than year one. The condition of the herd at planned start of calving is an important determinant of reproductive performance. The case farmer changed his target for average herd condition at calving from 4.50 to 4.75 condition score units in year one to help improve his reproductive performance. For these reasons, he continued to use this higher target in year two (Table 5).

The case farmer used several targets to control the implementation of his plans through the summer-autumn period. However, unlike year one when the farm was in a good feed position, year two was a dry year and feed was short. In these conditions, the case farmer did not adhere as strictly to some of his targets, and in some cases he reduced them. The main reason for this was that the case farmer's primary aim was to get as many cows as possible through the summer in a lactating state. In order to do this, the case farmer had to make compromises, and in particular, sacrifice cow condition and milk production in order to achieve this goal. For example, over early January, the case farmer allowed milk production to fall below his target of 1.13 kg MS/cow/day for the introduction of supplements, and below his normal minimum milk production level of 1.04 kg MS/cow/day for the summer so that he could delay the grazing of the grass silage until the date he had set in his plan. While feeding the grass silage and the first half of the forage crop, he maintained milk production at 1.04 kg MS/cow/day. However, in mid February, he decided to extend the use of the forage crop and allowed milk production to decline to 0.96 kg MS/cow/day. During the summer-autumn, the case farmer was not as strict in keeping milk production above 1.04 kg MS/cow/day as in year one and it tended to range between 0.99 - 1.043 kg MS/cow/day. In the latter part of lactation, despite high feeding levels, the case farmer could not increase milk production above 1.01 - 1.04 kg MS/cow/day due to the physiological state of the herd. Similarly, the case farmer aimed to maintain cow intakes above 12.0 kg DM/cow/day, but he went below this level on several occasions as a result of relaxing his milk production targets.

Unlike year one, the case farmer kept the herd on a minimum rotation length of 23 - 24 days through the summer. This was primarily because, unlike year one, there was insufficient feed to extend the rotation, and reducing it further would have limited pasture growth rates in the longer term. Once the case farmer sources additional supplements in April and May, he set targets for a longer rotation length (Table 5). As in year one, the milk production targets dictated what happened to cow condition. In year two, because the case farmer allowed milk production to fall below 1.04 kg MS/cow/day, he did not maintain the average condition of the herd above 4.0 condition score units. However, he protected cow condition, and cow intake to a reasonable extent by drying off mobs of thin younger cows when their condition fell to around 3.5 condition score units during February and March. During the summer, the case farmer did not have minimum average pasture cover targets.

A number of target dates were used by the case farmer in year two. He did not want to initiate grass silage feeding until January 10th due to the dry conditions and because he only had sufficient grass silage on-hand to feed the herd for three weeks. There was no such target in year one. As in year one, the case farmer wanted to initiate the grazing of the forage crop at the end of January, early February to ensure optimum yield, and that it would be grazed off by the end of the February. However, the perspective was different. In year one, the case farmer wanted the forage crop grazed off by the end of February so that it could be resown in pasture. In contrast, in year two, the case farmer wanted the forage crop to last at least until the end of February because he knew cow intakes would fall by 25 - 33% when the forage crop was finished. He later changed this target to March 7th as conditions became drier.

During autumn, unlike year one, condition score targets were less important. This was because the case farmer had dried off 90 thin cows during the summer and as a result, the condition of the remaining cows was quite reasonable (4.2 versus 4.0 condition score units). The case farmer also purchased additional supplements in April and May, which in combination with the reduced cow numbers allowed the case farmer to feed the herd well through most of the autumn. For these reasons, the 172 cows on-hand at drying off had an average condition score of 5.0. As in year one, the case farmer increased his condition score targets for his thin cows through time from April, at the rate of 0.25 condition score units per half month (Table 5). The reason for this was that the case farmer did not want to put condition on cows after early June because at this time conditions were cold and feed was limiting. He therefore set his condition score targets on the basis of the time it would take to put a condition score on a cow. Thus, in early April, because he had more time to increase cow condition, the target he used to dry off thin cows was 3.5 condition score units. In late April, this target was increased 0.25 condition score units because the case farmer had 15 days less to increase condition score and in early May, the minimum was increased to 4.0 condition score units. These targets were designed to protect the condition of the younger cows in the herd and ensure they calved at target in the spring.

Unlike year one, average pasture cover targets did not play an important role in the autumn management in year two. With reduced cow number, additional bought-in feed, and the high level of winter, early spring supplement, there was sufficient feed on-hand to milk the reduced cow numbers through to June 10th. As such, average pasture cover and cow condition remained above target levels throughout the autumn. The case farmer also had different target rotation lengths for the year two autumn compared to year one. This again reflected the feed situation on the farm. The case farmer could not extend the rotation length until he purchased in feed in April. This bought-in feed allowed the case farmer to extend the rotation. The case farmer aimed for a 30 -34 day rotation in April, and a 50 day rotation in May prior to drying off. At drying off, the rotation length was extended out to 100 days as in year one. The case farmer had a target for milk production of 1.04 kg MS/cow/day, but as in year one, admitted that late in lactation this is not always possible.

The control process

The control process used by the case farmer was the same as reported in year one.

Monitoring - differences between year one and year two

The monitoring process used in year two was similar in most respects to that used in year one with a few important differences. The major difference over the summer was that the case farmer did not objectively measure average pasture cover and pasture growth rates at fortnightly intervals. This was because in year one the case farmer had monitored average pasture cover and pasture growth rates to assess how well the farm was performing after a period of rapid development and expansion. He also used this to validate his other measures. Having done this in year one, the case farmer was confident that his monitoring system was accurate over the summer and ceased objective pasture scoring. Average pasture cover was monitored objectively for the first time on March 13th and this was undertaken so that the case farmer could prepare a feed budget to estimate his likely drying of date. The case farmer did not undertake another objective measurement of average pasture cover until May 8th. His reason for this was that he had been busy building a large feedpad and because his informal and indirect measures had shown that average pasture cover had been increasing and was above target, he had not been worried about undertaking another formal measurement. Therefore, the case farmer only measured average pasture cover objectively twice during the summer-autumn, and in each case the information was used to assess the likely drying off date, i.e. the information was used for planning and plan revision. It was not used to for concurrent control purposes. This can be represented in a decision rule (Figure 1).

IF the feed budget shows the farm is in a good feed position,
AND there is limited time to objectively monitor average pasture cover because of some major project,
AND the feed budget predicts a drying off date in June,
AND the other indicators suggest that the feed position is at or above target,
THEN delay the next objective monitoring until the project is completed, the feed position deteriorates, or information is required to revise the plan.

Figure 1. A decision rule used by the case farmer to minimise objective monitoring during periods of high workload.

The case farmer discussed the method he used for assessing the average pasture cover on the farm subjectively. He pasture scored the paddock the herd has just gone out of, and the paddock the herd had just gone into. These were in effect, the longest and shortest paddocks on the farm. He then assessed the distribution of feed on the farm and adjusted the average between these two paddocks to account for any skewness in the distribution. This skewness results from changes in management that influenced the post-grazing residual such as the addition of supplements or a change in rotation length.

The case farmer began formally monitoring the cow condition of the herd and individual cows earlier in year two because cow condition was much lower at the start of summer than in year one (4.1 versus 4.5 condition score units). Because the calves were on the milking area through January, the monthly weighing of this stock class was recorded as one of the factors monitored during the study period.

In the spring of year one, the case farmer began monitoring cow liveweight on a monthly basis from mid September because firstly, he had recently purchased electronic scales, and secondly, cow condition and body weight was low as a result of the wet spring. Mid September was chosen as the date to initiate the liveweight monitoring because it was the point at which cow condition was at its lowest. This process continued through the summer-autumn, but the data was not used in decision making other than to confirm that the case farmer's other measures of cow condition were correct. The case farmer monitored a weighted sample of 30 cows from the herd. It was weighted towards the lighter cows in the herd, because these were the cows the case farmer wanted to monitor. Therefore, the primary reason for weighing the cows, was to monitor the liveweight of the thinner cows in the mob. This data was not representative of the average liveweight of the herd and because many of the thinner cows were dried off, the sample reduced in size throughout the season.

The other information monitored by the case farmer in year two that was not monitored in year one was the maize crop (yield and quality), the greenfeed maize and the cut pasture. These were all new inputs, not used in year one.

New information on monitoring identified in year two that also applies to year one

The case farmer stated that he converted his milk docket information from the dairy company into kilograms of milkfat[39] per cow per day for use in decision making. He stated that milk volume will quickly indicate a change in cow intake, but that he prefers to use milkfat per cow per day in his decision making.

The case farmer collected rainfall information about both the distribution, and total quantity of rain received in a month. For example, he stated that if 32 mm of rain fell as scattered rainfall incidents, this would have different implications for decision making than if it all fell in one day. The case farmer noted that he generates "*expectations*" from his rainfall data in terms of how much feed he expects will grow over the next few weeks. He stressed that this is a forecast and not a "*guaranteed*" prediction.

The case farmer used his "*expectations*" of pasture growth rates and his post-grazing residual to predict the likely pasture cover on a paddock at the next grazing in 23 - 24 days time (or whatever the current rotation length is). From this he estimated likely cow intakes and compared this to his target (Figure 2). He used this information to determine whether or not he could feed the herd to requirements in 3 - 4 weeks time. This information was used in a number of decisions because it provided an early warning of the likely feed situation on the farm in 3 - 4 weeks time. This information is used to indicate the likely date at which supplements are required, or indicate the need for the case farmer to destock through culling, or drying off thin cows. It was also used in the decision to change the summer plan.

[39] Note, although milk production is given in milksolids per cow per day, this unit was not used until year three when the local dairy company changed from milkfat to milksolids.

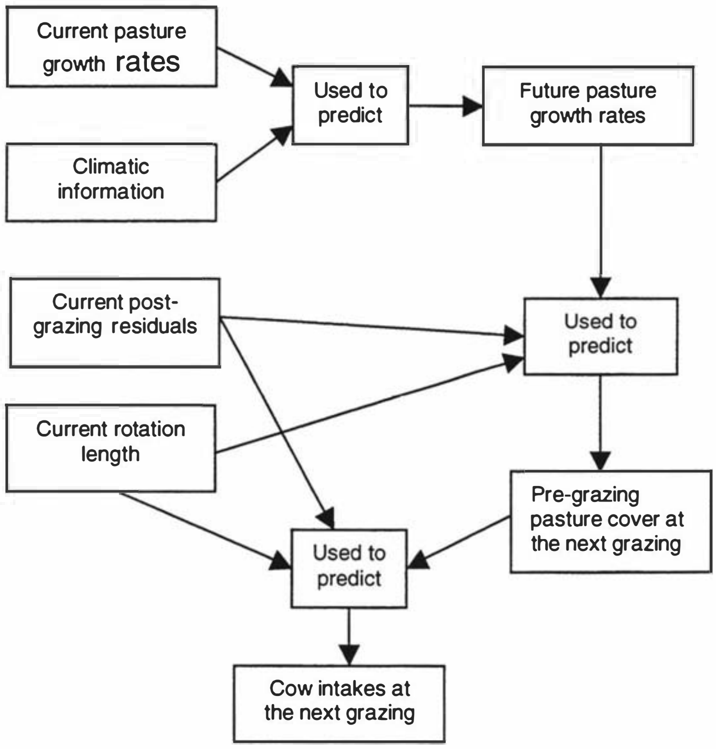

Figure 2. The process used by the case farmer to predict future cow intakes.

The case farmer also worked out the feed demand for the herd in kilograms of dry matter per hectare per day and then estimated pasture growth rates on the basis of the change in average pasture cover over a specific time period. This information was used to confirm what had happened over a previous period, and also to predict, along with climatic data, likely future pasture growth rates. The case farmer not only reacted to daily milk production and other such data, but he was also predicting a month out to consider pro-actively what actions he would need to take. He made the point in year one, although he was still making the same predictions, most of his decisions were based on historical data, whereas in year two, his predictions played a much more important role. He attributed the difference to the feed situation in year two, where conditions were so good that he did not have to take a pro-active approach.

As in year one, the case farmer used post-grazing residuals as an indicator of cow intakes. He referred to this measure as reflecting the "*grazing pressure*" the herd was under. The case farmer monitored schedule and store prices for cull cows, and this information was used to determine the timing of sales. As with last season, the case farmer was actively searching for alternative feed sources. However, during the dry year two season, these played a more important role in the overall management process.

Recording and data processing

Cow intake information was calculated for the current situation, and a prediction in 3 – 4 weeks time when the herd returned to the paddock they had just grazed.

Control responses and their selection

The control responses used by the case farmer in year two are summarised in Appendix XVII, Volume II.

Examples of the three types of control were found during the study of the case farmer in year two. By far the most common type of control used by the case farmer was concurrent control. The case farmer had a large number of contingency plans which he implemented when a deviation from the plan occurred. Some examples of preventative control were found. For example, the case farmer grows forage crops and harvests silage to provide feed during a period when pasture growth is highly variable. Some examples of historical control were also identified. The case farmer increased his average pasture cover target for planned start of calving and balance date by 100 kg DM/ha because he thought it would improve cow intakes and hence milk production over the early spring. The case farmer also identified several opportunities in the form of external feed sources and introduced these into the plan.

A range of control responses were used by the case farmer during year two. The primary control response was the use of contingency plans to minimise the impact of a deviation from the plan. External feed sources were identified, purchased and introduced into the plan, increasing the case farmer's "systems variety". The case farmer also changed his basic summer plan and associated targets to cope with deviations from the norm. The case farmer however, did not change his goals in response to a deviation from the plan although the emphasis on the summer plan was more on ensuring the maximum number of lactating cows were on-hand at the end of summer than optimising summer milk production.

Contingency plans

The main control response used by the case farmer in year two was the use of contingency plans. The case farmer used a combination of "*pre-defined*" contingency plans, and "*opportunistic*" contingency plans. The latter are contingencies that were not available to the case farmer when he first put his plan in place. Rather, the case farmer searched for additional options throughout the summer-autumn, and then introduced them to the plan as they were discovered and acquired. These tended to be options that involved bought-in feed in some form (e.g. urea, grazing, greenfeed maize and maize silage crops, pasture harvested and fed to the herd). The use of *opportunistic* contingencies increased the case farmer's ability to cope with variation in the environment. If the case farmer had only used the contingencies specified within his original plan, he would have dried off the herd much earlier and foregone additional milk production. Provided the cost of the opportunistic contingency is less than the revenue generated from it, this type of control response provides the case farmer with greater control over variation in his environment and improves productivity and profitability.

As in year one, the contingency plans used by the case farmer can be classified under four headings in relation to their impact on feed supply and feed demand (Table 6). The case farmer used four options to increase feed supply: apply urea, feed bought-in greenfeed maize, delaying the extension of the rotation, purchase maize for maize silage, and feed bought-in standing pasture. Feed supply was reduced by reducing the forage crop ration and increasing the rotation length. Feed demand was increased through delaying the sale of cull cows and the drying off of the herd. Feed demand was reduced through: grazing off the young stock, reducing the milk production target and associated cow intakes, drying off thin cows earlier than planned and drying off the herd earlier than planned. The second option, reducing cow intakes, utilised cow body condition as another form of supplement. It was used as an important contingency plan in year two. It was also used occasionally in year one, but nowhere near to the extent as in year two because feed was much more plentiful.

Table 6. The case farmer's contingency plans.

Category	Option
Increase feed supply	Apply urea Purchase and feed greenfeed maize Delay extension of rotation length Purchase standing maize for maize silage Purchase and feed standing pasture
Decrease feed supply	Reduce forage crop ration Extend the rotation length[40]
Increase feed demand	Delay sale of cull cows[41] Extend the lactation length[42]
Decrease feed demand	Graze off young stock Reduce milk production target and associated cow intakes Dry off thin cows earlier than planned Dry off the herd earlier than planned[43]

Contingency plan selection

When a deviation from the plan was identified by a key indicator crossing the target threshold, the case farmer did not use some form of partial budget to quantitatively analyse alternative courses of action. Rather, a qualitative process was used that can best be represented by decision rules (Figure 3). The decision rules take the form of an "IF" statement that specifies the conditions that indicate a problem exists, then normally several "AND" and/or "OR" statements that specify important characteristics that define the problem situation, followed by a "THEN" statement which specifies the contingency plan that should be instigated. The problem situation characteristics are important, because they are used to distinguish between alternative courses of action in most instances. In other words, the problem situation characteristics are matched to a problem solution.

