MANAGEMENT ASPECTS

OF

PHOSPHATE FERTILISER USE

ON

HILL COUNTRY

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of the requirements for the degree
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ABSTRACT

Farmer decisions relating to phosphate fertiliser use greatly influence farm profitability, and Farm Advisory Officers receive many requests for assistance in making fertiliser decisions.

The Cornforth/Sinclair Phosphate Maintenance Model predicts the annual loss of phosphate from grazed pasture production systems. This model is studied in this thesis and used as the basis for an investigation of phosphate use strategies on a sample of Manawatu hill country properties. Alternative management strategies on three case study farms are analysed.

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LIST OF ABBREVIATIONS

ALF	Animal Loss Factor
CC	Potential Carrying Capacity (su/ha)
csu	Cattle Stock Units
DM	Pasture Dry Matter (kg)
GM	Gross Margin ($)
Hf	Heifers
P	Phosphate
PU	Pasture Utilisation (%)
RY	Pasture DM Yield relative to Ymax (%)
s:c	Sheep to Cattle Ratio
SLF	Soil Loss Factor
SR	Stocking Rate (su/ha)
ssu	Standard Stock Units
st	Steers
TGM	Total Gross Margin ($)
Y	Pasture DM Yield (kg)
Ymax	Maximum Pasture DM Yield (kg/ha)

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CHAPTER 1

INTRODUCTION AND OUTLINE OF THE STUDY

1.1 Introduction

Much of New Zealand pastoral agriculture is based on the low cost symbiotic relationship between pasture legumes (mainly white clover) and rhizobia bacteria species. One important output from this relationship is the supply of nitrogen to other pasture species. In order for white clover to compete and persist in New Zealand pastures, regular inputs of phosphate fertiliser must be applied.

This form of nitrogen nutrition of pastures is by far the most important in New Zealand, and allows hill country production systems to continue at high output levels without the input of expensive fertiliser nitrogen. Approximately 2.0 million tonnes of fertiliser superphosphate have been applied annually to New Zealand farms. However in recent years, especially since the oil price increases of the early 1970's, the cost of phosphate fertilisers have increased markedly, both in the manufacturing process and particularly transportation. On New Zealand hill country properties, phosphate fertiliser maintenance expenditure is a major input cost.

The rapid escalation in the cost of phosphate fertiliser to the farmer has highlighted the need for quantitative information on the relationship between fertiliser input and resultant pasture and animal output. Production economics principles for optimum resource use require this specification of the production function before efficient resource decisions can be made. Agricultural research in New Zealand has in the past elucidated many factors which influence the fertiliser needs of specific farming situations.

In order to make the best use of soil fertility information and to provide a basis for fertiliser advice as a part of farm management advisory services, Research Division scientists of the New Zealand Ministry of Agriculture and Fisheries have developed a scheme for fertiliser recommendations to incorporate all relevant available information. The Cornforth/Sinclair Phosphate Maintenance Requirement Model is part of that scheme.

1.2 Objectives of this Study

The prime objective of this study is to raise issues for discussion between Farm Advisory Officers and Research Scientists relating to the application of the Cornforth/Sinclair model to assist in farmer decisions about phosphate fertiliser use. The approach adopted uses case studies of three Northern Manawatu hill country sheep and cattle properties.

The Cornforth/Sinclair model was still under development during the duration of this study, and the scope of the study is insufficient to allow for a complete evaluation of the model as an aid to farmer decision making.

1.3 Thesis Outline

Chapter two describes the Cornforth/Sinclair model for calculating maintenance phosphate requirements for grazed pasture. Traditional production economics principles are followed rather than the original presentation by Cornforth and Sinclair (1981). The basis for the balance sheet approach to phosphate maintenance requirements is also presented.

Chapter three describes the areas of farm production that require analysis with respect to improving efficiency of phosphate fertiliser use, and presents an example economic analysis based on the Cornforth/Sinclair model.

Other approaches to phosphate maintenance requirement determination, both via systems modelling and traditional experimentation, are reviewed in Chapter four.

Chapter five describes the survey of farms undertaken and discusses application of the Cornforth/Sinclair model to survey farms.

In Chapter six, three case study farms are described in more detail, with stock policies and management strategies specified.

Chapter seven discusses the alternative phosphate fertiliser use and management strategies available on the case study farms, based on the Cornforth/Sinclair model.

A summary of the study is presented in Chapter eight.

CHAPTER 2

THE CORNFORTH/SINCLAIR MODEL FOR CALCULATING MAINTENANCE PHOSPHATE REQUIREMENTS FOR GRAZED PASTURE

2.1 Introduction

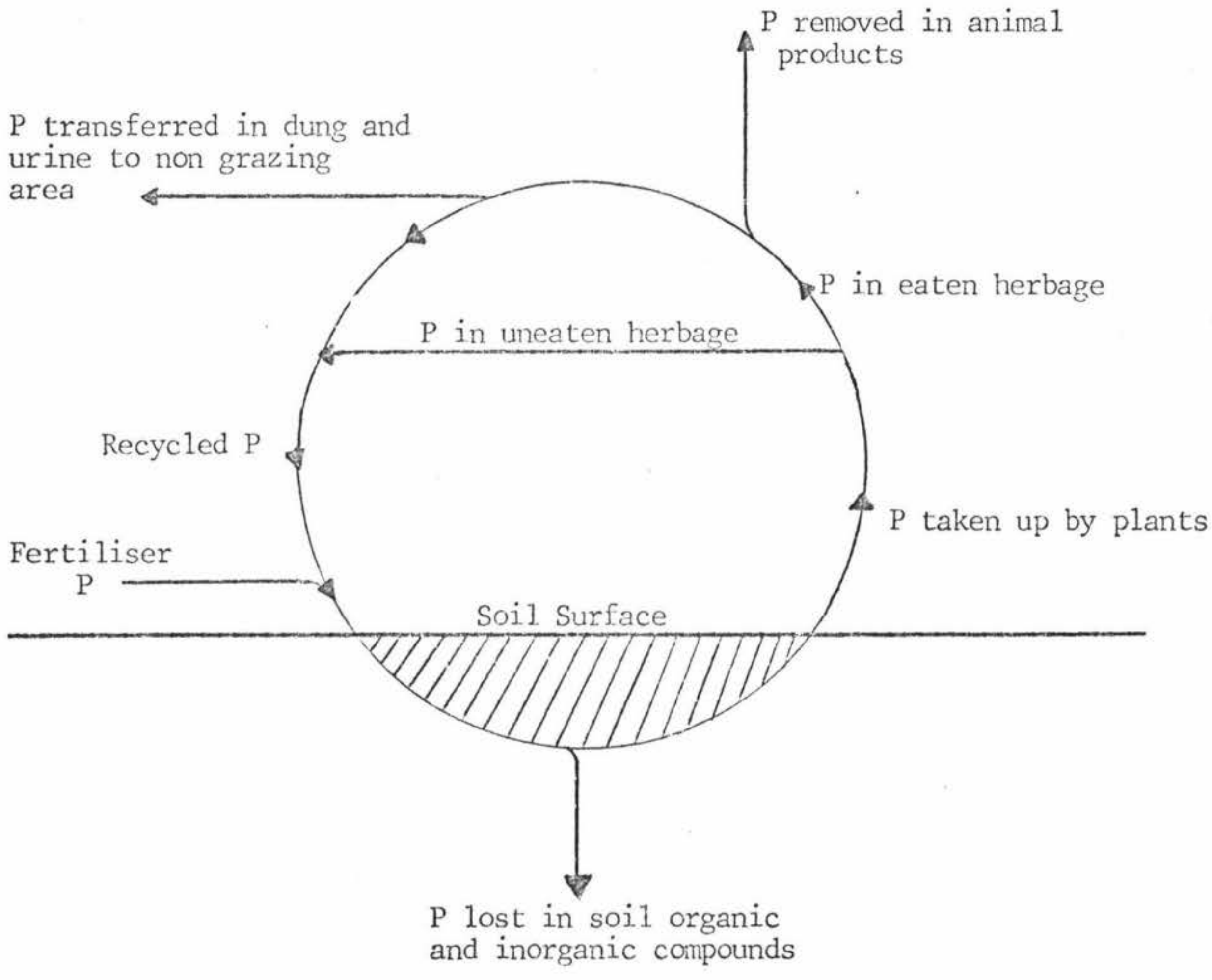
With few exceptions, New Zealand soils are naturally deficient in phosphate and must receive fertiliser phosphate to achieve and maintain high levels of pasture production. The need to apply fertiliser phosphate to maintain production implies a continuous loss of phosphate from the grazing system. Prediction of these losses forms the basis of the Cornforth/Sinclair model for determining the maintenance phosphate requirements of livestock grazing systems, (Cornforth and Sinclair, 1982).

Losses of phosphate in a grazed pasture system occur below and above ground. A simplified version of the Phosphate Cycle in grazed pasture systems, forming the basis of the Cornforth/Sinclair model, is presented in Figure 2.1. Reference to Figure 2.1 indicates the following components of the Cornforth/Sinclair Maintenance Phosphate model:

(a) Phosphate uptake by plants. The amount of phosphate uptake by pasture plants depends on average pasture dry matter production, and percentage phosphate concentration in the herbage. Total annual phosphate uptake by herbage is either consumed by animals or returned to the soil via decay of uneaten herbage.

(b) Phosphate uptake by animals. This depends on the average annual pasture dry matter consumed by livestock and percentage phosphate concentration in the herbage. Some fraction of phosphate uptake by

Figure 2.1 Simplified Phosphate Cycle in Grazed Pasture



animals is returned to the grazing system via dung, while the remainder is lost to the system as either animal products removed, or dung transferred to non grazing areas. This fraction is animal phosphate loss.

(c) Below ground or soil losses of phosphate. These occur mainly through the accumulation of inorganic and organic phosphate compounds from which plants cannot readily extract phosphate. Leaching and erosion are generally minor contributors to soil phosphate losses.

Any given farming situation must therefore be characterised by: average annual dry matter production; phosphate concentration in the herbage produced; the amount of pasture produced that is consumed by animals; the amount of phosphate lost via animal products and dung transfer out of the system; and the amount of phosphate lost in the soil. The system is assumed to be in balance (maintenance) if fertiliser phosphate input equates with total phosphate loss. Fertiliser phosphate is assumed to be the only Phosphorus input from outside the cycling pool of phosphate.

2.2 The Cornforth/Sinclair Model Components

The Cornforth/Sinclair model requires that any farming situation be characterised in terms of the following basic parameters:

(a) Ymax : Maximum average annual pasture dry matter yield for the farming situation. Ymax refers to a grass/legume pasture of appropriate botanical composition for its situation where plant nutrients are unlimiting. Ymax values for different situations can be obtained from the Ministry of Works and Development, Soil and Water Division, land use capability maps or from field trials designed to estimate potential pasture dry matter yield.

Alternatively, the farming situation can be characterised in terms of potential carrying capacity (CC) where:

$$CC = \left(\frac{95}{100}\right)\left(\frac{90}{100}\right) \text{Ymax } 550^{-1} \qquad \ldots. \ (2.1)$$

Thus CC is the number of standard stock units (ssu) that could be carried in a particular situation where:-

(i) Each standard stock unit requires 550 kg dry matter annually.

(ii) Actual pasture dry matter production is 95% of Ymax.

(iii) 90% of actual pasture dry matter yield is harvested by livestock.

(b) Percentage Phosphate in the Herbage at RY(90) : According to Cornforth and Sinclair (1982), percentage phosphate in pasture herbage at RY(90) varies with maximum average annual pasture dry matter yield for any given situation.

% P in herbage at RY(90) = (0.005 CC + 0.275) .... (2.2)

For a situation where CC = 15 ssu/hectare (ie Ymax = 9650 kg dry matter/hectare, percentage phosphate in herbage at RY(90) is predicted to be 0.35%.

(c) Soil Loss Factor (SLF): The SLF for a soil is the P lost in the soil, expressed as a fraction of the P uptake in herbage in a pasture maintaining a yield of 90% relative to Ymax, ie at RY(90).

(d) Soil P Loss at RY(90): Since P uptake in the herbage is the product of dry matter yield and P concentration in herbage, soil P loss from a system maintaining a pasture yield of 90% relative to Ymax is given by:

$$\text{Soil P loss at RY(90)} = \text{SLF } (0.9\text{Ymax})\left(\frac{\text{\% P in herbage}}{100}\right)$$

Substituting for Ymax in terms of CC (equation 2.1) and for percentage P in herbage (equation 2.2) we obtain:

$$\text{Soil P loss at RY(90)} = \text{SLF } \left(\frac{550}{95}\right) \text{CC } (0.005 \text{ CC} + 0.275) \quad .... (2.3)$$

Soils in New Zealand have been categorised by Cornforth/Sinclair into three soil P loss groups on the basis of P balance calculations of losses from field trials on representative soils. Provisional soil loss factors for representative soil groups are presented in Table 2.1.

Table 2.1 Provisional Soil Loss Factors for New Zealand Soil Groups

Source : Cornforth and Sinclair (1982)

Soil Loss Group		Soil Loss Factor
(a) South Island Soils:		
Low	Brown Grey earths Dry subhygrous and subhygrous Yellow grey earths Recent soils with < 1000 mm rainfall	0.1
Medium	Dry-hygrous Yellow-grey earths Recent soils with > 1000 mm rainfall Yellow Brown earths Gley soils, podzols, rendzinas, Brown granular clays and loams	0.25
High	Yellow-brown Loams	0.4
(b) North Island Soils:		
Low	Yellow-grey earths Steepland Yellow-brown earths	0.1
Medium	Recent soils, rendzinas, yellow-brown earths, yellow-brown loam/yellow-brown earths, Brown granular clays, Central yellow-brown sands, Yellow-brown pumice soils, Gley soils, Yellow-grey/Yellow - brown earths	0.25
High	Yellow-brown loams, Organic soils, Red and brown loams, Steepland yellow-grey earths, steepland Northern yellow-brown earths, Northern podzols, Northern yellow-brown sands	0.4

(e) Animal Loss Factor (ALF)

The ALF for a farming situation is the amount (kg) of P lost via animal products and dung transfer to non grazing areas, for each 550 kg of pasture dry matter consumed by livestock grazing pasture with a herbage P content of 0.35%, and maintained at a pasture dry matter yield of 90% relative to Ymax. The ALF for a given farming situation will vary according to the livestock production system, and increase with land slope due to increased "tracking" and "camping". Estimates of ALF for different livestock production systems (stock types) and land slopes are presented in Table 2.2.

Table 2.2 Animal Loss Factors*
Source : Gillingham 1980

Stock Type	Topography	Animal Loss Factor (kg P/su)
Sheep & Beef	Flat and rolling	0.7
Dairy cows	Flat and rolling	0.9
Sheep & Beef	"Easy" hill country	0.9
Sheep & Beef	"Steep" hill country	1.1

"Easy" hill country contains no large areas with slopes greater than 25°.

"Steep" hill country contains about 33% of steep slopes greater than 35°.

* for pasture consumed containing 0.35% P

(f) Animal P Loss at RY(90) : Consider now the calculation of animal P loss at RY(90) for a particular farming situation. For herbage containing 0.35% P, animal P loss is given by the product:

$$\frac{\text{ALF x Pasture DM consumed by livestock at RY(90)}}{550}$$

For herbage containing concentrations of P other than 0.35%, this product must be adjusted by the factor (% P in herbage) x $(0.35\%)^{-1}$. Pasture consumed by livestock in 550 kg DM units, is equivalent to stocking rate, and from equation (2.1) SR at RY(90) is given by:

$$\frac{\text{PU x CC}}{95}$$

Substituting for % P in the herbage at RY(90) from equation (2.2) we obtain:

$$\text{Animal P loss at RY(90)} = \text{ALF x } \frac{(\text{PU x CC})}{95} (0.005 \text{ CC} + 0.275)(0.35)^{-1} \quad \ldots. \ (2.4)$$

(g) Total P loss at RY(90)

Total P loss at RY(90), for given values of the basic parameters (CC, ALF, SLF) and a selected value for PU is obtained by summing equations (2.3) and (2.4).

Total P loss at RY(90) =

$$\text{CC } (0.005 \text{ CC} + 0.275) \left[0.0301 \text{ x PU x ALF} + 5.79 \text{ SLF}\right] \quad \ldots. \ (2.5)$$

2.3 Mathematical Form of the Cornforth/Sinclair Model

The Cornforth/Sinclair model assumes a diminishing returns relationship between total P loss (and hence P input) from a grazing system, and Relative Yield. The relationship adopted by Cornforth and Sinclair is the Mitscherlich equation

$$RY = 100\,(1 - 10^{-Z}) \qquad \text{.... (2.6)}$$

where,

$$Z = \frac{\text{Total P loss at RY}}{\text{Total P loss at RY(90)}} \qquad \text{.... (2.7)}$$

and where the PU value for any given situation of interest is also that used to calculate the denominator value in equation (2.7).

In conventional production economics terminology, 'Total P loss at RY' is the annual P input level required to maintain, on average, RY.

The model assumes that where there is no P loss from the system, RY will be zero.

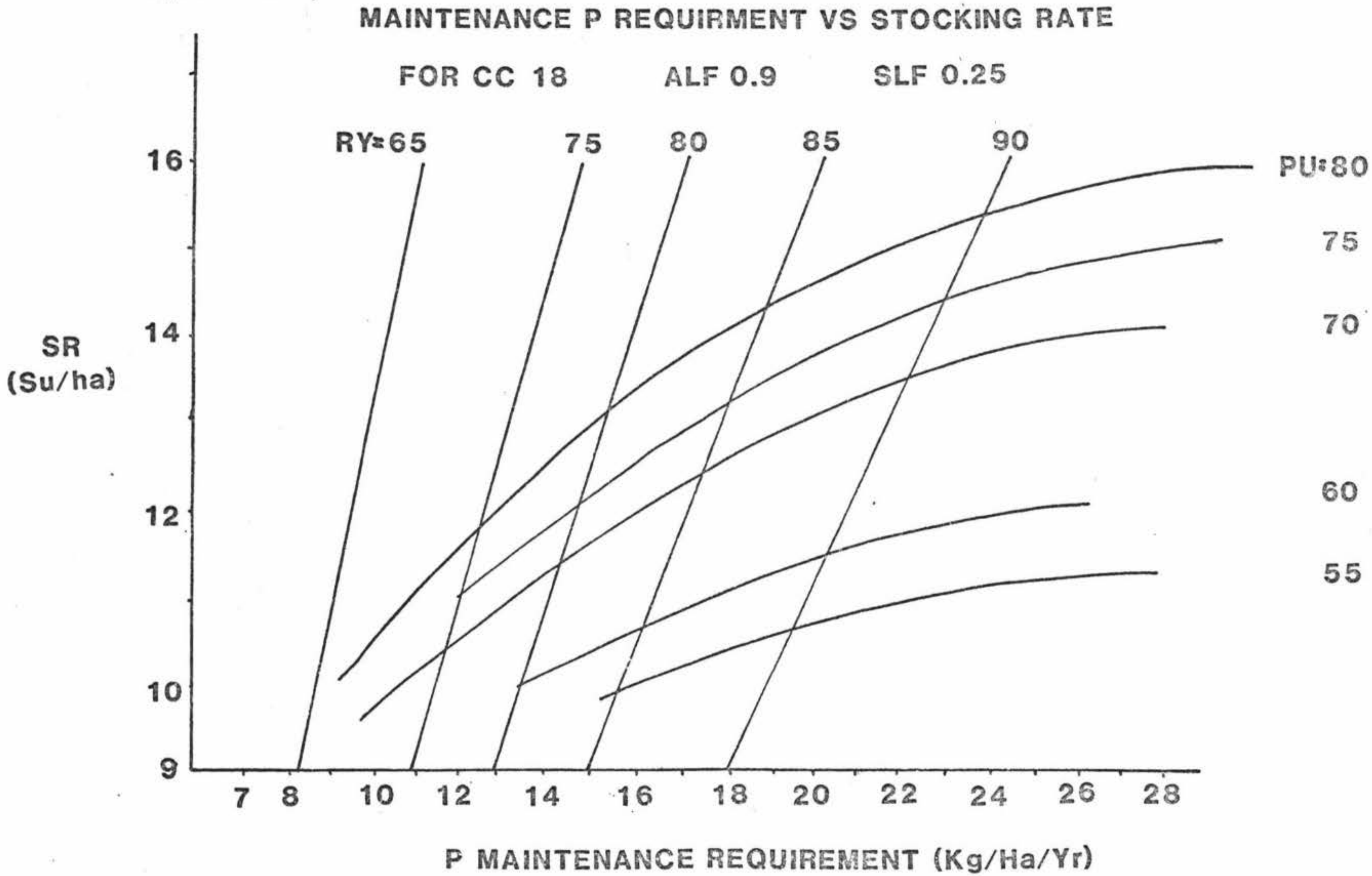
The mathematical formulation of the Cornforth/Sinclair model presented in this section follows traditional production economics principles wherein values for the input variables (P input and PU) are selected, and the production function is then used to predict system output (RY) for given parameter values (CC, ALF, SLF).

Since RY and PU for any value for CC (or Ymax) determine pasture DM consumed by livestock, system output can also be expressed in terms of standard stock units (SR) carried:

$$SR = \frac{PU}{100} \times \frac{RY}{100} \times \frac{Ymax}{550}$$

$$= \frac{PU \times RY \times CC}{8550} \qquad \text{.... (2.8)}$$

Figure 2.2


MAINTENANCE P REQUIRMENT VS STOCKING RATE
FOR CC 18
ALF 0.9
SLF 0.25
RY=65
75
80
85
90
PU=80
75
70
60
55
SR
(Su/ha)
16
14
12
10
9
7
8
10
12
14
16
18
20
22
24
26
28
P MAINTENANCE REQUIREMENT (Kg/Ha/Yr)

The Cornforth/Sinclair model formally comprises equations (2.5), (2.6), (2.7) and (2.8). Given values for CC, SLF, ALF and PU, we can calculate total P loss at RY(90) from equation (2.5). For any given total P loss (fertiliser P input), we can calculate RY from equations (2.6) and (2.7). And for this calculated RY value, we can calculate SR using equation (2.8) since PU is assumed to be the same for RY(90) and the calculated RY.

For any given PU we can therefore derive the relationship between SR and total P loss that must be replaced to maintain the system. Figure 2.2 presents an example of this relationship for different PU values. Since RY is also predicted for the given values (CC, ALF, SLF) and the selected value for PU, these RY values are also presented in Figure 2.2.

Since Farm Advisory Officers and farmers are more likely to specify system performance and then seek the input level required to maintain the system, the Cornforth/Sinclair model is commonly rearranged to estimate P losses.

From equation (2.6) we have $Z = \log_{10}\left(\frac{100}{100 - RY}\right)$

Substituting for Z from equation (2.7) and rearranging:

$$\text{Total P loss at RY} = \log_{10}\left(\frac{100}{100 - RY}\right) \text{ Total P loss at RY(90)} \quad \ldots\ldots (2.9)$$

It should be noted that although Total P loss at RY(90) is decomposed into Soil P loss at RY(90) and Animal P loss at RY(90), the Cornforth/

Sinclair model makes no corresponding decomposition of other relative yields.[1] Thus Soil P loss at RY is not defined by Cornforth/Sinclair (1982) as:

$$\text{Soil P loss at RY} = \text{Log}_{10}\left(\frac{100}{100 - \text{RY}}\right) \text{Soil P loss at RY(90)}$$

2.4 Interpretation of the Cornforth/Sinclair Model

In any particular situation, quantified in terms of the basic parameters (CC, ALF, SLF), system performance is described in terms of values for any two of the variables (PU, SR, RY). The values for any two of the performance variables determines the third via equation (2.8).

