A FRAMEWORK FOR ANALYSING THE ADOPTION OF NEW ZEALAND PASTORAL FARMING SYSTEMS IN CENTRAL VERACRUZ STATE, MEXICO.

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for the degree of Master of Agricultural Science

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By:

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ABSTRACT

Tropical areas of developing countries have significant potential for increased food production. In the case of Mexico, an important economic activity in the tropics is livestock production based on pasture. Tropical regions represent 25% of the total area of Mexico and support more than 50% of the country's cow production. Historically, however, animal production in Mexican, and other tropical areas, has been low. Low pasture utilisation, and associated poor herbage quality, is one factor that contributes to poor animal performance in the tropics. This situation contrasts with the success of New Zealand pastoral systems, which in comparative terms have been able to obtain high levels of animal production and efficient use of pasture.

Differences in pasture productivity (both in quality and quantity) and social and economic conditions between the Mexican tropics and New Zealand are large. Nevertheless it was proposed that some of the pastoral farming methods used in New Zealand, could be adapted to the conditions of tropical farmers in Mexico, particularly in relation to effective planning and control of the farming system. To test this hypothesis, the consequences of implementing some of New Zealand's pastoral farming techniques under tropical conditions in Central Veracruz State were explored by developing a spreadsheet model to simulate local farming systems. The model included linked sub-models for pasture growth and quality, livestock transactions, milk production and enterprise gross margins. The effect of improved farming systems of milk output and cash returns were evaluated relative to the average levels of performance currently achieved from a medium-sized farm in the Central region of Veracruz State in Mexico. Straight forward changes in the design of the farming system, such as synchronising calving with the pattern of pasture growth rather than year-round calving, would significantly affect milk production and cash returns to the farm family.

The modelling process was seriously constrained by the lack of farm-level data on pasture production and animal performance. Nevertheless, the model framework clearly identifies which data should be collected, and priority should now be given to assembling these data so simulation decision support models such as that developed in this study, can be effectively used to plan improved farming systems.

Keywords: tropical agricultural, Mexico, farming systems, spreadsheet model.

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Chapter One: Introduction.

1.1. Introduction.

Tropical areas of developing countries have significant potential for increased food production. In the case of Mexico, an important economic activity in the tropics is livestock production based on pasture. Historically, however, animal production in Mexican, and other tropical areas, has been low. Low pasture utilisation, and associated poor herbage quality, is one factor that contributes to poor animal performance in the tropics. This situation contrasts with the success of New Zealand pastoral systems, which in comparative terms have been able to obtain high levels of animal production and efficient use of pasture (Bryant, 1992). While climatic conditions in New Zealand are a significant part of the success of its pastoral-based systems, other factors need to be considered. For instance, although New Zealand farmers face similar problems to their Mexican counterparts because of the seasonality of herbage production, they have been able to reduce many of these through effective planning and control of their farming systems (Milligan et al. 1987).

Differences in pasture productivity (both in quality and quantity) between the Mexican tropics and New Zealand temperate climate are important, but Simmonds (1985) proposed that the farm management methods used in temperate regions of the world, such as New Zealand, could be adapted to the conditions of tropical small farmers. The hypothesis of the present study is that despite differences in climate and the state of agricultural development, principles of New Zealand pastoral-based farming systems could be adopted in the Central region of Veracruz State in Mexico in order to improve animal productivity and financial returns. To test this hypothesis the consequences of implementing some of New Zealand's pastoral farming techniques under tropical conditions in Central Veracruz State were explored by developing a spreadsheet model that simulated local farming systems.

1.2 Background.

1.2.1. Role of pasture farming in tropical areas of Mexico.

During the last thirty years, the demand for food in Mexico has exceeded the country's ability to satisfy it (Menocal et al., 1992). This is reflected by the quantity food imports, both as animal products and as grains, and represents an important item of government expenditure (Menocal et al., 1992; OECD, 1992). Government policies in agriculture have therefore focused on development programmes that will improve the efficiency and productivity of this sector of the Mexican economy.

Tropical regions represent 25% of the total area of Mexico (Mexico's total area = 1,973,000 sq km; agricultural area = 394,600 sq km; O.E.C.D. 1992), and support more than 50% of the country's cow population (Ramos, 1983; Menocal et al., 1992). Livestock production in the tropical regions is one of the most important economic activities, both because of the resources involved and its contribution to Gross Domestic Product (GDP) (Ramos, 1983; Menocal et al., 1992). Nevertheless, while the potential of these zones for agricultural production is high, production levels have remained relatively low (Menocal et al., 1992), despite substantial efforts to improve the productivity of tropical farming systems. Ramos (1983) identified some reasons for this failure. First, most research has been carried out at research centres, without appropriate consideration of the farmer's needs, circumstances or goals. Second, most of the research is component-based rather than considering the farming system as a whole. Thus, while biological aspects of farming systems have received a lot of attention, less effort has been focused on the socioeconomic environment of farms and farmers. Third, several programmes to improve the productivity of tropical farming systems have utilised tools and technologies developed under different climatic conditions, without attempting to modify these technologies to meet the particular attributes of tropical systems.

The advantages to the Mexican economy of pastoral-based livestock systems in the tropical regions, as an alternative to intensive animal production systems based on grains, was related by Menocal et al. (1992). First, animal production is the main land use in tropical regions and the area of land available is increasing; second, existing resources are underutilised; and third, the use of pasture as the main feed resource in the tropics means that production costs are lower for this region than for the Altiplano, where the main feed source is grains.

This potential for increased production in the tropics of Mexico, combined with the country's need for improved efficiency and productivity in the agricultural sector, means that every effort should be made to improve farm productivity but to avoid the mistakes made in the past. A possible approach to overcome these mistakes, is for more research to be done *in situ* (i.e. on-farm), using a farming systems approach (see Section 1.6), rather than at research centres. This approach allows constraints imposed by the farm characteristics and farmer's circumstances to be considered alongside the off-farm conditions (environmental, sociocultural, economic) that pertain to tropical regions.

1.2.2. Characteristics of Central Veracruz State.

The present review applies to the Central Veracruz State, because this is the area where CIEEGT (Centre of Research, Teaching and Extension in Tropical Livestock Production or Centro para la Investigación, Enseñanza y Extensión en Ganadería Tropical) of the Faculty of Veterinary Medicine and Husbandry (Facultad de Medicina Veterinaria y Zootecnia, FMVZ) from the National Autonomous University of Mexico (Universidad Nacional Autónoma de México, UNAM) is focusing its research effort. CIEEGT is located 360 km northeast of Mexico City and

5 km from the city of Martinez de la Torre, Veracruz State (CIEEGT, 1979). The study area is located in the north-central part of the Veracruz State, Mexico (Figure 1.1). It comprises the municipios (counties) of Atzalan, Martinez de la Torre, Tlapacoyan and Vega de Alatorre, and can be divided in two zones: the coastal plain of the Gulf of Mexico, from zero to 500 m.a.s.l.; and the mountainous area, above 500 m.a.s.l.

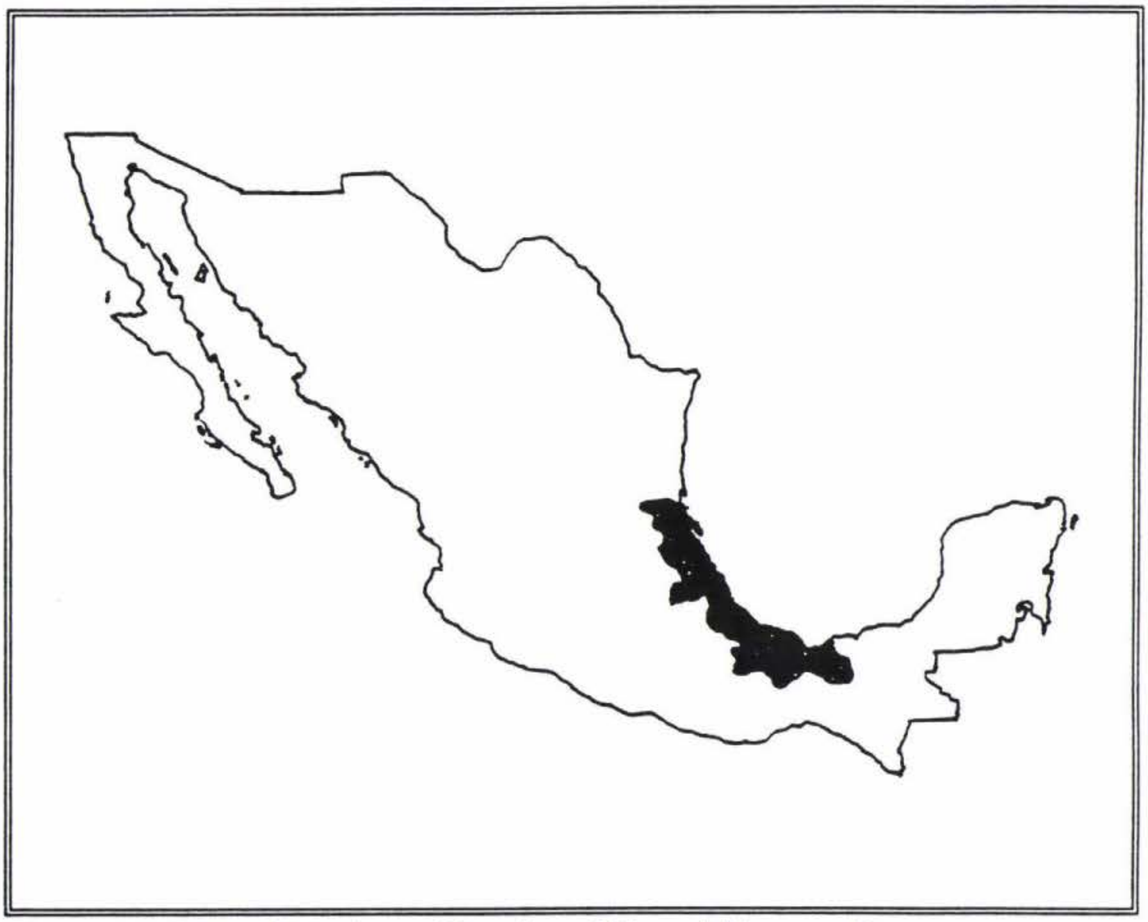


Figure 1.1. Map of Mexico and location of Central Veracruz State.