IF milk production is ≤ 1.13 kg MS/cow/day,	) Indicates a problem exists.
AND the forage crop is not mature and growing actively,	) Specifies the characteristics that define
AND surplus grass silage is available,	) the problem situation.
THEN begin feed the silage at a level that	) Specifies the contingency plan that
maintains milk production at or above	) should be implemented to match the
1.04 kg MS/cow/day until the forage crop is ready.	) the characteristics of the problem situation.

Figure 3. The structure of a contingency plan selection decision rule.

[40] This option was used relative to the plan devised at the start of January when the case farmer thought the herd would be dried off before mid May.
[41] The in-calf culls were retained until May because they were worth more if sold as replacement animals to other dairy farmers then if sold to the works in early April as planned.
[42] The original plan set at the start of January indicated the herd would probably be dry before mid May.
[43] The herd was dried off 14 days earlier than planned in the feed budget (as opposed to the plan developed at the start of January) because the case farmer had to send them away to grazing at the end of May.

Post-planning, the case farmer obtained grazing for the calves and mobs of thin dry cows. However, no formal analysis was undertaken of these options. The case farmer negotiated a price that he was comfortable with and then accepted the grazing. The case farmer had base prices at which he believed these feed options were profitable, and if he could obtain feed at or below that price, he purchased it. These base prices were based on previous analyses undertaken by the case farmer. Such analyses were only revised if costs or output prices changed significantly. The case farmer also mentioned that such analyses were also undertaken at discussion group meetings. The case farmer did undertake a qualitative form of analysis of options when deciding whether or not to buy a greenfeed maize crop in April. This is discussed under the evaluation section

There was one example of where the case farmer decided between several courses of action recorded in year two. This was where in early April, the case farmer decided between an option in the plan, drying off further thin cows, and three external options: applying urea, buying in maize to feed as chopped green feed, or buying it in to feed as maize silage. He analysed these options because at that point in time, the level of feed on the farm was inadequate to support the existing cow numbers. The case farmer compared the three external options in terms of costs, risk, and immediacy of effect. The analysis was qualitative in nature and was not written down and the greenfeed maize was selected. This was then compared to the internal option on the basis of costs and returns. The greenfeed maize was selected as the most profitable option.

Opportunity selection

The case farmer used an opportunity recognition and selection process to improve his ability to cope with the extreme conditions experienced in year two (Figure 4).

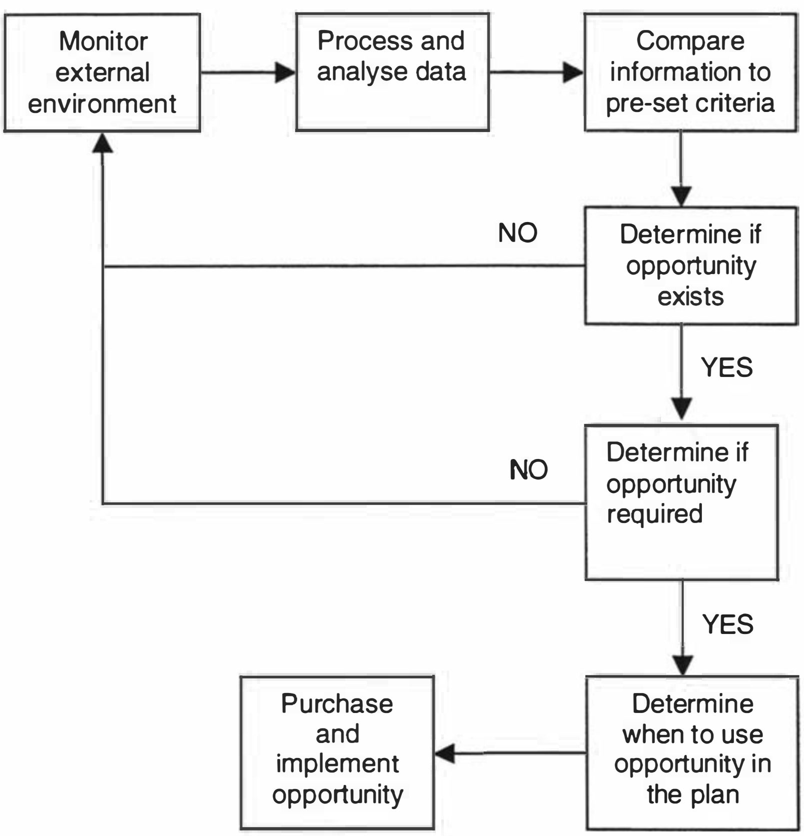

Figure 4. The opportunity recognition process and selection process.

The case farmer monitored the external environment, mainly through the newspaper and his network of local farmers. He collected information on external feed sources that included feed type, quality, price, and locality. He also had some pre-set criteria against which to compare this information. The information was processed and analysed. The analysis converted the price for the feed source to a common unit. The feed cost and other information was compared to the criteria. If it matched, the case farmer had to decide whether he wanted to take advantage of the opportunity. In the previous year, when feed was plentiful, the case farmer had not taken advantage of external feed source opportunities. If the case farmer decided to take advantage of the opportunity, he then had to determine where to fit the new feed source in his plan. Once he had done this, he purchased the feed source and implemented it into the plan. Opportunities considered in year two included calf and dry cow grazing, urea, maize silage and greenfeed maize (see previous section).

Changing plans

In year two, the case farmer also changed his basic summer plan to cope with deviations from the norm. Prior to the start of summer, he decided that the climatic conditions, and state of the farm (average pasture cover, pasture growth, supplements, cow condition and milk production) indicated that it would be a dry summer. He had also decided to graze his replacement calves at home rather than graze them off as he had done in the past. As such, he changed several aspects of his "*typical*" summer plan as used in year one. The main alterations to the plan included changing the timing and sequence of events and adjustments to the associated targets. For example, the case farmer planned to feed the grass silage before the forage crop rather than after it, as was the case in year one. Similarly he planned to dry off thin cows through February rather than in April. As part of his changes to the plan, the case farmer also adjusted some of his targets (see next section).

The case farmer had also changed one other aspect of his plan at a more strategic level. After the cold, wet spring of year one, the case farmer had evaluated the level of supplement he had on-hand to cope with variations in spring pasture growth rates and decided it was inadequate. He had therefore planted a paddock of maize for maize silage, and his aim was to set aside a proportion of this for insurance in the advent of another cold, wet spring. Therefore, the summer plan included an area that was not in pasture because it was growing maize for silage. Similarly, the autumn plan had this area out as new grass, and the early spring plan now incorporated an important contingency plan that could be used in the advent of a poor spring.

Changing targets

The case farmer changed his targets to manage deviations from the norm. In year two, three types of target changes were identified. The first was where targets were changed along with the plan at the start of the planning period. In this case, two types of targets were changed. The first were intermediate targets that controlled the implementation of the plan, and the second were terminating targets that influenced systems performance in the subsequent planning period. The third form of change was where intermediate targets were changed part-way through the implementation process to minimise the impact of some deviation from the plan.

Examples of the first type of target adjustment occurred prior to the start of the summer when the case farmer put in place a new plan, because he believed the summer was going to be abnormally dry. Associated with this new plan was a set of different targets. In effect, the case farmer relaxed or reduced his targets for milk production, cow condition and cow intakes through January. The reason he did this was to use cow body condition as a supplement so that he could delay the grazing of the grass silage and forage crop. This would then improve the likelihood of ensuring as many cows as possible made it through the summer in a lactating state. The case farmer also changed his intermediate target for milk production from 1.04 kg MS/cow/day to 0.96 kg MS/cow/day in mid February when the herd was grazing the forage crop, a concurrent control response. He made this decision because conditions had remained dry and he decided that he should make the forage crop last another week to enhance his chances of having a large proportion of the herd in a lactating state at the end of summer. This change, in effect, allowed the case farmer to use cow body condition as a supplement.

The final type of change the case farmer made to his targets was to change his terminating target for average pasture cover at balance date from 1700 kg DM/ha to 1800 kg DM/ha when he developed his feed budget plan for the period March 13th to September 30th. The case farmer made this change because he believed it would increase cow intakes over early lactation and therefore increase milk production. As a results of this change, he also had to increase his intermediate targets at planned start of calving, and drying off by 100 kg DM/ha.

Diagnosis, evaluation and learning

The most interesting point to come out of the study in relation to evaluation was that the case farmer rarely consciously defined or diagnosed the reason for a short-term deviation from the plan (problem) (Table 7). He used indicators to identify feed problems (in most cases a feed deficit), and then implemented an option from his set of contingency plans without undertaking any form of conscious problem definition or diagnosis. Problem definition may not be an issue because at this time of the year, the primary problem the case farmer expects to face is a feed deficit. The holistic nature of his monitoring system also verifies the existence of a feed problem, making the need for diagnosis redundant. For example, before his primary indicator, milk production, has indicated a feed problem, he will know from climatic data that the season is becoming drier. He will also identify a decline in intakes, pre- and post-grazing residuals, and milk production before the threshold is reached.

Table 7. The evaluations carried out by the case farmer in year two.

Primary category	Sub-category and instance	Initiated by	Method of evaluation	Criteria	Criteria met	Diagnosis undertaken	Unusual Situations
Planning							
	Activities **Choice and use of inputs**						
	Grazing the calves off	Poor performance	Comparison to standards	Match	No	No	New grazier
	Grazing the calves on the milking area	Good performance	Comparison to standards	Match	Yes	No	Yes[44]
	Level of supplement on-hand as insurance in the spring	Systems performance during the wet, cold year one spring	Compared the actual situation with a simulated situation where additional supplement was available	Effect of change on productivity and profitability	No	No	Yes

[44] Prior to this, the case farmer had tended to graze the calves off the milking area over summer.

Primary category	Sub-category and instance	Initiated by	Method of evaluation	Criteria	Criteria met	Diagnosis undertaken	Unusual Situations
	Ability of maize silage reserves to cope with cold, wet spring	Maize silage placed in the stack and feed budget revision	The percent reduction in pasture growth rates over August, September, the supplement can cover.	30%	Yes	No	New policy
	Use of nitrogen (diammonium phosphate) in the spring	Feed budget revision	Estimated APC at balance date using the feed budget without nitrogen	APC < 1800 kg DM/ha	No	No	No
	Activities Management practices						
	Planning assumptions						
	Assess the validity of the pasture growth rate assumptions for August, September in the spring of yr one	On-going evaluation	Comparison of actual to expected	Match, given conditions	Yes	No	Second year on the farm
	Evaluation of plan						
	Revision of summer plan	Completion of summer period	Comparison to expectations	Expectations met	Yes	No	Dry, but not extreme
	Revision of feed budget	On-going revision	Re-estimation of drying off date	Comparison to previous estimation	Yes	No	No
Control							
	Monitoring systems						
	Calibrate average pasture cover, intake and pre- and post-grazing residuals and level of supplement feeding against milk production date	On-going	Comparison	Match	Yes	No	No
	Date cow weighting was initiated	Case farmer reflecting	Comparison of what he had done with what he should have done	Match	No	No	May change the date at which he starts monitoring cow liveweights

Primary category	Sub-category and instance	Initiated by	Method of evaluation	Criteria	Criteria met	Diagnosis undertaken	Unusual Situations
	Contingency plan selection						
	Choice of and use of inputs						
	Quantity of supplements made in the spring	Lack of supplements on-hand at start of summer due to a cold, wet spring	Comparison to previous year, and requirements	Match	No	No	Yes
	Grazing the heifer calves on a higher quality property	Liveweight results	Comparison to target and year one	Match	Both exceeded	No	New grazier
	Use of urea	The act of applying urea	Observation of colour of pasture	Colour changes to dark green	Yes	No	Dry, but not extreme
	The choice between drying off additional cows, applying urea or buying in maize to feed as chopped greenfeed or maize silage	Declining post-grazing residuals and below average pasture growth rates in March. Opportunity to buy greenfeed maize identified.	Comparison of the four options	Impact of the option on productivity and profitability, risk, immediacy of effect	Green-feed maize option best	No	Dry, but not extreme
	The use of cut pasture	Feeding of cut pasture completed	Comparison to expectations	Expectations met	Yes	No	Yes (new practice)
	Revision of overall control	Completion of summer period	Comparison to expectations	Expectations met	Yes	No	Dry, but not extreme
Systems performance							
	Productive performance						
	General farm performance	Farm did not appear to be performing as well as the case farmer expected	Comparison to milk production and stocking rate data of farms in the district. Analysis of common factors on high performing farms.	Match	No	Yes	Two years of wet, cold springs
	Liveweight of replacement stock	The liveweight of the stock was below target.	Comparison to standards.	Match	No[45] Yes[46]	No No	New grazier Retained at home

[45] In this instance, the case farmer had evaluated the performance of his young stock on grazing in year one, and decided on the basis of the results to graze his replacement calves on the milking area.
[46] In this instance, the case farmer was evaluating the performance of the calves in year one when they were grazed on the milking area, and then placed on good grazing in February.

Diagnosis was primarily used where the case farmer's expectations or targets were not met and in extreme situations that were beyond the experience of the case farmer (Table 7). Although the summer of year two was dry, it did not rate as an "extreme" situation that was outside the experience of the case farmer. For example, he reported an earlier experience where he had dried the herd off before the middle of February. However, the spring of year one had been extreme, and the case farmer stated that as a result of that, he had been comparing the performance of his property to that of other similar farms in the district. He found that his farm was not performing as well as the other farms in terms of milk production. The case farmer analysed high performing farms relative to his own and found that the common factor on these farms was that they all had intensive drainage systems. Several factors (low pasture production, yellowing of pasture over summer, pugging) indicated the reason for the poorer performance on his farm was drainage. When he investigated this further, he found that this was the case and the majority of the mole drains on the farm were in need of remoling[47].

Although the case farmer undertook limited diagnosis in year two, he undertook a lot more evaluation than in year one(Table 7). This can be attributed to the much drier conditions in year two and the poor state of the farm at the start of the summer. The evaluations undertaken by the case farmer can be classified into three main categories, planning, control, and systems performance (Table 7). Given the nature of an extremely cold, wet spring, followed by a dry summer, it was not surprising that most of the evaluations undertaken by the case farmer were in relation to input use, either in terms of the use of these activities in the plan, or in terms of control, and their selection as contingency plans. Interestingly, no management practices were evaluated in year two.

The case farmer had evaluated his use of grazing for his heifer calves on a sand country property in year one and decided that the quality of the grazing was not up to standard. He therefore changed his plan and grazed the calves on the milking area. He evaluated this decision in late January when he weighed the calves and found that they were performing much better than at the same date in year one. The case farmer had also evaluated the level of supplement he had on-hand during the cold, wet spring of year one. He decided that it was inadequate for such conditions. As a result, he included in his summer-autumn plan, the harvesting of sufficient maize silage to act as insurance in the advent of a cold, wet spring. Once the maize silage had been harvested, and while revising his feed budget, the case farmer evaluated the degree to which the maize silage he had set aside as insurance could cope with a reduction in pasture growth rates over August, September.

The case farmer also evaluated the validity of the pasture growth rate assumptions he had made in his year one plan for the months of August and September. He decided these were still valid given the extreme conditions of year one. The case farmer briefly evaluated his summer plan and decided with the benefit of hindsight, that there was nothing he would have changed. The case farmer undertook one revision of his feed budget prior to drying off. During this exercise, he also evaluated whether or not he needed to apply nitrogen in the early spring, given he had recently purchased additional maize silage. The analysis showed that this option could be emitted from the plan, and he would still meet his average pasture cover target of 1800 kg DM/ha at balance date. Unlike, year one, the case farmer did not involve his consultant in the feed budget revision process prior to drying off. This was because firstly, the case farmer was busy installing a feed pad over the autumn, and secondly, the farm was in a good feed position once the maize crops had been purchased in early April. The consultant helped the case farmer revise his feed budget in early June of year two.

[47] A large proportion of the farm had been an arable farm and had been converted to dairying two years ago.