Since the Cornforth/Sinclair model predicts total P loss at RY(X) as a function of total P loss at RY(90), where PU is constant for both relative yields, total P loss at RY(90) can be written in terms of system performance variables SR and RY.

Total P loss at RY(90) =

$$\text{CC}\ (0.005\ \text{CC} + 0.275)\left[5.29\ \text{SLF} + \frac{257.1\ \text{SR ALF}}{\text{RY . CC}}\right] \qquad \text{.... (2.10)}$$

Substitution of equation (2.10) in (2.9) results in the linear relationship between total P input (loss) and SR (for given RY and CC, ALF, SLF) illustrated in Figure 2.2 .

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(1) I am grateful to Mr R W Tillman, Soil Science Department, Massey University, for drawing this situation to my attention.

The diminishing returns relationship for any given PU, illustrated in Figure 2.2 is obtained by substituting for RY from equation (2.8) in equation (2.9). System performance is then described in terms of SR and PU.

The alternative mathematical forms of the Cornforth/Sinclair model have been emphasized since some Farm Advisory Officers appear to expect that any increase in SR will automatically be accompanied by an increase in PU. The Cornforth/Sinclair model makes it clear that this need not be the case. An increase in SR may be accompanied by an increase, no change, or decrease in PU, depending on the associated change in total P input and hence change in RY.

The alternative mathematical forms of the Cornforth/Sinclair model have also emphasized the choices available for describing system performance. Where annual pasture DM yields are being monitored in on-farm situations, it is possible that advisers should specify the value for RY in any situation, to avoid losing sight of the definition of PU. Similarly there may be advantages in estimating Ymax to avoid losing sight of the definition of CC.

Since economic returns will be related directly in some way to livestock production, SR will almost certainly be one of the performance values specified. SR values in the Cornforth/Sinclair model are expressed as standard stock units, each having an annual dry matter requirement of 550 kg. Table 2.3 presents factors for converting various stock classes to standard stock units. The standard stock unit to which all classes are compared is a 55 kg liveweight breeding ewe, weaning 100% of lambs with an annual pasture dry matter requirement of 550 kg. (Rattray 1978).

Table 2.3 Factors for Converting Stock Classes to Standard Stock Units

Sources : Coop (1965), Rattray (1978) and Scott et al (1980)

Stock Type	Weight	Percent Lambs Weaned	Factor
Ewes	35	100	0.80
	45	100	0.90
	55	100	1.00
	65	100	1.10
	55	110	1.05
	55	120	1.10
	55	130	1.15
	55	140	1.20
Hogget November - November			0.7
Hogget January - January			0.8
Angus Beef Cow - hard conditions			4.1
Angus Beef Cow - good conditions			4.8
Fattening Steer 8-10 months			3.6
Jersey Cow			6.0
Friesian X Jersey Cow			6.7
Friesian Cow (Town Milk)			8.0
Jersey Yearling 0-12 months			1.7
Friesian X Jersey Yearly 0-12 months			1.8
Jersey Heifer 12-24 months			3.0
Friesian X Jersey Heifer 12-24 months			3.2

2.5 Comparison of Cornforth/Sinclair and Karlovsky Models for Maintenance Phosphate Requirements

The balance sheet approach to estimating maintenance P requirements, that forms the basis of the Cornforth/Sinclair model, was originally proposed by Karlovsky (1963, 1966).

While the minimum maintenance rates of P application for 'high' pasture DM production from New Zealand soils had been established earlier, Karlovsky recognised the need for information on the maintenance P requirements for different steady state pasture DM yields. In any such steady state, Karlovsky proposed that the maintenance P requirement would depend on:

(a) Inorganic and organic fixation of P by soils and the downward movement of P in soils.

(b) The removal of P in animal products, and the voiding of dung outside the grazing area.

(c) The level of pasture DM production.

On the basis of field trials and laboratory studies, Karlovsky proposed that the major soil groups of New Zealand could be categorised according to their rate of phosphate fixation into high, medium, low and very low P-fixing soils.

Within each category, Karlovsky used mowing trials to establish relationships between:

(a) P output and total pasture DM production

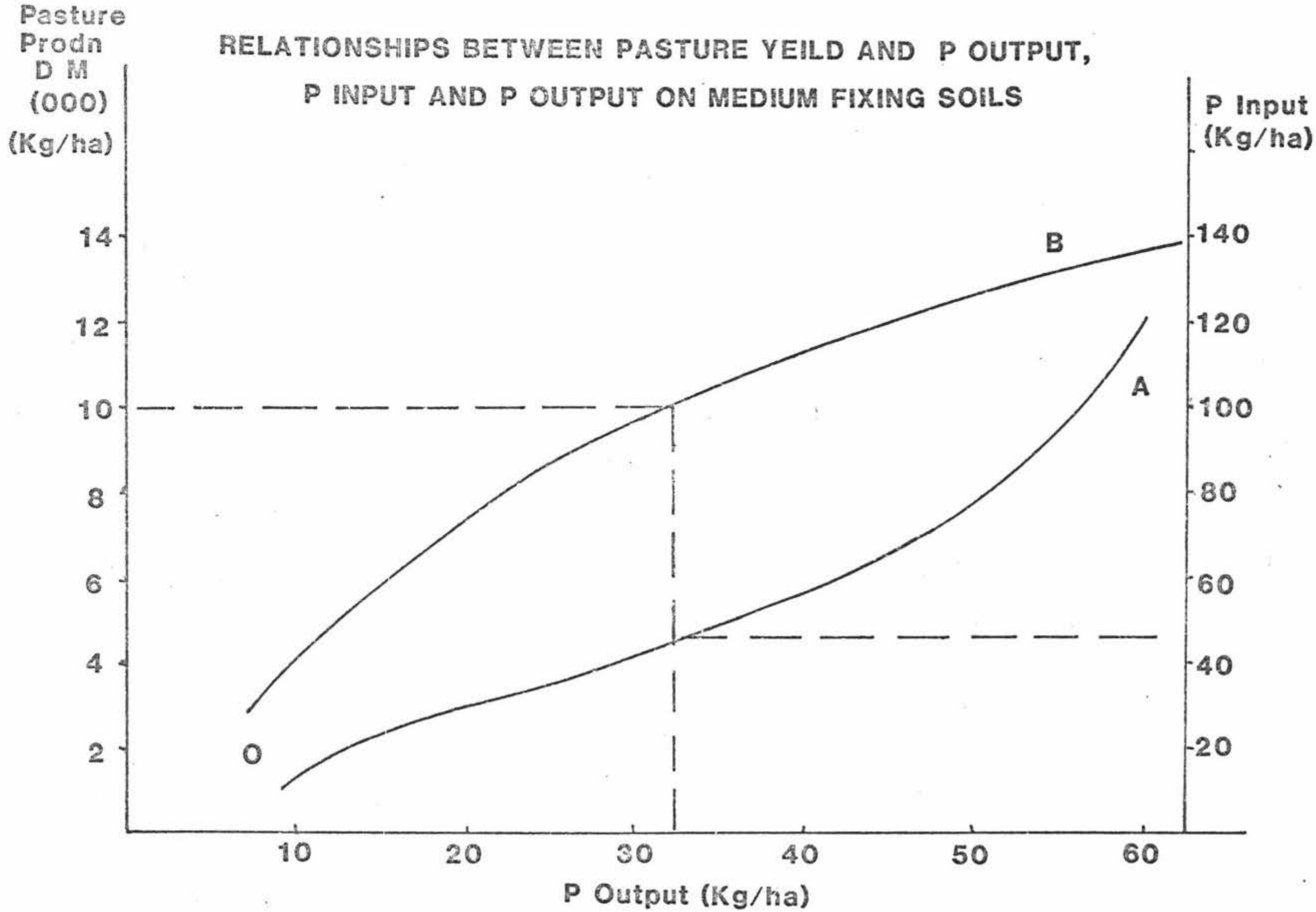
(b) P input and P output.

The P output/Pasture DM relationship describes the amount of P removed from the soil as herbage corresponding to different levels of pasture DM production. This relationship exhibits conventional diminishing returns in that increasing quantities of soil P must be removed for successive increments of pasture DM produced. Put another way, this relationship describes the way in which percentage P in herbage changes with pasture DM produced. This relationship is not defined explicitly in the Cornforth/Sinclair model.

The P input/P output relationship describes the amount of P input required to maintain different levels of P output from the system. This relationship also exhibits conventional diminishing returns in that increasing quantities of P inputs are required for successive increments of P output.

Figure 2.3 shows these two relationships for medium fixing soils with high pasture production potential, (Karlovsky 1966). Curve OB shows the relationship between P output and total pasture DM production. Curve OA shows the relationship between P input and P output. Thus to maintain an average annual pasture DM yield of 10,000 kg/ha, annual P output must be 32.5 kg/ha and this in turn requires an annual P input of 46 kg/ha for medium P fixing soils. Since these relationships were obtained from mowing trials with full return of mown herbage, the difference between P input and P output represents an estimate of soil P loss, that must be replaced by fertiliser, in this example 13.5 kg/ha per year. Under zero grazing (full clippings return)
P input (for maintenance) - P output = soil P losses.

Figure 2.3


RELATIONSHIPS BETWEEN PASTURE YEILD AND P OUTPUT,
P INPUT AND P OUTPUT ON MEDIUM FIXING SOILS
Pasture Prodn D M (000) (Kg/ha)
P Input (Kg/ha)
P Output (Kg/ha)
2
4
6
8
10
12
14
20
40
60
80
100
120
140
10
20
30
40
50
60
O
A
B

Curve OA in Figure 2.3 represents decreasing efficiency of P utilisation in the soil as P output, and hence pasture production, increases towards a maximum.

To calculate the losses of P from the system under grazing, Karlovsky made assumptions about the effect of the grazing animal:

1. 80% of the grass grown in a year is utilised at any pasture productivity level.

2. Removal of P in animal products:-

	kg P/ha	
	P Output	P Removed
(a) Dairy	50.44	7.29
	39.23	5.60
	28.02	3.92
(b) Sheep	50.44	4.04
	39.23	3.14
	28.02	2.24

3. Transfer of dung P outside the grazing area:-

   (a) Dairy - 12½% of dung P is excreted in milking sheds and races, and 12½% of dung P is excreted under hedges, at gateways or in other areas where it can be considered as lost for all practical purposes.

   (b) Sheep - under sheep grazing, Karlovsky assumed that losses of dung P outside the grazing area were 10%.

Comparison of the fate of phosphate and maintenance P requirements between the Karlovsky model on the one hand, and the Cornforth/Sinclair model on the other, is not straightforward.

Although both models estimate maintenance P requirements at various levels of pasture DM production, Karlovsky restricts his estimates to a situation where pasture utilisation equals 80 percent; while the Cornforth/Sinclair model specified percentage P in herbage, animal and soil P loss, only at RY(90). At other levels of pasture production, the Cornforth/Sinclair model only predicts total P losses.

While these differences are of minimal or no significance to this particular study, the estimation of relationships for percentage P in herbage, animal and soil P losses, at relative yields other than RY(90), may well assist in the process of model validation and monitoring system performance. Estimation of the relationship between pasture DM yield and percentage P in herbage for different Ymax situations for example, might provide the opportunity to estimate relative yield for a system based on observed average herbage P levels.

For the reasons presented above, comparison of the Karlovsky and Cornforth/Sinclair models is restricted here to the situation of RY(90) and PU = 80. In the following example we assume a medium P fixing soil where Ymax = 14570 kg/ha. This situation corresponds to CC = 22.66 su/ha in the Cornforth/Sinclair model. At RY(90), actual pasture DM yield is 13113 kg/ha. At PU = 80 we have SR = 19.1 su/ha. Using Figure 2.3, and extrapolating to higher levels of P output for Karlovsky's animal loss assumptions, enables the comparison presented in Table 2.4.

In this example, soil losses predicted by the Cornforth/Sinclair model are considerably lower than those predicted by Karlovsky, but under both sheep and dairy grazing, losses due to animal products and transfer losses are significantly higher.

2.6 Summary

The Cornforth/Sinclair Model for calculating P maintenance requirements for grazed pasture builds on the P balance calculations proposed by Karlovsky. Animal losses in the Cornforth/Sinclair model are more clearly defined and specified by allowing for variation in PU and the influence of land slope on transfers of P outside the grazing area. At RY(90) the Cornforth/Sinclair Model is explicit in the relationship between potential pasture production and herbage P content, and clearly defines the relationship between P uptake in the herbage at RY(90) and soil losses of P. At other relative yields, the comparison between the Karlovsky and Cornforth/Sinlcair models can only be made in terms of total P requirements.

Table 2.4 Comparison of Fate of P between Karlovsky and Cornforth/Sinclair (kg P/ha/yr)

	Karlovsky		Cornforth/Sinclair	
P Output	54.5	(Fig 2.3)		50.92
% P in herbage	.415			.388 (Equation 2.2)
Soil Loss	(Fig 2.3) (93 - 54.5)	38.5	12.74	(Equation 2.3) (SLF = 0.25)
Returned in Dead Herbage	10.9			10.18
Ingested by Animals	43.6			40.74
For Sheep				
Lost in animal Products		4.36		ALF = 0.7
Excreted	39.24			
Excreted outside Grazing area		3.92		
Returned	35.32		(Difference)	25.92
Total Animal Losses		8.28	14.82	(Equation 2.4)
TOTAL LOSSES		46.78	27.56	
For Dairy				
Lost in animal Products		7.89		ALF = 0.9
Excreted	35.71			
Excreted outside Grazing area		8.93		
Returned	26.78			
Total Animal Losses		16.82	19.05	
TOTAL LOSSES		55.32	31.79	

CHAPTER 3

ECONOMIC ANALYSIS OF MAINTENANCE PHOSPHATE FERTILISER REQUIREMENTS USING THE CORNFORTH/SINCLAIR MODEL

3.1 Introduction

Examination of the components of the Cornforth/Sinclair model indicate two areas for economic analysis.

(i) Increases in technical efficiency of P fertiliser use, through reductions in maintenance P input for any given stocking rate, or increases in stocking rate for any given level of P input. The effect of either of these alternatives is increased output (ssu) per unit of fertiliser P input.

(ii) Increases in economic efficiency by movements around the response function towards the point where marginal value product from additional P input equals the marginal cost of the additional input. The marginal value product from additional P input depends on the extra stock units (ssu) carried per hectare, the gross margin (GM) per ssu, and costs other than fertiliser P associated with the extra stock units.

Any economic analysis of alternative production strategies based on the Cornforth/Sinclair model is limited by two considerations:

1. The Cornforth/Sinclair maintenance P model refers to average pasture dry matter and livestock production for any given management system. Seasonal fluctuations in rainfall and

other factors, will influence the actual level of pasture dry matter production, animal production, and thus P loss from the farming system. The Cornforth/Sinclair model predicts P losses from the system for an average season and thus, over time, can be expected to estimate the P input required to maintain that production system. Economic analysis of alternative fertiliser use strategies in production systems involving climatic variability should include some consideration of risk and uncertainty. Consider two possible situations with respect to Figure 2.2.

	PU%	RY%	SR	P Requirement
Situation A	75	85	13.2	18
Situation B	60	88	11.1	18

It is expected that A is more risky than B, although both are producing at similar pasture dry matter (DM) levels. At situation B, there is considerably more scope for increasing PU%. Thus in a poor pasture production season, stock performance at A is likely to suffer more than in B, due to reduced feed intake by livestock. In such a season, PU at situation B will probably increase, but the scope for doing the same at situation A is considerably less. However, without information on the variability of pasture DM production, it is not possible to evaluate the riskiness of alternative stocking rate and phosphate input alternatives.

2. The Cornforth/Sinclair model refers to maintenance P inputs. The maintenance requirement curves (Figure 2.2) describe the relationship between P inputs and production measured in standard stock units at various steady states; they do not describe the P input required to move from one steady state to another. Economic analysis of alternative P input/SR decisions using the Cornforth/Sinclair model is therefore restricted to comparisons of steady states, and does not include any capital or development P fertiliser costs that may be associated with any particular time path of transition from one steady state to another.

   Economic analysis of alternative P input/SR decisions using the Cornforth/Sinclair model is appropriate only if the Cornforth/Sinclair model is applicable for all alternatives. Conditions under which a maintenance P input as determined using the Cornforth/Sinclair model is appropriate are discussed in more detail in Chapter 4.

3.2.1 Increases in Technical Efficiency

From Figure 2.2 it is clear that increases in technical efficiency may be possible by either maintaining stocking rate, increasing PU and hence decreasing maintenance P input, or by increasing both stocking rate and PU at any given maintenance P input.

Increases in PU are likely to be associated with changes in input costs needed to maintain a higher level of PU. Such inputs might include additional subdivision and water supply. Grazing management strategies to match feed intake of animals more closely with pasture DM production may also be required.

Higher levels of PU might also require changes in stock policies, as it may not be technically feasible under an existing stock policy to match feed demand to pasture DM production despite "optimum" grazing management strategies. Such changes in stock policy might involve alterations in the ratio of cattle to sheep, or a change in the classes and ages of cattle and/or sheep carried.

Where PU is increased at any given stocking rate, pasture DM production required will decrease and hence maintenance P input will also decrease, since, by definition

$$PU\% = \frac{SR \times 550}{Y} \times \frac{100}{1}$$

an increase in PU for given SR implies a corresponding decrease in Y (and hence RY).

Where P input remains constant and management changes result in an increase in both SR and PU, there will be a small decrease in Y (and hence RY).

Economic analysis of changes in technical efficiency will therefore require estimates of costs associated with changing levels of PU, in addition to changes in Gross Margin associated with stocking rate or stock policy changes, or changes in P input cost.

3.2.2 Increases in Economic Efficiency

Movements around the response surface may involve

(a) holding PU constant

(b) holding RY constant, or

(c) varying both PU and RY.

In all of these cases both SR and maintenance P input will change simultaneously.

From Figure 2.2 it is clear that at constant PU, the relationship between SR and P input exhibits diminishing marginal returns. If constant PU implies no change in grazing management, and hence level of subdivision or water supply, it would be possible to identify the economically optimum level of maintenance P input use by equating the marginal Gross Margin for stocking rate with the marginal P input cost. An example is presented in a subsequent section.

At constant RY there is a linear relationship between SR and maintenance P requirement, according to the Cornforth/Sinclair model. This situation is of interest since the writer is aware of some advisory officers who make P input recommendations on the basis of x kg of P per additional stock unit. For constant RY, increases in SR clearly imply increases in PU (as well as P input). Some increases in SR however at any given RY may automatically result in the increased PU needed to support the system. If this is the case, and if for any RY the marginal return from additional stock exceeds the marginal cost of the additional P input, then SR and P input should be increased at least to the point where PU increases cease to become costless, or risk considerations become important.

Alternatively if increases in SR in themselves are not costless because of total stock number handling problems, it may be most economical to increase PU by reducing P input and holding SR constant.

3.3 Factors Affecting Pasture Utilisation

Economic analysis of alternative P use decisions using the Cornforth/Sinclair model involves changes in the performance variables SR, PU and RY.

One of the major difficulties in such analyses is likely to be estimating the cost (if any) associated with changes in PU. In order to estimate these costs, it is necessary to take account of the management factors and policies which may give rise to changes in PU.

Three management factors thought to influence PU% are:

1. Stock Grazing Density
2. Sheep:Cattle Ratio
3. Summer/autumn stock numbers, particularly cattle.

1. Stock Grazing Density

For different farms with the same stocking rate and classes of livestock, PU may differ between farms depending on stock grazing density. Stock Grazing density is defined as the number of stock units per hectare grazed at any one time. Thus, where grazing management involves mob-stocking on a rotation around the farm, grazing density will be higher than for a similar farm where set-stocking is practised. Stock grazing density will be influenced by mob size and paddock size.

Higher stock grazing densities are thought to result in higher levels of overall pasture utilisation. When low stock grazing densities predominate, it is not unusual to observe situations where large areas of a paddock remain relatively ungrazed, while stock severely overgraze the remainder of the pasture.

2. Sheep:Cattle Ratio

The ratio of sheep su to cattle su, normally calculated on mid-winter stock numbers, is believed to influence the level of PU achievable. With higher proportions of cattle, greater scope is available for increased total animal intake in response to higher levels of available pasture DM. As sheep:cattle ratios decline, the ease with which high levels of PU can be attained is thought to increase.

3. Stock Numbers in Summer/Autumn

   Considerable variation between farms can occur in the number of sheep, and particularly cattle, that are carried through the summer/autumn period, while winter stock numbers are similar. Changes in sale dates of lambs, cull ewes and particularly cattle, can result in manipulation of feed demand to more closely match supply. Stock policies which do not allow this opportunity for flexibility are unlikely to result in consistently high levels of PU.

Analysis of differences between farm properties with regard to these three factors should give indications of likely differences in PU achievable, and the costs associated with changing stock policies, management strategies or levels of farm subdivision.

3.4 Using the Cornforth/Sinclair Model to Predict Pasture Utilisation or Relative Yield

In any economic analysis of alternative strategies using the Cornforth/ Sinclair model, an essential part of the analysis is the estimation or prediction of PU or RY under the current management policies operating. Estimation of PU or RY allows calculation of P input required to maintain the current situation.

If SR and P input are known from farm records over recent years, the Cornforth/Sinclair model can be used to predict the level of PU and thus RY that has been achieved under existing policies. Using the Cornforth/Sinclair model in this manner requires acceptance of the assumption that the property was in P balance or a maintenance situation over the recent period. An indication of whether the balance situation has occurred can be gained from stock number and performance records, P inputs if constant, and measures of soil reserves of P, or fertiliser P stocks held in the soil. If soil reserves have been constant, then neither investment in soil fertiliser stocks, nor drawings from these stocks has occurred and P inputs have matched P losses. However, any combination of SR and P input will eventually become a maintenance situation. If P inputs are in reality greater than P losses from a system, the soil reserves of P will increase, and provided there is scope, pasture production will increase and thus soil P losses will also increase. Under constant stock numbers in this situation, either PU will decline so that animal P losses do not change, or PU remains constant, animal intake, production and P losses will increase to the point where P balance is reached.

An example of using the Cornforth/Sinclair model to predict PU or RY can be illustrated using Figure 2.2.

Consider a farm for which the basic Cornforth/Sinclair model parameters are as described in Figure 2.2, ie

CC = 18 ALF = 0.9 SLF = 0.25

If in recent years the SR has been 13 su/ha and consistently 20 kg P/ha per year have been applied, then the model predicts that PU achieved has been approximately 70%. Using equation (2.8) then

$$RY = \frac{8550 \times SR}{CC \times PU}$$

$$= 79.39\%$$

From equation (2.1)

$$Ymax = CC \times 643$$

$$= 12860 \text{ kg DM/ha}$$

$$\text{Average Pasture DM production} = 12860 \times .7939$$

$$= 10159 \text{ kg/ha}$$

When the Cornforth/Sinclair model is used to predict PU and RY as in the above example, the predicted level can be examined in relation to observed feed shortages and surpluses. After consideration of these, and grazing management and stock policies, opportunities for changing management practices may be highlighted.