Eighty percent of the area available for agricultural purposes in Central Veracruz State is dedicated solely to livestock production. All livestock production in this area is pasture-based (Menocal et al., 1992). Fifteen percent of the farmers own sheep, with most sheep production (81%) being used for family consumption (CIEEGT, 1991). The main cattle production system is based on dual-purpose breeds for milk and beef production. The average farm has 90 animals (Table 1.1). The typical herd comprises 62% cows (milk and calf production), 4% breeding bulls and 35% bulls for beef production. Almost two thirds of the farms have between 11 and 90 animals, and these are stocked at an average rate of 0.76 animal units[1] (AU) per ha (CIEEGT, 1991).

Table 1.1. Herd size distribution in Central Veracruz State (Source: CIEEGT, 1991).

Herd size (no.of animals)	Percentage
3-10	5.5
11-30	27.5
31-60	22.9
61-90	11.0
91-120	5.5
121-150	10.2
151-180	2.7
>180	14.9

Six main animal production systems are present in the Central Veracruz State (CIEEGT, 1991) (Table 1.2). Milk production systems provide milk for family consumption or sale to meet family living costs. Calves are usually sold when they are one week old. Beef production is based on weaner calves purchased to be finished to a market weight of 400-450 kg liveweight (LW). With calf production

[1] Animal unit (AU) is the stock unit used in Mexico. It is equivalent to the amount of TND needed by a 400 kg cow producing 4 kg of 4% fat milk.

systems, cows are not milked but instead rear calves until they are sold at weaning. Calf and beef production involves the retention of calves till they reach a slaughter weight. Milk and beef production systems are dual purpose. Cows are milked, to either meet the farm's family needs or provide products for sale, and the calves are grown until they reach a marketable weight (400-450 kg LW). Milk and calf production systems are similar, except calves are sold at weaning. Farms range from 4 to 400 ha in size, with 67% of the farms being between 11 and 90 ha, and 9% having 10 or less hectares of land (Table 1.3; CIEEGT, 1991).

Table 1.2. Cattle production systems in Central Veracruz State, Mexico (Source: CIEEGT, 1991).

Production system of farms	Definition	Percentage
Milk and calf	Milk for sale and family consumption; calves sold at weaning	38.5
Calves	No milking, calves sold at weaning	16.5
Beef	Weaner calves purchased to be finished	11
Calves and beef	Calves retained until they reach slaughter weight	9.2
Milk and beef	Milk for sale and family consumption; calves grown until they reach the market weight	5.5
Milk	Milk for sale and family consumption; calves sold at one week of age	3.7

Pasture is the main feed source for livestock in Central Veracruz State. Supplementation is used by few farmers (Ramos, 1983). There are three irrigation districts in the area (La Antigua, Actopan and Tlalixcoyan-Tierra Blanca), which represent a potentially important source of agro-industry and farm by-products (mainly from rice and sugar cane). Furthermore, there are citrus by-products from the neighbouring San Rafael county and fish meal production is important in Alvarado county. In areas near the mountains, significant animal food resources are derived from by-products of coffee production. There is also an important poultry production sector in the area, which represents another source of by-products for animal feed (Menocal et al., 1992).

Table 1.3. The size of farms (ha) in Central Veracruz State (Source: CIEEGT, 1991).

Size (ha)	Percentage
4-10	9
11-30	22
31-60	22
61-90	22
91-120	8
121-150	4
151-180	4
180-400	7

The potential for animal production from Central Veracruz State is related to dual purpose cattle production from grazed pastures because the largest proportion of farms have this type of system; milk provides regular cashflow. As shown previously, most farms are relatively small (more than 76% of the farms are less than 90 ha and have fewer than 90 animals), and this means that research attention needs to be focused on the small to medium sized farm. Although significant quantities of agricultural by-products can be used as animal feeds, supplements are in fact rarely used for livestock, despite the pronounced seasonality of the herbage feed supply (see Section 1.2.3).

1.2.3. Climate, soils and productivity of tropical pastoral farming systems in Central Veracruz State.

Climatic conditions.

The climate of the region is classified as Af(m)(e) (Koeppen modified by García) (García, 1973), which is warm to sub-humid, with rainfall in summer and a well-defined dry period. The average annual rainfall is 1500 mm, 75% of which falls between May and October. September is the wettest month. The dry period lasts between five and seven months (December to May). The average mean daily temperature is 23.5°C, and this ranges between 14 and 40°C (Figure 1.2).

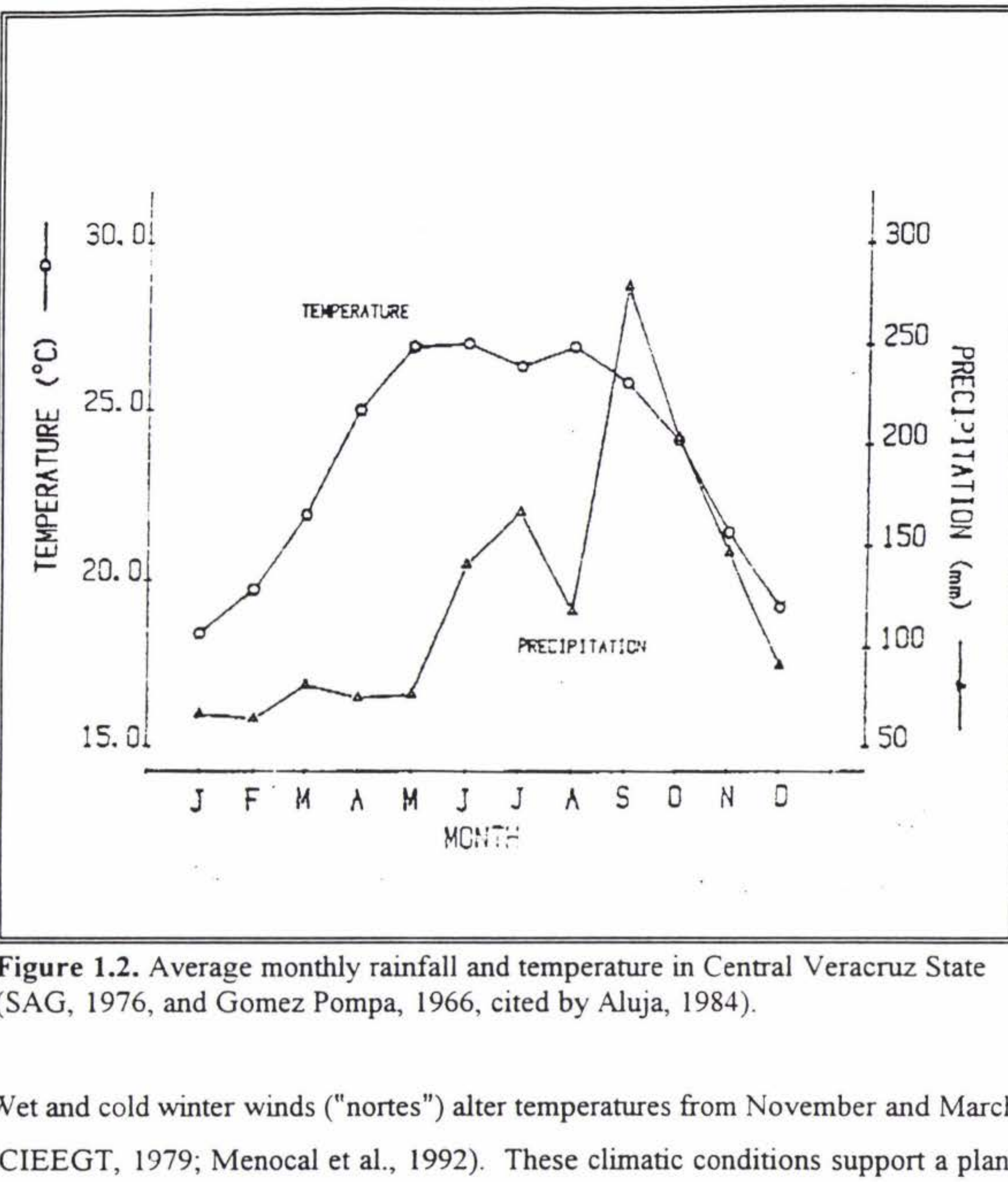


Figure 1.2. Average monthly rainfall and temperature in Central Veracruz State (SAG, 1976, and Gomez Pompa, 1966, cited by Aluja, 1984).

Wet and cold winter winds ("nortes") alter temperatures from November and March (CIEEGT, 1979; Menocal et al., 1992). These climatic conditions support a plant population which is ample and varied. In the coastal regions the chief vegetation is mangrove and palm trees over sandy, waterlogged areas. There are also areas where savannah is predominant. Here a ground cover of grasses and other herbaceous plants has established following the clearing of tropical forest. It is in these savannah areas that livestock production is currently carried out. The area of savannah is constantly increasing. Cleared land is also assigned to the production of crops such as oranges, coffee, bananas, sugar cane, corn and beans (Aluja, 1984; Menocal et al., 1992).

Soils.

The soils of the region are mainly derived from degraded sandstones that originate from rivers. The texture varies from sandy-clay to clay-sandy, and the average clay content is 35-40%. The soil has a hard pan consistency ("tepetate") when is dry. The soil texture results in problems with inadequate drainage and susceptibility to rain erosion (Ultisols) (CIEEGT, 1979). The surface cover contains medium quantities of organic matter (0.8%), with good levels of sulphur but inadequate levels of calcium, phosphorus, nitrogen and molybdenum for pasture production. The pH is acid, and ranges from 4.1 to 5.2. The top soil is commonly 10-30 cm in depth.

Herbage production (and species).

Pasture growth is a function of weather. There are two seasons of pasture production (Figure 1.3). During the rainy season, pasture supply exceeds animal demand (see Chapter Three), but this is reversed during the dry season. This seasonal variability is one of the main reasons for the low levels of livestock productivity in the region (Menocal et al., 1992). The seasonality of animal production reflects changes in temperature and water availability (Aluja, 1984). When temperatures are around 10-15^{0}C, species such as *Paspalum dilatatum* and *Axonopus affinis* (which represent the largest part in the average pasture composition in the region) are much less productive. This happens during December-February (CIEEGT, 1982), while low precipitation restricts growth between January and May (less than 85 mm of rainfall is usual during this period) (Figures 1.2. and 1.3).