Throughout the summer-autumn, one area of control that the case farmer evaluated was the accuracy of his monitoring system. He used milk production data to calibrate his estimates of average pasture cover, cow intakes and pre- and post-grazing residuals. This form of evaluation was on-going and used to ensure the accuracy of the case farmer's monitoring system. The case farmer also evaluated the date at which he started monitoring cow liveweights, and decided that in order to learn more about this area, he should have started monitoring at calving, rather than in mid September. The other area of control the case farmer evaluated was his selection of contingency plans, and in particular, those contingency plans relating to the choice and use of inputs. During the summer, the case farmer evaluated the quantity of supplements he had made during the spring of year one. His evaluation suggested that he had to be more proactive in obtaining supplements. The case farmer had to graze the replacement heifer calves off in February due to the dry conditions. During the autumn, he evaluated his choice of grazier and the basis of the performance of the calves.

The case farmer also evaluated his decisions to use urea in March, and purchase, cut and cart pasture to the herd from a neighbours airstrip[48]. Although the latter performed to his expectations, the case farmer admitted that he had difficulty assessing the response of his pastures to nitrogen when he had applied it across the whole farm (no control block). In this instance, the case farmer used the change in the colour of the sward to indicate that a response had been obtained. The case farmer also briefly reviewed his control of the summer plan, and decided that he would not have changed any of the decisions he made over the summer.

Four examples of systems performance evaluation were identified: general farm performance, liveweight of replacement stock in years one and two, and pasture growth rates over the summer-autumn. With the exception of the year two replacement stock, these evaluations were all triggered when the case farmer found performance to be below his expectations. The general farm performance evaluation and the replacement liveweight evaluations are discussed above. The case farmer believed that his pasture growth rates were below optimum over the summer-autumn because his average pasture cover was low, and because he did not have sufficient supplement on-hand to increase his post-grazing residuals.

A range of factors initiated the evaluation process. In some instances, it was because the outcome deviated from some standard or target. Alternatively, the case farmer initiated the evaluation after the decision had been implemented and the outcome of the decision was known. Finally, some evaluations were undertaken on an on-going basis, such as those used to ensure the accuracy of the case farmer's monitoring system.

The means by which the case farmer evaluated each of the three areas could be classified into three main areas. The simplest method was to compare the outcome to some target, standard, norm, or expectation and the criteria used to evaluate the decision or factor was the degree of match between the two. If the criteria were not met, and the case farmer did not know the reason for the deviation, then diagnosis was undertaken. The second approach, an ex-poste evaluation, was to undertake an historical simulation of what would have happened if the decision of interest had not been made, or a different decision had been made, and compare this to the actual outcome. The criteria used to evaluate the decision of interest was whether the outcome was better than the alternative. This was normally measured in terms of feed on hand, or cow condition. In these cases no diagnosis was undertaken because the case farmer had a full understanding of the situation.

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[48] Aerial spray contractor.

The third form of evaluation was ex-ante, where the case farmer evaluated a decision before it was made. In this case the case farmer either compared the decision to doing nothing, or compared across several options. In effect, the case farmer simulated the effect of the decision or option on the production system, and then evaluated it in terms of certain criteria. In all cases, nothing was written down, and the criteria were qualitative in nature. When evaluating multiple options, the case farmer quickly screened out potential options before considering in more detail the most feasible options. For example, when the farm was short of feed in early April, the case farmer had three possible options to alleviate this problem: urea, buying in maize and feeding it as chopped greenfeed, or buying in maize, ensiling it as maize silage for a week and feeding it. Urea was quickly dismissed because its effect was not immediate, as was the maize silage option because of double handling and cost. This left the options of selling cull cows or buying in maize for greenfeed. This was then compared to the alternative in the plan, selling cull cows early. The case farmer stated that he would rather retain the cull cows and buy in greenfeed maize than sell them. He believed that it would be more profitable to retain the cows and buy in feed, then sell them and forego milk production. The case farmer undertook a rough mental partial budget, but it was not written down.

Learning

One of the products of the evaluation process is learning. Several examples of learning were identified during year two (Table 8). Much of the learning mentioned by the case farmer over the summer-autumn of year two related to year one, and in particular the cold, wet spring of that year. Therefore this learning encompassed new knowledge about his production system and its interaction with the environment, in this case, an extremely cold, and wet spring. The case farmer learnt that under such conditions, it took the system a long time to recover. This had implications for milk production, reproductive performance and the amount of supplements that could be made. The case farmer learnt that if he was to minimise the effect of such conditions, he needed a large quantity of supplement on-hand. As such, he has changed his normal plan, and has incorporate a quantity of maize silage into the plan to act as insurance against such extreme spring conditions. Therefore learning also occurred in relation to planning and input use. Similarly, the case farmer reviewed the control processes he used during the spring of year one, and more particularly, his contingency plan selection rules. On this basis he decided that he would need to incorporate new contingency plans within his plan that were of a more proactive nature to ensure he has sufficient supplements on hand at the start of the summer.

Table 8. Instances of learning undertaken by the case farmer in year two.

Instances of learning	Areas of learning	Outcome of learning
The case farmer learnt that during a cold, wet spring, if he did not have a large quantity of supplement on-hand, it took a long time for systems performance to improve.	Production system, environment, input use interaction Planning, input use	The case farmer now incorporates a quantity of maize silage in his plan that acts as insurance. There is sufficient supplement to counter a 30% decline in pasture growth rates through August and September.
The case farmer learnt that in a cold, wet spring such as in year one, he had to be more proactive in ensuring he generated adequate supplements.	Production system, environment interaction Control, contingency plan selection, input use	The case farmer will put in place contingency plans to ensure sufficient supplements are secured in a cold, wet spring.
The case farmer learnt that his farm was not performing as well as others in the district. Diagnosis of the problem identified that the farm's drainage system was inadequate and the cold, wet springs experienced over the last two years had exacerbated the drainage problem..	Production system, environment interaction, Capital input use	The case farmer learnt why the farm had not been performing as well as he had expected over the last few years when it had experienced cold, wet springs. As a result of this, he had the farm mole ploughed.

Instances of learning	Areas of learning	Outcome of learning
The case farmer leamt that graziers on sand country cannot rear replacement stock as well as graziers on better country. The grazier he had last year, who farmed sand country did not rear his replacement stock to a suitable standard.	Production system, environment interaction Planning, input use	The case farmer leamt that to ensure he has well reared replacement stock, he should source grazing on more productive country.
The case farmer leamt that he could cut and carry pasture from a neighbours airstrip and feed it to the herd as a milking supplement.	Control, contingency plan selection, input use	The case farmer will add this option to his repertoire of contingency plans.
The case farmer leamt that if he was going to obtain useful information about cow liveweights, then he should begin monitoring this at calving rather than from mid September on.	Control, monitoring system	The case farmer would change the date at which he starts weighing the herd if he did it again.

The case farmer had also compared his farm performance to that of other farmer's in the district, and found that he was not performing as well as the top producing farms. Analysis of similarities and differences between his farm, and the top producing farms identified that these farms had intensive drainage systems. Analysis of the drainage system on his farm identified that the mole drainage system was in need of remoling. The case farmer learnt the importance of an intensive drainage system on his soil type. The areas of learning encompassed production system, environment interactions, and planning at a more strategic level in terms of capital inputs.

The case farmer had grazed his replacement stock on a sand country farm in year one. The performance of the stock on this farm was poor. The case farmer believed that this problem could be attributed to the poor quality of the sand country for rearing young stock. The case farmer then grazed them on his home farm and then a property on better country when feed became short in February. He found the performance of the stock was much better in year one and learnt that stock performance was a function of the quality of the country they were grazed on. The areas of learning encompassed the production system, environment interaction, planning and input use. The case farmer also tried cutting and carrying pasture from a neighbours air field to the herd. This was a new process and it worked as the case farmer expected. The area of learning encompasses control, contingency plan selection, input use. The case farmer also learnt that if monitoring cow condition he should start at calving, rather than in mid September, if he wants to obtain more useful information about changes in cow liveweight over early lactation. This area of learning can be classified as control, monitoring.

The outcome from the learning process depended on the learning areas. In most cases, the information was added to the case farmer's general understanding of the production system and how it interacted with the environment. In other cases it resulted in a change in the case farmer's plan and planning rules, primarily in the area of input use. The learning also resulted in the case farmer changing his decision rules in relation to contingency plan selection. Again, this was mainly in relation to new input use options. Some learning occurred in relation to monitoring, and this changed the case farmers decision rules for the date at which cow liveweight monitoring was initiated.

It is apparent from the data that the case farmer uses his learning about his production system, how it interacts with the environment, and the effect of various management practices and inputs to develop planning rules that determine the sequence of activities the case farmer undertakes, the targets he sets, and the contingency plans he puts in place. This learning is also used to develop monitoring rules, and rules for the selection of the most appropriate contingency plans for the conditions. Not mentioned in the above process, is the role of reinforcement of learning that ensures the case farmer retains those rules that are effective through time.

Appendix XXV. Farmer B – Summary of Year Three

A description of year three year and comparison to years one and two.

During November, there had been heavy rainfall and floods. However, from the start of December until January 1st, the farm had five weeks with no rainfall and dry, hot, windy conditions. As a result, the farm went from very wet, to very dry over a short period. The case farmer stated that during early December, he had feed ahead of the herd as a result of pasture that had grown through November, but his major concern was that the regrowth behind the herd was minimal and that at the start of the next round, cow intakes of pasture would be severely restricted. Pre-grazing pasture cover levels were declining, and as a result, cow intakes and the post-grazing residuals were also declining. The case farmer decided to begin feeding grass silage on the 20th December because he estimated future cow intakes would decline rapidly unless they were fed supplements. The main problem was that the farm was growing 30 - 35 kg DM/ha/day and the herd was eating 45 kg DM/ha/day. At the 20th December, average pasture cover was around 2100 kg DM/ha. The case farmer noted that this level of average pasture cover over December would have been good, provided the farm had received rain. By the start of January, the herd was on its second rotation with no rain. Regrowth had been adequate for the first two weeks of December before the ground dried out, but had declined after that as it got drier. Moisture stress had become evident by mid December.

On January 1st, the case farmer was milking 327 cows at condition score 4.75 producing 1.31 - 1.36 kg MS/cow/day on a 23 - 24 day rotation (Table 1). Milk production had gradually declined from 1.45 kg MS/cow/day (0.83 kg MS/cow/day) in early December, but cow condition has remained unchanged. The herd was being fed 10 kg DM/cow/day of pasture and 3 - 4 kg DM/cow/day of grass silage or a total of 13 - 14 kg DM/cow/day. It was going into paddocks at an average pasture cover of 2300 kg DM/ha and leaving behind around 1500 kg DM/ha. Pasture growth rates were estimated at 30 - 35 kg DM/ha/day, while feed demand was 45 kg DM/ha/day. The average pasture cover was 2000 - 2050 kg DM/ha.

Table 1. A comparison of the conditions on Farm B during years one, two and three[49].

Factor	Year 3	Year 2	Year 1
January 1st			
Area (ha)	104.0	104.0	94.0
Average pasture cover (Kg DM/ha)	2000	1700	2000
Cow condition	4.75	4.10	4.5 - 5.0
Milk production (kg MS/cow/day)	1.31 – 1.36	1.04	1.31
Cow intake (kg DM/cow/day)	13 - 14[50]	12.0	14.0
Cow numbers	327	320	323
Forage crop area (ha)	8.0	3.2	5.2
Maize silage crop area (ha)	8.0[51]	4.0	0
Grass silage (wet tonnes)	550[52]	75	120
Maize silage (wet tonnes)	350[53]	0[54]	300[55]

[49] Because data could not always be collected on the first of the month, these figures are extrapolated from the data.
[50] Included 3.0 - 4.0 kg DM/cow/day of grass silage.
[51] This was a maize silage crop and it was grown on a neighbour's property.
[52] The case farmer fed 50 wet tonnes from December 20th to 31st December.
[53] There was 250 wet tonnes of this available for use over the summer-autumn.
[54] The case farmer later purchased 420 wet tonnes of maize silage off the neighbour in April.
[55] Only 100 wet tonnes of maize silage is available for the summer-autumn period.

Factor	Year 3	Year 2	Year 1
Hay (bales)	0	1210	2250[56]
Rotation length (days)	23 - 24	23 - 24	21 - 22
Calf numbers	0	84	0
February 1st			
Average pasture cover (Kg DM/ha)	1700	1600	1980
Cow condition	4.65	3.8	4.4
Milk production (kg MS/cow/day)	1.04	1.04	1.05
Cow intakes (kg DM/cow/day)	14.0	12.0	13.0
Cow numbers	319	320	323
Rotation length (days)	23 - 24	23 - 24	21 – 22
Calf numbers	0	84	0
March 1st			
Average pasture cover (Kg DM/ha)	1450	1530	1990
Cow condition	4.25	3.8	4.0
Milk production (kg MS/cow/day)	1.04	0.96 - 1.04	1.04
Cow intakes (kg DM/cow/day)	11.0 - 13.0	11.0	12.5
Cow numbers	319	270	319
Rotation length (days)	23 - 24	23 - 24	32
Periods when the forage crop was fed	8th February until 6th March	28th January to 8th March	1 - 18th February 1 - 5th March
Area (ha)	8.0	3.2	5.2
Yield/ha (kg DM/ha)	5,000 - 6,000	10,000	7,000[57] 3,500[58]
Periods when grass silage fed	20th December to 22nd March	10 - 27th January	19 - 29th February, 6th March to 7th April
Amount fed (wet tonnes)	500	75	120
Date urea applied to pasture	NA	5th March	NA
Amount applied (Tonnes)	0	4.0	0
April 1st			
Average pasture cover (Kg DM/ha)	1950	1480	1840
Cow condition	4.1	4.2	4.0
Milk production (kg MS/cow/day)	1.04	0.99 – 1.01	1.04
Cow intakes (kg DM/cow/day)	15.0	11.0	12.0
Cow numbers	319	242	319
Rotation length (days)	23 - 24	23 - 24	42
Period of Maize silage feeding	7th March to April 13th	NA	8th April to 5th May
Amount (wet tonnes)	350[59]	0	100
Period of green feed maize feeding	NA	11th April to 5th May	NA
Amount (wet tonnes)	0	125	0
Period cut grass fed	NA	6 - 20th May	NA
Amount fed (kg DM)	0	10,000	0
May 1st			
Average pasture cover (Kg DM/ha)	2700	1650	2014
Cow condition	4.4	4.6	4.5
Milk production (kg MS/cow/day)	1.20	1.01 – 1.04	1.01 – 1.04
Cow intakes (kg DM/cow/day)	16.0	15.0	14.0

[56] Purchased in January.
[57] At first grazing.
[58] At second grazing.
[59] In mid December, the case farmer thought that he would be able to use all the maize silage during the autumn. However, after discussions with the owner later in the season, the case farmer was asked to leave 100 wet tonnes of the maize silage in the stack. This reduced the amount of maize silage he could use through the autumn to 250 wet tonnes.

Factor	Year 3	Year 2	Year 1
Cow numbers	297	233	230
Rotation length (days)	30 - 35	30 - 34 [60]	60
Drying off date	**27th May**	**26th May**	**13th May**
Cow numbers at drying off	206	172	230
Milk production (kg MS/cow/day)	1.01	1.01	1.01
Condition score	5.0	5.0	4.6
Average pasture cover (Kg DM/ha)	2000	1800	1926
Date herd on once-a-day	20th May	20th May	6th May
Rotation length at drying off (days)	100	100	100
Winter supplements[61]			
Nitrogen planned for early spring	NA	9.4 tonnes DAP[62]	4.0 tonnes of urea
Winter grazing	NA	7 - 8 weeks for the herd	6 weeks for 200 cows
Maize silage on-hand (wet tonnes)	NA	420	200
Hay on hand (bales)	NA	1100[63]	2250

The farm has no hay or silage shut up, and there is no hay reserves on-hand. However, 500 wet tonnes had been made on the case farmer's runoff, and a neighbour's property. The case farmer also had 350 wet tonnes of maize silage in a stack and 8.0 hectares of forage crop. The forage crop comprised 4.0 ha of Barkan turnips and 4.0 ha of Emerald rape. The case farmer had not grown Barkant turnips before, but had grown Emerald rape previously and it had performed well. The Barkant turnips were sown because they were supposed to yield up to 15 tonnes of dry matter per hectare. The case farmer believed that the Barkant turnip crop would only yield about 1500 kg DM/ha given its state in early January. He stated that it was the worst forage crop he had ever grown. The case farmer had also sown 8.0 ha of maize for maize silage on a neighbours property. Unlike the other crops, the maize was growing well, but was a month behind in terms of yield. This maize silage was to be used during the next spring.