3.5 Monitoring System Performance

In practice, recommended SR/P input relationships derived using the Cornforth/Sinclair model, either from estimates of PU and RY or by prediction using the Cornforth/Sinclair model, must be carefully examined in relation to the implied system performance. There is a clear need to monitor RY, PU and thus SR (including animal performance) in a number of cases where the Cornforth/Sinclair model is implemented, so that the validation and development of the model can continue. Differences between predicted system performance using the Cornforth/Sinclair model and measurement of performance must be highlighted so that the Cornforth/Sinclair model can be modified to better mirror reality.

3.6 Example Economic Analysis

To illustrate the use of the Cornforth/Sinclair model in the economic analysis of P fertiliser input, assume that for any given PU, the only increase in cost associated with increased SR is the cost of increased fertiliser required to maintain the system.

The Cornforth/Sinclair production function described in equation (2.7) can be written

$$RY = 100\,(1 - 10^{-z})$$

Substituting for RY from equation (2.8) and rearranging we obtain

$$SR = \frac{100\ .\ CC\ .\ PU\ (1 - 10^{-z})}{8550} \qquad \text{.... (3.1)}$$

Where z is defined in equation (2.7).

For example : where CC = 20, PU = 75, ALF = 1.1, SLF = 0.25, then from equation (2.6) total P loss at RY 90 = 29.48 kg/ha and Z = P loss at $RY(29.48)^{-1}$ from equation (2.7).

Let P loss at RY = X

Then for this example the production function is:

$$SR = 17.54\ (1 - 10^{-x(29.48)^{-1}}) \qquad \ldots.\ (3.2)$$

and the marginal product of fertiliser input:

$$\frac{dSR}{dX} = -17.54\ (-29.48^{-1}\ \log_e 10)\ 10^{-X(29.48)^{-1}} \qquad \ldots.\ (3.3)$$

$$= 1.37\ .\ 10^{-X(-29.48)^{-1}}$$

In order to calculate the marginal value product at any level of P fertiliser input, an estimate of the Gross Margin per standard stock unit is required.

New Zealand Meat and Wool Board Economic Service survey data has been used to estimate GM/su for class IV North Island hill country sheep and cattle properties.

The 1978/79 survey data has been adjusted for movements in farm input and product terms of exchange (Economic Service Papers 1824 and 1833) to estimate GM/su for 1979/80 net of fertiliser input costs:

	$
Farm Income	77191
Variable Expenses less fertiliser	27427
GM for 3565 su	49764
GM/su	13.96

Assuming this GM/su remains constant, at least in the short run, for various stocking rates, then:

Marginal Value product of 1 kg P = $13.96 (1.37)\ 10^{-X(29.48)^{-1}}$ .... (3.4)

In 1979/80 the average cost of superphosphate applied in the Northern Manawatu hill country was \$140 per tonne. This product contains 8% available P.

The marginal cost of 1 kg of P then is \$1.75. Equating marginal value product of P to unit P price and solving for X, we obtain:

X = 30.65 kg P/ha (383 kg superphosphate/ha)

= Total P loss at RY (Optimum)

Solving for SR from equation (3.2) we obtain:

SR (optimum) = 15.94 su/ha

The corresponding value for RY = 90.86 and GM/ha = \$168.88.

For the situation where cc = 18, ALF = 0.9 and SLF = 0.25, Table 3.1 estimates the financial loss from applying less than optimal fertiliser P input levels at the given product and input prices, and for varying levels of pasture utilisation, and hence RY. A variety of similar calculations can be performed to indicate the economic impact of less than optimal fertiliser input decisions, or the impact of changing product price to fertiliser input cost ratios, for comparative P input maintenance situations.

Table 3.1 Financial Loss from Applying Less Than Optimum Maintenance Phosphate Applications, and Achieving Less Than Maximum Pasture Utilisations

P Input kg/ha	PU%	RY%	SR	GM/ha	Loss/ha
25.21	75	92.09	14.54	158.84	0
18	75	83.66	13.21	152.96	5.88
10	75	63.46	10.02	122.42	36.42
25	65	93.47	12.79	134.83	24.00
17	65	84.40	11.55	131.45	27.39
10	65	66.43	9.09	109.46	49.39
20	55	90.77	10.51	111.77	47.07
15	55	83.34	9.65	108.39	50.45
10	55	69.70	8.07	95.12	63.72

For CC = 18 ALF = 0.9 SLF = 0.25 GM/su = 13.96

Cost/kg P = $1.75

Functions :

75% PU : $SR = 15.7895\ (1 - 10^{-P\ \text{loss}\ (22.8587)^{-1}})$

65% PU : $SR = 13.68421\ (1 - 10^{-P\ \text{loss}\ (21.07886)^{-1}})$

55% PU : $SR = 11.57895\ (1 - 10^{-P\ \text{loss}\ (19.29905)^{-1}})$

CHAPTER 4

REVIEW OF SELECTED FERTILISER RESPONSE FUNCTION RESEARCH

4.1 Middleton's Model

Middleton (1973,1) maintains that optimum fertiliser rates should be calculated through production function analysis of long term field trials designed for that purpose. The most suitable model on which to base production function analysis, according to Middleton is the Mitscherlich curve, generally described by

$$Y = A + B \cdot 10^{rx} \qquad \ldots. (4.1)$$

Where A, B and r are constants obtained by fitting the equation to yield (Y) response data to fertiliser input (X).

Trial designs to allow estimation response curves should comprise three treatment levels of fertiliser, aimed to maintain pasture at 70, 85 and 96% of maximum obtainable yield for sufficiently long enough to determine seasonal variation and hence average yield (Middleton 1977). In such trials, a "mowings-and-clippings discarded" technique should be used, with the effect of the grazing animal simulated by returning a calculated fraction of the mineral and nitrogen content of the discarded clippings. A vital condition to trials of the type proposed by Middleton is that fertiliser applications should be expressed as units of a balanced fertiliser mixture. The basis for this argument are studies concerned with nutrient cycling between animals, pasture and the plant rooting zone in the soil (Middleton 1973, 2). In these studies (Karlovsky 1966, Hutton et al 1967, Davies et al 1962) estimates of likely losses of major nutrients from the soil, plant and animal system are made. These estimates are based for example on the balance sheet approach of Karlovsky (1966).

The production functions estimated by Middleton account for variation in efficiency of use of P, via the constants in the regression model. Variation in pasture utilisation affects the monetary value of the pasture grown when calculating the profitability of different maintenance rates of fertiliser. The optimum level of fertiliser use is calculated in a similar manner as described in Chapter 3. In the Cornforth/Sinclair model, average monetary values for pasture are calculated by assuming that a standard stock unit consumes 550 kg of pasture dry matter and the return from a stock unit does not vary with different pasture yields.

Middleton (1973, 1) presents a method for calculating the monetary value of pasture production which depends on monetary return from stock, nutritive value of pasture, degree of pasture utilisation, average metabolic efficiency of animals and grazing costs. Optimum fertiliser application rates can then be calculated.

Middleton's proposals require long term field trials which occupy a large number of resources. In the opinion of Cornforth/Sinclair, their model gathers together the best information currently available and presents it in a framework such that modification of the model is possible as a result of thorough monitoring of the production systems to which it is applied.

4.2 During and Ludecke Approach

A somewhat more traditional research approach to the determination of maintenance P fertiliser requirements in grazed pasture has been suggested by Ludecke (1966) and During (1966).

Ludecke suggests an experimental design such that maintenance fertiliser requirements are determined under a set stocking system of grazing management so that maximum pasture utilisation is obtained. A system of paddocks in which subtrials are established in successive years is proposed, with subtrials not receiving fertiliser in the year they are established. Withholding fertiliser from the current subtrial area allows the assessment of the residual effects of previous topdressing in the subtrial control plots.

During (1966) proposed experiments to study maintenance requirements involving short term shifting plots, or long term trials superimposed on paddocks receiving a controlled rate of fertiliser P. The rates of fertiliser are changed over time in response to yield results on the small plots. During states that a maintenance study attempts to adapt rates of application to changing soil conditions so that the total amount of nutrients (both soil supplied and fertiliser) available to plants remains approximately constant.

During also raises the problem of residual effects of past fertiliser dressings and management strategies. Information gained from response curves drawn from yields to increasing rates of fertiliser application to pasture over a period of time is confounded by residual effects.

As well, the degree of deficiency of the elements involved is often not defined in these trials, and the degree of deficiency will change with time, according to During. As a result, he believed that field trials served primarily as reference points for various means of chemical diagnosis.

During (1966) suggests that the difficulties encountered in long term trials expressed above may be reduced by superimposing short term small plot trials on a number of paddocks kept under grazing involving two or three rates of nutrients, most often P and potassium.

Experiments of this nature were carried out on four farm properties in the early 1960's and reported by During (1966). Information was obtained to allow these farmers to apply more efficient rates and ratios of P and potassium. Some problems remained, principally the residual effect, which During states can only be neglected if fertiliser applications do not effect the soils' phosphate retention power. Information on this aspect may require trials to run for up to twelve years.

In summary, During states the fertiliser economy of soils depends on:

1. The level at which soil can supply nutrients;
2. The rate of change in supply as nutrients are depleted;
3. The efficiency with which applied nutrients are held by the soil for use by plants.

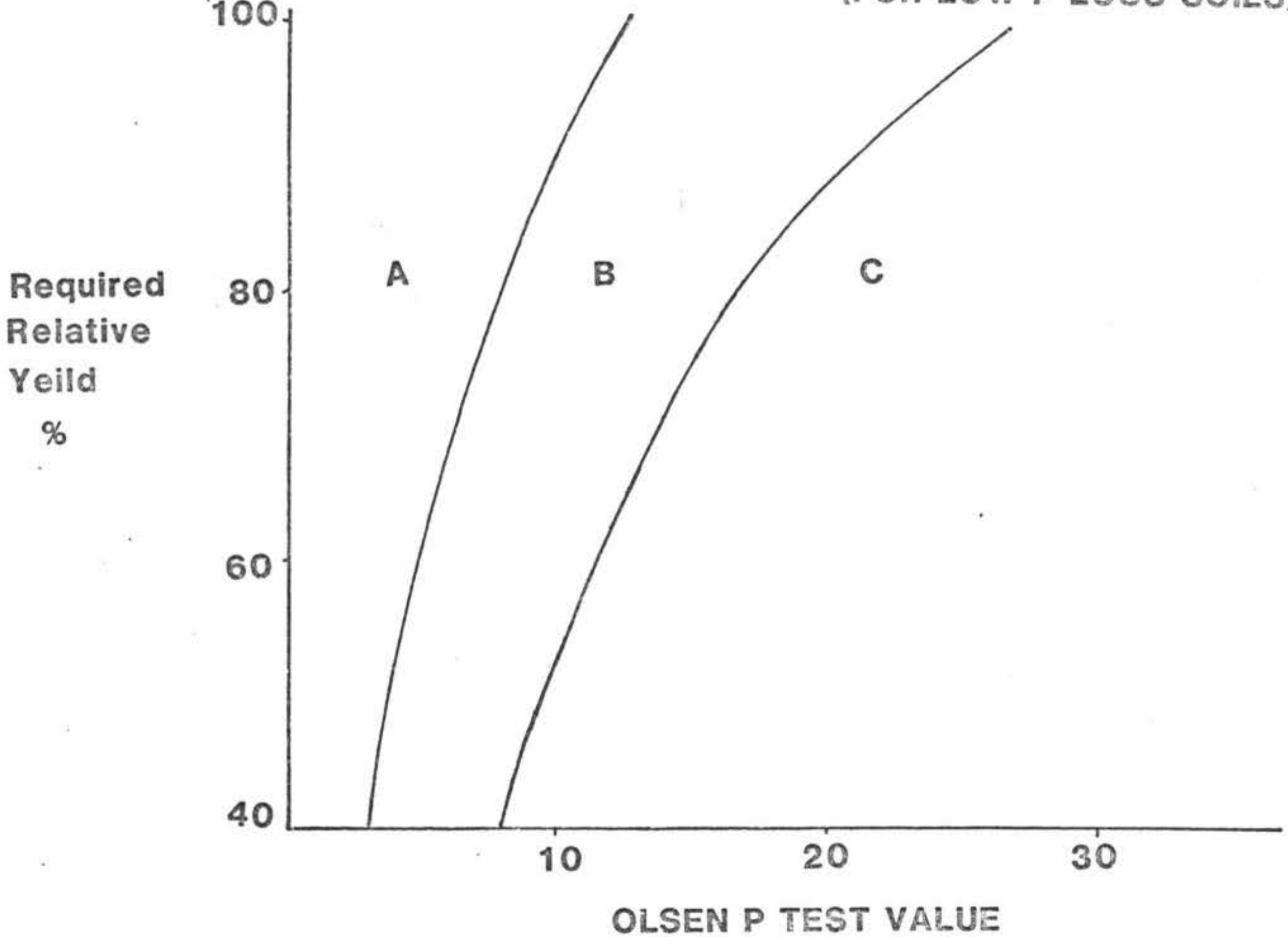
If these properties can be measured, and related to accurate field trials, long term fertiliser needs can be calculated. Soils may be grouped by these characteristics.

The Cornforth/Sinclair model takes account of these characteristics through soil loss factors, and by using Olsen P tests to determine whether a site is appropriate for maintenance application rates using the model. the ability of the soil to supply P, or its level of development, is determined by Olsen P test levels and relating these to the level of RY required to maintain the stocking rate on the property.

An example of the relationship is presented in Figure 4.1

Figure 4.1

DETERMINING IF MAINTENANCE P RATES ARE APPLICABLE
(FOR LOW P LOSS SOILS)



In Zone A, apply maintenance plus corrective P for one year, then retest. Here soil P levels are insufficient to maintain the required RY with only a maintenance application.

In zone B apply maintenance P calculated using the Cornforth/Sinclair model.

In zone C omit fertiliser P for one year and retest. Soil P supply is sufficiently high to maintain required RY without addition of fertiliser. Soil reserves are expected to fall (due to losses) and P test should drop into zone B.

The relative position of the zones to Olsen test level varies with soil P loss category. As soil P loss increases, a higher Olsen test level is required for maintenance rates to be applicable.

4.3 "Decide" Approach

4.3.1 Introduction

A model designed to integrate P fertiliser knowledge and provide users with a means of making fertiliser decisions has been developed in Western Australia by Bowden and Bennett (1974). Also based on the Mitscherlich curve, the scheme known as "Decide" has received widespread commercial application.

4.3.2 Model Parameters

Bowden and Bennett state the Mitscherlich curve as having advantages as a basis for prediction of optimum fertiliser input because of its ease of mathematical manipulation, and because the parameters have conceptual significance in themselves.

The form of the "Decide" response curve is

$$Y = A(1 - Be^{-cx}) \qquad \ldots. \ (4.2)$$

Where Y = Yield per unit area

A = Maximum Yield with P non limiting

B = Responsiveness of the site = $\frac{A - YO}{A}$

Where YO = Yield when fertiliser input X = 0

B ranges from 0 to 1, C is the coefficient of curvature, and X is fertiliser input per unit area.

4.3.3 Application of Decide

Application of the Decide model requires estimation of the parameters and the calculation of optimum fertiliser input assuming there is no soil P currently available to plants. Subsequently, estimations of the current value of past fertiliser dressings and the contribution of natural soil P to current yield are deducted from the amount first calculated.

Estimation of the contribution of previously applied fertiliser can be attempted by using soil test calibration curves, or by the use of residual value functions.

The Decide model uses residual value functions of the form

$$I = \sum_{t=1}^{n} Ft \,/\, (t + 1) \qquad \ldots. \ (4.3)$$

Where I = current value of past fertiliser applications

N = number of years for which fertiliser has been applied.

Ft = Rate of fertiliser application in t^{th} year.

Consider a sequence of fertiliser applications using the Decide model, and its residual value function, aimed at maintaining a constant yield or level of production. As the value of fertiliser residuals increases with fertiliser history, the annual application required to achieve the target yield, using the response curve, will decline. In the extreme case fertiliser residual value will reach a level where no current application is required in one year. Subsequently, fertiliser residual value will fall because of that omission, and annual applications will resume.

Godden and Helyar (1980) propose modifications to the "Decide" model that make distinctions between the response curve approach of "Decide" and the relationship between yield and maintenance application of fertiliser. The modifications attempt to take account of the three processes which occur on the application of fertiliser to a soil-plant system; those of increased production, and loss of nutrients by animals, and organic and inorganic conversions of available P to unavailable forms. Godden and Helyar propose that the relationships between losses of P and production can be quantified, depending on the state of the system in relation to three phases:

1. Development phase, where investment in fertiliser residuals, or the soil nutrient pool is occurring.

2. Steady state maintenance, where no change in the pool of P occurs over time; that is losses from the system are balanced by fertiliser applications.

3. Capital depreciation occurs, where fertiliser applications are less than losses.

Thus according to Godden and Helyar (1980), it is possible to define maintenance requirement curves if true maintenance fertiliser rates are related to corresponding yields. These maintenance requirement curves are the locus of points from all response curves where there is no net change in fertiliser residuals in the soil. Maintenance requirement curves then allow the optimisation of investment and disinvestment in fertiliser residuals or "stocks", (the pool of P in the soil) via planned fertiliser programmes. These decisions account for yield responses, nutrient losses, and changes in the soil's pool of nutrients.

The Cornforth/Sinclair model differs from the approach proposed by Godden and Helyar above in that only maintenance requirement curves are specified in the Cornforth/Sinclair model. No attempt is made to specify the input/output relationships involved when a production system is moving from one steady-state maintenance situation to another. Insufficient information is available in New Zealand to allow specification of these input/output relationships. As a result, the Cornforth/Sinclair model is limited in the extent to which it can be used in carrying out economic analyses of alternative investment/development strategies. For example, consider the situation according to Figure 2.2 where CC = 18, ALF = .9, SLF = .25 and a farm is operating at SR = 11, PU = 70. According to the Cornforth/Sinclair model P maintenance requirement is 13 kg/ha/year.

Assume a more economically desirable level of operation is 14 su/ha, at the same level of PU. RY is 74.6% in the present situation and 95% in the proposed target situation. P maintenance requirement for the target is 26 kg/ha/year.

Application of 26 kg P under the present situation will result in changes similar to those outlined in Chapter 3, section 4. However, to determine the quantitative output from this strategy, the input/output relationships between fertiliser application and SR or RY has to be previously specified.

An alternative strategy would be to apply 40 kg of P per hectare in year one, with 26 kg of P per hectare applied in subsequent years. The relative profitability of these strategies cannot be properly evaluated without specification of the input/output relationships.

CHAPTER 5

THE FARM SURVEY AND SURVEY RESULTS

5.1 Introduction

In order to obtain information about the relationship between the Cornforth/Sinclair model and farming practice, a survey of hill country sheep and cattle farms in the Kiwitea County of the Northern Manawatu was carried out as part of this study.

The objective of the survey was to collect information about the production levels, management systems and levels of P fertiliser use from a range of hill country properties.

It was anticipated that the survey information could be used in the following manner:

1. To allow application of the Cornforth/Sinclair model for the purpose of analysing existing production systems particularly with respect to predicting the level of PU or RY being achieved.

2. To allow comparison of phosphate use and levels of farm production, with those predicted using the Cornforth/ Sinclair model.

3. To use these farms as reference points for a study of alternative fertiliser use policies and management strategies on Manawatu hill country farms.

Farms were selected from the Kiwitea County using Farm Location Maps. Mr B Withell, Farm Advisory Officer, Ministry of Agriculture and Fisheries, Palmerston North assisted in the selection of 30 farms, in an attempt to select a cross section of farms with respect to fertiliser use and management strategies. Length of farm tenure by the current owner was also a consideration in the selection of the sample since information on fertiliser history was to be collected.

30 farmers were initially selected and surveyed. While time constraints dictated the small size of the sample, it was thought that Mr Withell's knowledge of the farms in the area would ensure that a cross section was obtained. Nevertheless, no attempt is made to draw wide inferences from the sample data.

Farmers were initially contacted by telephone and an appointment made to visit the farmer and farm property. Information about the farm production system was collected including farm area, soil type, topography, stock numbers, type and level of production, farm subdivision, management information relating to stock policies and grazing systems, produce values and fertiliser use.

Information relating to farm production over the period 1970-1979 was collected where possible. Shorter periods of current ownership in some instances resulted in a shorter period for which farm records were available. It was thought necessary to have farm production and fertiliser use records covering this length of time because of the nature of the model under study. It was necessary to establish whether production systems were at a reasonably stable or maintenance level. The ability of the soil to buffer against short term changes in fertiliser application for example, means that average fertiliser application rates over a long period of time coupled with subsequent levels of pasture and animal productivity should be collected.

A significant problem exists in collecting data of this nature from farmers. In many instances financial statements, prepared primarily for taxation purposes, are the only form of record of previous years' operations kept by farmers. When, as in this case, information from a number of years in the past is required, there are many occasions when explicit data is unobtainable.

5.2 Application of the Model to the Survey Farms

From the survey data collected, it was found that 25 farms had sufficiently complete information to allow application of the Cornforth/Sinclair model, and further analysis.

Application of the Cornforth/Sinclair model to farm properties for which a maintenance P requirement is needed, involves estimation or calculation for the farm or part thereof, of values for the basic parameters CC (or Ymax), ALF and SLF, and the performance variables SR and PU (or RY). The most difficult of these appears to be PU (or RY) especially in the context of this study where observation of the farming system over a considerable time span was not possible, and where pasture production levels have not been previously measured on farms.

While the Cornforth/Sinclair model was primarily designed to estimate the P maintenance requirement for farming systems, it can also be used to predict PU (or RY) for farming systems, using fertiliser history and the performance variable SR. This use of the model is described in detail in Chapter 3, section 4, under the assumption that the farm is in a maintenance P input/P output situation.

The survey data collected was specific to recrods of farm production, namely stocking rate and fertiliser input, rather than to measurements of farm pasture production (RY), or PU. Thus the Cornforth/Sinclair model was used to predict from the data collected from the farms, the level of PU (and thus RY) apparently being achieved under existing management practices and stock policies.

5.3 Determination of Model Parameters for the Survey Farms

1. Potential Carrying Capacity (CC)

All of the farms surveyed fall in the New Zealand Meat and Wool Board Economic Service classification Class IV, North Island Hill Country. These farms are on easier country than Class III hard hill country, and are smaller holdings. Mainly Romney sheep are run with generally more than 10 stock units per hectare carried. A high proportion of stock is sold in forward store or prime condition.

All survey farms are on moderately steep Yellow-Brown Earth/ Yellow-Grey earch intergrade hill soils with varying amounts of easier and flat land. Few farms have greater than 10% of farm area in flats. Typical soils are Atua Silt Loam and Taihape Silt Loam. A detailed soil map of the Kiwitea County is not available.

Farm Advisory Officers of the Ministry of Agriculture and Fisheries' Advisory Services Division recently completed estimates of stock carrying capacities and fertiliser use data for the New Zealand Land Resource Inventory Survey conducted by the Ministry of Works and Development. Using this information, and after discussion with local Advisors, it was decided the average potential carrying capacity for survey farms was 18 su/ha. This figure was increased for farms that had greater than average areas of flat land. This generalisation was made for the initial use of the model to predict PU (or RY).

2. <u>Soil Loss Factor</u> (SLF)

From Table 2.1 it can be seen that the Central Yellow-Brown Earth/ Yellow-Grey Earth soils fall into the category of medium soil loss, with a corresponding soil loss factor of 0.25.

3. <u>Animal Loss Factor</u> (ALF)

From Table 2.2 the animal loss factor for sheep and beef cattle varies with land slope. The majority of farms in the survey fall into the "easier" hill country, thus an ALF of 0.9 is used. Where hill country is steeper, an ALF of 1.1 applies.