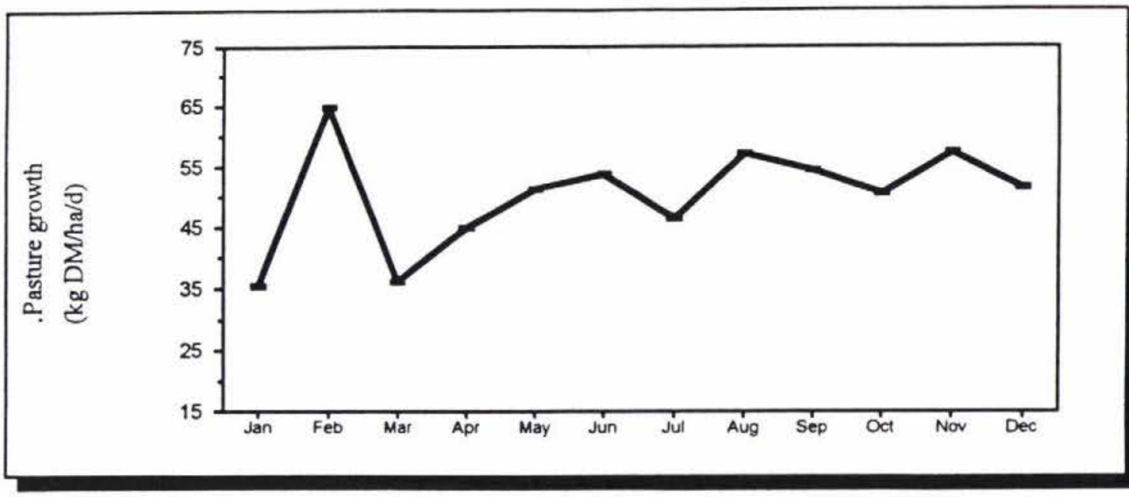


Figure 1.3. Average pasture growth rate in the Central Veracruz State, Mexico (Source: derived from Aluja, 1984).

Another important feature of annual pasture production is that the DM content of the herbage increases between February and April. High DM content, and low protein and digestibility values, both negatively influence pasture quality and thus animal intake and productivity (Waghorn and Barry, 1987). Figure 1.4 shows the proportion of dry matter (DM%), digestible organic matter (% True DOM) and crude protein (CP%) per month for pastures within the region. From this figure, it can be concluded that DOM is not a limiting factor by itself since the values shown are sufficient for good levels of animal production (Waghorn and Barry, 1987). However, CP is an important limitation to livestock production because levels are below those required by growing or lactating animals [at least 74 MJ ME/d and 454 g/MP/d for lactating cows producing 5 kg milk/day, and 74 MJ ME/d and 425 g/MP/d for bulls of late maturing breeds, weighing more than 400 kg and with a liveweight gain of 0.75 kg/d) (AFRC, 1993). This protein deficiency would contribute to low levels of milk and beef production in the region. The largest quantity of grass is available during August and the lowest in March and May. For legumes, most growth occurs in October-November, and the least in July.

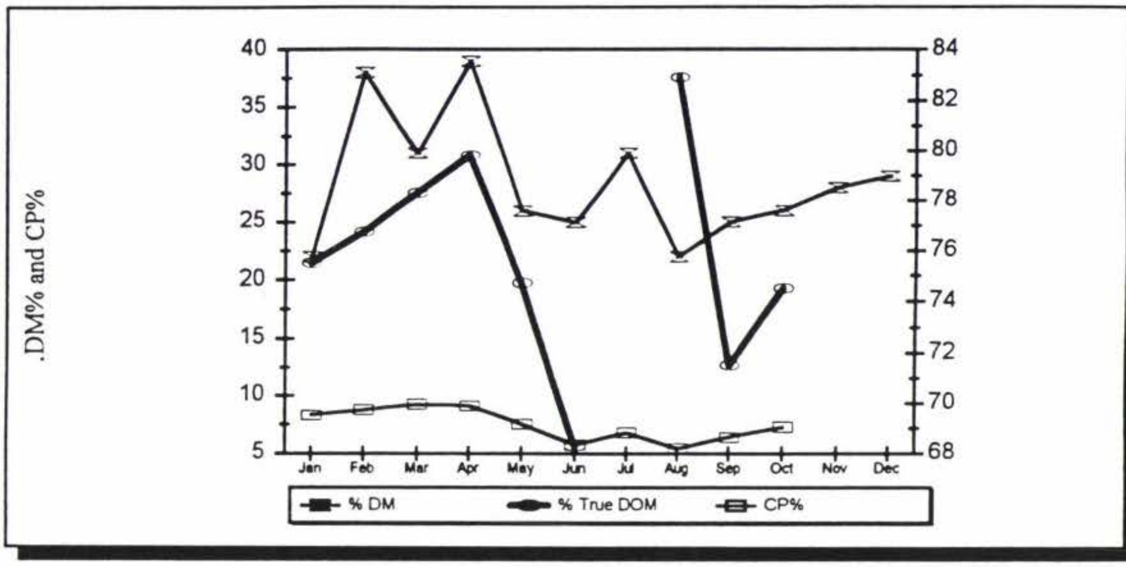


Figure 1.4. Proportion of dry matter (DM%), digestible organic matter (% True DOM) and Crude Protein (CP%) per month for pasture of average composition in Central Veracruz State, Mexico (Some values for True DOM and CP% are missing) (Source: derived from Aluja, 1984).

During the rainy season (from June onwards), the sward is usually undergrazed because most farmers adopt a stocking rate for the farm on the basis of herbage production levels during the dry season. From December to May, both pasture availability and pasture growth decrease because of the low rainfall and low temperature. In many cases this is mainly pasture not consumed by animals during the wet season. Consequently, pasture quality decreases, utilisation is low and animal production declines (Aluja, 1984). It is not surprising then that the most frequent problems for cattle farmers are those related to feed management, and specially grazing management (Table 1.5).

Table 1.5. Most frequent animal production problems in Central Veracruz State, Mexico (Source: CIEEGT, 1991).

Type of problem	Percentage of farms
Pastures	80
Land tenure	8
Reproduction	4
Genetics	4
Animal health	4

The situation is worsened by a poor standard of cattle and land management. In terms of pasture composition, for example, 44% of the paddocks comprise only native grasses (mainly *Sporobolus spp.*, *Axonopus affinis spp.* and *Setaria spp*). These species have lower productivity (both quantity and quality) than improved species. The balance of paddocks have some? improved species, with the most important of these being *Cynodon plectostachyus* ("Estrella de Africa"), *Digitaria decumbens* ("Pangola"), *Paspalum spp.* and *Panicum maximum* ("Guinea"). The average botannical composition of the paddocks (by area) is around 83% grasses, 6% legumes and 11% weeds (Aluja 1984; Menocal et al., 1992). In 1983 Ramos reported that farms with less than 25 animals used native grasses as their main feed resource, while those with more than 50 animals had introduced pasture species indicating that economies of scale influenced investment in pasture development. The use of improved pasture species was also associated with the suitability of topography for cultivation, infrastructure servicing local farms (e.g. roads), financial resources available, and farmers' attitude toward improved pastures and their performance.

Only 10% of the farms are fertilized. While the response to fertilization of native grasses is about 10.5 kg DM per kg of nitrogen, the rate of return on fertiliser expenditure is less than 10% (Göhl, 1981; Aluja, 1984; Menocal et al., 1992).

Seventy percent of farmers undertake weed control (Menocal et al., 1992). The time used by farmers to control weeds and overgrown pasture is significant (23% of the time spent at the farm) (Aluja, 1984). Twenty-eight percent control pasture pests and diseases (Menocal et al., 1992). Supplements are provided by 34% of the farmers, and of these, only 4% do so all the year round. The most frequently used supplement (diet additive) is common salt, followed by crops, crop residues and industry by-products (such as sugar cane and maize straw) (Menocal et al., 1992). The use of concentrates and molasses is not common. A few farmers (7%) use zero-grazing systems, with cut-and-carry grasses such as *Pennisetum purpureum* ("Elefante") or cut forage from roadsides and orchard groves, for livestock feed (Ramos, 1983; Aluja, 1984; Menocal et al., 1992).

The concept of rotational grazing amongst farmers in the region is different from the traditional meaning of intermittent grazing management (where part of the sward is grazed, allowing the remainder to rest and regrow), because the term "rotation" refers either to a situation where animals are grazed in areas with a large forage supply, but without grazing controlled through fencing, or situations where the animals are shifted between areas that are divided by geographical barriers such as rivers, roads and cliffs (Aluja, 1984). A small proportion of farmers (11%) have swards subdivided by post and wire fences. In these cases, rotational grazing occurs with no set time span, with forage availability being the main determinant of the grazing duration in individual paddocks.

1.2.3.1. Animal production.

All livestock production in Central Veracruz State, which is mainly centred around cattle, is based on grazed pasture. The predominant cattle breed is Zebu, with the rest made up of dual-purpose cattle (Zebu-Brown Swiss or Zebu-Holstein cross animals). Breeding programmes with intensive culling regimens are not widely practiced (Ramos, 1983).

Internal and external parasites are the most common animal health problem, but mastitis and tuberculosis also occur. The annual mortality for adult animals is 1% and 11% for calves (Menocal et al., 1992). Most of the farms in the region do not have well-defined anti-parasite programmes, although all farmers in the region have vaccination programmes and 96% give anthelmintics (Ramos, 1983).

Cows are milked manually, and in most cases only once a day. (Twice-daily milking could increase milk yields if better feeding was provided (see Chapter 3)). Calves are usually weaned at between eight and ten months of age (average 8.4 months; Menocal et al., 1992), according to the cow's milk production level. Water for livestock is generally not a limitation (Ramos, 1983).

The seasonality of pasture production (Figure 1.3) contributes to low beef and milk production levels, and this is exacerbated by a low level of management inputs. Nutrition depresses reproductive performance, with long calving intervals (more than 20 months) and a low calving percentage (58%) in herds. Seasonal calving occurs between March and July. Because of low rates of liveweight gain, heifers calve for the first time when they are 32 months of age (Menocal et al., 1992). Aluja (1984) estimated an average birth weight of 30 kg and average daily gain (ADG) of 0.36 kg, with the highest rate being 0.45 kg for heifers. Artificial insemination is used by only 2% of the farmers in the region, 9% used pregnancy diagnosis, and only 13% kept records (Menocal et al., 1992). Poor reproductive records prevent effective management of herd mating.

The low level of grazing technology and capital investment in farm improvements both contribute to low herd productivity. For example, only 57% of cows are milked every year, with an average yield of 3.9 l/cow/day. The typical lactation is seven months with an average annual yield of 846 l/cow. Milk production for herds averages 2.2 l/AU/day and 319 l/ha/yr. Beef production per hectare is only 61 kg/ha/yr (Menocal et al., 1992).

In summary, the low levels of animal productivity in Central Veracruz State are a direct outcome of two main physical factors: first, the pattern of herbage production (which is mainly due to climatic conditions and poor grazing management), and second low levels of animal management and inadequate capital investment on farm improvements. Thus, feed supply and animal demand are poorly matched, which creates consequent problems with the quantity and quality of the herbage offered to animals. Low animal productivity results in low farm incomes, and hence an inability to afford essential farm inputs such as fertiliser and subdivision.