Overall, the farm was in a better feed position in terms of pasture cover, cow condition and milk production at the start of January than in year two (Table 1). It was in an almost identical position to year one in regard to these factors. However, whereas in year one, the farm was receiving good rainfall and conditions were excellent for pasture growth, in year three, the farm had just experienced five weeks of hot, dry weather, pastures were under moisture stress, and pasture growth rates were less than feed demand and declining. Similarly, although the area in forage crop area was greater in year three than the other two years, the two forage crops were poor and at that point in time[64], the case farmer had only expected to obtain grazing for the herd of one weeks duration instead of the normal four weeks. The greater area in forage crop also meant that the case farmer had less area in pasture than in the two previous years, further compounding his feed problem in early January. The case farmer also had no hay on-hand at that point in time. However, he had a lot more supplement in the form of grass and maize silage on-hand at the start of January (Table 1) that he could use over the summer-autumn period. In effect,

[60] The rotation was extended out to 50 days as culls and thinner cows were dried off and removed from the property in early May.

[61] In June of year two, the case farmer moved to a new farm and therefore, the data on winter supplements was not relevant to the summer-autumn period. In this instance, the case farmer had to leave behind 100 tonnes of maize silage and an average pasture cover of 2000 kg DM/ha.

[62] The nitrogen was originally planned for the spring, but when the case farmer purchased an additional 100 - 120 wet tonnes of maize silage, this was removed from the plan.

[63] About 110 bales fed out during drying off.

[64] In early January, the case farmer had expected the forage crops to yield 1500 kg DM/ha. Actual yield had improved to 5000 - 6000 kg DM/ha by the time the forage crop was grazed as a result of good rains.

the case farmer had 850 wet tonnes of grass and maize silage available for use over the summer-autumn period as compared to 75 wet tonnes in year two and 220 wet tonnes in year one. Therefore, although conditions were dry and the forage crop was poor, the herd was in good condition and producing well because the case farmer had abundant reserves of silage with which he could supplement cow intakes. At the same point in time in year two, the herd was in poor condition and with production at the case farmer's minimum, lower pasture cover levels, and dry conditions and low pasture growth rates. The forage crop was also looking poor at that stage, and the case farmer had minimal supplements on-hand. In contrast, in year one, the herd was also in good condition and producing well, average pasture cover was high and conditions were moist with high pasture growth rates. The forage crop was on target at that stage, and the case farmer had a moderate level of supplements on-hand.

January was relatively dry with only 30 mm of rain falling over the month. Although this was adequate to maintain the sward in a growing state, it was insufficient to increase pasture growth rates, which have remained around 25 kg DM/ha/day throughout the month. This is reflected in the decline in average pasture cover by 300 kg DM/ha through January, despite the herd receiving 4.0 kg DM/cow/day of grass silage throughout the month (Table 1). The supplement minimised the impact of the dry conditions on cow condition although milk production declined to 1.1. kg MS/cow/day. Pasture growth through January was similar to that recorded in year two, but almost half of that recorded in the wet summer of year one (Table 2).

At the start of February, there were 319 cows producing 1.04 kg MS/cow/day, at condition score 4.65. Milk production had fallen 0.27 – 0.32 kg MS/cow/day and cow condition had declined 0.10 condition score units. The herd was still on a 23-24 day round and consuming 14.0 kg DM/cow/day. Average pasture cover was 1700 kg DM/ha.

Table 2. Estimated pasture growth rates[65] (kg DM/ha/day) for the summer-autumn over the study period.

Month	Year 3	Year 2	Year 1
January	25	24	44
February	8	25	32
March	45	24	37
April	62	30	44
May	25	25	18
Total (kg DM/ha)	**5029**	**3863**	**5285**

The farm received around 30 mm of rain at the start of February, followed by a week of strong, dry easterly winds and then no further rain until the end of February. On the 22nd February the farm received 15 mm, then 10 mm on the 23rd, 5 mm on the 24th, 20 mm on the 25th and 5mm on the 27th February, a total of 50 mm in the latter part of the month. Although pasture growth rates averaged around 8 kg DM/ha/day through February, since the rain, the case farmer estimated that pasture growth rates had increased and were in the high 30's. Conditions were dry, hot and windy through most of the month. The rain was warm, and conditions remained warm without wind through March, providing excellent growing conditions at the end of the month.

[65] These figures are based on the case farmer's estimates and provide an idea of the relative pasture growth rates in each month for the three years of the study.

By the end of February, the case farmer was still milking 319 cows and production had declined slightly to 1.04 kg MS/cow/day. Cow condition had dropped to 4.25 condition score units. Cow intakes were 4.0 kg DM/cow/day of grass silage, 5 - 6 kg DM/cow/day of forage crop, and 2 - 4 kg DM/cow/day of pasture, a total of 11 - 13 kg DM/cow/day. The herd was still on a 23 - 24 day rotation. Pasture cover declined to around 1400 kg DM/ha before the rain in late February, and has since increased back up to 1450 kg DM/ha at the end of February. The herd was grazing down to 1300 kg DM/ha, and going into 1600 kg DM/ha at the end of February. At the end of February, the case farmer had 70 - 80 wet tonnes of silage on-hand or 10 - 12 days feeding left. The herd has grazed 6.5 ha of the forage crop and there is 1.5 ha left. The case farmer believed that the forage crop yield had doubled over the month of February to around 10,000 - 12,000 kg DM/ha.

During early March, the farm received good rain, and conditions were ideal for pasture growth. There was a mix of windy and warm weather. The second half of the month was wet and warm, providing superb growing conditions. . The farm received 80 mm of rain in March, the majority of which occurred in the latter part of the month. In contrast, in year one, the farm only received 39 mm of rain. This difference is reflected in the March pasture growth rates (Table 2). Pasture growth rates averaged 35 kg DM/ha through the first half of March, and increased to over 50 kg DM/ha/day in the second half of the month. This gave an average growth rate of 45 kg DM/ha/day for March which was higher the previous year (Table 2).

By the end of March, the case farmer was still milking 319 cows and production had declined slightly to 1.04 kg MS/cow/day. It increased to 1.20 kg MS/cow/day in early April. Cow condition had dropped to 4.1 condition score units. However, the thin cows have not declined to 3.5 condition score units by that stage. The case farmer attributed this to the increased feeding regime which allowed the thinner cows a chance to obtain a full level of intake because there is more feed available and they have time to eat it, unlike the competitive situation that occurs when feed is short. Cow intakes were 7.0 kg DM/cow/day of maize silage, and 8.0 kg DM/cow/day of pasture, a total of 15.0 kg DM/cow/day. The herd was on a 23 - 24 day rotation. Pasture cover was 1950 kg DM/ha at the end of March. The herd was grazing down to 1550 kg DM/ha, and going into 2200 kg DM/ha at the end of March. Pasture quality was excellent with a high proportion of clover.

By the end of April, the case farmer was still milking 297 and production was 1.20 kg MS/cow/day. Cow condition had improved over the period, but part of the increase in cow condition to 4.4 condition score units was because 22 thin cows had been removed. Cow intakes were 16.0 kg DM/cow/day of pasture. The herd was on a 30 - 35 day rotation. Average pasture cover was 2700 kg DM/ha at the end of April and still increasing. The herd was grazing down to 1600 - 1700 kg DM/ha, and going into 3300 kg DM/ha at the end of April. Growing conditions were optimal through April with warm conditions and adequate rainfall. As a result, pasture growth rates averaged 62 kg DM/ha/day. This was just over twice those recorded in year two and 41% higher than those recorded in year one (Table 2).

By the middle of May the case farmer was milking 206 producing 1.01 kg MS/cow/day at a condition score of 4.5. There were also 100 dry cows on the farm that the owner had brought on, on the 15th May. The cows were still being fed 15 kg DM/cow/day. Average pasture cover had fallen from 2700 kg DM/ha to 2300 kg DM/ha (1750 kg DM/ha in year two, 2050 kg DM/ha in year one). Pasture growth rates had fallen to 25 DM/ha/day. The herd was going into 3100 kg DM/ha and leaving behind 1500 kg DM/ha on a 40 - 50 day rotation. Pasture quality was excellent. Drying off was initiated on the 20th May and the herd was removed from the farm on the 27th May to go to the new farm. Prior to drying off, the herd was producing 1.01 kg MS/cow/day (1.04 kg MS/cow/day) at condition score

4.6. During the drying off process, the herd was put on a long rotation of approximately 100 days to reduce cow intakes. Pasture cover was estimated at around 2000 kg DM/ha at drying off. The next formal average pasture cover reading was taken on the 15th June at 1800 kg DM/ha. Conditions through May were typical with cooler weather. Pasture growth rates were 25 kg DM/ha/day, the same as in year two, but 44% above those recorded in year one (Table 2).

The difference between the pasture growth rates across the three years is summarised in Table 2. Each year is quite different. The first year can be classified as a wet summer. The farm is in a good state going into the period, and pasture growth rates are above average in all months except May. In total, the farm grows 5285 kg DM/ha over this period. The case farmer also obtains 54,600 kg DM from his forage crop and 66,000 kg DM from grass and maize silage over the summer-autumn period, a total of 120,600 kg DM. Averaged across the 104.0 ha this is 1160 kg DM/ha of supplements.

In year two, the farm suffered the effects of an extremely wet spring, which meant that the farm was in a poor feed position at the start of the summer. The subsequent summer-autumn was dry and this is reflected in the pasture growth rates, which never exceed 30 kg DM/ha throughout the period (Table 2). The total amount of pasture grown per hectare over the summer-autumn is 3863 kg DM/ha (Table 2). This is 27% down on year one. During year two, the case farmer fed 22500 kg DM of grass silage, 32,000 kg DM of forage crop, 10,000 kg DM of bought in cut pasture and 37,500 kg DM of bought-in greenfeed maize, a total of 102,000 kg DM of which 47,500 kg DM had been purchased from off-farm. Total supplements were still 15% less than those used in year one.

In year three, the although the farm had an adequate level of average pasture cover, and the herd were in good condition and producing well at the start of the summer, conditions were very dry. Conditions remained very dry until late February, but after this point, the farm received good rainfall and conditions remained warm until May, providing extremely good growing conditions through March and April. This is reflected in the pasture growth rates which are 31% lower than year two, the dry year, for January and February, but then exceed the pasture growth rates recorded in year one, a very good year, for March and April by 32%. As a result, the farm grows only 5% less grass per hectare than in year one, despite being dry through January and February. The case farmer also uses 48,000 kg DM of forage crop, 75, 000[66] kg DM of maize silage and 135,000[67] kg DM of grass silage, a total of 288,000 kg DM. This is equivalent to 2769 kg DM across the 104.0 ha. This is 182% more supplement than was used in year two, and 139% more than was used in year one.

Planning Horizons

In year three, the case farmer changed his planning horizon and initiated his summer plan eleven days earlier than normal on the 20th December. He did this because conditions had become extremely dry by mid December. He had a large supply of supplement on-hand, and therefore decided to feed the supplements ahead of his normal schedule to maintain milk production, cow condition and average pasture cover. The case farmer explained that he viewed the summer as the period from early January until mid March, because he did not expect pasture growth rates to exceed feed demand until after this point. As such, the transition from one planning period to the next was determined by the climatic conditions. Over summer, the case farmer did not expect pasture growth rates to

[66] This is based on the 250 wet tonnes of maize silage the case farmer had available after the owner negotiated that he leave 100 wet tonnes in the stack.
[67] The case farmer also used 15,000 kg DM of grass silage between the 20th - 31st December.

exceed feed demand because conditions were too dry. Therefore, this period was when he fed his forage crops and grass silage. However, after mid March, with the onset of the autumn rains and cooler conditions, the case farmer expected pasture growth rates to improve and exceed feed demand. Therefore, he expected to increase average pasture cover over this period.

In year three, the case farmer was planning out until mid March. He knew he had a good supply of supplements, but conditions were very dry and at that point in time, he only expected a weeks grazing from his forage crops. The second planning period used by the case farmer was from mid March until June 1st. This was different from other years when the case farmer normally planned through to balance date at the end of September. The reason for this change was that the case farmer was moving to a new farm. His sharemilking contract finished on June 1st, and as part of his agreement with the owner, he had to leave the farm with an average pasture cover of 2000 kg DM/ha and 100 tonnes of maize silage in the stack. Therefore, there was no point planning through until balance date for this property.

Unlike the previous two years, the case farmer did not undertake a gross feed budget in mid March, but delayed this until early April because the farm was in a good feed position. The case farmer stated that he initiated the formal planning process at that point because although his subjective information suggested the farm was in a good feed position, he decided that he should assess the situation formally because it was important that he met his target of 2000 kg DM/ha at June 1st. He was legally obliged to leave the farm with this amount of average pasture cover on-hand. The case farmer did not bother to revise the feed budget in year three because the farm was in a good feed position.

At a lower level, the case farmer used shorter planning horizons of approximately two to four weeks' duration. These were event-driven and related to important activities within the longer planning time-frame. These included such activities as the period during which the herd was fed the grass silage, the period when the herd is fed the forage crop and so on. Analysis of the data suggested that at this level, the planning horizon is fairly fluid in that the case farmer's short-term planning horizon may only encompass one event, or it may encompass several events.

In previous years, a comment was made that the terminating state for the herd at the end of summer was a condition score of at least 4.0 and for as many cows as possible to be in a lactating state. The case farmer noted that he did not have a terminating target of cow condition at the end of the summer plan, rather, he used his decision rule for thin cows to protect the condition of the herd.

Values, and goals

There was little evidence that values influenced the tactical management of the case study. Interestingly, unlike years one and two, there was little evidence of the case farmer seeking opportunities in terms of alternative sources of feed. However, this is not surprising given the amount of supplement the case farmer had on-hand in year three. As such, there was little need to seek alternative feed sources. During the summer, the case farmer's goal was to optimise milk production and ensure the maximum number of lactating cows were on-hand when the autumn rains arrived with the constraint that he must leave the farm with an average pasture cover of 2000 kg DM/ha and ensure the herd calves at an average condition score of 5.0 condition score units. As such, the summer goal was subservient to the goal of the second planning period. Similarly, summer milk production was secondary to ensuring the maximum number of lactating cows were on-hand at the end of the summer. The case farmer made the point that he was aiming to maintain milk production above 1.0 kg MS/cow/day through the summer, but that this was not a hard and fast rule.

The goal for the second planning period was to optimise milk production in early lactation, ensure the herd would be at condition score 5.0 at calving and leave the farm with an average pasture cover of 2000 kg DM/ha at June 1st. Optimising autumn milk production was secondary to these other goals.

To ensure the summer goal was met, the case farmer used a set of targets that were designed to optimise milk production from the available feed supply while protecting average pasture cover and cow condition (See later section). Similarly, the terminating conditions specified in the second planning period dictated the average pasture cover required at June 1st and the cow condition score target required at planned start of calving. These in turn dictated the respective targets at drying off, therefore constraining autumn milk production.

Planning Process

As in previous years, the case farmer used an informal planning process to develop his summer plan and a formal process for his autumn plan. However, there were some important differences in year three. The case farmer identified that he had a feed problem (through his prediction of cow intakes at the next grazing) around mid December. At that point in time, the herd was consuming 45 kg DM/ha/day, and the farm was growing 30 kg DM/ha/day and pasture growth rates were declining. As such, average pasture cover, and pre- and post grazing residuals were declining at 15 kg DM/ha/day or around 360 kg DM/ha over the period of one grazing rotation. Climatic and visual data suggested growth rates would continue to decline and at growth rates of 25 kg DM/ha/day, average pasture cover, and pre- and post grazing residuals would decline at 480 kg DM/ha over the period of one grazing rotation. This rate of decline suggested the case farmer needed to consider some form of action. He had made a strategic decision to dramatically increase the level of grass and maize silage on-hand (Table 1). He therefore decided that rather than underfeed the herd in late spring, he would shift his planning horizon forward for the summer plan and modify his "typical" plan to minimise the impact of the dry conditions in late summer. He then used simulations (mental feed budgets) over several days to consider alternative ways of modifying the "typical" plan to make best use of his feed. This was a more conscious and deliberate process than in previous years. The case farmer analysed what he expected the herd to consume (kg DM/ha/day) from late December until mid March, what he expected the farm to grow in terms of pasture through this period, and the quantity of forage crop he expected to harvest. He then estimated how long his grass silage would last under this scenario. The case farmer had some constraints to his plan. Firstly, because he was increasing cow numbers next season, he did not want to cull any cows until they were pregnancy tested in late March. Secondly, although there was scope to graze 30 dry cows on the runoff, this option was not available for a month in order to allow silage paddocks to recover. Therefore, he could not dry off thin cows for at least a month. The final constraint on the plan was that the case farmer wanted to delay the grazing of the forage crop until March to ensure maximum yield. However, he could not leave it any later than this because this would prevent the new grass from being sown before the start of April. The case farmer found that given his expected pasture growth rates, he had sufficient grass silage to feed the herd 3 - 4 kg DM/cow/day from late December through until early March when he would graze the forage crop. He also had sufficient maize silage to feed the herd a similar ration through into May.