4. Actual Stock Rate (SR)

Numbers of stock in each class are calculated for each property in the survey, and converted to standard stock units according to the conversion factors in Table 2.3.

Where lambing percentages are less than 100 the information in Table 2.3 is extrapolated using the formula

$$su = 1 + (LP - 100)\ 0.005 \qquad \ldots. \qquad (5.1)$$

That is, for every 10% decrease in lambing percentage, standard stock unit ratio reduces by 0.05 for breeding ewes.

Table 2.3 has omissions with respect to replacement cattle in beef breeding herds in hill country situations. After a consideration of the work of Coop (1965), Nicol (1976), Walker (1963) and Joyce (1975), conversion factors for these classes of animals where chosen and are presented in Table 5.1.

Table 5.1 Factors For Converting Replacement Beef Cattle to Standard Stock Units (Hill Country)

Stock Class	Conversion Factor
Rising 2 yr heifers and steers	3.9
Rising 1 yr heifers and steers	3.6
Bulls and other	4.5

From Coop (1965), Joyce (1975), Nicol (1976) and Walker (1963)

The conversion factor for beef cows, in hill country conditions, as presented in Table 2.3 varies considerably from the factor most commonly used at present, that is 6.0 su/beef cow.

Stock carried at 30 June are converted to standard stock units for each farm. A complete list of this information from the survey farms is presented in Appendix I. A more detailed discussion of the effect of stock policy on stocking rate as determined in the Cornforth/Sinclair model is presented in a later chapter of this thesis.

A summary of the information gathered in the course of the farm survey is presented in Table 5.2. From the farm data, the Cornforth/Sinclair model was used to predict PU (or RY). The SR/P input relationship is presented in Figure 5.1 showing how PU is predicted in graphical form.

Farm properties whose levels of production or fertiliser input had fluctuated or changed markedly in the 1970-1979 period were not considered in this summary. It was assumed that these properties were not at "maintenance" and thus a maintenance fertiliser P requirement model was not applicable. For example (see Appendix I) farm 12 shows low to moderate levels of farm production with no fertiliser having been applied since 1974/75. Prior fertiliser history suggests that 10 kg P/ha/year was applied. The Cornforth/ Sinclair model does not offer any indication of how this situation can be sustained. Losses of P from the nutrient cycle can be expected, and with no P input from fertiliser, the size of the cycling pool will be reducing with time.

5.4 Discussion of Results of Applying the Cornforth/Sinclair Model to Existing Management Systems

Examination of the data in Table 5.2 indicates that, according to the Cornforth/Sinclair model, some farms may be receiving phosphate fertiliser at above maintenance rates. Very high estimated relative yields associated with low estimated pasture utilisations are unlikely to be observed in practice. It is more likely in these cases that actual RY is less than predicted, and that some portion of the fertiliser applied has contributed to increasing soil P reserves or increasing the cycling pool of P. Similarly, low estimated RY and high estimated PU values may be associated with a depletion of soil reserves of P, that is actual RY is greater than estimated or predicted.

Soil P reserves have almost certainly been increasing on farm number 13 where estimated RY is greater than 100%.

Farms where soil P reserves may have been increasing include numbers 1, 4, 6, 14 and 17.

Table 5.2 Results of Application of the Cornforth/Sinclair Model to Existing Management Systems

Farm Number	Average SR su/ha	Average P input kg/ha/yr	Apparent PU%	Apparent RY%
1	9.5	15.8	53	90
2	13.12	21.96	69	90
3	11.36	11.6	77	70
4	11.22	24.8	59	95
6	11.5	20	62	89
7	11.8	15.84	68	83
8	12.51	16	73	83
9	11.3	15.9	65	83
10	10.24	10.2	74	66
11	13	19.75	71	87
13	9.6	21.7	50	100
14	12.85	25.2	65	94
15	13	19.5	70	85
16*	13.7	17.3	75	79
17	10.7	23.29	54	94
18	10.5	13	65	76

* The carrying capacity of farm 16 was initially assessed at 20 su/ha. For all other farms CC = 18 su/ha.

According to the Cornforth/Sinclair model, long term continuation of present management strategies on these farms appears unwarranted. Changes in management policies should be possible to either reduce P input for current stocking rate, or increase animal output from existing levels of P input. Such changes have been occurring in the case of farm 4 and to a lesser extent on farm 17 (see Appendix I). It is possible that farm numbers 3 and 10 have been receiving less than maintenance applications of P and thus soil reserves of P have been depleted, that is production is maintained by drawing on soil P reserves. In this situation long term continuation of present policies would lead to reduction in stock performance levels, i.e. an effective reduction in stocking rate measured in ssu's.

5.5 Analysis of Fertiliser Use and Stocking Rate Alternatives

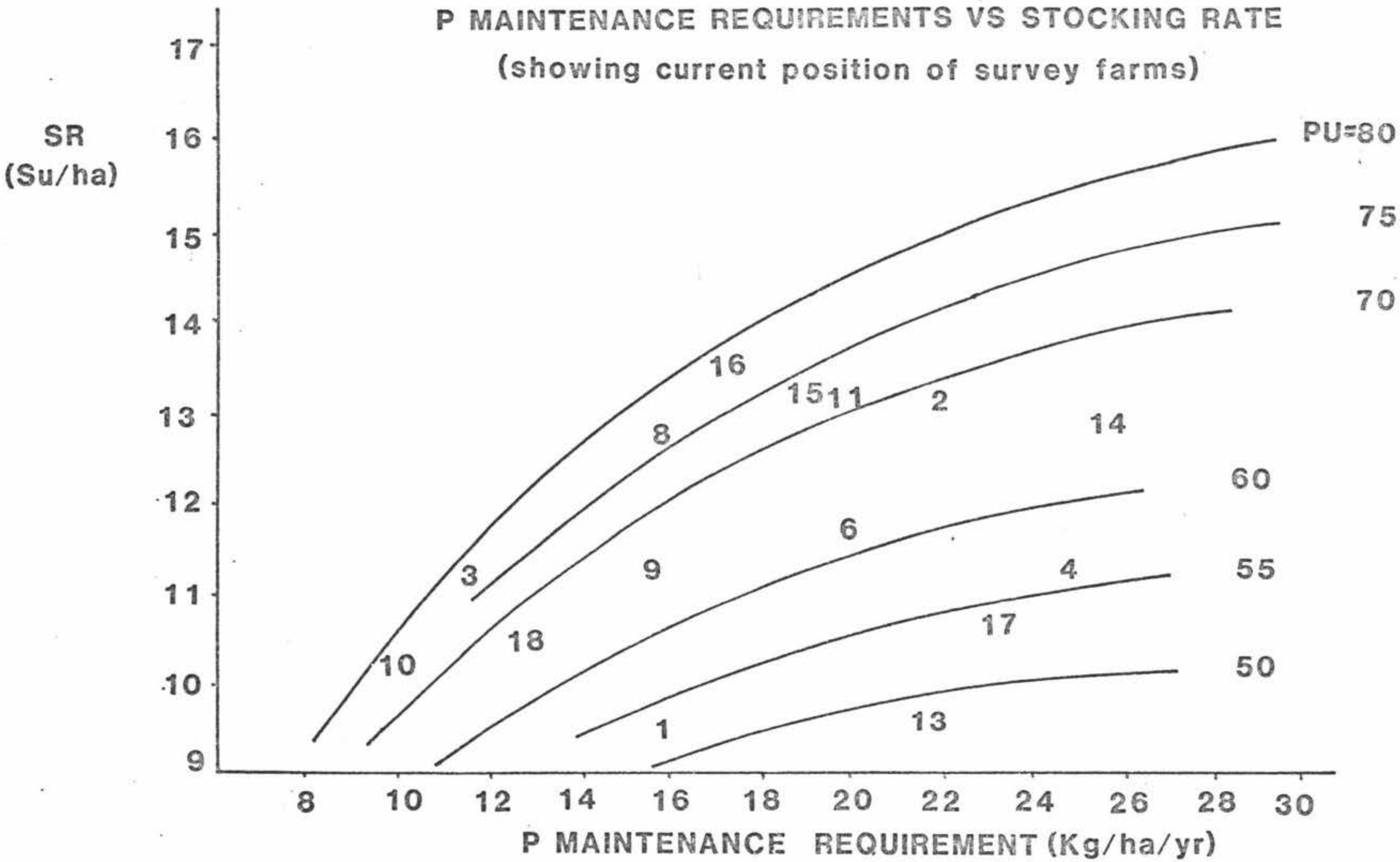
As described in Chapter 3, improvements in technical and economic efficiency can be obtained in a number of ways.

1. Achieving the same livestock production using less fertiliser, i.e. achieving a higher level of pasture utilisation, at lower RY.

2. Increasing livestock production at a fixed level of fertiliser P input, i.e. increased standard stocking rate.

3. Increasing pasture and animal production in such a way that average farm returns per hectare are increased.

Figure 5.1


P MAINTENANCE REQUIREMENTS VS STOCKING RATE
(showing current position of survey farms)
SR
(Su/ha)
17
16
15
14
13
12
11
10
9
8
10
12
14
16
18
20
22
24
26
28
30
P MAINTENANCE REQUIREMENT (Kg/ha/yr)
PU=80
75
70
60
55
50
16
15
11
2
14
8
6
9
3
4
18
17
10
1
13

The capacity of properties to "move" in any of the directions above depends on their present situation with respect to the performance variables, stocking rate and pasture utilisation (or relative yield), as presented in Figure 5.1.

Because differences in fertiliser use and stocking rate give rise to differences in economic return, differences between farms as specified by relative position in Figure 5.1 can be determined.

For example, farm 18, for the past five years has been sustaining 10.5 su/ha with a maintenance P input of 13 kg P/ha/year. Using income and expenditure figures from the New Zealand Meat and Wool Board Economic Service (Chapter 3.4) an estimate of profitability under current management strategies can be calculated.

Gross Margin/su (not including fertiliser)	=	\$13.96
Stocking rate	=	10.5/ha
Gross Margin/ha (not including fertiliser)	=	\$146.58
Fertiliser expenses 13 kg @ \$1.75	=	\$22.75
GROSS MARGIN/HA	=	\$123.83

Apparent PU% achieved by farm 18 is 65%

Relative pasture yield is 76%

Alternatives available to farm 18 are:

1. Increase pasture utilisation, at constant stocking rate.

2. Increase stocking rate, either with constant maintenance P fertiliser inputs or with increases in maintenance P fertiliser inputs.

In relation to alternative one, it is interesting to observe from the survey farms an apparent boundary on the upper level of pasture utilisation that can be achieved, or is being achieved, by farms in the area, and this level is approximately 75%.

This boundary is used then as the limit to which pasture utilisation can be increased. Stock performance may decline rapidly, if attempts were made to increase PU higher. However, degree of farm subdivision, land contour and aspect will have some effect on this upper limit.

If PU is increased to 75% on farm 18, a saving of 2.5 kg P/ha/year would be possible once the new steady state balance had been achieved. This results directly from a reduction in the required level of pasture production, from 76% Relative Yield to 66.5%, and saves $4.38/ha at 1979/80 costs of phosphate of $1.75/kg. The move to this new steady state balance will be profitable if the cost of achieving the higher level of pasture utilisation is less than $4.38/ha/year.

Significantly greater benefits are likely to acrue on farm 18 by adoption of alternative two above. A stocking rate of 11.5 su/ha can be maintained on farm 18 if fertiliser P input remains at 13 kg/ha/year, provided PU is increased to 75%. The additional stock unit, with performance maintained, can be expected to return an additional $13.96 to Gross Margin per hectare.

Examination of this example, along with the data of Table 3.1 and Figure 5.1 indicates that, provided initial pasture relative yields are not near 100%, most increases in return will result from higher stocking rates, compared with reductions in fertiliser use at constant stocking rate. Increases in stocking rate will continue to be most profitable provided the necessary expenditure to increase PU remains low, and is not greater than the cost of increases in pasture utilisation while P input is held constant.

Improvements in returns to fertiliser may continue to be made in the case of farm 18, by increasing stocking rate above the level obtainable by maximusing PU at current fertiliser input, that is above 11.5 su/ha. To increase SR further by moving along the 75% PU curve (see Figure 5.1) increases in fertiliser P maintenance applications are required at steady state balances on this path. Marginal returns to fertiliser will diminish as SR increases to the point where the additional fertiliser application cost will be equalled by the increased return from the higher stocking rate. This optimum point of fertiliser use for the 75% PU curve where the marginal value product from additional fertiliser equals the marginal cost of the additional input is calculated as presented in Chapter 3, section 3.6. For the situation of farm 18, where the GM/SU is $13.96 and fertiliser cost is $1.75/kg P, the optimum point occurs at a stocking rate of 14.55 su/ha. P maintenance requirement at this point is 25.22 kg/ha/year and relative pasture yield 92.15%. Gross margin for this optimum point, compared with the present situation (SR = 10.5, P input = 13 kg/ha/year) is increased by $35.15 to $159.00/ha/year.

Examination of Figure 5.1 indicates an apparent "boundary" to production, both in PU terms and SR. It is realistic to expect SR limits, given the earlier estimation and definition of CC, and limits on PU have been discussed.

Farms appearing to lie on the boundary are Numbers 10, 3, 8, 16, 15, 11, 2 and 14.

It is apparent from Figure 5.1 that few farms approach the "optimum" point for fertiliser use described above (SR = 14.55, P input = 25.22) It is reasonable to suggest then that interesting comparisions may be made between farms on the production "boundary" and those inside it, as well as amongst farms on the production boundary.

Considerable variation exists in fertiliser use at any particular stocking rate. Management systems and stock policies which allow high levels of technical efficiency of fertiliser use, for example farm 10, should be investigated to determine whether improvements can be made to farm systems exhibiting lower technical efficiencies, for example farm 4.

These two properties are the subject of more detailed case studies which follow. For comparative purposes, a property with high stocking rate and apparent high level of technical and economic efficiency (farm 16) is also included. An attempt will be made to identify the features of the management systems which are important in determining technical and economic efficiency of fertiliser use. Alternative phosphate maintenance fertiliser use and stocking rate strategies for each of the properties will also be investigated.

CHAPTER 6

SPECIFICATION OF STOCK POLICIES AND MANAGEMENT STRATEGIES ON THREE CASE STUDY FARMS

6.1 Introduction

Data collected from farms in the course of the farm survey, and presented in Appendix I, expresses the variation in stock numbers and production for each farm between years. The stock numbers shown are those on hand at 30 June at the end of the production year. Variation in these numbers for any farm between years at this time arises from a number of sources, even though the objective may be to maintain a constant average level of stock. Carry-over of stock from one year to the next because of variation in autumn and early winter feed supply, or adjustments to stock numbers around balance date for taxation purposes, are two examples.

Because this variation does not represent a true picture of the long term policy of the property, the derivation of "Example Policies" for each of the case study farms is necessary. The stock numbers incorporated in these "Example Policies" may not necessarily be simply the averages of the yearly figures collected in the survey data for the reasons stated above.

Management systems and stock policy specifications for case study farms are of interest because of their effect on animal feed demand and the relative profitability of the enterprise. The management variables of interest include lamb finishing dates, lamb sale policies, shearing practices, cattle buying and selling policies, and grazing management practices.

6.2 Example Policy for Farm 16

Farm area = 202 ha effective   80 ha flat
122 ha steep hill

6.2.1 Stock Reconciliation for Example Policy

(a) Sheep:

Opening Stock			Closing Stock
Mixed age breeding ewes	1110		1110
2-tooth ewes	450		450
Hoggets	680		680
Rams	35		35
	2275		2275
Purchases		**Sales**	
Rams	16	Lambs	771
		5 yr ewes	360
		Cull 2-th ewes	210
	16		1341
Natural Increases		**Deaths**	
Lambs 93%	1451	Rams	16
		Hoggets	20
		Ewes	90
	1451		126
	3742		3742

Sheep standard stock units = 2009.4

(b) Cattle:

Opening Stock			Closing Stock
Breeding cows	76		76
R 2yr heifers	19		19
R 1yr heifers	34		34
R 1yr steers	35		35
	164		164

Purchases		Sales	
	Nil	Cull cows	16
		R 2yr heifers	11
		R 2yr steers	34
	0		61

Natural increases		Deaths	
Calves	69	Cows	4
		Heifers	3
		Steers	1
	233		233

Cattle stock units = 651

Total stock units = 2655

Stocking Rate = 13.14 per effective hectare

Wool Production = 10753 kg/year

Ewes shorn twice per year

Lambs are sold in store condition from January through to March. Surplus replacement heifers are sold in the autumn prior to their second winter, as are all steers.

6.2.2 Management Strategies

Farm 16 is intensively subdivided to enable the implementation of a controlled mob grazing system throughout the year.

Lambing and calving take place in late August and September, with ewes and lambs set stocked till weaning in mid December. From weaning to next lambing, ewes are rotationally grazed in a minimum number of mobs.

Cattle are mob grazed in the hill country over summer and autumn. Cows spend some time in the winter on the flat land with intake supplemented by pasture silage. An important feature of the management from a pasture utilisation viewpoint, is the ability to close up flat areas in the spring and summer for the conservation of hay and silage. This allows the concentration of stock on the less easily controlled hill country, and the support of cattle with supplementary feed in the winter.

Management strategies and stock policies of importance in determining technical and economic efficiency in relation to pasture utilisation are discussed in Chapter 3.3

1. Maximum Stock Density

For farm 16 the maximum stock density in winter is 255 su/ha/day on the hill country, achieved by combining ewes and cows on paddocks averaging 7.2 ha in size. Summer maximum density is increased to 416 su/ha/day by the inclusion of 2-tooth ewes.

2. Sheep:Cattle Ratio

The sheep:cattle ratio for farm 16, based on winter stock numbers, is 3.08:1 on a stock unit basis.

3. Summer/Autumn Stock Numbers

Summer and autumn stock carried includes heifers and steers which are carried through two summer/autumn periods and sold prior to their second winter. Manipulation of sale date is used to match feed demand with supply. Lamb sale dates can also be manipulated to achieve this objective.

6.3 Example Policy for Farm 10

Farm ares = 350 ha effective	48 ha flat to easy
	302 ha moderate hill

6.3.1 Stock Reconciliation

(a) Sheep

Opening Stock		Closing Stock
Mixed age ewes	1344	1344
2-tooth ewes	520	520
Ewe hoggets	750	750
Rams	50	50
Wether hoggets	84	84
	2748	2748

Purchases		Sales	
Rams	18	Lambs	920
		Wether hoggets	80
		2-tooth ewes	200
		Cull 5 yr ewes	420
	18		1620
Natural Increases		Deaths	
Lambs 95%	1754	Rams	18
		Wether hoggets	4
		Ewe hoggets	30
		Ewes	100
	1754		152
	4520		4520

Sheep stock units = 2450

(b) Cattle

Opening Stock			Closing Stock
Breeding cows	70		70
R 1yr steers	90		90
R 2yr steers	88		88
R 3yr steers	29		29
Bulls	2		2
	279		279
Purchases		**Sales**	
R 1yr steers	65	Weaner heifers	30
R 3yr heifers	16	R 3yr steers	59
		R 4yr steers	29
		Cull cows	15
	81		133
Natural Increases		**Deaths**	
Calves	60	R 2yr steers	2
		R 1yr steers	5
		Cows	1
	60		8
	420		420

Cattle stock units = 1094

Total stock units = 3544

Stocking rate = 10.13 su/effective hectare

Wool production = 16000 kg

In this case lambs are sold primarily fat or prime, and are carried through to the autumn before sale. Few lambs are sold before late April. A small number are carried through the winter. All lambs are shorn on the property. Farm 10 is less well subdivided than 16, with 24 paddocks in total. Average paddock size is 17.4 ha on the hills, with similar sized paddocks on the flats except for five smaller handling paddocks close to the woolshed.

6.3.2 Management Strategies

This farm has exhibited a "set stocking" type grazing management policy in the past. Lambing and calving begin in September with lamb weaning in December. Less intensive use is made of the flat area, with the exception of 10-12 ha per year which is cultivated and sown to winter feed crops for young cattle. Approximately 10 ha per year of flats are conserved for pasture hay.

1. Maximum Stock Density

Average paddock size is 17.4 ha, and with maximum mob size in winter being 2104 su, a stock density of 120.9 su/ha/day is achievable. In summer this is increased to 151 su/ha/day.

2. Sheep:Cattle Ratio

A high proportion of mature cattle are carried through the summer.autumn period. The cattle policy involves selling all weaner heifers and buying R 3yr replacements in-calf. All steers are carried for two winters, with a proportion going through three winters on the property.

In total over the summer-autumn, cattle are:

60 cows plus calves

90 R 2yr steers

88 R 3yr steers

30 R 4yr steers

In addition all lambs are carried through to late autumn.

Manipulation of feed demand in autumn is achieved by sale of varying numbers of R 3yr steers, and adjustments to date of sale of R 4yr steers.

6.4 Example Policy for Farm 4

Farm Area = 325 ha effective 100% moderately steep

6.4.1 Stock Reconciliation for Example Policy

(a) Sheep

Opening Stock		Closing Stock
Mixed age breeding ewes	1518	1518
2-tooth ewes	500	500
Ewe hoggets	850	850
Rams	35	35
Wether hoggets	50	50
	2953	2953

Purchases		Sales	
Rams	8	Lambs	1118
		Cull ewes	390
		Cull 2-tooths	320
		Wether hoggets	40
	8		1864

Natural Increases		Deaths	
Lambs 100%	2018	Rams	8
		Hoggets	30
		Ewes	110
		Wether hoggets	10
	2018		158
	4979		4979

Sheep standard stock units = 2676

(b) Cattle

Opening Stock			Closing Stock
Breeding cows	161		161
R 2yr heifers	41		41
R lyr heifers	43		43
Bulls	3		3
	248		248

Purchases		Sales	
	Nil	Cull cows	35
		Weaner heifers	27
		Weaner steers	70
	0		132

Natural Increases		Deaths	
Calves	140	Heifers	2
		Cows	6
	140		8
	388		388

Cattle stock units = 849

Total stock units = 3525

Stocking rate = 10.85/effective hectare

Wool production = 15000 kg.

All lambs are sold in store condition from February to April. All weaner steers, and surplus weaner heifers are sold in the autumn.

6.4.2 Management Strategies

Farm 4 is less well subdivided than the other two case study properties, with 15 paddocks averaging 21.6 ha. A predominantly set stocking grazing policy has been employed with minimal mobbing up of stock, especially sheep.

Lambing begins in September with lamb weaning in mid December. With no flat land on the property, approximately 1000 bales of pasture hay are purchased each year, and fed to cattle during winter.

1. Maximum Stock Density

With the current level of subdivision, the average size of main grazing paddocks is 19.5 ha. Winter maximum stock density (assuming stock were mobed up) is 137.3 su/ha/day, while summer is 162.9 su/ha/day.

2. Sheep:Cattle Ratio

Sheep stock units at 30 June	=	2676
Cattle stock units at 30 June	=	849
Sheep:Cattle ratio	=	3.15:1

3. Summer/Autumn Stock Numbers

Because surplus weaner heifers and all weaner steers are sold, in any summer/autumn period, the only cattle carried are cows with calves and replacement heifers. This is significantly fewer than farm 10, even after allowing for the high total proportion of cattle in winter on farm 4.