However, other factors also affect animal production levels in Central Veracruz State. These include farmers' characteristics, form of land ownership, the degree of adoption of technology, and the economic infrastructure. These are discussed in the next section.

1.3. The Agricultural Community.

1.3.1. Farmer characteristics.

Sociocultural.

A 1983 survey (Ramos, 1983) of part of the Central Veracruz State indicated that 91% of the farmers were men. A more recent study (CIEEGT, 1991) revealed that about 50% of the farmers of the region are between 40 and 60 years old. Most had obtained school certificate, 35% had not attained an elementary level of education and 17% had graduated with a universitary degree. The educational level of the farmers was related to farm size, with the owners of large farms having higher levels of education. Forty eight percent of the farmers did not read regularly. Twenty-seven percent of the farmers lived permanently on the farm (CIEEGT, 1991), but according to Ramos (1983), at least 33% of the farmers had economic activities outside of agriculture as their main source of income. Forty-one percent of the farmers undertook all the work within the ranch and more than 70% of the farmers visited the farm on a daily basis. However, more than 80% of the farms did not have any records, mainly because they did not know about them (42%), or because they considered records to be unnecessary (43%). In general the owners of small farms wished to continue running their farm without modifications, but 50% of the owners of medium-sized farms and most of the large farm owners wanted to improve aspects of their production system (Ramos, 1983).

When asked what their main problems were: 37% of farmers stated lack of financial support (loans and credit), 29% answered lack of improved animals breeds, 24% said marketing of their products and 2% specified a lack of producer organisation (Menocal et al., 1992).

Farm labour.

An average of 3.1 permanent workers is employed per farm; but only one percent have a consultant (technician) to provide advice on topics such as animal health and reproduction (Menocal et. al., 1992). In 1983, 20% of the farm labour was provided by the farmer and his family, and 80% of the farms used hired labour. Of the farms that employed labour, 55% hired this on a temporary basis (Ramos, 1983).

The number of dual-purpose farming systems, mainly operated by small farmers and ejidos (where the pasture is owned collectivity, rather than by individuals; see Section 1.3.2), is increasing (84% in 1991; Menocal et al., 1992).

This is because the dual-purpose farm provides a source of daily cashflow from milk production to meet the running costs of the farm and family needs (Menocal et al., 1992). Almost 90% of the farmers sold milk in a raw form without pasteurisation. Of the total milk production, 8% is consumed by the farmer and his/her family, 3% by farm workers, 11% is used for cheese production and 77% is sold as it is (non-pasteurised or "leche bronca"). Most milk is sold to an intermediary, who in turn sells it in the nearest town. Some farmers retail milk from their own farm (Ramos, 1983; Menocal et al., 1992).

Regarding buildings and equipment, more than 40% of the farms have stockyards that are used to apply external animal treatments (e.g. dips, vaccinations and castration). Approximately the same proportion have milking sheds, but constructions such as silage bunkers and storage sheds are rare.

Eighty percent of farmers are members of the National Livestock Production Farmers' Confederation (Confederación Nacional Ganadera; CNG), the most important livestock production organisation for farmers; 1% are members of a milk producers organisation and 13% do not participate in any kind of organisation. Few efforts have been made to set up organisations to improve animal production and marketing of produce. Some milk (and beef) marketing problems are related to the physical distance between farms and processors or markets, but others relate to the existence of intermediaries, poor organisation and the low prices paid to the producer (Menocal et al., 1992).

1.3.2. Land tenure.

The basic productive resources in Central Veracruz State are unevenly distributed amongst farmers. Thus, 50% of the farmers possess 19% of the land and 17% of the animals, with the average herd size being 21 animals, while one fifth of the farmers own 54% of the animals and 51% of the land, with an average herd size of 152 animals. Seventy-four percent of the farmers have economic activities apart from cattle production within the farm. These aspects have important implications in relation to possible solutions for farming problems in the region (Menocal et al., 1992), as does the mix of farming enterprises.

There are three main forms of land tenure in Mexico: the ejido, communal and private (Table 1.6). In 1992 the ejidos possessed 57% of the agricultural land and 70% of farm operators were ejidatarios (OECD, 1992). The ejido was established to recreate both the pre-hispanic tenure arrangements of the Aztecs and the system which had prevailed in medieval Spain. To institute an ejido, a group of 20 or more persons apply for a land grant; eventually, a piece of land is assigned to the "ejido" as a legal entity and as a legal owner. The average ejido has around 100 members and 3,000 ha of land. The area of the ejido cropland is divided into plots or parcelas, one per member. The remaining land (pasture, forest, etc.) is communally owned by the ejido, and members have the right to graze animals on the pasture and cut firewood in the forest. Normally, each ejidatario posseses about 10 ha of cropland, but because most ejidatarios subdivide their plot among their sons (though this is illegal), around 60% of the plots are smaller than 5 ha. Only a small proportion (less than 4%) are larger than 20 ha (Yates, 1981). Once the ejido has been established, the plot cannot be rented or sold. If an ejidatario wishes to leave, he must return the parcela to the ejido, which will assign it to someone else, without any compensation for capital improvements. Consequently, there has been no investment in pasture improvement in these areas (such as reseeding, fertilizing, fencing, pests and weeds control, and the introduction of improved pasture species) (Yates, 1981; OECD, 1992).

Table 1.6. Land tenure in Mexico (Source: derived from Yates, 1981; and OECD, 1992).

Land tenure	Number (x1000)	Farm size (ha)		No. of members (x1000)	Land distribution (%)
		Ave.	Range		
Ejido	1719	3000	100-30,000	2000	57
Communities	129	7,400	150-17,000	167	7
Private farms	900	9	1-3,200	900	36

Community ownership is based on long-standing local traditions (Yates, 1981). The estimated 1,231 communities have around 200,000 members and own more than 11,200,000 ha. Most communities are located in the mountainous and remote zones. Fifty percent of the community land comprises forest and wasteland, 40% is pasture and 10% cropland. Land plots within communities cannot be sold or rented.

The private farms constitute four main groups: small farms that are part-time enterprises; irrigated land units of over 25 ha located in the northern states of Mexico; plantation owners of the coastal areas and the south who cultivate crops such as coffee, cacao, bananas, coconut, oil palms and sugar cane; and the cattlemen, mostly in the north, who are highly organised and politically influential (Yates, 1981). Most of the private farms are owner-occupied (more than 90%), and a number also rent additional land for farming. The problems faced by the private farms are related to their size. For instance, small farmers lack the services of an extensionist, because the official extension services are oriented mainly to the needs of the ejidatarios. Furthermore, because of the small size of their enterprises, they do not have access to farm credit. As for the ejidatarios, there are few cooperative organisations to market their products. In contrast, the larger farm owners are able to access bank credit, and obtain technical advice through their farm organisations. Nevertheless, they could not legally run mixed farming operations (crops and livestock); and there was uncertainty with respect to land tenure. This climate of insecurity dicouraged investment in agricultural development and has been one of the main causes of stagnation in Mexican agricultural production since the sixties.

In 1992, the Mexican Congress approved a major change in the Constitution, which allowed the establisment of full ownership rights for holders under the ejido system (the ejidatarios) (OECD, 1992). Individual ejidatarios now have the choice of becoming full owners of their plots or of remaining in the ejido system. They may buy ejido land, rent their plot, hire labour to work their land and associate with other producers and third parties, and they may conclude contracts or joint venture agreements with domestic and foreign partners. Domestic and foreign corporate entities may now also own and operate land for agriculture, livestock and forestry production within the limits established by the law. The net effect of the 1992 reforms is that entry barriers have been removed, economies of scale can be exploited, the operation of private credit markets in agriculture is possible, and restrictions on labour contracts and mobility have been reduced. Certainty of ownership and the ability to conclude long-term contracts has provided both incentives and scope for financing long-term private investments (OECD, 1992). However, the impact of these changes in the Mexican agricultural sector, along with the effects of liberalisation of agriculture, are too recent to be fully assessed.

In Central Veracruz State a study in 1991 found that 56% of farmers had inherited their farm, while 33% had bought their land. The size of livestock farms range from 4 to 400 ha, with 67% of farms being between 11 and 90 ha (Table 1.7).

Table 1.7. Farm size in the Central Veracruz State (Source: CIEEGT, 1991).

Range (ha)	Percentage of farms
4-10	9
11-30	22
31-60	22
61-90	22
91-120	8
121-150	4
151-180	4
180-400	7

1.3.3. Technology transfer practices and adoption of technology.

Several agencies carry out research and extension activities within the Central Veracruz State. However, the Livestock Production, Agriculture and Rural Development Secretariat (Secretaría de Agricultura, Ganaderia y Desarrollo Rural) has the main responsibility for agricultural extension to farmers (Menocal et al., 1992). There are some other local and federal agencies such as FIRA (Agricultural Trusteeship), Firco, the National Commitee of the Water Resource (Comisión Nacional del Agua), INIFAP (National Research Institute of Forestry, Agriculture and Fisheries), and the Agricultural and Fisheries Development Secretariat (Secretaría de Desarrollo Agropecuario y Pesquero) of the Veracruz State government, which give financial support either in the form of credit or technical advice to farmers. The Federal Government provides economic support for livestock production through farmer associations, but inadequate organisation amongst farmers has constrained the successful use of these resources (Menocal et al., 1992).

Research and training is available within the region from the Veracruzana University (Universidad Veracruzana), the National Autonomous University of Mexico (Universidad Nacional Autónoma de México) with its Centre of Research, Teaching and Extension in Tropical Livestock Production (Centro para la Investigación, Enseñanza y Extensión en Ganadería Tropical, CIEEGT), the Colegio de Posgraduados' Centre of Regional Research and Development of Humid Tropical Regions (Centro Regional de Investigación y Desarrollo de las Areas del Trópico húmedo), and the Autonomous University of Chapingo (Universidad Autónoma de Chapingo).

The Veracruz State government is promoting the creation of Groups of Livestock Production Farmers for Technology Validation and Transfer (Grupos de Ganaderos de Validación y Transferencia de Tecnología, Ggavatt) as a means of extension and technology transfer to the producer. These groups are organised by interested farmers who meet on a monthly basis, to obtain and test new technology to improve production.

Despite the size and scope of the infrastructure to provide research, and technical and extension support, the low level of organisation amongst farmers reduces its impact. However, this situation is changing because current government policies promote the transfer of these functions and responsibilities from the government to producers (OECD, 1992; Menocal et al., 1992).