The planning process in effect drew on the case farmer's decision rules for a "typical" plan and modified them. Quantitative analysis was used to assist with this process because the case farmer had not had this situation before. A simple mental feed budget was used to investigate the modified plan's feasibility. The analysis was undertaken mentally, and none of the calculations were written down. The case farmer stated that he worked this out during several milkings around mid December. The decision rules the case farmer used to develop the plan are summarised in Table 3. The input type and level rules determine the type and how much of an input to use e.g. feed sufficient grass silage to maintain production at, or above 1.04 kg MS/cow/day.

The case farmer predicted that the summer would be dry and that his forage crop yield would be low. This information was used to predict likely pasture growth rates and forage crop yield, and then assess the likely feed situation on the farm through the summer-autumn. The case farmer's analysis suggested that with his current level of supplements, the case farmer could milk through into May despite the dry conditions and poor forage crop. The case farmer made an important point in relation to his plan.

Table 3. Planning rules used by the case farmer for the summer plan in year three.

Planned event	Decision rule	Reasons behind the rules
Initiate summer plan early **Sequencing rule**	If the feed situation becomes serious in December, and there is sufficient supplement on-hand, and there are constraints on culling and/or grazing off dry cows, then initiate the summer plan ahead of schedule.	One option over December if conditions become dry is to destock through culling or drying off thin cows and grazing them off. However, in year three, the case farmer did not want to cull cows until he knew their pregnancy status as he wanted to increase cow number for the next season. He could not graze cows off on the runoff because silage had just been harvested and the paddocks needed several weeks to recover. However, the case farmer did have a considerable quantity of grass silage on-hand. He estimated that there was sufficient to feed the herd from late December through until when the forage crop would be ready to graze in early March. The grass silage would be used to maintain milk production, cow condition, average pasture cover and post-grazing residuals.
Select summer stocking rate **Input type and level rule**	Select the stocking rate at which the herd can be fed such that production can be maintained at, or above 1.04 kg MS/cow/day through until mid March. Assess the average pasture cover, climatic conditions, pasture growth rates and supplements on-hand, around late December. Estimate the likely forage crop yield. From this decide on the number of cows that can be taken through the summer.	The case farmer wants to take as many cows as possible through the summer to take advantage of the autumn rains. He believes that the most efficient use of feed is to run enough cows to produce at 1.04 kg MS/cow/day. Cull cows are sold prior to the start of the summer period.
Maintain the herd on a 23 - 24 day rotation and feed sufficient silage to maintain milk production above 1.0 kg MS/cow/day. **Sequencing rule** **Input type and level rule**	IF analysis of pre- and post-grazing residuals suggests pasture growth rates are declining and as a result, cow intakes will continue to decline, AND the rotation length = minimum, THEN maintain the herd on the current rotation length. IF it is late December, AND analysis of pre- and post-grazing residuals suggests pasture growth rates are declining and as a result, cow intakes will continue to decline,	IF the case farmer used a faster rotation, the herd the farm would be in a worse position at the start of the next round because average pasture cover would have been reduced more quickly. Extending the rotation would reduce cow intakes and post-grazing residuals. Low post-grazing residuals limit pasture growth rates. The case farmer had estimated that he had sufficient grass silage to feed the herd from late December until early March. His indicators suggested pasture cover, cow intakes, post-

Planned event	Decision rule	Reasons behind the rules
	AND there is sufficient grass silage on-hand to feed the herd from late December until early March when the forage crop will be ready to graze, THEN initiate grass silage feeding and provided sufficient grass silage (3 - 4 kg DM/cow/day) to maintain milk production ≥ 1.04 kg MS/cow/day.	grazing residuals and milk production would decline rapidly over the next 3 - 4 weeks unless he took some action. Given that he did not want to cull the herd, or graze any cows off, he decided to feed the grass silage. This would help maintain cow intakes, post-grazing residuals, average pasture cover, milk production and cow condition. Because the farmer was leaving the farm, there was no advantage in retaining the grass silage for use during another period. From March on, he had other options such as the forage crop, maize silage, culling and grazing off. His priority was to maintain the pasture in an actively growing state and ensure as many cows as possible made it through to March in a lactating state. The case farmer aimed to hold milk production at, or above 1.04 kg MS/cow/day because this minimised loss of condition in the herd and maintained post-grazing residuals at a reasonable level. The case farmer noted that this "*was not a hard and fast rule*" and that milk production might fall below this level, and he expected to lose some condition over the summer, especially if it remained dry.
Remove the bull in early February. **Termination rule**	IF date = early February, THEN remove the bull	The case farmer allows the bull to remain with the herd for a specified period to ensure that later cycling cows are mated.
Dry off thin cows if their condition falls below target from February onwards. **Termination rule**	IF individuals cows condition is ≤ target, AND the month ≥ February, THEN dry off the cow and place it on the runoff to increase condition.	The case farmer did not want to dry off any thin cows until February in order to allow the silage paddocks sufficient time to recover. Given the current condition of the herd and the feed position, he believed that he would not have to dry off thin cows until February. His plan was then to dry off cows as their condition declined to target and then place them on the runoff to increase condition for calving. In year three, the case farmer had increased his condition score target at calving from 4.75 to 5.00 condition score units. He therefore had to ensure his thinner cows were removed from the herd at a point in time that allowed them to put on sufficient condition to meet target.
Feed the forage crop at the beginning of March after the grass silage at a level that maintains milk production at 1.0 kg MS/cow/day. **Sequencing rule** **Activation rule** **Input type and level rule**	IF the forage crop yield is poor, AND analysis of pre- and post-grazing residuals suggests pasture growth rates are declining and as a result, cow intakes will continue to decline, AND there is sufficient grass silage on-hand to feed the herd to requirements, THEN use the grass silage first, and delay the grazing of the forage crop for as long as possible. IF it is early March,, THEN feed the forage crop at such a rate that milk production is held at 1.04 kg MS/cow/day.	The forage crop was used after the grass silage because it increases in yield with time, whereas, the grass silage yield does not change. The case farmer decided that with his current level of grass silage and the poor nature of his forage crop, that his best option was to allow it to grow for as long as possible to maximise yield. He estimated that the forage crop would provide a week grazing for the herd. He wanted to have the new grass resown by the start of April, and this limited how long he could leave the forage crop ungrazed. In order to ensure the new grass was sown on time, the case farmer had to graze the forage crop at the start of March.
	Terminate forage crop grazing by the end of February. IF estimates suggest the forage crop will provide a weeks grazing,	The forage crop is used to maintain milk production at target and ensure the post-grazing residual is maintained above a minimum level.

Planned event	Decision rule	Reasons behind the rules
Finish feeding the forage crop by the 7th March. **Termination rule**	AND there is sufficient silage on-hand to feed the herd through until early March, AND the forage crop must be grazed by the 7th March, THEN plan to begin grazing the forage crop at the start of March.	This prevents over-grazing, increases pasture growth rates and ensures pastures respond quickly to rain. The forage crop allows the case farmer to increase post-grazing residuals. The milk production target ensures higher post-grazing residuals and therefore higher pasture growth rates. At this level of milk production, intakes are sufficient to limit the rate at which the herd loses condition.
Sow the new grass by mid March. **Sequencing rule** **Activation rule**	The new grass should be sown by mid March after the forage crop has been grazed.	Good establishment of new pastures requires that they be sown in March.
Maintain the herd on a 23 -24 day rotation after the forage crop unless the feed situation improves. **Sequencing rule** **Input type and level rule**	IF average pasture cover is low, AND supplements are unavailable, THEN maintain rotation length at 23 - 24 days until the feed position improves.	The case farmer needs some form of supplement or high average pasture covers so that he can extend the rotation without reducing cow intakes and post-grazing residuals.
Feed maize silage after the forage crop to maintain milk production at, or above 1.0 kg MS/cow/day and hold or increase cow condition. **Sequencing rule** **Activation rule** **Input type and level rule**	IF the forage crop has been grazed, AND analysis of pre- and post-grazing residuals suggests cow intakes and milk production will decline below target, AND maize silage is on-hand, THEN feed sufficient maize silage to maintain milk production at, or above 1.0 kg MS/cow/day and hold or increase condition.	The case farmer uses maize silage during the autumn to extend the lactation, maintain or increase cow condition and increase average pasture cover.
Pregnancy test the herd 6 - 8 weeks after the bull is removed in late March. **Sequencing rule** **Activation rule**	IF the bull is removed on date = X, THEN pregnancy test the herd 6 - 8 weeks after this date.	To accurately diagnose pregnancy status, the herd should not be examined for at least six weeks after the bull has been removed.
Herd test in early April after pregnancy diagnosis. **Sequencing rule** **Activation rule**	IF the herd is to be pregnancy tested in late March, AND herd test information is required for culling decisions, THEN herd test in early April.	Herd testing provides important information for culling purposes. As culling occurs after pregnancy diagnosis, it is useful to undertake a herd test around the same time.
Sell cull cows around mid April after pregnancy diagnosis and herd testing. **Sequencing rule** Termination rule	Sell the cull cows after pregnancy diagnosis and herd testing. IF it is early April, AND the herd has been pregnancy tested, AND the herd has been herd tested, AND the cull cows have been identified, THEN sell the cull cows.	The case farmer does not want to cull in-calf cows because he wants to increase herd size for next season. Therefore he planned to delay culling until after pregnancy diagnosis and herd testing so that he knows exactly which cows are in-calf and which cows to retain for next season.
Harvest the 8.0 ha maize crop for maize silage. **Activation rule**	IF the maize crop is mature, THEN harvest it for maize silage.	Maize silage must be harvested at the right stage of maturity to maximise yield and quality. This normally occurs around mid April in the Manawatu.
Dry off the herd in May. **Sequencing rule** **Termination rule**	Dry off the herd after all other options are exhausted and the feed budget shows that the target of 2000 kg DM/ha at June 1st will be met.	This season the case farmer believes with the level of supplement on-hand, he can milk through until May. However, because he is moving to a new farm, he must leave the farm with an average pasture cover of 2000 kg DM/ha on June 1st. This target will dictate his drying off date. His cow condition target for calving will influence his decision to dry off thin cows through the autumn and it may also dictate the drying off date.

The case farmer stated that much of his plan consists of "possible" options that may change depending on the conditions. For example, he cannot predict exactly how many thin cows he will dry off, nor at what point in time. Similarly, although he aims to maintain milk production above 1.0 kg MS/cow/day, he may not be able to do this if conditions became extremely dry. His comments are supported by examples in year three, when he predicted the forage crop would provide one week grazing, and that he would probably dry off a mob of thin cows in February. In contrast, the forage crop provided four weeks grazing, and the first mob of thin cows was not dried off until late April. These comments and examples demonstrate that the case farmer views his plan as being flexible. He realised that his ability to forecast future conditions was limited, and this was reflected in the lack of detail he included in some aspects of his summer plan such as the number of, and date at which, he would dry off his thin cows. It also emphasises the importance of the control function and the role monitoring and contingency plan selection play in the overall process.

Unlike the two previous years, the case farmer did not change to a quantitative planning approach in mid March, but rather, he extended the summer plan until early April when he completed a feed budget through to June 1st. The "extension" process was based on simple on-going analysis drawing on decision rules and simple calculations of likely intake given expected pasture growth rates in 23 - 24 day's time (next round). The feed budgeting process was relatively simplistic in that the case farmer estimated how long he could milk all the cows he had on hand in early April given average pasture growth rates, the supplements on-hand, target intakes, and the need to have 2000 kg DM/ha/day on-hand at June 1st. The feed budget predicted that the herd could be milked through until May 10th. The case farmer stated that he thought he would have to dry off the thinner cows in the herd before this and that he would in fact milk less cows for longer into May. However, he did not develop a new feed budget. Nor did he revise the feed budget in early May as he had done in previous years. This was because he was in a good feed position he was in.

The case farmer was always reassessing his plan and considering alternative options should conditions improve, or deteriorate. His actual choice of option depended on the situation as it unfolded. Normally, the choice was between the course of action the case farmer originally specified in his plan, and some alternative option that he had identified should conditions deviate from that expected in the plan. For example, in relation to his plan outlined in Table 3, the case farmer also noted that if his forage crop yielded more than the weeks grazing he had predicted, he would revise the plan, and graze it earlier. When, in early February, he found the forage crop yield had increased dramatically as a result of the rain, he estimated the additional weeks grazing he might obtain from it by dividing the yield times the forage crop area by the number of cows times the forage crop ration he wanted to feed per cow per day. This calculation predicted that the forage crop would provide an additional two weeks grazing. Similarly, he stated that if it got very dry and he had to graze off more than 30 cows over the summer, he would look for additional grazing because he could only accommodate 30 cows on his runoff. This suggested he used a form of mental preparedness in that the case farmer is preparing himself to implement alternative options should conditions change from his expectations. During the interviews, the case farmer would describe what he planned to do, and then mention an alternative course of action if, for example, conditions became drier than he had expected. These options were often not implemented, although they were noted in the contingency plan section. However, the case farmer did not undertake any formal or quantitative analyses of alternatives during either the summer or autumn planning process. Rather, the case farmer uses decision rules to determine the optimum sequence of options within his plans. Nor was any form of risk analysis was undertaken in year three during the summer-autumn.

The plan

The outcome from each planning process comprised a schedule of events, a set of targets for controlling the implementation of the plan and a set of contingency plans and associated decision rules that were used to select the most appropriate contingency plan for the conditions should a deviation occur. The schedule of events specified in the case farmer's plan[68] for years three, two and one are summarised in Table 4. The plan for year three was to feed the herd 3 - 4 kg DM/cow/day of grass silage and maintain it on a 23 - 24 day rotation. The case farmer aimed to maintain milk production above 1.0 kg MS/cow/day and not cull any of the herd until after pregnancy testing. He said he would dry off thin cows as their condition fell to 3.5 condition score units. He noted that this was an option and the exact number depended on the conditions. He did not expect to have to dry any thin cows off until February. The bull will be removed from the herd on the 10th February. Silage would continue to be fed to the herd until late February, early March, and then the case farmer would feed the forage crop. He did not expect it to last much more than a week. However, he did note that if it rained and the forage crop yield improved, he would review the plan. The case farmer had culled most of the cows he did not wish to retain by late December and because he wanted to increase cow numbers for the following season, the culls that he plans to sell after pregnancy testing in late March will be primarily empty cows and any that are not empty will be sold as in-calf culls. The case farmer noted that he had not tried to find off farm grazing because he believed that with the maize silage, he would be able to milk through the autumn. If it became extremely dry, then he would seek off-farm grazing. The forage crop paddocks will be resown into new grass around mid March. During autumn, the case farmer will use his 250 wet tonnes of maize silage that is in the stack to milk into May. This will be fed after the forage crop and used to maintain or increase cow condition. The case farmer will also harvest the 8.0 hectares of maize for maize silage in April, and this will be reserved for the owner for next spring.

The first difference in the year three plan as compared to years one and two is that the case farmer initiates the summer plan 11 days earlier than normal. This was for a number of reasons. Firstly, conditions had become very dry, but the case farmer could not destock because he did not want to cull any of the herd until they were pregnancy tested because he planned to increase herd size for next season. Secondly, he could not dry off cows until February because he needed to spell the silage paddocks on the runoff. Finally, the case farmer had sufficient supplements on-hand that he could feed the herd a third of their ration from late December until early March. Therefore, the case farmer decided to implement the summer plan 11 days early and the herd a third of their ration as grass silage whilst maintaining them on a 23 - 24 day round.

Table 4. A comparison of the plan for years three, two and one.