6.5 Comparison of Farming Policies and Management Strategies Affecting Pasture Utilisation on Case Farms

Large differences in apparent pasture utilisation estimated using the Cornforth/Sinclair model exist between case study farms (Table 6.1). Farms 10 and 16 achieve higher levels of PU than farm 4, and do so at significantly different stocking rates.

Differences in PU estimated using the Cornforth/Sinclair model may arise because different stock policies achieve different levels of PU while farming systems operate in a maintenance situation. Farm 16 can achieve high levels of stock density due to intensive grazing practices on hill country with a high level of subdivision. This occurs despite having the lowest ratio of cattle to sheep. Farm 10 achieves a similarly high level of PU at a significantly lower level of stocking rate and stock density, but with a higher proportion of cattle, particularly mature cattle. In addition, farm 10 has a high proportion of sheep carried through to early winter.

Farm 4 however, achieves a low level of PU at a similar SR and density to farm 10. The cattle policy however involves considerably fewer mature cattle, and the ratio of cattle to sheep is lower. However, differences

Table 6.1 Summary of Management Strategies and Stock Policies for Case Study Farms

Farm Number	SR su/ha	P input kg/ha/yr	Estimated PU %	(RY) %	Maximum Stock Density su/ha/day	Sheep:cattle Ratio	Summer/autumn stock carried
16	13.14	17.3	75	(79)	298	3.08:1	Ewes, lambs, cows, R1 & R2 steers and heifers
10	10.13	10.2	74	(66)	151	2.24:1	Ewes, lambs, R2, R3 R4 yr steers, cows
4	10.85	24.8	59	(95)	162.9	3.15:1	Ewes, lambs, cows, replacement heifers

in estimated PU may also arise if, while the farms are considered to be still at a maintenance situation, the estimation of pasture intake by stock is incorrect.

Where apparent PU is low, in the case of farm 4, large pasture surpluses would be expected at some times of the year. However if in this case pasture intake by animals was greater than that calculated by stocking rate x 550 kg DM, these surpluses may not eventuate. Considerable variation in pasture intake per hectare can arise due to variation in stock buying and selling policies between years on one property.

Further differences in pasture utilisation in fact may occur between farms if one or more of those farms is not in the maintenance state. As already discussed in Chapter 3, some portion of annual fertiliser applications may be adding to soil reserves of P. Farm 4 may fall into this category. This situation arises when application of the Cornforth/ Sinclair model results in apparent low levels of PU being achieved, but examination of the property does not suggest that large feed surpluses occur at any time. If in the case of farm 4, actual RY is less than 95%, then soil P reserves would be increasing and real PU would be more than 59%. Intensive monitoring of the situation with respect to annual pasture production and soil P status would be necessary to confidently specify that this was the case. Such monitoring was not possible in the context of this study.

CHAPTER 7

ANALYSIS OF ALTERNATIVE P USE AND MANAGEMENT STRATEGIES ON CASE STUDY FARMS

7.1 Introduction

It is necessary as part of the re-appraisal of case study farms in relation to the Cornforth/Sinclair model, to more accurately specify model parameters and performance variables for these farms.

For farms 10 and 16 this involved the treatment of the flat and hill areas separately.

To investigate alternative strategies it was considered desirable to specify a "feasible region" of operation for each class of land on each farm. These feasible regions are specified in terms of RY and PU. Combinations of PU and RY falling outside these feasible regions were considered neither practically obtainable, nor economically desirable as realistic targets for production. As a result of the observation in relation to Figure 5.1 that maximum PU on hill country appeared close to 75%, this was considered the upper limit to the feasible region for that class of land. The lower boundary chosen is 60% PU.

For farms with significant areas of flat, the PU upper limit is raised to 85% because it is believed higher levels of PU can be achieved on flat land due to the absence of stock camps, stock tracks, and the generally more uniform pattern of pasture production on this land. The lower boundary chosen for PU on flat land is 65%.

7.2 Farm 16 : Re-estimation of Parameters and Analysis of Alternatives

7.2.1 Model Parameters

On more detailed inspection it was found that farm 16 contained a considerable area of hill country "harder" than first estimated. The CC of this hill area was consequently adjusted to 16 su/ha. This corresponds to an estimated potential pasture dry matter yield of 10288 kg/ha/year. Animal loss factor for the hills was determined at 1.1. Soil loss factor remained unchanged at 0.25.

For the flat area on farm 16, the estimated potential pasture dry matter yield is 14000 kg/ha/year, corresponding to CC = 21.77. ALF for the flats is 0.7, SLF 0.25.

The feasible region described in section 7.1 is presented in Figure 7.1 for farm 16, with the regions for the two land classes described. The boundaries of the feasible regions are specified in each case by:

(a) Hill Country

$$RY = 65\% : \quad SR = 1.4186 \text{ P loss} + 5.31762 \qquad \ldots. (7.1)$$

$$RY = 90\% : \quad SR = 0.8955 \text{ P loss} + 7.36305 \qquad \ldots. (7.2)$$

$$PU = 60\% : \quad SR = 11.23 \ (1 - 10^{-\text{P loss } (19.506)^{-1}}) \qquad \ldots. (7.3)$$

$$PU = 75\% : \quad SR = 14.035 \ (1 - 10^{-\text{P loss } (22.3266)^{-1}}) \qquad \ldots. (7.4)$$

(b) Flat Country

$$RY = 65\% : \quad SR = 2.06168 \text{ P loss} - 11.37008 \qquad \ldots. (7.5)$$

$$RY = 90\% : \quad SR = 1.30151 \text{ P loss} - 15.74297 \qquad \ldots. (7.6)$$

$$PU = 65\% : \quad SR = 16.55 \ (1 - 10^{-\text{P loss } (23.54)^{-1}}) \qquad \ldots. (7.7)$$

$$PU = 85\% : \quad SR = 21.64 \ (1 - 10^{-\text{P loss } (27.06)^{-1}}) \qquad \ldots. (7.8)$$

7.2.2 Current Position of Farm 16

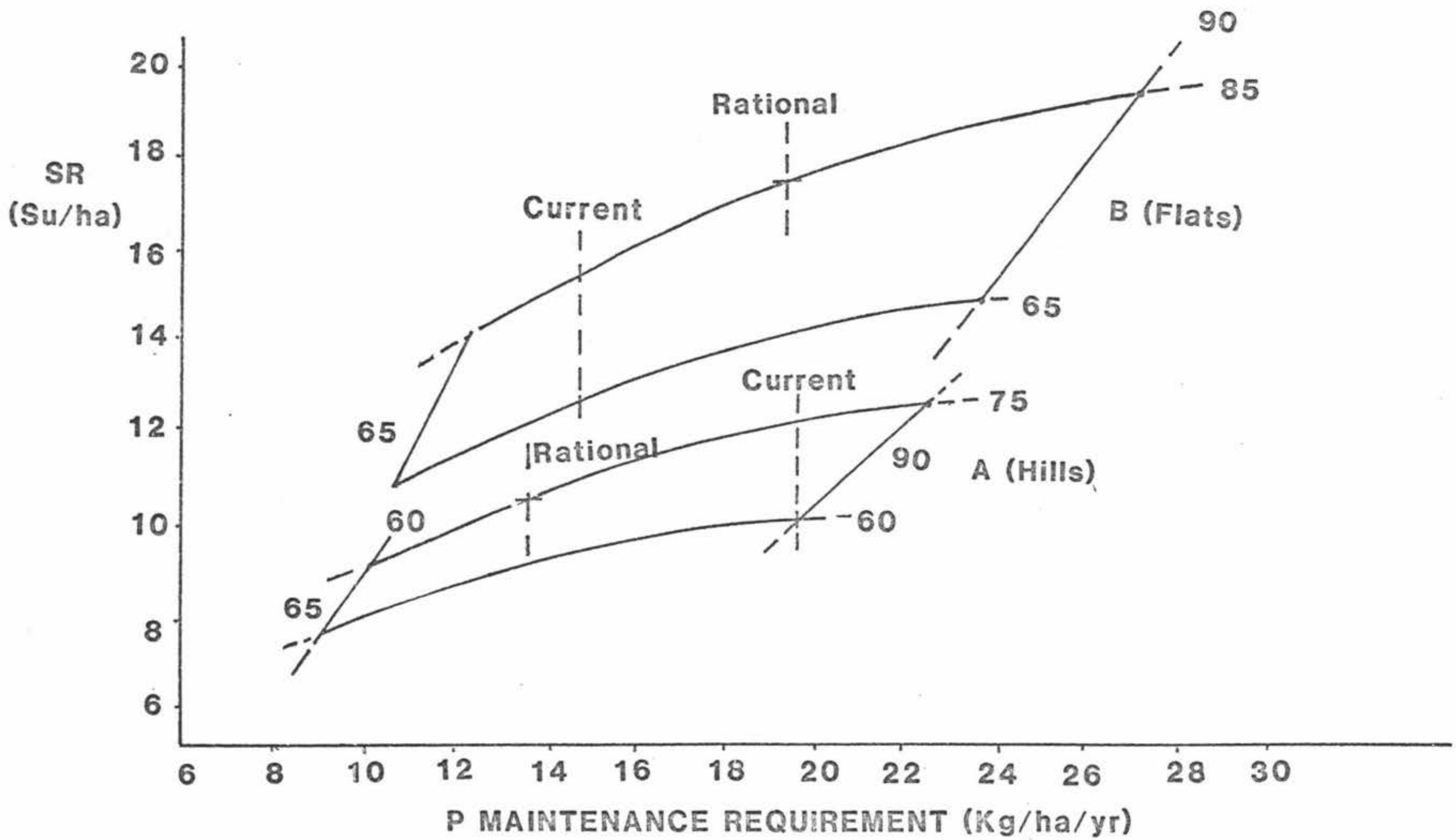
Farm records show that an average over the past five years, on the flat area (80 ha) 14.75 kg P/ha/year has been applied, and on the hill area (122 ha) an average of 19.48 kg/ha/year.

At first glance this breakdown of hill and flat fertiliser application seems irrational. If it is assumed the flat country is more productive one would expect a greater application of P maintenance fertiliser to the flat. Current use may be explained by an attempt to increase soil stocks of fertiliser on the hill, that is a portion of the hill country application is investment or development fertiliser. On properties such as 16, it is difficult to determine if production is increasing from one part of it when only total farm records are available.

From Figure 7.1, the position of applications of 19.48 kg/ha to hills, and 14.75 to flats, with respect to the "feasible regions" for each class of land, can be seen. Without defining Pasture Utilisation on each land class, the Relative Pasture Yields within the feasible regions for the respective fertiliser applications are:

Hill	RY range	=	86.63	to	90%
	for PU	=	75	to	60%
Flat	RY range	=	71.62	to	76.13%
	for PU	=	85	to	65%

Figure 7.1 FEASIBLE REGIONS FOR FARM 16



The hill country then is apparently operating at the high relative yield end of the feasible region, while the flat at the low end. Before more detailed analysis of the current position can be carried out, either more information about actual Relative Pasture Yield or actual pasture utilisation on the hills or the flats would need to be obtained, or some assumption made about one of these values. Because whole farm production data is all that is kept, it is necessary to assume one of these values.

If it is assumed that pasture utilisation on the hills is 75%, then using the Cornforth/Sinclair model, the Relative Pasture Yield, pasture utilisation and "stocking rate" for both the flat and the hill can be calculated.

PU Hill = 75% RY Hill = 86.63%

and SR hill for P loss of 19.48 = 12.16 su/ha. Using stock numbers from the Example Policy for farm 16 (Chapter 6 section 2.1) total stock units are 2655. Clearly, average stock units carried per hectare on the hills multiplied by area of hills (122 ha) plus average stock units per hectare on the flats (80 ha), equals the total number of stock units carried.

i.e. $80 \times SRF + 122 \times SRH = \text{Total stock units}$

where SRF = stocking rate of flat su/ha

SRH = stocking rate of hill su/ha

Thus if SRH = 12.16 as above	RYH	=	86.63%
	PU	=	75%
SRF = 14.64	RYF	=	73.71%
	PU	=	78%

Here, the relative pasture yield on the flats is lower than the hills. A more rational use of flats and hills on this property would be to operate such that the marginal value product of fertiliser would be the same on both classes of land. It would however be profitable also to increase PU if this were possible. From the assumptions and calculations above, this is so on the flat land. This is likely to be achieved at very little cost, simply by increasing the stocking rate on the flat, as the current position shows a lower stocking rate relative to potential on the flat, when compared to hills.

7.2.3 Alternative P Use and SR Policies

(i) Rational Use of Hills and Flats

Rational use of fertiliser on the hills and flats on this property would occur where the marginal value product of fertiliser on the hills (the slope of the 75% PU curve for hills) is equal to the marginal value product of fertiliser on the flats (the slope of the 85% PU curve for flats). The assumption has been made that PU on the flats will be increased to 85%. However the point of equal marginal value product is subject to the constraint that total stock units carried as a result, is equal to the total stock units carried on the property currently.

Two simultaneous equations result, requiring solution:

1. $80\ SRF + 122\ SRH = 2655$ .... (7.10)

2. $\frac{d\ SRH}{d\ PLH} - \frac{d\ SRF}{d\ PLF} = 0$ .... (7.11)

Appendix II presents the calculation of the solution to these simultaneous equations.

The solution is:

SRH = 10.43	Ploss Hill = 13.19	RY% = 74.31
SRF = 17.28	Ploss Flat = 18.51	RY% = 79.84

RY% has as expected, increased on the flat and decreased on the hill. Similarly fertiliser P maintenance requirement has changed with application to the flat significantly increased. The changed positions of the hills and flats is shown in Figure 7.1.

In comparison to the current situation then, under the assumptions outlined, stocking rate on the hills has been reduced to better utilise the potential of the flat land. Where before the hills were operating at an apparently high level of RY and an inherently less safe position, the balance of production has been shifted more towards the flats.

However, the underlying assumption that PU Hills was 75% to begin with has a major effect on this calculation.

(ii) Benefits Obtained from Rational Fertiliser Use on Hills and Flats

The estimated benefits of this change in steady state balance can be calculated and compared to the present position. Using the example stock policy outlined in Chapter 6 for farm 16, and based on costs incurred and prices received on farm 16 in the 1979/80 year, the Gross Margin for this property can be calculated.

			$	$
Farm Income:				
Lamb sales	771	@ 12.50	9637.50	
Sheep sales	210 2ths	@ 19.00	3990.00	
	360 ewes	@ 9.50	3420.00	
				17 047.50
Wool sales	10 750 kg	@ 2.20		23 650.00
Cattle sales				
	16 cull cows	@ 250	4000.00	
	11 R2yr heifers	@ 210	2310.00	
	34 R2yr steers	@ 240	8160.00	
				14 470.00
				55 167.50
Less sheep purchases				
	16 Rams @ 100			1 600.00
Farming Income				$53 567.50

Farming Expenses	$	$
Farm working expenses	10 510.84	
Fertiliser	6 223.98	
Vehicle expenses	1 636.20	
Repairs and maintenance	5 516.62	
Gross Margin Expenses		$23 887.64
GROSS MARGIN		$29 679.86

GM/ha = $146.93 GM/su = $11.18

Fertiliser expenses average $30.81/ha resulting in a GM per hectare, excluding fertiliser costs, of $177.74 or $13.53/su

(iii) Comparison with Returns from Rational Use of Fertiliser at Current Total Stock Units

Although stocking rate on the flats is increased as a result of this change, it is assumed costs associated with production remain constant per stock unit. Stocking rate is expressed in standardised stock units, which have constant performance levels. Consequently it is believed that production expenses such as feed and animal health remain constant per stock unit as stocking rates rise.

For hills, under rational use

SR = 10.43 P maintenance input = 13.19 kg

GM less fertiliser = \$141.12 / ha
Fertiliser expenses = \$23.08
GM/ha \$118.04

For flats

SR = 13.53 P input = 18.81 kg

GM less fertiliser = \$233.80 / ha
Fertiliser expenses = \$32.90
GM/ha \$200.88

Total GM for the whole farm in this case is then \$29 679.86, an increase over current plan of \$791.85 resulting from the saving of approximately 450 kg P/year.

Such a rationalisation of use of fertiliser on the two classes of land on this farm is the result of identification of their different productive capabilities. Intense monitoring of the number of days mobs of stock spend grazing each class of land, together with estimates of relative growth rates, would be necessary before these differences would be confirmed. Such monitoring is suggested by the author as an important feature of follow-up work after implementation of the Cornforth/Sinclair model on any farm property.

(iv) <u>The Alternative of Increased Stocking Rate After Pasture Utilisation is Maximised</u>

Farm total gross margin will continue to increase with increased maintenance P application on both the hills and the flat area of farm 16 until in each case the marginal value product of fertiliser application equals the marginal cost of the application.
The marginal product of fertiliser input is calculated from the first derivative of the response function.

For farm 16 hill country, the relationship between stocking rate and P loss is given by equation (7.4):

$$SR = 14.035\ (1 - 10^{-Ploss\ (22.3266)^{-1}})$$

$$\frac{dSR}{dPL} = 1.45\ .\ 10^{-PLHill(22.3266)^{-1}}$$

Marginal value product of fertiliser in this case

$$= GM/su \times \text{Marginal Product}$$

$$= 13.53\ (1.45)\ .\ 10^{-PLHill(22.3266)^{-1}}$$

Equating the marginal value product to the unit price of fertiliser (\$1.75) and solving for PLoss Hill:

PLoss Hill (optimum) = 23.42 kg/ha/year

Substituting in equation 7.4:

SR Hill (optimum) = 12.79 su/ha

Similarly for the flat country where Equation (7.8) describes the response curve, otpimum SR and PLoss for the flat can be calculated for PU = 85:

P loss Flat (optimum) = 31.21 kg/ha/yr

Substituting in Equation (7.8) we obtain:

SR Flat (optimum) = 20.12 su/ha

Total Gross Margin in the optimum case then is, for the hills, \$16 111.93 and flats \$17 408.20, a whole farm total of \$33 520.13, an advantage over current (1979/80) level of \$3840.20/year. Total stock units carried in this case are 3170, an increase of 515.

This optimum point however, falls outside the feasible region described earlier for both hills and flats, ie

RY Hills = 91.13% RY Flats = 92.96%

A feasible target to operate then, is at the corner points of each of the two feasible regions, ie

For hills	RY = 90	PU = 75
Flats	RY = 90	PU = 86

Farm total gross margin in this case is \$33,378.76, an increase over current total gross margin of \$3678.90

7.3 Farm 10 : Re-estimation of Parameters and Analysis of Alternatives

7.3.1 Model Parameters

Farm 10 has two distinct classes of land which are however less clearly defined in terms of subdivision and use than on farm 16. Forty-eight hectares of the total 350 are flat, drained and in improved pasture, with winter forage crop grown each year on 10–12 hectares.

This flat land has an estimated carrying capacity of 21 su/ha (13 503 kg DM/ha potential pasture DM yield). Because of its slope and principle stock type, ALF is 0.7. SLF is 0.25.

The hill area on farm 10 is less steep than 16, consequently ALF = 0.9, SLF 0.25, and CC is estimated as 17 su/ha (10 931 kg DM/ha) The feasible regions for production on the two classes of land as described in section 7.1 are shown for farm 10 in Figure 7.2. The boundaries of the feasible regions are specified by:

(a) Hill Country

$RY = 65\% \quad : \quad SR = 1.70976 \text{ P loss} - 7.5052$ .... (7.12)

$RY = 90\% \quad : \quad SR = 1.07936 \text{ P loss} - 9.5617$ .... (7.13)

$PU = 60\% \quad : \quad SR = 11.93\ (1 - 10^{-\text{Ploss}\ (18.8061)^{-1}})$ .... (7.14)

$PU = 75\% \quad : \quad SR = 14.9123\ (1 - 10^{-\text{Ploss}\ (21.29301)^{-1}})$ .... (7.15)

(b) Flat Country

$RY = 65\% \quad : \quad SR = 2.0825 \text{ P loss} - 10.96796$ .... (7.16)

$RY = 90\% \quad : \quad SR = 1.31472 \text{ P loss} - 15.1864$ .... (7.17)

$$PU = 65\% \quad : \quad SR = 15.9649\,(1 - 10^{-\,Ploss\,(22.48)^{-1}}) \qquad \ldots.\ (7.18)$$

$$PU = 85\% \quad : \quad SR = 20.8772\,(1 - 10^{-\,Ploss\,(25.8428)^{-1}}) \qquad \ldots.\ (7.19)$$

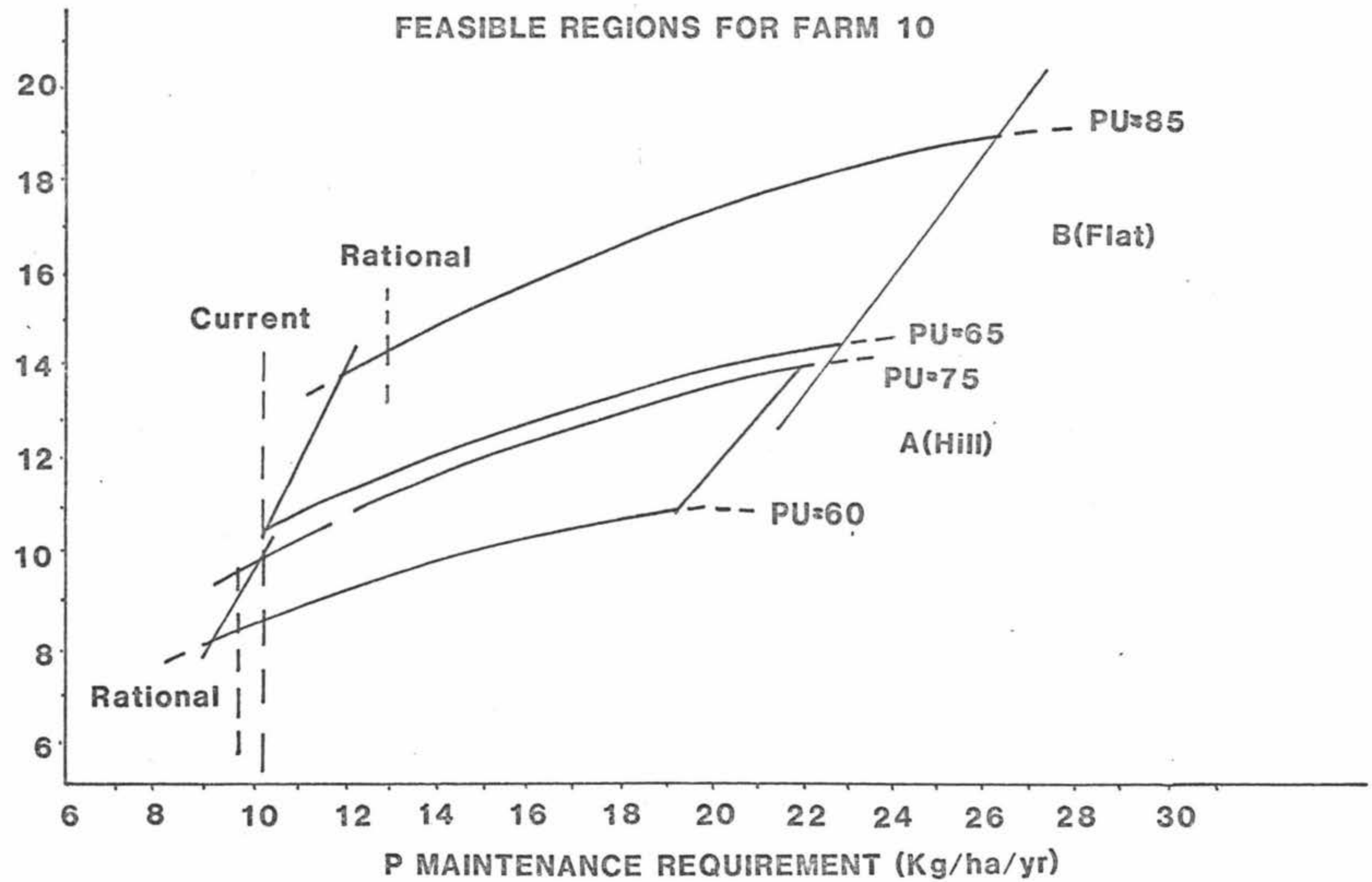
7.3.2 Current Position of Farm 10

The flat area plays a significantly less important role in the production and management of farm 10 compared to farm 16. Only 13.7% of total farm area is flat, while nearly 40% was flat in the case of farm 16. In the past all areas have been treated similarly with respect to fertiliser application, 10.2 kg P/ha/year being applied as a maintenance dressing (Appendix I).