Of those farmers who receive some form of technical advice, this is mostly for the diagnosis and treatment of disease (e.g. veterinary). Advice is provided on topics such as the purchase of animals, parasite treatments and the timing of vaccinations. Technical assistance is most widely used on the larger farms, which have a greater capacity to pay for external advice (Ramos, 1983).

A study in 1991 (CIEEGT) found that 64% of the producers wished to obtain technical assistance, especially in relation to animal nutrition (mainly grazing management) (Table 1.8).

Table 1.8. Technical advice requested by cattle farmers from the Central Veracruz State, Mexico (Randomly selected sample of 89 farms; CIEEGT, 1991).

Type of Advice	Percentage
Pastures (introduction of new varieties, pests, pasture improvements, weeds, cut-and-carry grasses, grazing management, soil management)	40
Reproduction (AI, general reproductive programmes)	15
Management (advice for milk and beef production and calf husbandry)	12
Animal health (parasites, preventive medicine)	11
Nutrition (concentrates)	9
Genetics (genetic improvement, milk breeds).	9
Financial aspects (credits and loans, administration)	3

1.3.4. Overview of factors contributing to poor farm performance.

The most relevant socio-economic features in terms of further development of the agricultural community in Central Veracruz State are farm size, land tenure and the level of farmer organisation. The educational level of the farmers and their desire to improve their production systems are both positively related to farm size. This suggests that improving the education level of small farmers and economic returns from their farms, should be a key goal of agricultural development. One mechanism to achieve this is to offer land ownership structures that provide compensation for capital development. The latter should lead to higher productivity and greater profits to fund education and purchase technical advice. A second goal should be to improve the productivity of farming systems by improving the use of existing resources through improved management. Improved effectiveness, and efficiency, of resource-use should contribute to higher net farm income.

The combination of factors such as one third of farmers have economic activities outside the agriculture as the main source of income, more than 70% of farmers have non-farm economic activities, less than one third of the farmers live on their farms and not all the farmers visit their properties on a daily basis, all suggest that inadequate time and attention is given by many to the farm business. Further, most (80%) farmers do not maintain farm records, and only a small proportion (1%) use the services of a consultant. Even then, the latter is mainly related to animal health and reproduction, rather than farm system design or business performance analysis.

The lack of cooperation amongst farmers to improve the value of animal products and their marketing has important consequences. First, the intermediaries, who buy most of the beef and milk produced pay low prices for these products (i.e. farmers are price-takers). This is exacerbated in many cases by the physical distance between the farm and final consumer. The lack of farmer organisations has also hindered Federal and local Government efforts in trying to improve livestock production systems within the region. Furthermore, the existence of units of around one ha (both ejidos and small farms), which have low levels of organisation and a small economic scale, have added to the difficulties created through low investment in capital improvements. Uncertainty of land tenure has not assisted this situation.

Earlier it was shown that the main physical problems for a typical farm in Central Veracruz State were related to the seasonality of herbage production (Sections 1.2.3.1 and 1.2.3.2). More specifically, herbage supply exceeds feed demand during the rainy season, but is insufficient to meet animal demand during the dry season.

Other problems are created by the predominance of pasture species that are highly susceptible to low temperatures, poor pasture composition, low fertiliser inputs, and a lack of subdivision. Some opportunities to improve pastoral farming in Central Veracruz State are analysed in Chapter Three.

1.4. Differences between animal production in New Zealand and Mexico.

In order to analyse the possibility of implementing New Zealand pastoral techniques in Central Veracruz State, the general characteristics of both economies and environments were compared. By identifying the main differences between New Zealand and Central Veracruz State farming systems, aspects of New Zealand technology which may be utilised can be described.

Basic statistics.

Table 1.9 shows a comparison of the main attributes of New Zealand and Mexico. The agricultural sector in New Zealand is much greater than in Mexico, with 66% of the total area of New Zealand used for agricultural purposes, versus 20% in Mexico. Furthermore, 55% of New Zealand's exports are agricultural products, versus 8.7% of those from Mexico. The percentage of the labour force (Total Civilian Employment; TCE) working in the agricultural sector in Mexico is 25.6% versus 10.6% in New Zealand. This fact, combined with higher levels of animal production indicates that the New Zealand agricultural sector has a more efficient labour force than its Mexican counterpart. Another important difference is the human population density, which in Mexico is more than threefold that of New Zealand (41 vs. 13 inhabitants per sq. km, respectively). This difference has widened through the relative population growth rates during the past ten years (Mexico = 2.3%; New Zealand = 0.7%).

While the GDP (first mentioned on p.2) of Mexico is the thirteenth largest in the world, its GDP per capita is less than US$3,000, which is more than four times smaller than that of New Zealand (US$13,020) (OECD, 1992 and 1994). Inflation has largely been brought under control in New Zealand but remains a serious problem in Mexico, and in combination with the difficulties highlighted in Section 1.3, has contributed to low rates of capital investment in the Mexican agricultural sector.

Table 1.9. Basic characteristics of New Zealand and Mexico (Source: derived from: OECD, 1992; and OECD, 1994).

Characteristic	Units	New Zealand	Mexico
Total area	sq. km.	270,500	1,973,000
Agricultural area (% of the total)	sq. km.	179,071 (66%)	394,600 (20%)
Population			
Total	Thousands	3,434.9	81,249
Inhabitants per sq. km	Number	13	41
Net average annual increase over previous 10 yrs.	%	0.7	2.3
Employment			
Total civilian employment (TCE):	Thousands	1,472	23,403
Of which: Agriculture	% of TCE	10.6	24.6
Industry	% of TCE	24.6	25.8
Services	% of TCE	64.8	49.6
Gross Domestic Product (GDP)			
At current prices and exchange rates	Bill. US $	44	237.7
Per capita	US $	13,020	2,930
Avg. annual growth over previous five years	%	2.7	2.3
Wages and prices (avg. annual increase over previous five years)			
Wages (earnings or rates according to availability)	%	8.1	64.3
Consumer prices	%	9.4	69.7
Foreign trade			
Agricultural exports	% of total	55.0	8.7

Climate.

The relatively uniform temperate climatic conditions of New Zealand allow pasture growth and outside animal grazing throughout the year. Furthermore, these climatic conditions (plus fertiliser inputs) make it possible to use ryegrass-white clover combinations as the basis of pasture composition. High grassland productivity is achieved through modifications to the natural environment including improvements in drainage, tactical application of fertilisers, and the replacement of low fertility demanding pasture species with ryegrass and white clover (Bryant, 1992). In contrast, the semi-tropical climate of Central Veracruz State, with a dry period longer than that usually experienced in New Zealand (5-7 months), provide conditions to support a savannah in which native pasture species dominate the average pasture composition (see Section 1.2.3). These native pasture species are highly susceptible to climatic changes, and have a low productivity in terms of quantity and quality.

Animal production.

The main animal production system in New Zealand is pastoral agriculture (Statistics New Zealand, 1994). Beef cattle are predominant in the far north, dairying in the Waikato and Taranaki regions, and sheep and beef cattle farming in the hill and southern areas of the North Island. In the South Island, the predominant pastoral agriculture is sheep farming, with some beef and dairy cattle. The New Zealand livestock in 1993 comprised around 52 million sheep, 4.6 million beef cattle, 3.5 million dairy cattle animals, and one million deer. The best sheep farms can carry up to 25 sheep/ha and the best dairy farms 4.0 cows/ha. The average flock size is 1,453 (range 1-10,000 or more) (Statistics New Zealand, 1994). Table 1.10 shows a comparison of the main features of animal production systems in New Zealand and Central Veracruz State (see Section 1.2.3.3 for further detail). In New Zealand, the average calving percentage of beef herds is around 82% (Fleming and Burtt, 1991), compared with 58% in Central Veracruz State. Meat production ranges from 85 to

180 kg/ha in New Zealand (Fleming and Burtt, 1991), against 61 kg/ha in Central Veracruz State. In New Zealand, the average milkfat production per cow is 150 kg, which is equivalent to 3,750 l/cow/year (4% milkfat per litre). The average per hectare production is 357 kg milkfat, which is equivalent to 8,925 l/ha/yr on the average dairy farm running 2.38 cows/ha (Fleming and Burtt, 1991). While some of these differences are partially related to management practices, others are related to the type of animals used (e.g. mature weight is less for *Bos Indicus* than for *Bos Taurus*; Friesian cows produce more milk than tropical cattle) (Webster and Wilson, 1986); and some are related to differences in the quality and quantity of herbage produced in temperate and semi-tropical zones pastures.

Table 1.10. Attributes of animal production in New Zealand and Central Veracruz State (Source: derived from Ramos, 1983; Aluja, 1984; CIEEGT, 1991; Fleming and Burtt, 1991; Menocal, 1992; and Parker, 1993).

Characteristic	New Zealand	Central Veracruz State
Animal production system	Sheep and beef, beef, dairy.	Dual purpose cattle.
Main cattle breeds	Friesian, Angus, Hereford.	Zebu, Brown Swiss, Holstein.
Calving percentage (%)	82	58
Average calving interval (months)	12	>20
Meat production (kg /ha)	85-180[a]	61
Milk production per cow (l/cow/year)	3,360	846
Milk production per hectare (l/ha/yr)	8064	319
Lactation length (days)	226	210
Stocking rate (cows/ha)	2.4	0.76

[a] Range from the averages of North Island (NI) hard hill country, NI hill country, and NI/South Island (SI) intensive finishing sheep and beef farms.

Pasture production.

Pasture production differences between New Zealand (temperate) and Central Veracruz State (tropical) are mainly due to local climatic conditions (Table 1.11; see also Section 1.2.3.). Climatic conditions such as light, temperature and moisture, along with soil nutrients and management, determine the species of herbage in a given region. These herbage species will define the conversion efficiency of the solar energy into dry matter, and the quality of the dry matter produced (Cooper, 1970).

Table 1.11. Pasture production differences between New Zealand and Central Veracruz State, Mexico (Source: derived from Cooper, 1970; Göhl, 1981; Aluja, 1984; Waghorn and Barry, 1987; Hodgson, 1990).