Year 3 Plan	Year 2 Plan	Year 1 Plan
	Set stock the calves across the entire farm over the summer-autumn.	
Maintain the herd on a 23 -24 day rotation and feed them 3 - 4 kg DM/cow/day of grass silage whilst maintaining milk production at, or above 1.04 kg MS/cow/day from the 20th December until early March.	Maintain the herd on a 23 - 24 day rotation feeding solely pasture until three weeks before the end of the month. During this period, allow milk production to fall below 1.04 kg MS/cow/day.	Maintain the herd on a 21 - 22 day rotation until late January or milk production falls to 1.13 kg MS/cow/day

[68] The schedule of events comprises those for the period of the study (January 1st - drying off). This schedule of events covers the summer period and the early part of the plan developed at March 13th. Events beyond drying off are not incorporated, although this would include the grazing off and return of the herd to the milking area, the feeding of supplements and the grazing rotations of the herd over winter and early spring.

Year 3 Plan	Year 2 Plan	Year 1 Plan
	Feed grass silage before the forage crop. Feed grass silage at the point when it can be used to feed the herd to target until the end of January. While feeding silage and the forage crop, maintain the herd on a 23 - 24 day rotation unless the feed situation improves.	
	Feed the forage crop at the end of January after the grass silage at a level that maintains milk production at 1.04 kg MS/cow/day. In a dry year make the forage crop last until the end of February, and reduce cow numbers if necessary to maintain milk production at 1.04 kg MS/cow/day.	When milk production falls to 1.13 kg MS/cow/day in early February, feed the forage crop for 3 weeks and maintain milk production at or above 1.04 kg MS/cow/day
Remove the bull in early February.	Remove the bull in early February.	Remove the bull in early February
		Herd test on the 20th February
Dry off the thin cows if cow condition declines below target.	Dry off thin cows if there is insufficient feed to maintain milk production at 1.04 kg MS/cow/day.	
Feed the forage crop for one week in early March. Maintain milk production at, or above 1.04 kg MS/cow/day.	Complete the grazing of the forage crop by the end of February.	When the forage crop is finished, feed grass silage for four weeks and use the grass silage to extend the rotation out to 35 - 42 days while holding milk production at 1.04 kg MS/cow/day.
Maintain the herd on a 23 -24 day rotation after the forage crop and feed maize silage to maintain or increase cow condition.	Maintain the herd on a 23 -24 day rotation after the forage crop unless the feed situation improves.	Regraze the forage crop for a week in late February and then continue to feed the grass silage. A third grazing may be obtained from the forage crop in March.
Sow the new grass by mid March.	Sow the new grass by mid March.	Sow the new grass by mid March.
Pregnancy test the herd 6 - 8 weeks after the bull is removed in late March.	Pregnancy test the herd 6 - 8 weeks after the bull is removed in late March.	Pregnancy test the herd 6 - 8 weeks after the bull is removed in late March.
Undertake a herd test in early April.		Undertake a herd test in early April.
Sell cull cows in mid April after pregnancy diagnosis and herd testing.	Sell cull cows in early April after pregnancy diagnosis.	Sell approximately forty cull cows in early April
		Dry off the thin induction and rising three year old cows in early April.
		Extend the rotation as the cull and dry cows are removed from the milking platform
		Feed 100 tonnes of maize silage through April.
		Production will decline to 0.87 kg MS/cow/day in the last month of lactation and the herd will hold condition on the maize silage
Dry off the herd in May.	Dry off the herd. Date is unknown, but is very dependent on pasture growth over the summer-autumn and the acquisition of other feed sources.	Dry off the herd in May

The case farmer had leased a runoff for his replacement stock and grazed them off the milking area in year three. As in year two, he planned to maintain the herd on a 23 - 24 day rotation through the summer because he believed that with the dry conditions, it would not be possible to extend the rotation. He also believed, based on his experience in year two, that a fixed round over summer-autumn produced better pasture regrowth than a rotation which was extended over this period. A major difference between the two previous years was that the forage crop yield was so poor in mid December, that the case farmer decided to delay grazing it until early March to allow it time to reach maximum yield. The case farmer could do this because he had so much more silage than in the previous two years (500 tonnes versus 75 and 120 tonnes). As in year two, the case farmer expected to dry off thin cows from February on-wards. However, whereas in year two, he had to dry off the thin cows because of both their condition and to provide feed for the remainder of the herd, in year three, feed was not expected to be as limiting, and condition would determine when the thinner cows had to be dried off. In contrast, in year one, the condition of the herd and feed situation was so good in late December that the case farmer did not expect to have to dry off thin cows until April.

Other elements of the year three plan were similar to those in years one and two. For example, the planned dates upon which the bull was to be removed, the new grass sown, and the pregnancy test undertaken were the same. The planned date for the sale of the cull cows was slightly later in year three because the case farmer wanted to utilise his herd test results which was undertaken in early April. As in year one, the case farmer believed that he would dry off the herd sometime in May. In contrast, in year two, the feed position was so poor in late December that the case farmer was not confident that the herd could be milked through to May. The other major difference between the case farmer's year three plan and the previous two years was that he planned to use the maize silage through March and April, and into May. In year two, the case farmer did not have maize silage on-hand to use in his plan, and in year one, although the case farmer had maize silage, he only had 100 tonnes, as opposed to the 250 tonnes in year three. In year one, he believed he would not need to feed the maize silage until April and he wanted to use it at that time to improve cow condition and average pasture cover prior to drying off. With only 100 tonnes of maize silage, he would not have been able to feed it through March as he did in year three.

As in the previous two years, the case farmer aimed to maintain milk production above 1.04 kg MS/cow/day. The dairy company had changed to milk solids and the conversion rate from milk fat to milk solids was 1.74. Therefore the figure of 0.60 kg MS/cow/day is equivalent to 1.04 kg MS/cow/day. Although the case farmer aimed to maintain milk production at 1.04 kg MS/cow/day, he noted that this "*was not a hard and fast rule*" and that if conditions became extremely dry, he might sacrifice milk production to ensure the maximum number of lactating cows made it through to the autumn. This was similar to year two, where the case farmer relaxed his summer milk production target for January because he believed he had insufficient feed on-hand to feed the herd to target. However, unlike year two, the case farmer believed that he had sufficient feed to hold milk production above 1.04 kg MS/cow/day over the summer except if conditions became extremely dry.

Implementation and comparison to the plan

The year three plan is compared to the actual outcome in Table 5 and the reasons for any deviation between the two are given. The first deviation from the plan occurred in early February when the case farmer had to double the grass silage ration to maintain post-grazing residuals, cow intakes, milk production and cow condition. Pasture growth rates had remained low through January despite 35 mm falling in the latter part of the month, and as a result, average pasture cover had declined to levels, which could not maintain cow intakes at target with only 4.0 kg DM/cow/day of grass silage. The case farmer had also re-estimated the forage crop yield and had found that it had increased dramatically in late January as a result of the 35 mm of rain the farm received over that period. His new estimate suggested he could obtain another two weeks grazing from the forage crop, and therefore he decided he could double the grass silage level because the forage crop would now be grazed two weeks earlier.

Table 5. A comparison of the plan to the actual outcome for year three.

The plan	The actual outcome	Reason for deviation
Maintain the herd of 327 cows on a 23 -24 day rotation and feed them 3 - 4 kg DM/cow/day of grass silage whilst maintaining milk production at, or above 1.04 kg MS/cow/day from the 20th December until early March.	The herd was fed 3 - 4 kg DM/cow/day of silage from December 20th until early February and milk production was maintained above 1.04 kg MS/cow/day.	
	In early February, the case farmer doubled the grass silage intake to 6 - 8 kg DM/cow/day.	Low pasture growth rates continued through January and into February. In early February, average pasture cover and pasture intake had declined and the case farmer's minimum of 1.04 kg MS/cow/day was threatened. Cow condition was declining, and importantly, post-grazing residuals were predicted to fall below 1400 kg DM/ha. During late January, the farm had received 35 mm of rain. The additional grass silage was fed to increase post-grazing residuals, take advantage of the rain, maintain milk production above 1.04 kg MS/cow/day and minimise the loss in condition. The case farmer also increased the silage ration because he estimated he had an additional two weeks grazing from the forage crop and this allowed him to feed more grass silage than he had originally planned.
	From February 8th, the grass silage was again fed at 4.0 kg DM/cow/day, and this continued through until the 22nd March.	The forage crop was fed three weeks earlier than expected because the yield was 3 - 4 times that initially predicted. This allowed the grass silage to be fed for an additional three weeks in March.
Remove the bull in early February.	The bull was removed in early February.	
Dry off thin cows if condition falls below target. This was expected to occur from February on-wards. The case farmer expected the runoff to graze 30 dry cows with additional cows being sent away to grazing.	The case farmer dried off 22 thin cows and sent them to the runoff on the 18th April. The case farmer dried off 75 thin cows and sent them to the runoff on the 10th May.	Due to the high level of supplements, better than expected forage crop yield, and high pasture growth rates through the autumn, the younger cows were better fed than expected through the summer-autumn. Therefore, the case farmer did not have to dry off the thin younger cows as early as he had expected. The later date at which the dry cows were dried off at, and the good growing conditions over the autumn also meant the runoff had surplus feed and could cope with almost 100 dry cows rather than the 30 the case farmer initially planned for.
Feed the forage crop for one week in early March. Maintain milk production at, or above 1.04 kg MS/cow/day.	The case farmer began feeding the forage crop on the 8th February. The herd was fed 5.0 kg DM/cow/day of forage crop, 4.0 kg DM/cow/day of grass silage and 4.0 kg DM/cow/day of pasture. The forage crop was fed at the rate of 4 - 6 kg DM/cow/day through until March 6th. The pasture component declined to 2 - 4 kg DM/cow/day in late February and then increased to 6.0 kg DM/cow/day in early March after the rain in late February. Silage intakes were maintained at 4.0 kg DM/cow/day while the forage crop was being fed.	Rainfall in late January increased the forage crop yield dramatically. Initial yield estimates in mid December were 1500 kg DM/ha. The actual yield was estimated at 5000 kg DM/ha in early February. This meant the forage crop had to be grazed earlier than March 1st to ensure the new grass was planted at the specified date. In early February, average pasture cover had fallen to the point, that pasture intakes were insufficient to maintain milk production at target. The case farmer did not want to feed more than 8.0 kg DM/cow/day of grass silage and decided that he would feed a combination of pasture, grass silage and forage crop. This approach allowed him to provide the herd with a

The plan	The actual outcome	Reason for deviation
		balanced ration, delay the grazing of a portion of the forage crop for as long as possible, while ensuring the forage crop was grazed by the 7th March, whilst ensuring his production targets were met. The forage crop yield increased to 10,000 kg DM/ha by the end of February. This allowed the case farmer to obtain four weeks grazing from the forage crop.
Maintain the herd on a 23 -24 day rotation after the forage crop and feed maize silage at 4.0 kg DM/cow/day to maintain or increase cow condition. The maize silage was expected to last until early May.	The case farmer began feeding maize silage on the 7th March. Up until the 22nd March, the herd received 4.0 kg DM/cow/day of maize silage, 4.0 kg DM/cow/day of grass silage and 6.0 kg DM/cow/day of pasture. When the grass silage was finished, the herd was fed 7.0 kg DM/cow/day of maize silage and 8.0 kg DM/cow/day of pasture until the 4th April. On the 5th April, the case farmer reduced the maize silage to 4.0 kg DM/cow/day because pasture cover had increased dramatically and the herd was receiving 11.0 kg DM/cow/day of pasture.	Grass silage was fed with the maize silage because it lasted longer than expected. This was because the forage crop yielded much more than was expected. The maize silage was fed with the grass silage to provide a more balanced ration. The case farmer believed that the ration would not be balanced if he fed his entire supplement as grass silage. The maize silage did not last quite as long as the case farmer had predicted. This was partly because he had to feed double rations for almost two weeks, and partly because cow numbers were higher than the case farmer had expected with the thin cows remaining above target condition score until late April, early May.
	At the same time he extended the rotation out to 30 days. This continued until April 13th by which stage the rotation length had been extended out to 35 days. When the maize silage finished on the 13th April, the case farmer reduced the rotation length to 30 days to maintain cow intakes at 15 kg DM/cow/day. The rotation was gradually extended out to 35 days by mid May and then to 100 days through the drying off process.	The case farmer had to extend the rotation in early April because the average pasture cover had increased rapidly and the herd was leaving behind too high a residual, creating pasture quality problems. When the maize silage was finished, the case farmer had to shorten the rotation to provide additional pasture to make up for the loss of the maize silage. However, as dry cows and culls were removed from the herd, the case farmer extended the rotation out to 35 days prior to drying off.
Sow the new grass by mid March.	The new grass was sown on the 28th March.	Other farm work delayed the cultivation and sowing of the new grass.
Pregnancy test the herd 6 - 8 weeks after the bull is removed in late March.	The herd was pregnancy tested in mid April.	
Undertake a herd test in early April.	A herd test was undertaken in early April.	
Sell cull cows in mid April after pregnancy diagnosis and herd testing.	The case farmer sold 8 cull cows on January 10th.	In early January, the case farmer had identified 8 cows that had not been mated to the bull. At that point in time, the feed situation had not improved and average pasture cover and cow intakes were declining. The case farmer believed that the cull cow price would not improve if the dry conditions persisted. He therefore, decided to sell the empty cows on the 10th January.
	In early May, 16 cull cows were sold.	The case farmer could not cull the herd until this point in time because the herd test had been delayed until mid April. It then took time to select the culls, dry them off and organise transport to the works.

The plan	The actual outcome	Reason for deviation
Dry off the herd in May. Dry off the herd on May 10th[69] at 2300 kg DM/ha.	The owner grazed 100 cows on the farm for three weeks from May 10th.	The 8.0 ha maize crop did not yield as well as expected, and the case farmer had to provide grazing for 100 of the owner's cows for three weeks through May to make up for the difference. This change was included in the feed budget calculated by the case farmer in early April.
	The herd was dried off on the 27th May.	The feed budget completed in early April predicted that the case farmer could milk the 319 cows through to May 10th and dry off on an average pasture cover of 2300 kg DM/ha. The herd of 206 cows was dried off 17 days later than this on a pasture cover of 2000 kg DM/ha. The case farmer noted that this in part was because, by drying off the thin cows, it allowed him to extend the lactation. The remainder of the difference can be attributed to the high pasture growth rates over April, which also allowed the herd to be milked for longer than was originally planned.

In December, the case farmer had expected that he would have to dry off some thin cows in February when their condition fell to 3.5 condition score units. He anticipated that he would then dry off subsequent mobs of thin cows as their condition declined to the target threshold. He did note, that the number and date at which the thin cows would be dried off was very dependent on feed conditions. In effect, the case farmer did not dry off any thin cows until late April (22), with a second mob of 75 dried off in early May. The thin cows did not fall below the case farmer's target threshold levels because with the high intake levels, combined with the high level of supplementation, the younger cows did not have to compete as much for feed during the summer-autumn and were able to obtain adequate intake. Therefore, their rate of loss of body condition was less than in other "dry" years.

The third deviation from the plan in year three was that the forage crop was grazed from February 8th to March 6th rather than from March 1st to March 7th. This occurred because average pasture cover continued to decline into February, and as a result, the pasture component of the herd's diet also declined. The case farmer did not want to feed more than 8.0 kg DM/cow/day of grass silage to the herd, so he decided to feed the forage crop with the grass silage on the 8th February. The forage crop lasted four weeks, a week longer than the revised estimate, and this was because yield continued to increase through February, providing additional grazing.

The fourth deviation from the plan in year three was that the maize silage was fed from March 7th to April 13th, whereas in the original plan it was to be fed from March 8th until early May. The maize silage did not last as long as first planned because (i) the case farmer had to feed almost double rations from March 23rd until April 4th, and (ii) the number of milking cows on-hand through this period was higher than expected. This was because the thin cows maintained condition through the summer better than expected and were not dried off until late April, early May.

Because he expected a dry summer, the case farmer planned to retain the herd on a 23 - 24 day rotation and extend this round if feed conditions allowed. The herd remained on a

[69] In early April, the case farmer completed a formal feed budget and predicted that on the basis of the current feed situation, the herd would be dried off on the 10th May.