Examination of Figure 7.2 reveals that an application of 10.2 kg P/ha per year to the hill country, corresponds to a low RY, irrespective of PU considered. If PU = 75%, RY = 65, that is farm 10 in this case would be operating at the corner point of the region and SR Hills = 10. Using total stock numbers for example policy (Chapter 6.3.1) total su = 3544. If 48 SRF + 302 SRH = 3544 and SRH = 10 if PU = 75, RY = 65, PL = 10.2, then SRF = 10.92 su/ha, and this combination falls on the corner point of the feasible region for the flats. If the SR selected for the hills is lower than 10.00, ie PU 75%, then for constant total stock numbers to be maintained, the corresponding SR for flats required will tend to move the operating point for the flats away from the feasible region.

For P loss flats = 10.2 kg/ha/year, PU = 85 then the maximum SR Flats is approximately 13 su/ha. The corresponding SR Hills = 9.6 su/ha.

Figure 7.2



FEASIBLE REGIONS FOR FARM 10
20
18
16
14
12
10
8
6
Rational
Current
Rational
PU=85
B(Flat)
PU=65
PU=75
A(Hill)
PU=60
6
8
10
12
14
16
18
20
22
24
26
28
30
P MAINTENANCE REQUIREMENT (Kg/ha/yr)

It is apparent therefore, that on farm 10 under the current management, the hill area is supporting between 9.6 and 10 su/ha and high utilisation is being achieved. However low levels of RY result from low P inputs.

The flats are supporting between 10.92 and 13 su/ha, the latter more likely, again with high PU but low RY. Both classes of land are being under-utilised, with increases in animal production per hectare most likely to result from a move to a higher stocking rate maintenance situation. Higher P maintenance applications will be required as a result.

7.3.3 Alternative Phosphate Use and SR Policies for Farm 10

(i) Rationalisation of hill and flat SR and P use at current total stock numbers

If it is assumed that 75 and 85% PU can be achieved on hill and flat respectively (close to current position) then rational fertiliser use and the balance of SR between hills and flats will occur where the marginal value products of fertiliser application are equal in each case, subject to the condition that total su are 3544. The solution to the simultaneous equations resulting is similar to that in section 7.2.3 for farm 16.

For farm 10

SRF = 14.26   P loss = 12.89 kg/ha

SRH = 9.68   P loss = 9.68 kg/ha

P use on the flat is increased by 2.69 kg/ha and reduced on hills by 0.52 kg/ha.

The advantage of this rational use is a total saving of 27.92 kg P, amounting to $48.86 per year at 1979/80 costs. The saving from this rationalisation is insignificant mainly because changes are being made where RY is low, that is savings in fertiliser by adjusting SR between flats and hills are small.

(ii) <u>Increased Stocking Rate, with PU Maximised</u>

Optimum SR and P use for each class of land on farm 10 is calculated in a similar manner to that for farm 16 (section 7.2.3)

For hill country 75% PU line Equation (7.15)

$$\frac{dSR}{dPL} = 1.6126 \cdot 10^{-Ploss(21.29301)^{-1}}$$

For flat country 85% PU line Equation (7.19)

$$\frac{dSR}{dPL} = 1.8601 \cdot 10^{-Ploss\ (25.8428)^{-1}}$$

Solution :

SR Hill optimum = 14.01 su/ha P loss = 25.97

SR Flat optimum = 19.79 su/ha P loss = 33.15

Total stock units = 5181

(iii) <u>Calculation of Current Total Gross Margin for Farm 10</u>

Using 1979/80 costs and prices on farm 10 with Example Policy numbers:

Farm Income:				$	$
Sheep	lamb sales 920 @ $16.00			14720	
	420 cull ewes @ $10.50			4410	
	200 cull 2-ths @ $22.00			4400	
	80 wether hoggets @ $15.00			1200	
					24 730
Wool sales	16000 kg @ $2.60				41 600
Cattle:	30 weaner heifers	@	$130	3900	
	59 R 3yr steers	@	$390	23010	
	29 R 4yr steers	@	$350	10150	
	15 cull cows	@	$230	3450	
					40 510
					$106 840
Less Ram purchases:	18	@	$100	1800	
Cattle purchases					
	65 weaner steers	@	$190	12350	
	16 R 3yr heifers	@	$300	4800	
					18 950
		FARMING INCOME			$87 890

Farm Expenses:

Farm working	$13 002.50	
Fertiliser	$6 247.50	
Repairs and maintenance	$5 600.00	
Vehicle expenses	5 499.50	
Gross Margin Expenses		$30 299.50
Farm Gross Margin		$57 590.50

GM/ha = $164.54 GM/su = $16.39

Fertiliser expenses are $17.85/ha resulting in a GM/ha, excluding fertiliser, of $183.39

or $18.00/su

Optimum SR calculated above (section 7.3.3 (ii)) results in total farm gross margin of $76 748.25, an increase of $19 157.75 over the current position. However, at optimum points for both hills and flats, RY hills = 93.95%

RY flats = 94.79%

both falling outside the feasible regions. Corner point operating (RY = 90 in both cases and PU hills = 75, PU flats = 85) result in a farm total gross margin of $75 850.80, an increase of $18 260.30 over the current position, and represents a realistic target.

7.4 Farm 4 : Re-estimation of Parameters and Analysis of Alternatives

7.4.1 Model Parameters

Farm 4 consists entirely of moderately steep hill country. Thus ALF = 0.9. The potential carrying capacity of the property is estimated at 17 su/ha, equivalent in the Cornforth/Sinclair Model to a potential pasture dry matter production of 10931 kg/ha/year. The SLF is set at 0.25 as in the other cases. The feasible region for production bounded by RY = 65 and 90% and PU = 60 and 75% is presented in Figure 7.3.

The boundaries of the feasible region are specified by:

RY = 65% : SR = 1.70976 P loss -7.5052 .... (7.20)

RY = 90% : SR = 1.07936 P loss -9.2379 .... (7.21)

PU = 60% : $SR = 11.93\ (1 - 10^{-\text{Ploss}\ (18.8061)^{-1}})$ .... (7.22)

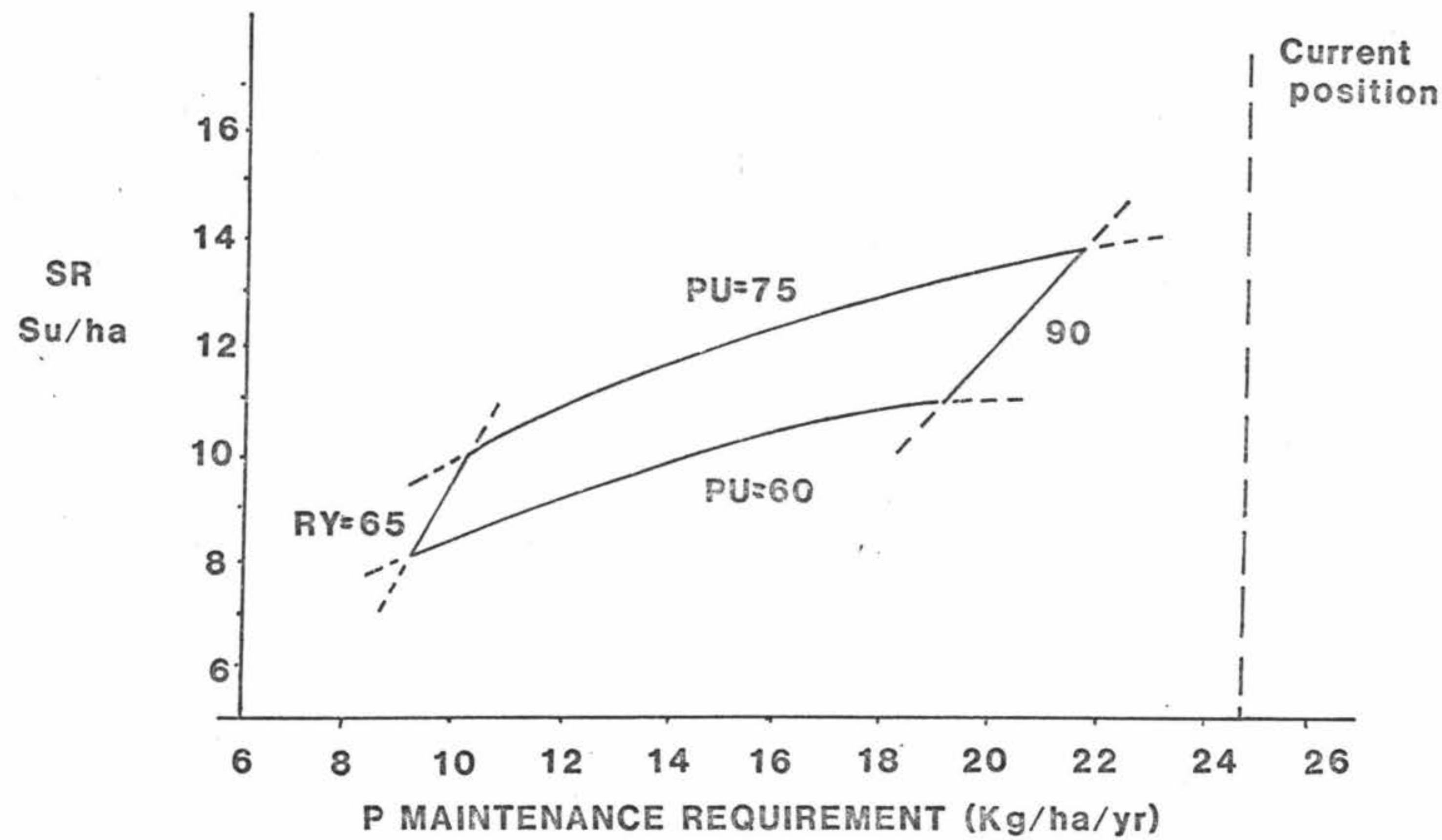
PU = 75% : $SR = 14.91\ (1 - 10^{-\text{Ploss}\ (21.293)^{-1}})$ .... (7.23)

7.4.2 Current Position of Farm 4

Average phosphate maintenance application on Farm 4 has been 24.8 kg/ha/year (Appendix I). From Example Stock Policy (Chapter 6.4.1) for Farm 4, this has been used to maintain approximately 10.85 su/ha. Examination of Figure 7.3 reveals that to maintain 10.85 su/ha in the situation of Farm 4 and remaining within the specified feasible region, requires between 12 and 19 kg P/ha/year.

Figure 7.3

FEASIBLE REGION FOR FARM 4



Closer investigation of Farm 4 revealed that a high level of pasture production was not being achieved, contrary to that which is expected by application of the Cornforth/Sinclair model. As a result, it is reasonable to suspect that a considerable portion of the 24.8 kg P/ha/year application was not being lost from the system, but contributing to soil reserves of phosphate.

From Figure 7.3, if RY was 90%, then 5.8 kg P/ha/year would be considered as investment fertiliser contributing to soil reserves. If the property was operating at this point, PU would be approximately 60%. This is the relatively "safe" portion of the feasible region, where pasture production is high, and utilisation is low. If seasonal variation in pasture production results in reduction in feed growth, then there is sufficient scope in the system for PU to increase and the same level of feed intake to be achieved.

Discussion with the farmer resulted in an understanding that a level of 20 kg/ha/year as a maintenance dressing was anticipated for the future. This decision was based in part on the fact that soil phosphate reserves as measured by the Olsen test were at a moderately high level, on average 18.

7.4.3 Alternative Phosphate Use and Stocking Rate Policies for Farm 4

(i) Increasing Pasture Utilisation at Current Stocking Rate

Movement to increase PU at constant SR with reductions in P maintenance requirement, represent savings in fertiliser input for a constant level of farm output. Such a movement is from a "safe" position to those that are relatively more risky. As PU increases, RY is allowed to fall. At the extreme opposite "corner" of the feasible region for Farm 4, at a stocking rate of 10.85, with PU at 75%, P maintenance requirement is approximately 12 kg/ha/year. RY in this situation is approximately 72.76%. Variation in pasture production due to climatic variation between years is much more likely to cause variation in animal performance in this situation, especially in poor growth years. There is little or no scope for increased utilisation of the pasture that is grown.

While this is the case on all properties where increases in efficiency via utilisation are attempted, it is especially risky on farms with little or no flat areas, where feed conservation and supplementation of animal intake in pinch periods cannot be easily implemented.

Increased pasture utilisation, at a constant stocking rate may not be achievable simply by reducing the amount of pasture produced. As discussed in Chapter 6, farms where high apparent levels of utilisation are being achieved have either high levels subdivision allowing the concentration of large stock densities if required to control growth, or higher proportions of mature cattle in the stock policy. Neither is the case in Farm 4 where subdivision is minimal (15 main paddocks) and a high sheep:cattle ratio with a low proportion of mature cattle, other than breeding cows.

Adjustments to sheep and cattle policies will be discussed in a later section. The alternative, under current policies and stocking rate, resulting in expected increased PU is to improve farm subdivision to allow greater control of distribution of feed intake by stock.

Assuming current maintenance P input to be 20 kg/ha/year, and target PU = 75%, a saving of 8 kg P/ha/year is made if the target is reached. At 1979/80 costs, this represents $14/ha or $4550/year for the whole farm. That is, Total Gross Margin would remain constant if a maintenance situation were achieved where PU = 75% with P input being 12 kg/ha and SR constant, if $14/ha/year were spent on fencing or other means to achieve that PU. Alternatively $14/ha capitalised over 20 years at a 12% discount rate is equivalent to $252/ha. Traditional fencing costs are approximately $50 per 20 m. Thus, using $252/ha, approximately 100 m of fencing per farm hectare could be erected, expected to last 20 years, with the saving in fertiliser resulting. Further investigation is required to determine if this increased subdivision would be more than sufficient to facilitate an increase in PU from 60% to 75%. If so the development of a more intensive system through increased subdivision and controlled grazing would be profitable, even at the relatively low stocking rate currently being achieved.

Increased PU is an obvious target, and may be most easily achieved by increasing SR for at least as long as the increases in PU required to maintain high SR's are relatively low cost.

In order to determine the return from additional stock units, the current Total Gross Margin for Farm 4 is calculated using 1979/80 costs and prices, and the example stock numbers specified in Chapter 6.

Farming Income		$	$	
Lamb sales	1118 lambs	@ $11.50	12 857	
Sheep	390 cull ewes	@ $81.00	3 120	
	320 cull 2th ewes	@ $16.00	5 120	
	40 wether hoggets	@ $15.00	600	
				21 697
Wool sales	15000 kg @ $2.40			36 000
Cattle sales	27 weaner heifers	@ $150	4050	
	70 weaner steers	@ $190	1330	
	35 Cull cows	@ $200	7000	
				24 350
Less Sheep purchases				
	8 rams @ $100			800
	FARMING INCOME			$81 277

Farming Expenses	$	$
Farm working	14 625.00	
Fertiliser	11 375.00	
Repairs and maintenance	10 136.75	
Vehicle expenses	1 982.50	
Gross Margin Expenses		38 119.25
FARM TOTAL GROSS MARGIN		$43 157.75

GM/ha = $132.79 GM/su = $12.24

Fertiliser expenses are $35/ha, resulting in a GM/ha excluding fertiliser of $167.79 or $15.46/su. Increasing SR at constant fertiliser input increases total gross margin by $12.24/su, assuming costs of production are constant for constant stock performance. Examination of Figure 7.3 reveals that at P use = 20 kg, an increase of approximately 2.5 su/ha from 11 to 13.5 su/ha increases PU from 60% to 75%. Provided the cost of increasing PU by this amount is less than $30.75/ha/year, then the increase in stocking rate is profitable, at constant P maintenance input at 20 kg/ha.

(ii) Increasing Stocking Rate with Pasture Utilisation Maximised

Calculation of optimum stocking rate and P maintenance use is similar to that for the other case farms studied. From the 75% PU function (Equation (7.23))

$$\frac{dSR}{dPL} = 1.613 \cdot 10^{-P\ \mathrm{loss}} (21.2930)^{-1}$$

and marginal value product of fertiliser for farm 10

$$= 15.46\ (1.613)10^{-\text{Ploss}}\ (21.2930)^{-1}$$

Optimum SR for farm 4 = 13.87 su/ha and the corresponding P maintenance requirement is 24.56 kg/ha/year.

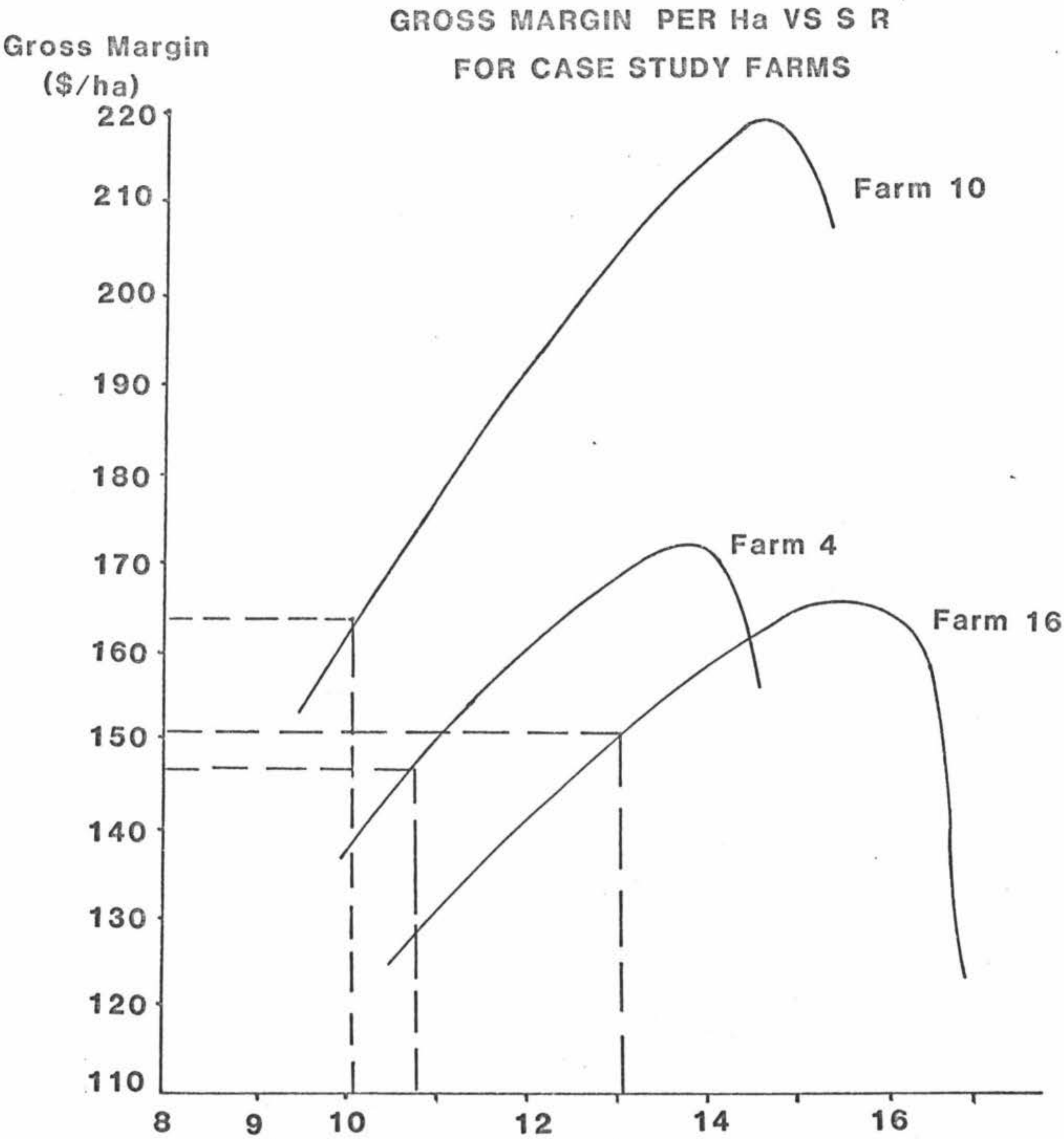
Gross margin at this optimum point is $56,535.71, an increase of $13,375.96 over the current position. However, the optimum point falls outside the feasible region (RY opt = 93%). As a result a likely target level of production is where PU = 75, RY = 90, SR = 13.42 su/ha, and total GM is $55,323.69, an increase of $12,163.94 over the current position.

7.5 Changes to Case Farm Policies to Increase Technical and Economic Efficiency

In earlier sections of this chapter, alternative strategies to increase returns to fertiliser under existing sheep and cattle policies on the case farms are discussed. These strategies involved maximisation of PU within theoretical boundaries, and increasing stocking rate in response to increased pasture production resulting from higher rates of fertiliser.

Figure 7.4 shows the effect of increased stocking rate on Gross Margin/ha for each of the three properties. In each case maximum pasture utilisation is assumed, as is the rational use of hills and flats on farms 10 and 16.

Figure 7.4


GROSS MARGIN PER Ha VS S R
FOR CASE STUDY FARMS
Gross Margin
($/ha)
220
210
200
190
180
170
160
150
140
130
120
110
8
9
10
12
14
16
SR (Su/ha)
Farm 10
Farm 4
Farm 16

Increases in Gross Margin with increased stocking rate has been calculated with farming expenses remaining constant per stock unit. These expenses include:

Animal Health
Electricity
Feed and grazing
Freight
Seeds
Shearing
Repairs and Maintenance
Vehicle expenses

and wages on farm 10 where some labour is already employed. Where farm labour is not employed, increases in stocking rate will result in considerably more work, to the point where extra labour is required. In the analysis earlier in this chapter, such expense was not included.

In the case of farm 16, 515 extra stock units are required to reach optimum point. This may be possible without extra labour. For farm 4 however, 982 extra stock units would maximise gross margin/ha. The advantage of optimum over current position in this case is $13,376 per year. A considerable amount of this benefit is likely to be used up in employing the extra labour required.

The alternative to increased stocking rate, under existing policies, is to change stock policies. Improvements to farm Gross Margin per unit of fertiliser will result from high levels of pasture utilisation by animals producing relatively high value products per unit of feed consumed.