Characteristic	New Zealand	Central Veracruz State
Main pasture species	*Lolium perenne, Trifolium repens, Poa annua, Agrostis spp., Dactilis glomerata.*	*Axonopus spp., Setaria spp., Sporobolus, spp., Paspalum spp., Cynodon plestostachyous, Panicum maximum.*
Potential pasture production		
Quantity	22-25 tn DM/ha/yr	30-45 tn DM/ha/yr
Quality (average)	10-25% CP/kg DM. 9-11 MJ ME/kg DM	6-9% CP (native grasses) to 4-20 % CP in improved species. 8-10.3 MJ ME/kg DM.
Response to fertiliser (N) (average)	10 kg DM/kg N	10 kg DM/kg N

The potential conversion of dry matter, at a 3% rate of incoming light, is about 37 t/ha/yr (115 kcal/cm^2/yr of total radiation) in regions with temperate climates such as New Zealand, while in tropical conditions the same potential could be as much as

51 t/ha yr (160 kcal/cm^2/yr) (Cooper, 1970). However, while DM yields of tropical swards may be higher, herbage digestibility and nutrient contents are often lower (e.g. crude protein (CP) is 11-15% DM for *Lolium perenne-Trifolium repens* pasture vs. 6-9% CP in species of Central Veracruz State, Figure 1.4) (Cooper, 1970; Aluja, 1984; Waghorn and Barry, 1987).

Social, cultural and economical (Human environment).

There are important socioeconomic differences between New Zealand and Mexican farmers. One of the most relevant is the form of farm ownership, which is mostly private in New Zealand (Moore, 1990) compared with the ejido and community structures in Mexico (see Section 1.3). Most New Zealand farms are owned and operated as a 'family farm', which means that most labour for the farming system is provided by the farm family (Fairweather, 1987). In 1985, 47% of the farms in New Zealand were owned by individual ownership, 39% by partnership, 9% by a private registered company and 3.4% by a trust (Fairweather, 1987).

Most farmers in both countries do not use the services of a consultant (76% vs. 99% in New Zealand and Mexico, respectively), and off-farm activities are the main source of income for about one third of farmers (30% in New Zealand vs. 33% in Central Veracruz State) (Moore, 1990; Menọcal, 1992). While most farms in both places are less than 200 ha, there is greater proportion of large farms in New Zealand (Table 1.12).

Five Crown-owned Research Institutes (New Zealand Pastoral Agricultural Research Institute, Horticultural and Food Research Institute of New Zealand, New Zealand Institute for Crop and Food Research, Land Care Research New Zealand, and the National Institute of Water and Fisheries) undertake research mainly related to the public good of agriculture. There is also an extensive research and extension infrastructure for farmers in Central Veracruz State (see Section 1.3.3). However, the efficiency of resources use for research in New Zealand appears to be greater because they are managed as business enterprises. Also, New Zealand farmers, and their organisations have a more active role in setting the research objectives than their Mexican counterparts (see Section 1.3.3).

Twenty percent of the money earned by New Zealand in international markets comes from meat sales (Statistics New Zealand, 1994). Within this context, the New Zealand Meat Producers Board (NZMPB) functions to maximise returns to New Zealand meat producers. On behalf of the producers, the board main responsibilities are: Licensing of meat exporters; meat classification and quality assurance, research and development; negotiation of freight services and rates; global promotion; market development and trade access (Statistics New Zealand, 1994). While the board does not directly sell meat, it provides market support through its overseas offices. The board is supported by a compulsory levy on stock; a per head charge collected at the time of slaughter.

One fifth of the total merchandise trade for New Zealand results from dairy exports, which represents more than 90% of the national milk production (Statistics New Zealand, 1994). The main groups of milk products sold are: milk powders (e.g. whole milk powder), cream products (e.g. butter), cheese, and protein products (e.g. casein and caseinates). There are 16 cooperative dairy companies throughout New Zealand, with each of these companies being managed by a board of directors who are elected by farmers suppliers. Cooperative company representatives are accountable to the New Zealand Dairy Board, which has sole responsibility for marketing dairy products. The Dairy Board exports to more than 100 countries annually, which makes the board the largest multinational dairy marketing organisation in the world (Statistics New Zealand, 1994). While there are some small cooperatives among farmers of the region, no comparable organisations to the New Zealand Producers Boards exists in Central Veracruz State.

1.4.1. Summary of New Zealand-Mexico Comparison

The successful New Zealand economy is agricultural-based, with more than half of total export earnings derived from agriculture. Different climatic (and soil) conditions between New Zealand and the Central Veracruz State (temperate and tropical, respectively) contribute to the differences in pasture and animal production as do differences in the type of cattle (*Bos Indicus* v *Bos Taurus*), pasture species and management. Nevertheless, both New Zealand and Central Veracruz State's animal production systems are pastoral-based, and common problems of seasonality of pasture growth and quality exist. While the potential for dry matter production of Veracruz' pastures is greater than in New Zealand, factors such as digestibility, M/D value and crude protein content (%) are lower for tropical pastures. These pose important constraints to animal productivity in Veracruz. The response of pasture to nitrogen fertilisation is similar for both New Zealand and Central Veracruz State, but utilisation of the resultant extra-pasture has been less successful in the latter area.

An important difference between New Zealand and Mexican agriculture is land tenure. Most agricultural land in New Zealand is owned privately, whereas ejido is dominant in Mexico. New Zealand farmers can invest in capital improvements on their lands, with security provided through property entitlements, and this has consequent effects on agricultural productivity.

The level of organisation of New Zealand farmers is greater than that of their Mexican counterparts. New Zealand Producers Boards (Meat, Wool, Dairy) seek to maximise returns to farmers by promoting product sales. No comparable organisations in size and power exist in Mexico.

Finally, it should be stressed that, despite their differences, both New Zealand and Central Veracruz State's animal farming systems share very important similarities, such as the reliance on pasture production, with the consequent seasonality of the feed supply (see previous sections), and the fact that most farms are medium to small in area. These similarities provided a basis for the present study to be concluded using aspects of the farming systems research (FSR) framework. FSR was originally conceived as a tool to help small farmers in tropical regions to enhance the productivity of their farms (Simmonds, 1985). The features of FSR and its applicability as a theoretical framework to the present study, are discussed in Chapter Two (Section 2.6).

1.5. New Zealand pastoral production systems.

As stated earlier, New Zealand farmers fundamentally face the same kind of problems with pasture-based livestock systems as their Mexican counterparts. In general they have been able to minimise them, by using a range of animal and pasture management techniques, and this in turn has improved farm returns and allowed additional inputs (e.g. fertilisers) to be funded. Therefore, it is appropriate to review the techniques and tools used in New Zealand, which may be useful for overcoming the problems in Central Veracruz State.

The success of New Zealand "style" pastoral livestock systems is indicated by a strong export performance in competitive international markets without any form of state subsidy (Bryant, 1992). Furthermore, a heavy reliance on export prices, has forced farmers to devise production systems which have cost structures that are lower than those of their international competitors. This has been achieved by an almost complete dependence on pasture (more than 90% of the annual feed requirements come from this source), the cheapest feed, and minimum use of high energy supplements, hired labour and machinery (Bryant, 1992; Parker, 1993). Annual feed crops and the use of nitrogen fertiliser both provide relatively low cost feed for livestock. Finally, systems have been devised to optimise the use of labour (Holmes, undated; Parker, 1993).

A key factor in pastoral systems is the matching of feed supply with animal demand. This can be achieved by controlling both pastures and animals to ensure the efficient use of feed for animal production. Management must cope with the fact that the animal-plant system is highly interactive; thus small changes in one aspect may greatly affect another (Hodgson, 1990; Smetham, 1993). Decision-making ability with respect to factors such as grazing duration and stocking rate is also a vital component of profitable grassland farming (Gray and Parker, undated).

For a given amount of herbage, animal production per hectare relies on the efficiency with which animals harvest the herbage and the proportion of the herbage grown that is actually eaten by the animals (McMeekan, 1961; Bryant, 1992). This is influenced by the seasonal supply of feed (in New Zealand, up to 80% of annual growth occurs during the late spring-summer period) and the quality of the herbage offered (Bryant, 1992). In broad terms, animal productivity and profitability both depend on the degree to which animal feed requirements can be matched with this seasonal pattern of herbage production. While costs can be minimised by this approach, one negative outcome is that animal production is seasonal, and this has historically resulted in the marketing of commodity, rather than speciality, products. Factors that determine the match of feed supply and demand can be divided into animal and grazing factors (Bryant, 1992).

Animal Factors.

The success of any grazing management relies on a good stock policy (Bryant, 1992; Sheath, 1993). There must be planned and controlled changes in stocking rate, the physiological status of animals and expected target performances to match animal demand with seasonal supply.

Stocking rate (SR) is a powerful tool that can modify animal output per ha when pasture is almost the only feed resource (Bryant and Holmes, 1985). As SR increases, herbage intake per hectare, and pasture utilization and animal output per hectare increase up to a maximum level (Wright and Pringle, 1983). At SRs above the critical point, herbage intake per animal, total annual dry matter production, and the proportion of pasture lost through senescence and decay all decline (McMeekan, 1956; McMeekan and Walsh, 1963; Stockdale and King, 1980; McRae and Townsley, 1980; Hodgson, 1990; Bryant, 1992; Holmes and Parker, 1992). The SR selected affects both pasture composition and quality, through grazing effects on species survival, tiller population density, and the ratio of stem to leaf material (Campbell, 1966; Baker and Leaver, 1986). If overall herbage allowance is high, pasture is underutilised, coarse grasses dominate, weeds may establish and nutritive value is reduced (Greenhalgh, 1970; Taylor, 1976; Marsh and Brunswick, 1978; Smetham, 1993). Under these circumstances, high wastage occurs through tissue death and decay (Korte et al., 1987; Hodgson, 1990). Conversely, if grazing is too hard, inadequate leaf area may restrict pasture growth rates (Brougham, 1973). If herbage allowances are low, pasture is over grazed, poaching and erosion may occur, and herd performance is reduced through inadequate animal health and/or productive performance (Holmes, 1980; McRae and Morris, 1984). Production per animal often shows a curvilinear relationship with SR (Peterson et al., 1965). Thus, gain per unit area increases linearly as SR increases to a critical point, then decreases linearly with further increases in SR (McMeekan and Walsh, 1963; Peterson, et al., 1965; Owen and Ridgman, 1968; Conniffe et al., 1970; Bryant and Parker, 1971; Wright and Pringle, 1983; Ahlborn and Bryant, 1992).

Stocking rate must be adjusted during the season in accordance to feed supply and the required level of animal performance. Changes in farm pasture cover, and the net difference between pasture and feed intake of animals, will reflect these adjustments. Pasture cover needs to be managed with a minimum and maximum level during the year in order to optimise pasture and animal production (Milligan et al., 1987). This can be achieved by modifying SR (purchase or sale of livestock), modifying the timing of various animal physiological states (calving and lambing date, rationing stock, delay weaning) and/or increasing the area available for grazing (Gray and Parker, undated). A calving or lambing date which is too early relative to pasture growth and the stocking date selected will make feed deficits worse. Timing of mating is therefore a powerful way to control animal demand and to ensure that peak intake requirements occur at a time when herbage production is high. The practice of preferentially feeding different stock classes through the allocation of pasture resources is another means of using grazing management to optimise animal production. This requires at least temporary internal fencing (Poppi et al., 1987; Sheath, 1993).