23 - 24 day round through until April 4th. Average pasture cover had increased dramatically through late March, early April as a result of good rain and warm growing conditions with pasture growth rates of 50 kg DM/ha/day recorded. As a result, the herd was leaving behind high residuals (> 1700 kg DM/ha) that were "clumpy" and pasture quality was declining. To maintain pasture quality and reduce the post-grazing residual, the case farmer extended the rotation length out to 30 days and reduced the maize silage ration by half. The rotation length was extended out to 35 days over the next eight days as average pasture cover continued to increase. On the 13th April, the maize silage was finished, and the case farmer reduced the rotation length back to 30 days to maintain cow intakes. The herd remained on this rotation length until early May when with the removal of 16 culls and 75 dry cows, the case farmer was able to extend the rotation out to 35 days by mid May.

There was some discrepancy between the plan and the actual outcome in relation to culling. Originally, the case farmer had planned to cull the herd in mid April. However, in early January, he identified eight culls that had not been mated by the bull and decided to cull them at that point. Conditions were very dry, and the schedule was falling so he decided to sell them. The second discrepancy was that the majority of the culls were not sold until early May. This was primarily because the pregnancy test was delayed until mid April, three weeks after the original planned date. This was delayed because of the good feed conditions.

The 8.0 hectares of maize the case farmer had grown for maize silage which he had to leave on the farm as part of his sharemilking agreement had not yielded as well as had been expected. The case farmer agreed to graze 100 of the owner's cows on the milking area for three weeks from May 10th to compensate for the reduced maize yield. He then built this change into his plan and the feed budget that he completed in early April.

The final discrepancy in the plan was the drying off date. The case farmer undertook a feed budget in early April, which predicted the entire herd of 319 cows, could be milked through until May 10th. The herd was actually dried off on May 27th and the number of lactating cows was 206. When the case farmer had drawn up the plan, he stated that he expected some of the thin cows to be dried off before May 10th, and that he would milk fewer cows for longer. This is what happened, and the reduction in herd size combined with above average pasture growth rates through April, allowed the case farmer to dry off the herd 17 days later than predicted in the feed budget.

The targets

In order to control the implementation of the plan, the case farmer had a set of targets (Table 6) and associated contingency plans. The targets can be separated into two types, those that act as terminating conditions at the end of the second planning, and those that are used to control the implementation of the plan through time. The terminating conditions act as constraints to the second plan and ensure systems performance is "optimised" during this period. Interestingly, there are no terminating targets for the summer plan. Rather, the case farmer's aim is to have as many cows as possible in a lactating state in mid March. The case farmer uses his condition score targets along with his milk production target to protect the condition score of the herd. The milk production and rotation length targets are also used to protect average pasture cover and pre-grazing residuals, important determinants of pasture growth.

Table 6. Targets specified in the plan that is used in the control process for years three, two and one.

Targets	Year 3	Year 2	Year 1
Summer			
Milk production[70]			
Pre-supplement[71] **crop** . kg MS/cow/day	NA	≥ 0.96	> 1.13
Forage crop. Introduction kg MS/cow/day	NA	NA	1.13
Maintenance kg MS/cow/day	≥ 1.04	≥ 0.96	≥ 1.04
Grass silage kg MS/cow/day	≥ 1.04	≥ 1.04	≥ 1.04
Date at which forage crop grazing must be initiated by	March 1st, then revised to February 8th	End of January/early February	End of January,/early February
Date at which grass silage feeding must be initiated on	20th December	January 10th	NA
Rotation length (days)			
Pre-forage crop	23 - 24	23 - 24	21 - 22
Forage crop	23 - 24	23 - 24	21 - 22
Grass silage	23 - 24	23 - 24	35 - 42[72]
Cow intakes kg DM/cow/day	≥12.0 ≥15.0[73]	≥12.0	≥12.0
Individual cow condition condition score units February March	≥ 3.50 ≥ 3.50	≥ 3.50 ≥ 3.50	≥ 3.50 ≥ 3.50
Average herd condition condition score units	No target	No target	No target
Average pasture cover	No target	No target	No target
Post grazing residuals			
Minimum[74]	≥ 1400	≥ 1400	≥ 1400
Maximum .	≤ 1700	NA	NA
Significant rainfall (mm)	≥ 50	NA	NA
Date forage crop must be grazed by	March 7th	≤ February 28th	≤ February 28th
Date new grass must be sown by	March 15th	March 15th	March 31st

[70] In year three the case farmer used units of kilograms of milk solids per cow, and the target was 1.04 kg MS/cow/day.
[71] The supplement may be silage or the forage crop.
[72] If conditions are dry, the target is only 25 - 28 days.
[73] From mid March until drying off, the case farmer aimed to feed the herd 15.0 kg DM/cow/day.
[74] Ideal target, but not strictly adhered to.

Targets	Year 3	Year 2	Year 1
Autumn			
Rotation length (days)			
pre-culling	23 - 24	23 - 24	35 - 42
Post culling & destocking	23 - 24	50	60
Drying off	100	100	100
Thin cows condition score			
Early April	≥ 3.50	≥ 3.50	≥ 3.50
Late April	≥ 3.75	≥ 3.75	≥ 3.75
Early May	≥ 4.00	≥ 4.00	≥ 4.00[75]
Average herd condition			
Calving	5.00	4.75	4.75[76]
Average pasture cover (kg DM/ha)			
Drying off	2300	1800	2000
June 1st[77]	2000	NA	NA
Winter maximum	NA	2300	2300
Planned start of calving	NA	2100	2000
Balance date	NA	1800	1700
Milk production[78]			
kg MS/cow/day	≥ 1.04	≥ 1.04	≥ 1.04
Date herd must be grazed off	May 31st	June 1st	NA

The majority of the targets used in year three such as milk production, post-grazing residuals, cow intakes, individual cow condition score were the same as those used in years one and two (Table 5). Some targets were not applicable in year three such as the pre-forage crop target, and forage crop introduction target, because the case farmer fed grass silage at the start of the summer period. Similarly, because the case farmer was moving to a new farm in June, he did not need to specify average pasture cover targets for the Kairanga property for planned start of calving and balance date. Rather, his terminating average pasture cover target for his autumn plan was 2000 kg DM/ha at June 1st. The farm owner as part of the sharemilking agreement set this target for the date when the case farmer left the property.

The case farmer changed his target date for the initiation and termination of the grazing of the forage crop. He changed the initiation date by four weeks because at the start of summer, he predicted that the forage crop would only provide a week grazing if left ungrazed for an additional four weeks. He therefore decided to extend the terminating date by a week to maximise yield. He still maintained the same sowing date as used in year two, of mid March, for the new grass. The case farmer increased his target intake figure from 12.0 to 15.0 kg DM/cow/day in mid March. This was because he had a considerable quantity of supplement on-hand that had to be used up by drying off, and average pasture cover and pasture growth rates were exceptional. He also found that under these growing conditions he had to feed the herd to this level to maintain milk production above target and hold condition. The rotation length targets used by the case

[75] In year one, the herd was dried off in April, and the May target for condition score was not used.

[76] The target condition score for the herd at planned start of calving was 4.5 condition score units. When the case farmer found he had a high empty rate, he decided to increase this target to 4.75 condition score units to enhance reproductive performance next season.

[77] The case farmer shifted to a new farm in year three, and part of his agreement when leaving the property on June 1st was to ensure the farm had an average pasture cover of 2000 kg DM/ha. As such, average pasture cover targets at planned start of calving and balance date were not relevant to the autumn plan in year three.

[78] In year three the case farmer used units of kilograms of milk solids per cow, and the target was 1.04 kg MS/cow/day.

farmer were similar to those used in year two, another dry year. The case farmer did not attempt to extend the rotation as he had in year one (see comments on learning), when feed conditions improved. Rather, he was forced to extend the rotation to maintain pasture quality in early April. The herd was then placed on a 30 - 35 day rotation until the drying off process was initiated on the 20th May.

Two targets that were used in year three, that was not used in the previous two years were significant rainfall target of 50 mm or more and a maximum post-grazing residual of 1700 kg DM/ha. The rainfall target was used because the case farmer stated that if he received significant rainfall after a prolonged dry spell, cow intakes would decline as dead matter in the sward decomposed. In the previous two years, he had not experienced such conditions. The maximum post-grazing residual target was used in year three because the high pasture growth rates had created a pasture quality problem. This was not used in the previous two years because average pasture cover, and post-grazing residuals did not reach the high levels recorded in year three. The case farmer found that pasture quality deteriorated once the post-grazing residual exceeded this level, and the pasture became "clumpy". To avoid this problem, the case farmer extended the rotation, effectively reducing the post-grazing residual.

The case farmer had an average pasture cover target for drying off that was 300 kg DM/ha higher than year one, and 500 kg DM/ha higher than in year two. This was because the owner had specified that the average pasture cover at June 1st, when the case farmer's sharemilking agreement terminated, had to be 2000 kg DM/ha. The owner, had also negotiated to graze 100 additional cows on the farm from May 10th, which meant, the case farmer had to dry off with a higher average pasture cover than if he only had his own cows on through May. One important change the case farmer had made to his targets was to increase the target for the average condition of the herd at planned start of calving from 4.75 to 5.00 condition score units. The case farmer changed this target to improve milk production in early lactation and enhance reproductive performance. He believed the advantages of the extra 0.25 condition score units outweighed the feed cost required to increase the herd to this condition score.

Cow intake and milk production targets played an important role in the implementation of the plan through year three. The case farmer was in a position where he had sufficient supplements to ensure cow intakes and consequent milk production never fell below target. Therefore, throughout, the majority of the summer-autumn period, the case farmer was responding to these indicators to manipulate the level of supplement fed. Cow condition only became important in late April, early May, because the herd had been so well fed through the summer-autumn. Average pasture cover, rather than cow condition was the important target, which determined the drying off date.

The control process

The control process used by the case farmer in year three was the same as used in years one and two.

Monitoring - differences between year three, and years one and two

As in year two, the case farmer undertook limited objective pasture scoring, preferring to use his more time-efficient subjective pasture scoring system based on pre-and post-grazing residuals with some adjustment for the distribution of pasture cover across the farm. The first, and only objective pasture measurement was undertaken on April 6th. This is almost a month later than in previous years. Additional objective measurements were not undertaken because the farm was in a good feed position, and the case farmer was comfortable with the accuracy of his subjective measurement system.

The case farmer also estimated his feed demand in terms of kilograms of dry matter per hectare per day. He did this by estimating his cow intakes using pre and post-grazing residuals, and then multiplied the intake by the stocking rate for the cow numbers he had on the farm at that particular point in time. He could then compare this to his estimate of average pasture growth rates to obtain an indication of the difference between feed supply from pasture and feed demand. He could also use this information to forecast likely future feed demand and compare this to his predictions of future pasture growth rates to indicate the likely need for supplements, or the impact of such actions as culling or drying off thin cows.

The case farmer noted importantly, that he did not use average herd condition targets over the summer for management purposes, but rather, he relied on his individual cow condition targets ensure the condition of the herd did not fall too low. In year three, he began to actively monitor the condition of the herd in March when it had fallen from 4.65 condition score units at the start of February to 4.25 condition score units at the end of the month. He stated that time of year initiated the active monitoring and that he was particularly interested in the condition of the younger cows in the herd. The case farmer was more aware of cow condition at that point in time, because up until then, he had not dried off any of the younger cows on condition (Figure 1). He noted that he monitors their condition when drenching at milking time, or when he is feeding them supplements on the feed pad. He stated that he does not write down this information.

IF date = March,
AND the condition of the younger cows in the herd is not being actively monitored,
THEN actively monitor condition of younger cows in the herd.

Figure 1. A decision rule that activates the monitoring of individual cow condition.

The case farmer reiterated that he does not use the weather forecast for decision making because it is too unreliable. Rather, he waits until the "*weather happens*" and then reacts to it. He also noted that he verifies his views on "*how dry it is*" with his estimates of pasture growth rates.

During this season, the case farmer spent a lot of time monitoring supplements, pre- and post-grazing residuals, cow intakes and milk production. This was because during much of the summer-autumn, the herd was fed supplements. The case farmer used milk production, along with the other indicators to verify his estimates of supplement yield (grass silage, forage crop, maize silage). Using such information he revised his estimate of both the amount of grass silage he had on-hand and the forage crop yield. The case farmer monitored intakes quite intensively from March until early April because he believed the herd was not producing as well as their intakes should indicate. He attributed this to the spring-like pasture that grew through March and April as a result of the autumn flush. The "quality" of the pasture changes in early April, and production and intakes came back into line.

Pre- and post-grazing residuals were particularly important for monitoring average pasture cover and cow intakes and for predicting likely changes in cow intakes 23 - 24 days in advance. The latter was important in terms of allowing the case farmer to react pro-actively to changing conditions.

The case farmer sought information on estimating crop yields from a local consultant, and sought out information on maize feeding and rations from nutritionists at the local university where he completed his Diploma in Agriculture.

Recording and data processing

The case farmer noted that he does not record the condition score of the herd. Otherwise, recording and data processing was the same as for years one and two.

Control responses and their selection

Examples of the three types of control were found during the study of the case farmer in year three. By far the most common type of control used by the case farmer was concurrent control. The case farmer had a large number of contingency plans, which he implemented when a deviation from the plan occurred. Some examples of preventative control were found. For example, the case farmer grows forage crops and harvests both grass and maize silage to provide feed during a period when pasture growth is highly variable. Some examples of historical control were also identified. The case farmer increased his average herd condition target for planned start of calving by 0.25 condition score units because he thought it would improve milk production and reproductive performance. He also changed to a fixed rotation over the summer-autumn because on the basis of the previous year he believed this improved pasture regrowth.

The case farmer used a range of control responses during year three. The primary control response was the use of contingency plans to minimise the impact of a deviation from the plan. The case farmer also changed his basic plan and the planning horizon for the summer period to cope with deviations from the norm. The case farmer however, did not change his goals or targets over summer in response to a deviation from the plan. During autumn, the case farmer did change two targets to cope with deviations from the plan.

Contingency plans

The main control response used by the case farmer in year three was the use of contingency plans (Appendix XVI, Volume II). In year three, in contrast to year two, he only used "*pre-defined*" contingency plans, and did not proactively search for "*opportunistic*" contingency plans. This was because of the level of supplement he had on-hand, and the excellent growing conditions over the autumn.

The contingency plans used by the case farmer in year three can be classified under four headings in relation to their impact on feed supply and feed demand (Table 7). Thirteen contingency plan options were used in year three, similar to the thirteen used in year two, and slightly more than the eleven used in year one. The case farmer used five options to increase feed supply: increase pasture silage ration, extend the period over which the grass silage was fed, graze the forage crop earlier than planned, increase the maize silage ration, and reduce rotation length. Reducing both the pasture and maize silage rations and increasing the rotation length reduced feed supply. The options the case farmer used for increasing feed demand was delay the drying off of thin cows, increase cow intakes, retain cull cows for longer than planned, and extend the lactation length. Feed demand was reduced through selling cull cows earlier than planned.

Table 7. The case farmer's contingency plans.

Category	Option
Increase feed supply	Increase pasture silage ration Extend feeding period for pasture silage Graze the forage crop earlier than planned Increase maize silage ration Reduce rotation length
Decrease feed supply	Reduce pasture silage ration Reduce the maize silage ration Extend rotation length
Increase feed demand	Delay drying off of thin cows Increase cow intakes Retain cull cows for longer than planned Extend lactation length
Decrease feed demand	Sell cull cows earlier than planned

Contingency plan selection

In year three the case farmer used the same contingency plan selection process as he used in years one and two (see Appendix XVI, Volume II for examples).

Changing plans

Changing plans as a control response can be viewed from a strategic perspective and a tactical perspective. At the strategic level, this involves changes between plans across years. In year three, at the strategic level, the case farmer had made a decision to greatly increase the level of supplements he used over the summer autumn. In year three he had 8.0 ha of forage crop compared to 3.2 ha in year two, and 5.2 ha in year one. He had also made 500 tonnes of grass silage compared to 75 tonnes in year two, and 120 tonnes in year one and had 250 tonnes of maize silage available compared to no maize silage in year two, and 100 tonnes in year one. These changes to the plan can be considered as historical forms of control, which are designed to reduce the impact of deviations from the plan. The case farmer had also leased a runoff on which he grazed his young stock. This meant the calves were not grazed on the milking area in year one, and that the dry cows would be grazed on the runoff rather than sent to a grazier.