Table 7.1 Income and Expenditure 1979/80 for Case Farms

Farm Number	16	10	4
Sheep su/ha	9.95	7.00	8.23
Cattle su/ha	3.22	3.13	2.16
Sheep and Wool Income/ sheep su	19.46	26.33	21.26
Cattle Income/cattle su	22.22	21.35	28.68
Sheep and Wool Income/ha	193.63	184.31	174.97
Cattle Income/ha	71.55	66.82	74.85
Expenses/ha			
Repairs and maintenance	27.31	16.00	31.19
Farm Working (excluding fertiliser)	52.00	37.15	45.00
Vehicle Expenses	8.09	15.71	6.10
	$87.40	$68.87	$82.29

Table 7.1 shows the breakdown of incomes and Gross Margin expenditure not including fertiliser, for the three case study farms at the current stocking rates operating. They correspond to the example policies of Chapter 6, and current fertiliser use. 1979/80 costs and returns operate.

From Table 7.1 it can be seen that in the case of farm 16 and 4, cattle income per stock unit is higher than sheep and wool income per sheep stock unit. Farm 10 however, with a higher proportion of older cattle, and a relatively more profitable sheep policy, represents the reverse situation. The widespread belief in recent years that sheep are more profitable than cattle seems not to be supported by two of these three farms at least. The major factor influencing this situation however, is the relative feed requirement of sheep and different classes of cattle, that is the conversion factors (Table 2.3).

Traditionally, breeding cows have been considered as equivalent to six stock units. In the Cornforth/Sinclair model, and as a result in this analysis, they are treated as 4.1 stock units. Where a cattle policy involves a high proportion of breeding cows, i.e. farm 4, then cattle income per stock unit will be considerably higher in this case than when the conversion factor is 6.0. With all conversion factors for cattle lower than those applied more traditionally, cattle policies per stock unit are likely to compete more favourably with sheep policies.

Farming expenditure figures, extracted from farm accounts prepared for taxation purposes are often difficult to use in determining relative profitability of different sheep and cattle policies. Variation in total

Gross Margin expenses (excluding fertiliser) for the three case farms however is only $18/ha. The major variation between policies is expected to arise in animal health, feed and grazing and shearing expenses. Repairs and maintenance expenses could be considered important where higher levels of subdivision are operating.

Figures extracted from farm accounts however will include levels of expenditure undertaken on repairs and maintenance for example, which do not exactly relate to the expenditure level required to maintain the operation. The influence of the owner or operators circumstance with respect to taxation liability could give rise to significant variation. However, if the levels of income and expenditure for the three farms in the 1979/80 year are assumed to represent the levels of income gained and costs incurred in the policies involved, observations can be made about the benefits of changes in general policies between farms.

The most profitable sheep policy appears to involve the retaining of the majority of lambs until they can be sold fat. Such an enterprise could be more dependant on reliable summer and autumn pasture growth, or operate at a sufficiently low stocking rate (farm 10) to be certain that a high proportion of lambs will be able to be slaughtered at that time.

Under the conversion ratios operating for cattle in the Cornforth/Sinclair model, cattle policies involving a high proportion of breeding cows with all surplus weaners (excess to replacement requirements) being sold, appear most profitable. Feed costs however could be expected to be high in years of poor autumn or early spring growth. A shift to a policy similar to this (farm 4) from one where larger numbers of older non-breeding stock are carried (farm 10) is likely however, to reduce flexibility in the summer and autumn. Increased feed demand in late winter and spring is also likely.

Farm 10, then shows under 1979/80 levels of costs and prices, an advantage in Gross Margin per hectare, at current stocking rates. While apparent levels of pasture utilisation are high on farm 10, the policies operating allow a high degree of flexibility in autumn feed requirement, while having lower proportions of breeding cattle in the periods of the year when feed supply is likely to be most variable. It may not be possible to sustain such policies with high profitability at higher stocking rates.

CHAPTER 8

SUMMARY AND CONCLUSIONS

The main objective of this study was to raise issues for discussion between Farm Advisory Officers and Research Scientists relating to the application of the Cornforth/Sinclair model to assist with farmer decisions about maintenance phosphate fertiliser use.

Recommendations made by Farm Advisory Officers in the past, based on information other than that integrated by the Cornforth/Sinclair model, were studied by Parker (1982) as part of an assessment of Adviser reaction to introduction of the Cornforth/Sinclair model. Parker found little uniformity amongst advisers on their approach to fertiliser recommendations, and furthermore, there were few areas where advisers felt confident in their recommendations on phosphate requirement. Parker concluded by supporting the implementation of the Cornforth/Sinclair model provided further research and evaluation of the model was undertaken to improve the basis for estimation of several of the model parameters and performance variables.

Uniformity amongst advisers in making phosphate fertiliser requirement recommendations is only likely to result from improved understanding of the model components, and accuracy of estimation of the parameters and performance variables. According to Parker (1982), many advisers consider the performance variable PU the most difficult to assess accurately when using the model to make fertiliser recommendations. In many instances insufficient farm records exist to allow the use of the Cornforth/Sinclair model to predict apparent PU achieved on the property in the past, as described in Chapter 3, section 4.

Many requests for fertiliser advice received by Farm Advisory Officers may involve, for various reasons, a single farm visit. In such circumstances it is obviously very difficult to make accurate assessments of RY or PU. Although farm records may facilitate prediction of RY or PU, often these predicted levels will not be able to be compared with observed feed shortages or surpluses.

Simplified Versions

Cornforth and Sinclair (1981) have provided simplified versions of their model where estimates of CC, PU and recent fertiliser history, are not readily available. For example, where the farmer is aiming for high levels of pasture production, under fairly intensive grazing management, the simplified model is:

$$\text{P Loss} = (1.07\ \text{ALF} + 2.58\ \text{SLF}) \times \text{SR} \qquad \text{.... (8.1)}$$

where SR is the target stocking rate. The simplified model is derived from the full model on the assumption that RY = 90, PU = 80, and CC = 20. Under these assumptions we can calculate SR corresponding to the full model:

$$\text{SR} = \frac{90 \times 80 \times 20}{8550} = 16.84 \text{ su/ha}$$

The basic assumptions of the Cornforth/Sinclair model indicate that whenever SR is greater than 80-85 percent of CC, the farming system is operating at high values for PU and RY. At any RY and SR, P loss increases and PU decreases, as CC increases. At any CC and SR, P loss increases and PU decreases, as RY increases.

Examining the simplified model of P loss (Equation 8.1) relative to the full model, we find that where SR is conservative relative to CC, then either:

(i) estimated P input is more than estimated P loss obtained from the full model and PU values are moderately high (75-80), or

(ii) estimated P input is less than estimated P loss obtained from the full model and PU values are moderately low (65-70).

Under (i) it could be expected that RY would increase and hence PU decrease, and vice versa under (ii). The dynamics of the phosphate cycle would then reach some feasible equilibrium over time for the target SR and P input values.

Where SR is optimistic relative to CC, the simplified model over-estimates P loss. This should ensure that the system is as 'feasible as possible', in the sense that RY should be high and hence PU relatively low. However, SR may be sufficiently high relative to CC that the (RY, PU) values required to sustain the system simply cannot be achieved. In this situation stock performance will decline at the target SR, and hence ssu carried will decline. The situation is illustrated in Appendix III.

Performance Monitoring and Model Validation

System performance described in terms of SR (ssu/ha), Y actual or PU, will vary between years on a farm property. Changes in average system performance levels from those predicted using the Cornforth/Sinclair model will indicate the need for revision of the management strategy applied to that property, or an adjustment to model parameters.

To the extent that the observed values for system performance variables (SR, PU or RY) values depart from those used to estimate P loss, we would expect consequent changes in percentage P in herbage and soil P levels. However, even where observed SR and PU values coincide with those used to estimate P loss, errors in estimating ALF, SLF or CC in any particular situation could be expected to provide consequent changes in percentage herbage P and soil P levels.

Clearly the question of model validation requires considerable consideration beyond that possible in this study. However, it would seem reasonable to assume that this process would be assisted by decomposition of estimated total P loss, at any RY, into soil loss and animal loss components.

The Cornforth/Sinclair Model and Management Decisions

This study has involved the investigation of past fertiliser use, and other management strategies on a number of Northern Manawatu sheep and cattle properties. Three case study farms were selected to allow identification of opportunities for increasing farm profitability. The Cornforth/Sinclair model has been used as the basis for determining the P fertiliser requirement to maintain alternative levels of system performance in each case. Opportunities for increasing technical and economic efficiency have been identified, involving changes to levels of pasture production, farm subdivision and pasture utilisation, and stock policies and grazing management strategies.

Use of the Cornforth/Sinclair model in this study has allowed the identification of the general direction of changes required to meet the objectives of improved technical and economic efficiency. However, the magnitude of changes still require clearer definition. For example, there is insufficient understanding of the change in the amount of farm subdivision that will result in a particular change in the level of PU achieved. Nevertheless, the Cornforth/Sinclair model has provided a very useful framework for the integration of the components of the production system, facilitating analysis of the current level of production of any farm property in terms of the site parameters and performance variables.

Use of the Cornforth/Sinclair model has provided a consistent framework for the analysis of similar farm properties achieving different levels of system performance. The discipline encouraged by the Cornforth/ Sinclair model has focussed attention on factors affecting farm performance in a way likely to be useful from an agricultural extension viewpoint. The resulting analysis has highlighted the direction of changes in management strategies likely to achieve higher and more profitable levels of farm production.

APPENDIX I

SURVEY FARM DATA

FARM NUMBER 1

Area 404.8 ha	All effective	40 ha flat-easy

Stock Numbers at 30 June

	1980	1979
Ewes	2200	2156
Ewe hoggets	730	740
Others	65	67
Total Sheep	2995	2963
Sheep stock units	2851	2706.04
Cows	65	42
Bullocks	15	17
R3 steers	41	40
R2 steers	48	44
R1 steers	25	28
Bulls	3	2
Total cattle	197	173
Cattle stock units	804	710.1
Total stock units	3655.7	3416.14
su/ha	9.03	8.44
Sheep:cattle	3.54	3.81
Lambing %	108	97
Wool weight (Kg)	15450	15500
Kg P/ha	13.52	13.52

FARM NUMBER 2

Part of Farm 14 prior to amalgamation in 1977/78

243 ha effective 60 ha easy

Stock Numbers at 30 June

	1977	1976	1975	1974	1973	1972
Ewes	1668	1704	1692	1615	1692	1682
Hoggets	645	625	702	704	698	701
Others	93	89	112	88	93	94
Total sheep	2406	2418	2506	2407	2483	2477
Sheep stock units	2260.6	2314.9	2357.6	2307.4	2390.36	2348.82
Cows	86	79	96	87	81	44
R2 heifers	10	45	9	8	6	63
R1 heifers	50	-	21	34	33	
R1 steers	17	40	21	31	30	32
R2 steers	2	2	17	3	2	21
R3 steers	2	3	1	-	7	1
Bulls	1	2	2	1	2	2
Total cattle	168	171	167	164	161	163
Cattle stock units	654.1	673.7	659.7	638.1	630.6	636.7
Total stock units	2914.7	2988.6	3017.3	2945.5	3020.96	2985.52
su/ha	3.64	3.44	3.57	3.62	3.79	3.69
Lambing %	107	112	109	115	116	112
Wool weight (kg)				12691	13505	14278
Kg P/ha	19.76	19.76	19.76	19.76	19.76	19.76

Prices ($)

	1977	1976	1975	1974	1973	1972
Lambs	15.00	9.70	6.10	9.00	8.50	4.50
2th ewes	17.00	17.00	9.20	15.90	13.70	7.02
5 yr ewes	14.00	9.00	5.00	9.00		4.40
2 yr heifers			65	77		
1 yr steers	112		89	106		123
2 yr steers	130				160	

FARM NUMBER 3

Area up to 75/76 284 Pakihakura
+ 37 Feilding
321 ha Father-son partnership 316 ha effective
75/76-78/79 284 ha 279 ha effective
79/80 321 ha again 88.5 ha easy

Stock Numbers at 30 June

	1980	1979	1978	1977	1976	1975	1974	1973
Ewes	1480	1452	1489	1482	1452	1450	1730	1706
Ewe hoggets	1282	1381	830	655	607	605	830	805
Others	36	42	37	41	40	42	50	40
Total sheep	2798	285	2356	2178	2099	2097	2610	2551
Sheep stock units	2250	2314	2017	1908	1848	1846	2268	2221
Cows	124	99	85	85	80	65	56	64
R2 heifers	45	35	20	21	23	30	18	1
R1 heifers	45	47	36	27	32	24	28	18
R1 steers	48	30	40	44	29	23	30	55
R2 steers	2	42	29	47	21	25	54	103
R3 steers	-	7	2	1	64	79	101	47
Bulls	3	3	3	2	2	2	2	1
Total cattle	267	263	215	227	251	248	289	289
Cattle stock units	1343	1299	1060	1115	1252	1231	1407	1384
Total stock units	3593	3613	3077	3023	3100	3077	3675	3605
Sheep:cattle	1.68	2.78	1.90	1.71	1.48	1.50	1.61	1.60
su/ha	11.37	11.43	11.03	10.84	11.11	11.03	11.63	11.41
Kg Wool/ha	52.75	46.96	46.86	46.78	45.26	48.09	48.76	32.06
Lambing %	110	96	108	104	98	101	100	103
Calving %	95	91	87	90	88	88	92	92
Kg P/ha *	2.03	19.78	6.57	18.35	13.48	11.14	10.38	12.15

* Variable amounts and areas over which P spread - average for area each year.

Prices ($)

	1980	1979	1978	1977	1976	1975	1974	1973
Lambs	18.30	22.15	11.63	13.22	9.99	6.76	8.36	8.85
Hoggets	20.78	16.00	-	-	9.34	6.78	-	6.49
2th ewes	32.25	24.30	15.00	26.50	18.30	7.90	14.65	-
Mixed age ewes	19.00	12.50	10.00	13.50	11.06	4.20	-	-
Works	12.91	12.42	9.79	11.02	5.90	3.12	9.02	8.65
Cattle - ox	333	230	147	167	134	96	171	185
heifers	-	-	-	70	70	-	-	-
cull cows	223	208	80	85	-	-	114	-

FARM NUMBER 4

Area 340.1 ha | 330 ha effective | 12 ha easy-flat

Stock Numbers at 30 June

	1980	1979	1978	1977	1976
Ewes	2080	2055	1920	1830	1835
Hoggets	1110	830	800	875	786
Rams	30	51	35	35	30
Others	50	50	65	64	60
Total sheep	3270	2986	2770	2805	2711
Sheep stock units	2800	2623.8	2437	2411	2366.6
Cows & heifers	170	157	155	130	88
R2 heifers	40	43	40	-	-
R1 heifers & steers	43	110	110	-	80
Others	27	20	45	80	40
Total cattle	270	330	350	210	208
Cattle stock units	1507	1675.5	1755	1180	1048
Total stock units	4307	4299.3	4212	3605	3414.6
Sheep:cattle	1.86	1.57	1.39	2.38	2.26
su/ha	13.05	10.03	12.76	10.92	10.35
Lambing %	115	97	93	88	86
Kg P/ha	20.93	25.84	25.84	25.84	25.95
Prices ($)					
Lambs	12.80	13.12	10.79	11.92	8.00
2th ewes	24.00	22.00	15.80	20.00	16.00
Works ewes	8.87	9.80	8.20	8.00	7.00
Cows	190.00	63.00			
3½ yr steers	300.00			131	80
2½ yr steers					
2½ yr heifers	276	85			
Weaner heifers	154	140	40	63	
Weaner steers	180	170	80	74	

FARM NUMBER 5

Area 378.5 ha | All effective | 24.3 ha easy-flat (6%)

Stock Numbers at 30 June

	1980	1979	1978	1977
Ewes	2400	2400	2440	2400
Hoggets	1200	952	630	730
Others	65	65	62	49
Total sheep	3665	3417	3132	3179
Sheep stock units	3172	3023.2	2867	2877
Cows	128	114	127	140
R2 heifers	40	29	29	39
R2 steers	47	34	27	46
R3 steers	-	18	45	-
Weaners	97	87	64	72
Bulls	4	3	4	4
Total cattle	316	285	296	301
Cattle stock units	1567	1420	1515	1530
Total stock units	4740	4444	4647	4408
su/ha	12.52	11.74	12.28	11.65
Sheep:cattle	2.02	2.13	1.90	1.88
Lambing %	93	103	98	85
Kg Wool/ha	44.91	36.99	41.21	40.16
Kg Wool/ssu	5.62	4.88	5.42	
Calving %	90	90	90	90
Kg P/ha	0	0	21.4	0

Prices ($)

	1980	1979	1978	1977
Lambs - works	16.50	18.70	9.45	12.40
- store	11.50	10.50	7.50	-
2th ewes	-	-	10.00	18.00
Mixed age ewes	14.00	13.00	11.00	9.50
R1 heifers	-	-	19.00	36.50
R1 steers	-	-	30.00	
Bullocks	300			
2 yr steers	-	178	-	160
Cows	-	178	-	100

FARM NUMBER 6

Area 322.9 ha All effective No flat

Static stock numbers since 1970

Example Stock Numbers

Ewes	2300
Ewe hoggets	860
Rams	60
Others	30
Total sheep	3250
Sheep stock units	2882

Cows & heifers	190
R2 heifers	24
R1 heifers	27
Bulls	4
Total cattle	245
Cattle stock units	1376

Total stock units	4259
su/ha	10.69
Sheep:cattle	2.09

Lambing %	115
Kg Wool/ha	47.60
Kg Wool/ssu	6.59
Kg P/ha	20.09

FARM NUMBER 7

Area 316.6 ha 303.6 ha effective 3.24 flat-easy

Stock Numbers at 30 June

	1980	1979	1978	1977	1976	1975	1974	1973	1972
Ewes	2306	2259	2282	2256	2259	2223	2256	2282	2223
Hoggets	900	1021	923	1024	1006	1026	1029	1030	694
Rams	80	85	85	82	83	76	67	68	57
Others	40	35	35	30	63	48	62	40	50
Total sheep	3326	3400	3325	3392	3411	3373	3414	3420	3024
Sheep stock units	2934	2961	2925	2954	2967	2928	2964	2978	2715
R2 steers		67	34	124	122	96	105		
R3 steers	150	150	30	126	28	16	37	27	104
R4 steers			16						
Others			2	7	6	7	12	11	25
Total cattle	150	150	115	167	168	145	145	143	129
Cattle stock units	750	750	541	815	775	660.5	671	657	632.5
Total stock units	3684	3711	3465	3768	3742	3588	3635	3635	3347
Sheep:cattle	3.91	3.95	5.41	3.62	3.88	4.44	4.42	4.53	4.30
su/ha	12.13	12.22	11.41	12.41	12.33	11.82	11.97	11.97	11.02
Kg Wool/ha	55.67	51.39	50.30	56.24	45.43	51.33	53.10	50.73	44.50
Kg Wool/ssu	5.71	5.33	5.17	5.75	4.71	5.26	5.41	5.67	
Lambing %	101	100	97	98	89.5	102	97	103	101
Kg P/ha	15.84	15.84	15.84	15.84	15.84	15.84	15.84	15.84	15.84
Prices ($)									
Lamb	13.37	13.38	10.48	11.55	8.34	6.00	8.22	6.50	4.51
2th Perendales	26.50	19.00	11.50	17.00	14.00	8.00	11.56	11.00	6.00
2th Romneys			11.89	21.20	14.75			9.82	
5 yr ewes	15.00	9.00	9.50	14.00	8.00	3.00	9.00		3.00
2½ yr steers			145	182	142	90	141	144	130

FARM NUMBER 8

Area 259 ha   249 ha effective   52.6 ha easy-flat (21%)

Stock numbers constant for the last 10 years.

Example Stock Numbers

Ewes	1600
Ewe hoggets	600
Rams	20
Total sheep	2220
Sheep stock units	2120
Cows & heifers	40
R1 steers	20
R1 heifers	20
R2 steers	50
R3 steers	45
Total cattle	175
Cattle stock units	850
Total stock units	2970
Sheep:cattle	2.49
Lambing %	120
Kg Wool/ha	56.49
Kg Wool/ssu	6.37
Kg P/ha	160
Lamb weight	13-15 kg
R3 steers	320 kg

FARM NUMBER 9

Area 210.5 ha — 210.5 ha effective — 28.3 ha flat-easy

Stock Numbers at 30 June

	1980	1979	1977	1975	1974	1973
Ewes	1594	1508	1400	1405	1405	1393
Hoggets	504	523	550	488	495	519
Total sheep	2098	2021	1950	1893	1900	1912
Sheep stock units	1846	1822	1730	1698	1702	1704
Cows	55	49	76	103	103	101
R2 heifers			14	14	28	15
R1 heifers & steers			19	12		16
R3 steers	45	59				
R2 steers	24	20				
Bulls	1	1	2	2	3	3
Total cattle	125	129	111	131	134	135
Cattle stock units	668	684	605	739	759	752
Total stock units	2766	2506	2335	2437	2659	2457
Sheep:cattle	2.83	2.66	2.85	2.29	2.24	
su/ha	13.14	11.90	11.09	11.58	12.63	11.67
Kg Wool/ha	54.85	51.56	58.01	-	-	43.36
Kg Wool/ssu	6.35	5.20	7.11	-	-	5.36
Lambing %	103	97	95	88	92	
Kg P/ha	15.99	15.99	15.99	15.99	15.99	15.99

FARM NUMBER 10

Area 356ha 350 ha effective 48 ha easy-flat

Stock Numbers at 30 June

	1980	1979	1978	1977	1976	1975
Ewes	1871	1869	1876	1866	1850	1850
Ewe hoggets	756	760	750	750	750	750
Rams	54	42	55	52	54	52
Others	65	98	88	82	85	90
Total sheep	2746	2760	2769	2750	2739	2742
Sheep stock units	2407	2408	2423	2406	2394	2396
Cows	78	48	43	37	64	76
R3 heifers	13	38	-	23	4	17
R2 heifers						26
R3 steers	27	29	33	30	29	28
R2 steers	68	93	87	99	92	91
R1 steers	60	71	108	109	100	96
Bulls	2	2	2	2	2	3
Total cattle	248	281	273	300	291	337
Cattle stock units	1237	1374	1257	1404	1377	1624
Total stock units	2644	3782	3680	3808	3771	4022
su/ha	10.32	10.71	10.42	10.79	10.69	11.39
Sheep:cattle	1.94	1.75	1.92	1.71	1.73	1.48
Lambing %	98	94	90	95	93	
Kg Wool/ha	49.18	45.43	47.40	43.13	41.48	
Kg Wool/ssu	7.21	6.62	6.95	6.36	6.12	
Kg P/ha	10.2	10.2	10.2	10.2	10.2	10.2

Prices ($)

	1980	1979	1978	1977	1976
Lambs	17.13	10.82	10.21	11.67	9.43
2th ewes	30.00	25.50	15.30	24.20	17.03
5 yr ewes	11.79	10.14	7.76	11.39	9.55
R1 heifers	125	140	43	40	
2½ yr steers	340	190	143		174
3½ yr steers	380	330	158	160	181

FARM NUMBER 11

Area 247 ha | 243 ha effective | 4 ha flat-easy

Stock Numbers at 30 June

	1980	1979	1978	1977	1976	1975	1974
Ewes	1630	1540	1520	1500	1500	1490	1480
Ewe hoggets	630	1360	1032	1000	900	700	800
Others	740						
Total sheep	3000	2900	2552	2500	2400	2190	2280
Sheep stock units	2728.2	2492	2272.8	2305	1200	2039.6	2099.2
Cows	82	78	85	85	80	89	90
R1 heifers	10	14	9		10	6	5
R1 steers	5	8	3		7	14	
R2 steers	68		96	75	65	66	60
R3 steers	41	72	14	15			14
Bulls	2	1	1	1	1	2	2
Total cattle	203	179	212	176	159	171	176
Cattle stock units	848.9	727	833.6	713	647.2	703.3	693
Total stock units	3577.1	3219.5	3106.4	3018	2748.2	2742.9	2792.2
Sheep:cattle	3.2	3.43	2.73	3.23	3.24	2.90	3.03
su/ha	14.72	13.25	12.78	12.42	11.31	11.29	11.49
Wool	13100	13500	12000	12000	11000	10500	10750
Lambing %	107	100	104	114	96	107	107
Kg P/ha	19.75	19.75	19.75	19.75	19.75	19.75	19.75