In pastoral systems, animal feed demand is matched mainly to pasture growth rate and pasture cover, but other factors such as animal reserves (body condition) and supplement inputs (hay, silage, nitrogen, meal) are important (Milligan et al., 1987; Matthews, 1993). In New Zealand, concentrates are seldom used because their costs are high relative to other feed sources. Therefore, the common practice when animals are short of feed has been to use silage or hay, or to let them go hungry (Bryant, 1992). The latter option implies that energy has previously been preserved in the animal as extra body condition. In dairy situations achieving extra condition requires either extra feed during the winter, or that cows are dried-off earlier and in a fatter condition (Holmes, undated).

Both the total, and pattern, of feed supply can be altered by the use of fertilizer or supplements (Holmes et al., 1987). The marginal economic return from increased fertilizer inputs can be significant if the SR is close to the economic optimum and fertilizer input is small, but if the SR is sub-optimal, or the fertilizer inputs considerable, there may be no advantage because overall feed utilisation declines (Gordon, 1973; Stockdale and King, 1980; White, 1987).

Grazing management.

A successful grazing management system should provide a supply of nutritious herbage over the growing season at low cost, avoid physical waste of herbage, and inefficient utilization by the animal, and maintain the productive capacity of the sward (Hodgson, 1990). The needs of both the animal and the pasture must be considered, and severe adverse effects on either avoided (Holmes, 1987a). Management techniques assist the effective use of herbage but have relatively little effect on how much is grown (Bryant, 1982; Bryant and L'Huillier, 1986; Hodgson, 1990; Matthews, 1993), but does affect animal intake and animal productivity.

Net herbage accumulation (NHA) is the result of the gross pasture growth rate (PGR) less decomposition (D), as expressed in the following formula (Matthews, 1993):

$$NHA = PGR - D$$

Therefore, net herbage accumulation can be increased either by an increase in pasture growth rate or a decrease in decomposition. Typically, NHA is measured, rather than PGR. Thus, Harvested Dry Matter (HDM) can be expressed by the following formula:

$$HDM = PGR - D$$

where D is decay and:

$$HDM = NHA$$

at the end of the time interval studied. Therefore, it is possible to increase NHA through more efficient use of pasture (e.g. better utilisation) (Matthews, 1993). To achieve this, tools that control the rate of feed use, such as the timing, severity and length of grazing are used. These techniques can be used to control feed surpluses, and to transfer feed from periods of low to high animal responsiveness (e.g. winter rationing of pasture to cows in order to transfer to early lactation in Spring) (Bryant, 1992). There must be a balance between SR (demand for feed), and the ability of the pasture to supply this above a minimum level of quality. Managing pasture quantity and quality becomes more important as seasonal and annual variation in pasture production increases and the intensity of farming increases too (Korte et al., 1987; Matthews, 1993; Sheath, 1993). Within certain boundaries (1,200-2,500 kg DM/ha, or 3-4 to 10-12 cm of height for temperate pastures) grazing management has a significant role in the allocation of pasture and the maintenance of its quality. Low pasture quality restricts animal weight gains (Waghorn and Barry, 1987; Sheath, 1993).

The amount of legumes in a sward can be used as an indicator of its quality. Legumes differ from grasses in terms of the effect of maturity on their structural and chemical composition and digestibility (Warghorn and Barry, 1987). Most legumes maintain a higher leaf:steam ratio with advancing maturity compared with grasses and their leaves retain a greater digestibility than grass leaves at a comparable stage of maturity (Warghorn and Barry, 1987). In broad terms, the legume (clover) content of a sward will increase as SR increases (Stockdale and King, 1980; Holmes and MacMillan, 1982). The converse occurs at low SRs, mainly due to shading by taller growing grasses in the sward.

Another mechanism to manipulate pasture quality is to use a mixture of animal species for grazing. If cattle dominate grazing a greater quantity of legumes and fewer herbaceous weed will be present compared with sheep-only grazing (Sheath, 1993). These differences in grazing behaviour can be used to prevent uneven grazing within a sward. Differences in animal species and short-term grazing pressures in order to modify pasture species have a larger affect than the general all-year method of grazing (e.g. intermittent v. continuous) on sward composition and quality (Sheath, 1993).

Grazing methods

In most circumstances, continuous stocking and rotational grazing management should be regarded as complementary rather than alternative procedures, and used in combination to make efficient use of sward resources. For instance, the use of continuous grazing systems avoids difficulties in planning field allocations in advance, but reduces flexibility to react to unexpected climatic variations, and reduces the potential for conservation programmes. Nevertheless, continuous grazing can be used to feed animals *ad-libitum* when pasture production is higher than animal demand (e.g., spring) (Thompson and MacEwan, 1983; Gray and Parker, undated). Conversely, the use of some form of intermittent grazing management can help in the forward planning of feed resources and is particularly useful for feed rationing during periods of low pasture growth (e.g. winter) (Hodgson, 1990). Full benefits of 'controlled' rotational grazing are obtained in association with increased stocking rate (McMeekan, 1961). These benefits are generally not the consequence of more grass produced under rotational grazing, but of better herbage utilisation (McMeekan and Walshe, 1963; Campbell, 1966; Kissock, 1966). When herbage mass reaches certain low levels during continuous grazing (around 1000 kg DM/ha for temperate pastures), such as in times of drought or in winter, grazing animals find it impossible to maintain intake by increasing grazing time to compensate for small bite size even with an increased rate of bitting (Jamieson and Hodgson, 1979). Under these conditions animal net growth and intake can be increased by changing to a rotational system with longer intervals between defoliations (Chapman and Clark, 1984).

The choice of grazing management should therefore not be influenced by erroneous assumptions about the anticipated effects on herbage and animal production. It is best made to fit the layout and access routes of a particular farm, the constraints set by other enterprises and the aptittudes of the farmer (Hodgson, 1990).

1.5.1. Summary of New Zealand grazing techniques.

The review of techniques used by New Zealand's farmers to overcome problems associated with the seasonality of pasture production has highlighted some interesting points. First, animal production itself becomes seasonal when herd feed requirements are matched with herbage growth. The latter is achieved through planned modifications to stocking rate (purchase/selling dates for animals), the physiological status of the livestock (birthing and weaning date), condition score/rationing stock, and by setting animal production targets (liveweights, milk production levels). Second, grazing management techniques are less influential than animal factors on overall system performance. The main role of grazing management techniques is to achieve effective and efficient use of the pasture grown. Third, differences in animal production due to the method of grazing management are small.

Therefore, in most circumstances continuous and intermittent grazing management should be seen as complementary tools. Grazing management techniques, however, are useful for allocating herbage to different times of the year, optimising herbage utilisation and maintaining sward quality (amount of green leaf and legumes in the sward).

The New Zealand experience suggests that the objectives of any grazing management policy should include the following: keep herbage growth rates and quality at their maximum in order to ensure good animal performance; avoid under-utilization of pasture growth by integrating grazing techniques and stock classes (sheep and cattle); and where possible conserve surplus pasture as hay or silage to maintain pasture quality during periods of high pasture growth; avoid over-grazing during dry conditions by the use of intermittent grazing techniques; ensure pasture leaf area is maintained at a level to maximise pasture growth; maintain average pasture cover in the range of 1000- 2500 kg DM/ha and avoid pasture damage when soils are waterlogged through excessive pugging.

Finally, pasture management must be flexible. The primary objective of management for specific times of the year in order to meet the needs of pasture and animals must be identified. This will often required a compromise between animal and pasture factors. A fuller discussion of the application of the techniques reviewed here is provided in Chapter Three.

1.6. Conclusions to Chapter One and Thesis Outline.

The nature and problem of pastoral agriculture in Central Veracruz State, Mexico, have been presented in this Chapter. The possibility of implementing some elements of New Zealand grassland technologies to rectify the current low levels of animal production in Central Veracruz State were explored. It was concluded that

Mexican and New Zealand farmers confront similar problems with respect to the seasonality of pasture production and its quality, and that New Zealand farmers apply a range of animal and pasture management techniques, to achieve much higher levels of animal output.

Socioeconomic aspects such farm size, land tenure and poor organisation and low education levels of farmers, and lack of capital all contribute to the low productivity of livestock farming systems in Central Veracruz State. Mechanisms to address these problems, which in many cases need to be resolved before improving pasture productivity, are discussed in Chapter Two. In addition, the adoption of New Zealand grazing technology will require significant changes to the management processes used on Central Veracruz State farms. Literature related to the farm management process and its stages (planning, implementing and control), modelling of agricultural systems and features of farming systems research, are therefore reviewed in the following Chapter.

In Chapter Three the development and application of a spreadsheet model for analysing pastoral farming systems in CVS is described. The analysis includes a physical and financial evaluation of some New Zealand pasture technologies on a medium-sized case farm. In the final chapter (four) conclusions are drawn about how the productivity and financial performance of CVS farms could be improved. Attention is also paid to describing the data that needs to be collected from farms to allow a more objective and comprehensive analysis of pastoral farming systems.

Chapter Two: Literature Review: Farm Management and Computer Modelling

2.0. Introduction.

In the first Section of this Chapter, the farm management process and the functions of planning, implementation and control are reviewed. In the next Section the data needed to construct a feed budget, to aid the planning and control of grazing, is outlined. The use of models as decision support (DSS) tools and spreadsheets for feed budgeting are then reviewed. The Chapter provides a theoretical background for Chapter Three, where the feasibility of New Zealand pasture management techniques in Central Veracruz State are analysed using a spreadsheet feed budget and financial models.

2.1. Farm Management Processes.

Farm management is (modified from Dillon, 1980):

"... the process by which limited resources (land, labour and capital) and situations (market, weather, Government policies) are manipulated by the farm manager under a given environment (social, economic and physical) in trying with less than full information to achieve his/her goals..."

The farm management process involves three different functions: planning, implementation and control (Bohlje and Eidman, 1984; Parker, 1992). Planning is deciding in advance, with the best information available at the time, how to allocate limited resources. It also provides benchmarks or standards to "control" against. An important purpose of planning is to contribute to the achievement of the farmer's goals, by determining objectives and how to achieve them. Planning can be used to forecast scenarios ("what if" questions), to make marginal changes to the current farm system or to design an entirely new system. Factors influencing planning include personal objectives (profit, risk, etc.), available resources and their characteristics (land, labour and capital), technical constraints (e.g. availability of technology), institutional constraints (e.g. legal requirements), and personal preferences (e.g. attitude towards risk).