Tactical changes include those changes to the plan that occur because of a short-term change in conditions. In this case, the dry December forced the case farmer to change both his basic summer plan and his planning horizon. The dry December limited crop yield and started to impact on cow intakes and milk production. As a result, the case farmer changed his summer plan to initiate grass silage feeding on the on the 20th December rather than in March after the forage crop. Similarly, because the forage crop was poor, the case farmer planned to feed it in early March, after feeding the grass silage. The case farmer also had to make a tactical change to the autumn plan when he found that his maize crop would not provide sufficient maize silage to meet his termination conditions under his sharemilking agreement. As a result, the case farmer had to make allowance in the feed budget completed on April 6th for grazing 100 cows of the owners from May 10th to 31st as compensation for the poor maize crop.

Changing targets

The case farmer changed few targets in year three to cope with deviations from the plan. Those changes that were made occurred during the autumn. The first target he changed was his minimum cow intake target, which he increased from 12.0 to 15.0 kg DM/cow/day. This change was undertaken for a number of reasons. The first was that the farm was in a very good feed position in the autumn and the herd could be fed to this level. The second point was that the lush pasture that was produced during a period of very high pasture growth rates over the autumn did not provide the herd with sufficient energy to maintain condition and milk production at the level the case farmer would expect for the feed eaten. The case farmer found that in order to hold condition and maintain milk production above 1.04 kg MS/cow/day, he had to feed the herd 15.0 kg DM/cow/day. The case farmer also had to increase his average pasture cover target for drying off when he found out he would have to carry an additional 100 cows on the farm for three weeks in May. The case farmer had hoped to maintain the herd on a 23 - 24 day rotation up until the drying off process was initiated. However, because of the high average pasture cover levels through the autumn, the case farmer had to extend the rotation out to 30 - 35 days to limit post-grazing residuals to a maximum of 1700 kg DM/ha to maintain pasture quality.

Diagnosis, evaluation and learning

The most interesting point to come out of the study in relation to evaluation was that the case farmer rarely consciously defined or diagnosed the reason for a short-term deviation from the plan (problem) (Table 8). He used indicators to identify feed problems (in most cases a feed deficit), and then implemented an option from his set of contingency plans without undertaking any form of conscious problem definition or diagnosis. Problem definition may not be an issue because at this time of the year, the primary problem the case farmer expects to face is a feed deficit. The holistic nature of his monitoring system also tends to verify the existence of a feed problem, making the need for diagnosis redundant. For example, before his primary indicator, milk production, has indicated a feed problem, he will know from climatic data that the season is becoming drier. He will also identify a decline in intakes, pre- and post-grazing residuals, and milk production before the threshold is reached.

Table 8. The evaluations carried out by the case farmer in year three.

Primary category	Sub-category and instance	Initiated by	Method of evaluation	Criteria	Criteria met	Diagnosis undertaken	Unusual Situations
Planning							
	Activities **Choice of and use of inputs**						
	New forage crop variety	Poor yield	Comparison to previous years crops	Similar yield	No	No	Yes
	The use of cow condition as a supplement through the summer, instead of alternative forms of supplement	Cow condition fell more than expected through February.	Reflection on outcome with and without additional supplement.	Impact on feed situation over summer-autumn.	Unsure of possible outcome.	No	Yes Very dry February, and a very large quantity of suppleme nt on-hand.

Primary category	Sub-category and instance	Initiated by	Method of evaluation	Criteria	Criteria met	Diagnosis undertaken	Unusual Situations
	The decision to delay the grazing of the forage crop and sow his new grass crop later.	Implement-ation of decision.	Comparison of situation with and without decision.	Impact on feed situation.	Positive for the forage crop. Unsure for the new grass.	No	Yes Very dry December
	Management practices						
	Planning assumptions						
	Evaluation of plan						
Implementation							
	Use of inputs						
	Method of feeding maize silage	Decline in milk production and intake	Comparison to expectations	Expecta-tions met	No	No	Yes
Control							
	Monitoring systems						
	Calibrate average pasture cover, intake and pre- and post-grazing residuals, supplement yield and level of supplement feeding against milk production date	On-going	Comparison	Match	No, in some instances	Yes	Yes
	Comparison of estimate of dryness of conditions against pasture growth rate estimates	On-going	Comparison	Match	Yes	No	No
	Revision of overall control						
Systems performance							
	Productive performance						
	Forage crop yield of new variety	Poor yield	Comparison to previous crop's yield	Match	No	No	Yes
	Milk yield and condition score change	Below expecta-tions	Comparison to expectations	Match	No	Yes	Yes

Diagnosis was primarily used where the case farmer's expectations or targets were not met and in extreme situations that were beyond the experience of the case farmer (Table 8). The summer of year three was different from most others in that conditions turned dry at the start of December, and remained dry until the late February. However, the case farmer also had a much larger quantity of supplement on-hand than he had in previous years. In contrast, pasture growth rates through March and April were extremely high resembling those experienced during the spring. This made year three, an unusual year for the case farmer. This is reflected in the amount of evaluation undertaken by the case farmer (Table 8).

Not surprisingly, the diagnoses undertaken by the case farmer in year three related to the reasons why the herd was not performing as well as possible in relation to its intake of pasture and supplements, or his over-estimation of the grass silage yield. These diagnoses were initiated when the case farmer found that the performance of the herd was below his expectations given his estimate of cow intakes. The case farmer used his information about cow intakes to diagnose why the herd was not producing as well expected given its high level of intake in late February. Milk production was lower and the herd had lost more condition than the case farmer expected through February. The case farmer undertook some diagnosis in relation to this problem, and hypothesised a number of reasons for this, including incorrect estimation of forage crop yield, the 50 mm of rain in late February, and pasture quality. He had a consultant, independently assess the forage crop yield, and this confirmed the case farmer's own estimates. Eventually, the case farmer attributed the problem to the 50 mm of rain that fell in late February which caused the pasture to decompose and reduced cow intakes.

Similarly, in March, the herd did not produce as well as expected for their level of intake. The case farmer attributed this to the type of pasture produced during this period, when pasture growth rates exceeded 50 kg DM/ha for part of the month. He diagnosed that the problem might be because of the low dry matter content of the pasture, which he thought was similar to pasture in the early spring. The case farmer was faced with the opposite problem in early April when milk production increased, but the case farmer had not increased cow intakes. He attributed this to the lush feed "hardening off", something that he observed normally occurs in the spring, but he had not experienced during the autumn.

The case farmer spent a lot of time verifying cow intakes, and the supplement yields (grass silage, forage crop, maize silage) against cow performance. This information was used to revise his forage crop and grass silage yield estimates. The case farmer diagnosed the reason for his over-estimation of the grass silage yield. He attributed this to the conversion factor provided by the contractor. This conversion factor was for silage in an excavated silage pit. The case farmer made his silage as a stack above the ground. He believes that this method of silage storage prevents the level of compaction obtained in an excavated pit. He believed the problem was further compounded because he made the silage late and it had more stem then earlier silage, and was therefore less easily compacted. He estimated that the bulk density of his silage was 1.04 tonnes per cubic metro as opposed to the 0.80 tonnes per cubic metre estimated by the silage contractors.

The case farmer undertook evaluations in relation to planning and control as in previous years, the difference in year three, was that the case farmer also evaluated an area of implementation (Table 8). The areas of evaluation under planning were solely related to the use of inputs. The case farmer evaluated the new forage crop, Barkant turnips, and reflected on his normal plan of using cow condition as a form of supplement through the summer, and then replacing it through the autumn and winter. The Barkant turnips was a new forage crop and was grown because it was purported to yield around 15,000 kg DM/ha, about 5,000 kg DM/ha more than the Emerald rape crop. On the January 19th, the case farmer stated that the Barkant turnip was the worst forage crop he had ever grown. The low yield was attributed to five weeks of dry weather post-crop establishment. The case farmer was also seriously considering whether his policy of using the body condition of the herd through the summer and then putting it back on over the autumn and winter was the most efficient use of feed. The alternative was to feed sufficient supplement through the summer to maintain cow condition. The trade-off related to this choice is that the case farmer would have less supplement on-hand for the autumn. This reflection appeared to have been triggered by the case farmer's change to the use of a large quantity of supplement through the summer and into the autumn and because the herd had lost more condition through the summer than the case farmer had expected. At that stage the case farmer had not decided which approach was more beneficial. However, is interesting to note that during this period there was the beginning of a shift in focus away from per hectare to per cow production. One of the new management practices being used by innovative farmers was to use supplements over summer to maintain high post-grazing residuals to optimise pasture growth rates and achieve high levels of milk production per cow. The high level of supplementation also meant that cow condition did not decline as much through the summer. The case farmer also reflected on his plan to delay the grazing of the forage crop to increase its yield which resulted in the new grass being sown later than was optimal. The decision allowed him to grow more forage crop, but he was unsure of its impact on the new grass. However, later in April, he found that with the good growing conditions, the new grass was as well established as in any previous year.

In contrast to other years, year three was the first year of the study where the case farmer was recorded evaluating an aspect of his implementation related to input use (Table 8). The case farmer changed the way in which he fed maize silage to the herd in mid April. Based on his experience with feeding maize silage the previous spring, he had postulated a means of improving maize silage intake. Normally, the herd was fed a new break in the morning, and then given the rest of the break and some maize silage in the afternoon. The case farmer then changed his system and instead, gave them a fresh break after the maize silage had been eaten. The herd was not happy going back into the same break in the afternoon. They ate more maize silage, but they also ate less pasture. As a result, total intake declined as did milk production and cow condition. The change in routine also upset the herd, and the net result was a decline in milk production and cow condition. The case farmer stated that this was an experiment that did not work.

Evaluations in relation to control encompassed both the monitoring process, and the contingency plan selection process (Table 8). Given the nature of the season and the level of supplement on hand, it was not surprising to find that an important area of control that the case farmer evaluated was the accuracy of his monitoring system. He used milk production and cow condition score data to calibrate his estimates of average pasture cover, cow intakes and pre- and post-grazing residuals and his supplement yields (grass silage, forage crop, maize silage). This form of evaluation was on-going and used to ensure the accuracy of the case farmer's monitoring system.

The other area of control the case farmer evaluated was his selection of contingency plans, and in particular, those contingency plans relating to the choice and use of inputs. The case farmer reflected on two areas in relation to contingency plan selection. Firstly, he evaluated whether he should have fed maize silage through February to increase post-grazing residuals and subsequent pasture growth rates. However, although he knew higher post-grazing residuals increased pasture growth rates, he was unsure as to the level of response he would obtain under dry conditions. He did note that it would increase pasture growth rates after the rains arrived, but the trade-off was that he would have less supplement for the autumn. The evaluation was inconclusive because the case farmer was unsure of the effect of increased post-grazing residuals on pasture growth rates during extremely dry conditions.

The case farmer also reflected on whether he should have fed additional grass silage after 50 mm of rain fell in late February. He had identified that this level of rainfall had caused the sward to decompose and reduced cow intakes for a week after the rain. This in turn reduced milk production and cow condition.

Only two examples of systems performance evaluation were identified in year three: forage crops yield, and milk yield and condition score change and these have both been discussed above under diagnosis.

The data (Table 8) shows that a range of factors initiated the evaluation process. In some instances, it was because the outcome deviated from some target or expectation. Alternatively, the case farmer initiated the evaluation after the decision had been implemented and the outcome of the decision was known. Finally, some evaluations were undertaken on an on-going basis, such as those used to ensure the accuracy of the case farmer's monitoring system.

The means by which the case farmer evaluated each of the three areas could be classified into three main areas. The simplest method was to compare the outcome to some target, standard, norm, or expectation and the criteria used to evaluate the decision or factor was the degree of match between the two. If the criteria were not met, and the case farmer did not know the reason for the deviation, then diagnosis was undertaken. The second approach, an ex-poste evaluation, was to undertake an historical simulation of what would have happened if the decision of interest had not been made, or a different decision had been made, and compare this to the actual outcome. The criterion used to evaluate the decision of interest was whether the outcome was better than the alternative. This was normally measured in terms of feed on hand, or cow condition. In these cases no diagnosis was undertaken because the case farmer had a full understanding of the situation.

Learning

During the year three year, much of the learning undertaken by the case farmer could be classified under the "production system, environment interaction" category. This was either in relation to the dry December and its impact on forage crop establishment, or in relation to the impact of good growing conditions after a prolonged dry spell on pasture growth rates, pasture quality and cow intakes (Table 9). The case farmer also learnt more in relation to his monitoring system. This was in relation to measuring grass silage and his new forage crop yield, and also the measurement of pasture intake under conditions of extremely high pasture growth. The case farmer also identified some additional targets that needed to be included in his plan for control purposes. The case farmer learnt that if the farm received significant rain (50 mm) after a prolonged dry spell, this would indicate that subsequent decomposition of pasture and a decline in intakes. Similarly, the case farmer found that under conditions of extremely high autumn pasture growth rates (≥ 50 kg DM/ha/day) and high pasture cover levels (> 2000 kg DM/ha), if post-grazing residuals exceeded 1700 kg DM/ha, pasture quality problems occurred. This problem was further compounded if some form of supplement was also being fed.

Another area of learning was in relation to contingency plan selection in the areas of input use and management practice. The case farmer learnt that he should double his grass silage ration for a week in a situation where the farm receives significant rainfall (50 mm) after a prolonged dry spell in order to maintain cow intakes, milk production and cow condition. Similarly, he learnt that under conditions of very high pasture growth rates (≥ 50 kg DM/cow/day) post-dry spell, cow intakes had to be increased to maintain milk production and cow condition. The case farmer also learnt that under such conditions, if the post-grazing residual exceeded 1700 kg DM/ha, pasture quality problems occurred. This problem was minimised by reducing the level of supplement being fed, and extending the rotation to reduce the post-grazing residual to around 1700 kg DM/ha.

Table 9. Instances of learning undertaken by the case farmer in year two.

Instances of learning	Areas of learning	Outcome of learning
The case farmer learnt that his forage crops did not perform well if conditions were dry through December.	Production system, environment interaction.	Knowledge for future reference.
The case farmer learnt how to estimate grass silage and his new forage crop yields	Production system, monitoring system	He acquired additional rules of thumb for estimating supplement yield.
The case farmer learnt that if a considerable amount of rain (≥ 50 mm) fell after a prolonged dry spell, cow intakes declined because of decomposition in the sward. Supplements had to be fed for a week after the rain to hold cow intakes and milk production.	Production system, environment interaction, planning, targets, control, contingency plan selection, input use.	The case farmer developed a contingency plan selection rule, that if 50 mm of rain or more fell after a prolonged dry spell, then he had to feed additional supplements to maintain cow intakes and milk production.
The case farmer learnt that under conditions of very high pasture growth rates in autumn, the quality of the pasture changed, such that it contained less energy per unit of dry matter than at other times of the year. Under such conditions, additional pasture and/or supplements had to be fed to maintain cow condition and milk production.	Production system, environment interaction, control, monitoring system, contingency plan selection, input use.	The case farmer realised that monitoring rainfall data was important other than for predicting pasture growth rates. He also developed a new contingency plan selection rule to cope with these extreme conditions.
The case farmer learnt that in an extremely good autumn with high pasture growth rates, pasture quality could create a problem, particularly when maize silage was being fed.	Production system, environment interaction, planning, target selection, control, contingency plan selection, input use, management practice.	The case farmer learnt that under such conditions, he needed contingency plan selection rules that specified a reduction in supplement use, and/or an extension of the rotation length, to maintain pasture quality.
The case farmer learnt that delaying placing the herd on a new break increased the herd's intake of maize silage, but reduced both their pasture and total intake.	Production system, implementation, use of inputs.	The case farmer learnt that although this approach did increase maize intake, it reduced pasture and total intake and defeated the purpose of the change.

The final area of learning was in relation to implementation. The case farmer had planned to feed maize silage to the herd, and part-way through the implementation of this aspect of the plan he decided to change the way he fed the herd to increase maize silage intake and therefore increase milk production and cow condition. The change the case farmer implemented did increase maize silage intake, but it also reduced pasture intake and total dry matter intake. As a result, milk production and cow condition declined during the "experiment".

Unlike, most of the other learning situations, where the case farmer learnt from experience, there were two examples where the case farmer learnt from other people, in this case, a silage contractor and a consultant. However, in the former example, the case farmer challenged the information provided by the contractor on silage yield when his experience did not tie in with the theory. In this case, he diagnosed the reason for the deviation, and then adjusted the theory. During the three years, the case farmer had drawn on the expertise of a number of outside individuals including contractors (maize and grass), consultants and university staff.