Prices ($)

	1980	1979	1978	1977	1976	1975	1974
Hoggets	19.29	16.05	13.38	15.23	10.77	6.92	9.81
2th ewes	28.00	28.00	23.00	18.00			
5 yr ewes	23.70	13.50	10.80	14.10	10.50		
Heifers	187	200	55	53	49	22	60
Weaner steers	214	210	69	87	72	50	71.50

FARM NUMBER 12

Area 556.8 ha | 534.4 ha effective | 81.0 ha Flat

Stock Numbers at 30 June

	1980	1979	1978	1977	1976	1975
Ewes	2800	2250	2150	2170	2250	2200
Ewe hoggets	870	870	850	820	750	750
Others	110	140	120	135	110	98
Total sheep	3780	3260	3120	3125	3110	3048
Sheep stock units	3301	2813.5	2690	2808.6	2705.5	2649.4
Cows	204	157	123	190	227	163
R2 heifers	52	110	50	45	35	30
R2 Bulls & steers	5	4	1	51	32	56
R1 heifers & steers	120	92	171	151	180	113
R1 Bulls	18	4	2	2	2	1
Herd Bulls	6	7	5	3	4	5
Total cattle	405	375	352	392	480	369
Cattle stock units	1582.5	1483.4	1348.5	1717.7	1865.2	1436
Total stock units	4883.5	4296.9	4039	4526.3	4570.7	4086
Sheep:cattle	2.09	1.90	2.00	1.64	1.45	1.84
su/ha	9.14	8.04	7.56	8.47	8.55	7.65
Lambing %	85	86	87	95	86	85
Wool weight (Kg)	18000					
Kg P/ha	0	0	0	0	0	0

FARM NUMBER 13

Area 854 ha   795 ha effective   79.5 ha easy

Stock Numbers at 30 June

	1979	1978	1977	1976	1975	1974	1973	1972
Ewes	3900	3800	3606	3130	3100	3050	3250	3580
Ewe hoggets	1650	1500	1433	1400	1355	1400	1180	1605
Others	113	125	94	78	97	105	97	127
Total sheep	5618	5425	5133	4608	4552	4555	4527	5312
Sheep stock units	5191.9	4950	4467.9	4141.1	4126.1	4083.5	4088.6	4626.1
Cows	325	382	454	543	537	524	518	404
R1 heifers	57		50	65	67	80	80	63
R2 heifers		58	61	63	75	74	72	38
R1 steers	100	100	4	6	5			
R2 steers	98		6	5				
R3 steers			5	8	6			4
Bulls	6	12	14	13	9	13	11	9
Total cattle	586	552	594	703	699	691	681	518
Cattle stock units	2306.9	2206.4	2402.6	2841.6	2820.9	2783.5	2742.1	2089.9
Total stock units	7498.8	7156.4	6870.5	6982.7	6947	6867	6830.7	6716
Sheep:cattle	2.25	2.24	1.86	1.46	1.46	1.47	1.49	2.21
su/ha	9.43	9.00	8.64	8.78	8.74	8.64	8.59	8.45
Lambing %	103	99	88	97	100	98	96	89
Wool weight (Kg)	35119	30057	29159	28854	26235	26789	24129	87
Kg P/ha		20.13	20.53	22.64	30.19	30.19	30.19	30.12

Prices ($)

	1979	1978	1977	1976	1975	1974	1973	1972
Lambs	14.98	11.16	9.45	6.81	6.12	8.05	6.67	4.69
Hoggets	22.00	11.53	13.50	10.80	6.50	12.50	12.58	5.70
2th ewes	14.60	11.10	15.12	13.10	7.70		13.32	4.97
Mixed age ewes	13.66	11.00	14.20	11.35	5.50	11.06	11.02	4.47
Works	14.28	5.90	8.35	5.71	2.85	5.82	10.03	
Ox		207		142	72.50			141.50
Cow	245	78	73	81	27	38	90	75.50
Weaner heifers	160	51	60	37	20	43	53	65
Weaner steers	165	64	74	62	35	63	74	81

FARM NUMBER 14

A combination of two farms, farmed separately till 1977/78.

Area 498 ha 486 ha effective 60 ha easy

Stock Numbers at 30 June

	1980	1979	1978
Ewes	3330	3281	3297
Ewe hoggets	1076	1206	1270
Others	100	110	105
Total sheep	4506	4597	4622
Sheep stock units	4329.7	4213.2	4434.85
Cows	166	148	159
R2 heifers	30	31	30
R2 steers	30	29	61
R1 heifers			
R1 steers	120	121	122
R3 steers	11	21	13
Bulls	3	3	3
Total cattle	360	353	388
Cattle stock units	1409.6	1384.4	1518
Total stock units	5739.3	5597.6	5952.85
Sheep:cattle	3.07	3.04	2.92
su/ha	11.81	11.52	12.25
Lambing %	110	100	110
Wool weight (Kg)	27872	24577	24975
Kg P/ha	29.6	29.6	16.4

Prices ($)

	1980	1979	1978
Lambs	15.30	14.95	11.78
2th ewes		15.70	
Works ewes	11.00	8.50	9.00
1 yr steers	278	172	
18 mth heifers	259	269	
Cows	272	296	
Bullocks	512	327	

FARM NUMBER 15

Area 199.2 ha All effective

Stock Numbers at 30 June

	1980	1979	1978	1977	1976	1975
Ewes	1713	1672	1629	1675	1720	1740
Ewe hoggets	629	620	575	635	600	630
Rams	29	28	52	43	34	54
Others	43	25	28	30	25	34
Total sheep	2414	2319	2284	2385	2379	2458
Sheep stock units	2279.42	2165.12	2062.92	2127.65	2152.8	2216.6
Cows	66	65	65	65	66	78
R1 heifers	12	13	12	11	12	13
R2 heifers	14	12	10	11	12	12
Bulls	2	2	2	3	4	3
Steers	3	3	3	2	2	2
Total cattle	97	95	92	92	96	108
Cattle stock units	389.1	380.8	373	370.3	386.4	434.7
Total stock units	2668.52	2545.92	2435.92	2497.95	2539.2	2651.3
Sheep:cattle	5.86	5.69	5.53	5.75	5.57	5.10
su/effective ha	13.40	12.78	12.23	12.54	12.75	13.31
Wool weight (Kg)	13581	10983	14537			
Lambing %	107	101	96	94	95	95
Kg P/ha	15.47	20.49	20.49	20.49	20.49	20.49

FARM NUMBER 16

Area 259.1 ha   202 ha effective   80 ha flat-easy

Stock Numbers at 30 June

	1980	1979	1978	1977	1976	1975
Ewes	1614	1566	1490	1570	1545	1573
Ewe hoggets	831	610	902	705	587	530
Rams	35	34	35	36	36	35
Others	20	15		140		
Total sheep	2500	2225	2427	2451	2168	2138
Sheep stock units	2265.7	2009.3	2026.7	2120.0	1880.7	1817.3
Cows	73	72	71	84	81	76
R2 heifers	22	18	18	18	26	18
Weaners	66	66	64	73	68	76
Bulls	3	3	2	3	2	3
Others			11			
Total cattle	164	159	166	178	177	173
Cattle stock units	636.2	616.5	650.2	690.9	687.3	668.9
Total stock units	2901.9	2625.8	2676.9	2810.9	2568.0	2486.2
Sheep:cattle	3.56	3.26	3.12	3.07	2.74	2.72
su/effective ha	14.37	13.0	13.25	13.92	12.71	12.31
Wool weight (Kg)	11811	13489	10486	9980	8799	9954
Lambing %	103.9	97.7	84	91.5	87	79
Kg P/ha	21.19	20.00	18.22	12.67	17.43	14.26

Prices ($)

Lambs	12.44	13.70
Heifers	200	90
Cows	240	238
Steers	247	210

FARM NUMBER 17

Area 473.6 ha   453.3 ha effective   60 ha flat-easy

Stock Numbers at 30 June

	1980	1978	1977	1976	1975	1974	1973
Ewes	3460	2950	3000	2304	1850	2033	2041
Ewe hoggets	1000	650	450	730	550	500	600
Others	130	140	120	75	80	112	135
Total sheep	4590	3740	3570	3109	2480	2645	2776
Sheep stock units	4091	3328.2	3160.5	2759.8	2208	2407.5	2464.9
Cows	120	106	127	225	200	200	179
R1 heifers	45	20	45	50	80	142	104
R2 heifers	55	45	26	70	62	107	90
R1 steers	90	80	80	10	70	60	93
R2 steers	55	55	60	90	65	2	63
R1 bulls						41	
R2 bulls					36	25	
Herd bulls	9	2	9	20	9	9	12
Total cattle	374	308	347	465	548	630	556
Cattle stock units	1447.5	1193.6	1346.6	1852.5	2153.3	2451.4	2161.3
Total stock units	5338.5	4521.8	4507.1	4612.3	4346.1	4859	4626.2
Sheep:cattle	2.86	2.79	2.35	1.49	1.02	0.98	1.14
su/effective ha	12.22	9.97	9.94	10.17	9.62	10.71	10.21
Lambing %	90	87.2	83.3	90	90.2	93.6	89.8
Wool weight (kg)		18909	17109	13634	11942	12369	12843
Kg P/ha	19.51	23.57	23.57	23.57	23.57	23.57	27.6

Average Prices ($)

	1980	1978	1977	1976	1975	1974	1973
Wool		180.3	192.0		95.[illegible]	149.3	136.6
Sheep & wool income/SEE		14.79	16.74		8.94	12.2	11.17
Cattle income/CEE		3.97	6.80		2.00	6.1	25.49
Fat lambs			10.09			8.19	7.40
Store lamb					5.07	8.11	6.50

FARM NUMBER 18

Area 457.5 ha   405 ha effective   8 ha flat balance moderate hill

Stock Numbers at 30 June

	1980	1979	1978	1977	1976
Ewes	2700	2300	2270	2260	2280
Ewe hoggets	1050	870	870	1000	820
Others	150	150	150	150	150
Total sheep	3900	3320	3290	3410	3250
Sheep stock units	3460.5	2948.5	2919.5	3000.9	2894.2
Cows					67
R1 steers	50				60
R2 steers	140	155	135	146	60
R3 steers	150	137	157	145	65
R4 steers					40
Total cattle	340	292	292	291	292
Cattle stock units	1401	1221	1233	1221.9	1197.2
Total stock units	4861.5	4169.5	4152	4222.8	4091.4
Sheep:cattle	2.47	2.41	2.37	2.46	2.42
su/effective ha	12.00	10.29	10.25	10.43	10.10
Lambing %		90-96%	average 63%		
Wool weight (Kg)	19200	15300	15400	15700	14500
Kg P/ha	12.96	14.81	12.96	11.85	11.85

Average Prices ($)

Lambs	12.80	11.00	8.29	11.37	6.41
Culled ewes	13.70	8.21	7.66	10.83	6.28
2th ewes	18.00	15.19	11.48	16.70	14.87
Bullocks	364.00	320.98	179.21	191.00	135.86

FARM NUMBER 19

Area 1498 ha 1417 ha effective 32 ha flat

Stock Numbers at 30 June

	1980	1979	1978	1977	1976	1975	1974	1973
Sheep stock units	6954	6050	5712	5750	5782	5735	6069	6043
Cattle stock units	8248	8157	8092	7219	7219	7028	7034	7194
Total stock units	15202	14207	13804	12969	13001	12763	13103	13237
su/ha	10.73	10.03	9.74	9.15	9.18	9.01	9.25	9.34
Sheep:cattle	.84	.74	.71	.80	.80	.80	.86	.84
Lambing %	100	100	100	100	100	100	100	100
Kg Wool/ha	30.43							
Kg P/ha	19.76	19.76	19.76	16.94	22.5	16.94		

Prices ($)

Lambs	15.00
2th Ewes	27.00
Cows	320.00
Weaners	192.00

FARM NUMBER 20

Area 259 ha 257.5 effective no flat - all steep

Estimates of stock numbers below. Some grazing out.

Stock Numbers at 30 June

	1980	1979	1978	1977	1976	1975	1974	1973
Ewes	1664	1606	1550	1450	1100	1200	1250	1300
Ewe hoggets	636	570	570	633	300	350	375	430
Others	70	34	34	40				
Total sheep	2370	2210	2154	2123	1400	1550	1625	1730
Sheep stock units	2102	1975.2	1919	1862	1280	1410	1475	1558
Cows	115	115	115	66	60	60	60	60
R2 heifers	49	49	43	28	25	30	30	30
R1 steers								
Bulls								
Total cattle	164	104	158	122	85	90	90	90
Cattle stock units	910.5	910.5	884	649	472.5	495	495	495
Total stock units	3012.5	2886	2803	2511	1753	1905	1970	2053
su/ha	11.70	11.21	10.88	9.75	6.81	7.40	7.65	7.97
Sheep:cattle	2.31	2.17	2.17	3.02	2.71	2.85	2.98	3.15
Kg P/ha	0	0	18.53	18.53	0	18.53	18.53	18.53
Kg Wool/ha	34.95							
Lambing %	97	97	97	97	97	97	97	97

FARM NUMBER 21

Area 255 ha effective

No flat

Stock Numbers at 30 June

	1980	1979	1978	1977	1976	1975
Ewes	2050	2030	1990	1400	1375	1365
Ewe hoggets	985	970	875	700	680	700
Others	55	57	140	110	80	92
Total sheep	3090	3057	3005	2210	2135	2175
Sheep stock units	2824.5	2754.6	2814	2020	1956.25	1928.6
Cows				54	50	46
R2 heifers					13	13
R2 steers	150	200	160	120	128	65
R3 steers	50	20	35		10	70
Bulls				2	2	1
Total cattle	200	220	195	176	203	195
Cattle stock units	810	870	781.5	698.4	808.9	812.3
Total stock units	3634.5	3624.6	3595.5	2718.4	2765.15	2740.9
su/ha	14.12	14.21	14.10	10.66	10.84	10.75
Sheep:cattle	3.49	3.17	3.60	2.89	2.42	2.37
Lambing %	104	100	110	106	106	100
Kg P/ha	20.39	20.39	20.39	20.39	20.39	20.39

Prices ($)

Lambs	15.00	14.00	13.00
Cattle	260 c/c wt		

APPENDIX II

Calculation of SR Hill and SR Flat for Farm 16, that results in equal marginal value product of fertiliser for the two areas, under current total stock numbers.

(i) For Hill area CC = 16, ALF = 1.1, SLF = 0.25, PU = 75

The Cornforth/Sinclair model estimates P loss as

$$PLH = \text{Log}_{10}\left(\frac{100}{100 - 7.125SR}\right) \times 22.32666$$

and thus

$$SR = 14.0351 - (7.125)^{-1}\ 10^{2} \times 10^{-0.4478962PLH} \quad \ldots. (1)$$

$$\text{and } \frac{dSR}{dPLH} = 1.44746543 \ .\ 10^{-0.04478962PLH} \quad \ldots. (2)$$

(ii) For the flat area CC = 21.77, ALF = 0.7, SLF 0.25, PU = 85

$$PLF = \text{Log}_{10}\left(\frac{100}{100 - 4.6025SR}\right) \times 27.0618305$$

and thus

$$SR = 21.64 - (4.6205)^{-1}\ 10^{2} \times 10^{-0.03952415PLF} \quad \ldots. (3)$$

$$\text{and } \frac{dSR}{dPLF} = 1.841490752 \ .\ 10^{-0.036952415PLF} \quad \ldots. (4)$$

Total stock units = 2655 $\therefore$ the two equations are:

$$80 \text{ SRF} + 122 \text{ SRH} = 2655 \qquad \text{.... (5)}$$

and

$$\frac{d\text{SRH}}{d\text{PLH}} - \frac{d\text{SRF}}{d\text{PLF}} = 0 \qquad \text{.... (6)}$$

Substituting for SRH and SRF from Equations (1) and (2) in Equation (5):

$$80 \ (21.64 - (4.6205)^{-1} \ 10^2 \ 10^{-0.036952415 \text{ PLF}})$$
$$+ 122 \ (14.0351 - (7.125)^{-1} \ 10^2 \ 10^{-0.04478962 \text{ PLH}})$$
$$= 2655$$

$$\therefore 788.69538 = 1731.4144.. \ 10^{-0.036952415 \text{ PLF}} +$$
$$1712.28098 \ . \ 10^{-0.04478962 \text{ PLH}}$$

If $X = 10^{-0.036952415 \text{ PLF}}$ and $Y = 10^{-0.04478962 \text{ PLH}}$

Then substituting in Equation (6) from Equations (2) and (4), the two equations become:

$$788.69538 = 1731.4144 \ X + 1712.28098 \ Y \qquad \text{.... (7)}$$

$$0 = 1841490752 \ X - 1.44746543 \ Y$$

Solving for X and Y $\qquad X = .201722$

$\qquad Y = .256634$

and $\therefore$ $\qquad$ PLH = 13.188

$\qquad$ PLF = 18.51

Substituting these values in Equations (1) and (3) respective and solving for SR:

$$SRH = 10.43$$

$$SRF = 17.28$$

APPENDIX III

Examination of Simplified Cornforth/Sinclair model relative to full model.

Simplified Model:

$$P\ loss = (1.07\ ALF + 2.58\ SLF) \times SR$$

Example : ALF = 0.9

SLF = 0.25

Target SR = 19.0 su/ha

P loss = 30.6 kg P/ha = P input.

Figure A1 presents P loss and PU values for different CC and RY combinations at SR = 19 ssu/ha when ALF = 0.9, SLF = 0.25, as predicted from the full Cornforth/Sinclair model. Also shown in Figure A1 are the CC and RY combinations for which P loss = 30.6, and the CC and RY combinations for which PU = 80 when SR = 19.

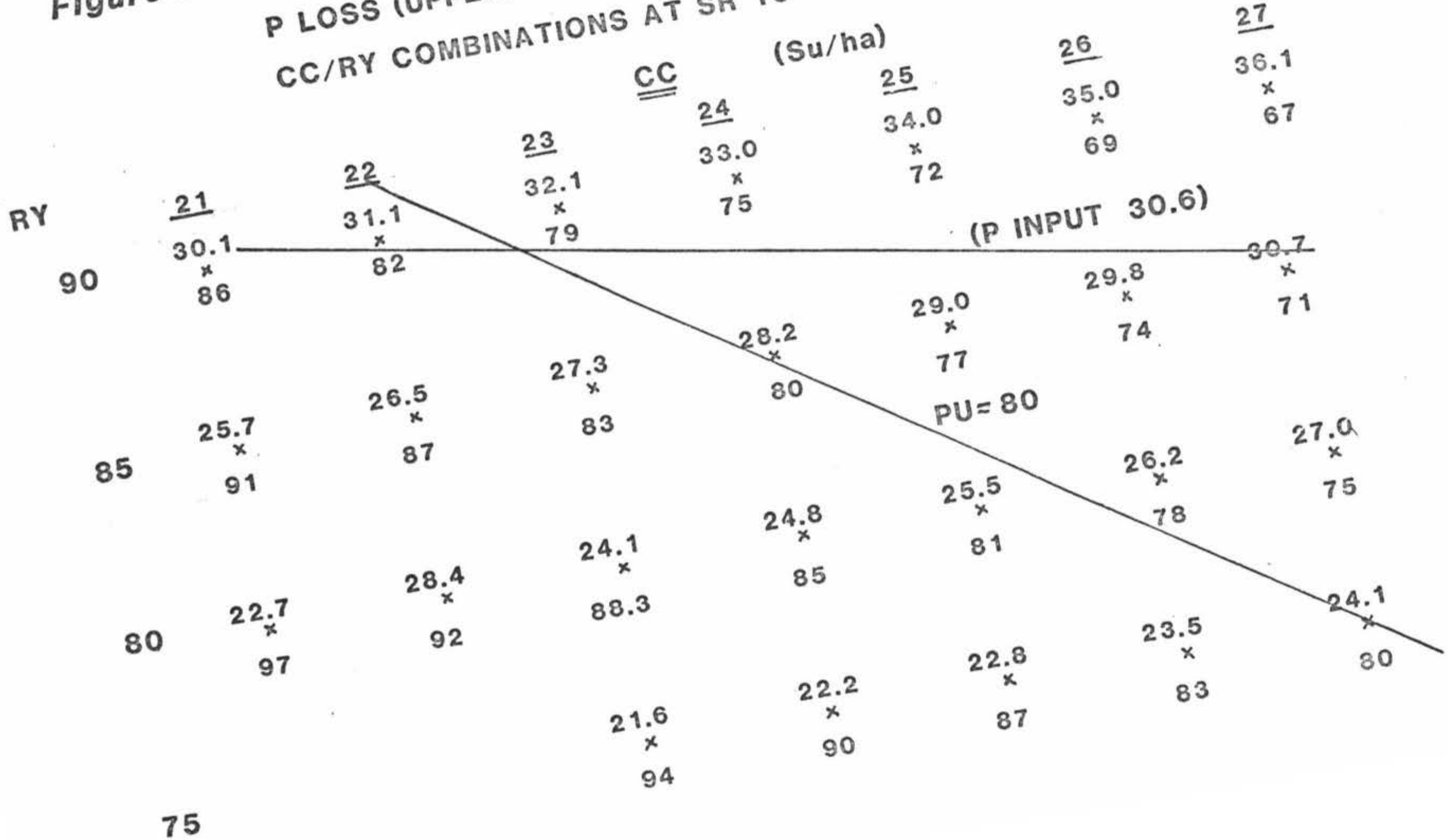
From Figure A1, it can be observed that where SR = 19 is optimistic relative to CC (eg CC = 21 or 22), then 30.6 kg of P/ha is sufficient to replace P loss only at high (PU, RY) values. If the necessary PU levels are not achieved then stock performance (and hence ssu carried) will decline. Thus actual stocking rate will become more conservative relative to CC.

Where SR = 19 is conservative relative to CC (eg CC = 25 or 26), then 30.6 kg P/ha is sufficient to replace P loss at moderate (PU, RY) values. At PU = 80 for CC = 25-26, P loss is about 26 kg P/ha. For P input = 30.6 kg/ha we would expect soil P and/or RY levels to increase.

At PU = 70 for CC = 25-26, P loss is about 34.5 kg P/ha. For P input = 30.6 kg/ha then we would expect soil P and/or RY levels to decrease. In either case, the equilibrium (RY, PU) values appear within the range of good grazing management practice.

It is also clear from Figure Al that the difference between P input values from the full and simplified model could vary considerable, though for most practical situations the maximum difference would seem to be about 6-7 kg P/ha. If CC = 25 when target SR = 19, and if it were possible to attain PU = 85, then P loss according to the full model is 23.6 kg P/ha, i.e. 7 kg P/ha less than the value obtained from the simplified model value.

Figure A.1 P LOSS (UPPER) AND PU (LOWER) VALUES FOR DIFFERENT CC/RY COMBINATIONS AT SR 19



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