Organisation or implementation the second function of management, involves the grouping and structuring activities to achieve predetermined objectives. It implies the ordered allocation of resources in a manner consistent with the objectives and within the environmental constraints of the farm system. As such, implementation involves the timing of the events, use of appropriate materials and consideration of work methods.

Control is the function of evaluating outcomes, and if required adjusting activities, to ensure that planned objectives are achieved. Control is dependent on planning, because it is through planning that targets are established (e.g. physical, financial, quality) against which actual outcomes can be assessed. If actual values fall outside a predetermined band of 'acceptable' performance, a decision should be taken to rectify the cause(s) of the deviation. This may involve revising or rejecting the original plan. Control can be applied at three different stages: *ex-post,* based on historical records; current using real-time information systems; or *ex ante*, alterations to plans in anticipation of likely future deviations. Control based on historical data is reactive and often too late to impact on farm performance. Proactive control (i.e. *ex ante*) on the other hand, allows the manager to anticipate potential problems and take remedial actions. This is a critical aspect of successful grazing management.

Some differences in production can be explained by farm management factors such as the farmer's managerial ability and goals, and his/her equity in the business. Hodgson (1990) believed that farm profitability could be increased by more effective use of pasture and animal resources, through proper planning, implementation and control of grazing management. The challenge to management is to balance animal feed requirements with seasonal, and annual fluctuations, in pasture production (see Sections 1.2.2. and 1.4. in Chapter One). Factors that should be considered when planning a pastoral farming system include (Parker, 1992; Matthews, 1993): the farmer's characteristics (strengths and weaknesses); farm constraints, including those related to land, labour, and capital; technical constraints, including the availability and capability of machinery and other technology; biological factors such as pasture cover targets within the year; and institutional constraints, including legal requirements and market characteristics.

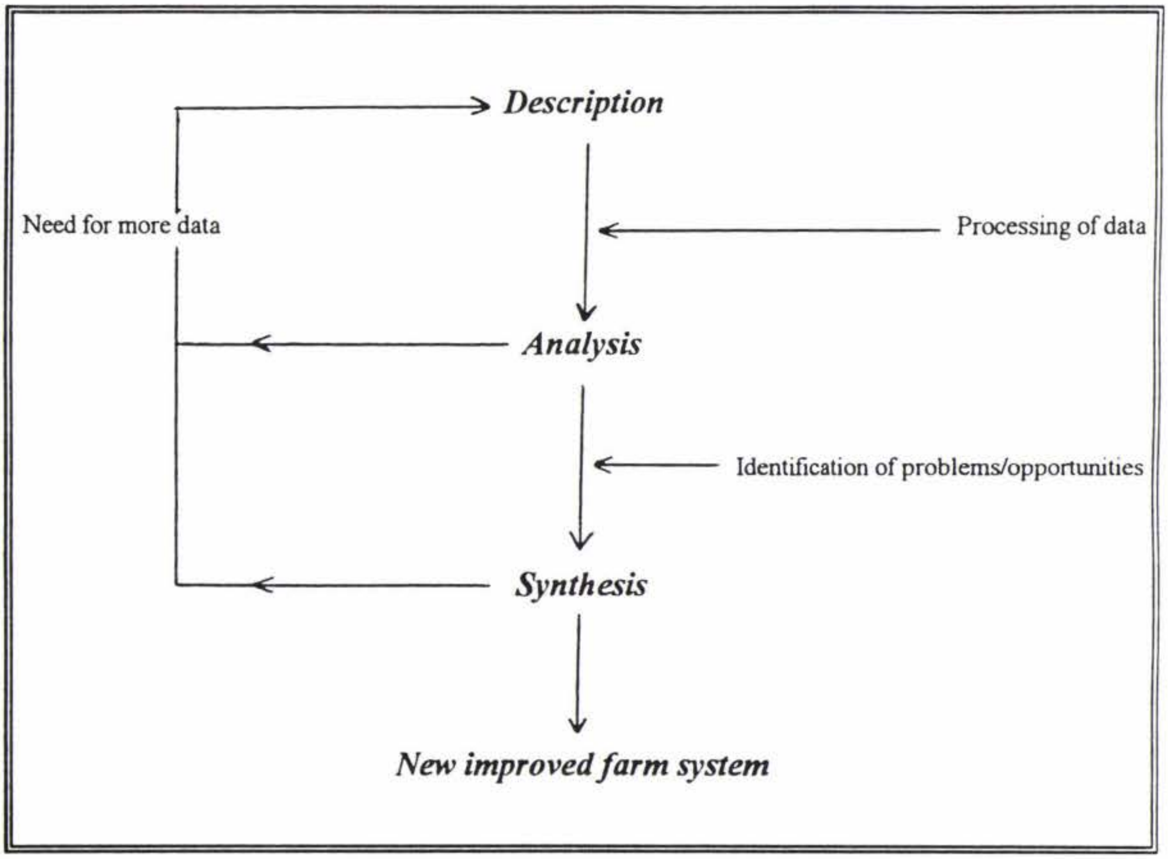
The control of pastoral farming systems requires a monitoring system to be established to record changes in variables that can be controlled. These include biological factors; marketing issues (prices, demand/offer, quality); and financial factors (bank interest rates). To monitor biological aspects of systems, records can be obtained for animal liveweight or condition score at certain times of the year (at the start of calving and at mating time in the autumn), and for the amount and quality of feed on the farm at certain key times within the year (e.g. at the start of calving) (Bryant, 1992).

2.2. Data required for feed budgeting.

To design and implement the best possible programme for an individual farm, data from the farm should be collected, interpreted and presented in a clear way. This involves three steps: understanding or describing the system, analysing the data available to define the problem and/or to identify opportunities for change, and the design and evaluation of alternative systems (Figure 2.1; Parker, 1992). Understanding the farm system is a critical first step because it enables the manager to describe the resources, explain how these work together, and predict what is likely to happen if a change is made (Parker, 1992).

Data analysis involves the collection and processing of data into information that can be used for decision making (e.g., representing pasture cut data as pasture growth information for use in a feed budget). The information derived can then be compared with that from other sources such as scientific research reports, neighbouring farms, historical records, and previous plans.

Figure 2.1. Schematic representation of steps followed in studying farming systems (Parker, 1992).



The purpose of such comparisons is to identify problems and opportunities for the farmer, and to confirm the accuracy of the data. This process may identify a requirement for additional data collection (Parker, 1992). Once the problem has been

been correctly diagnosed, a "new" modified system can be designed and evaluated by using techniques such as feed budgeting.

There are two major elements in a pastoral livestock system: feed supply and feed demand (see Section 1. 5). Both are influenced by management (Parker, 1992). Within the farm management process previously described, feed planning techniques are a useful way to improve the pastoral livestock system by achieving more effective use of feed, reducing risk and controlling the enterprise (Milligan et al., 1987). Both feed demand and supply should be estimated, monitored and adjusted throughout the season. Feed planning for pasture systems is complicated by wide variation in pasture growth rates and feeding value, and changes in animal weights and production (Milligan et al., 1987; Parker, 1992). Nevertheless, feed planning provides an objective basis for controlling the feed resource and determining the relationship between pasture growth and animal requirements over time (Parker, 1992).

Milligan et al. (1987) described three main feed planning tools: feed budgeting, feed profiling and grazing plan. Feed budgeting was defined as "...a plan that matches the supply of pasture and other feeds with the requirements of livestock in the medium term (3-6 months)...". A feed profile was described as "...a planned match of pasture supply (and other feeds) and animal feed demand over the long term (year)...". A grazing plan was explained as a "...short term plan...involving decision of how long mobs of animals should graze particular paddocks...(in order to)... determine rotational lengths...". In New Zealand, a feed profile is used to study annual (i.e. strategic) stock policy decisions such as stocking rate, birth dates, disposal dates and target performance. Feed budgets are used in tactical management to identify periods of pasture surplus or deficit for planning periods of one to three months. Day-to-day, or operational, grazing plans allow the adjustment of feeding to recommended levels through rotation lengths, grazing severity and animal demand (Milligan et al., 1987; Parker, 1992; Gray and Parker, undated). A feed profile can be used to assess the likely consequences of alternative future farm plans (i.e. the farm planning process). Furthermore, they can be used as a guide against which livestock production can be compared as the plan is implemented (control process) in order to modify system performance so that production targets are achieved.

The first step in feed planning is to calculate feed supply and demand (Table 2.1). Feed demand can be expressed as kg DM/ha on either a daily or annual basis, and is calculated from the energy needs of all animals on the farm to meet given production targets. Targets can be expressed in terms of liveweight change, milk production, condition score, or a combination of these. Because feed demand is usually calculated for mobs of animals, the average values for animal production within a mob are calculated.

Table 2.1. Feed supply and demand in a pastoral livestock system.

Feed demand (kg DM/ha/d)	**Feed supply (kg DM/ha/d).**
Daily and/or monthly average requirements in quantity (kg DM/ha/d), and quality (ME and CP or MP) of every class of animals within the mob. Determined by: Stocking rate, livestock classes and numbers, animal species and breeds; physiological status (e.g. pregnancy stage, lactation stage, age); production targets (liveweights; liveweight gains; condition score; birthing dates).	Daily and/or monthly average amount of feed supplied in quantity (kg DM/ha/d), and quality (ME and CP or MP) to the animals. Determined by: Pasture growth rates (climatic conditions such as temperature, rainfall, evapotranspiration, season of the year); soil types and use of fertilisers; pasture species; pasture cover, feed quality (determined by pasture species, physiological status of the plant; and sward composition); and supplementary feeds.

Ideally, feed demand should be considered not only in terms of DM, but also in terms of diet components (e.g. metabolisable energy (ME) and crude protein (CP)) to meet

desired production targets (Milligan et al., 1987). Simple spreadsheet feed budgets usually do not have this capacity, but this is often a feature of more sophisticated fixed programming models such as GRAZPLAN (Stuth et al., 1993).

Feed supply is a function of pasture growth rate, pasture cover, pasture conservation and supplementary feed use (Table 2.1). Pasture growth rate information can be obtained from several sources (e.g. research stations, simulation models, estimation from changes in pasture cover and/or pasture consumption, or *in situ* measurements). When forecasting pasture growth rates, local factors such as climate, soil fertility, pasture type and particular paddock conditions need to be considered (Milligan et al., 1987). Grazing management and stocking rate may also affect sward characteristics and hence pasture growth (see Section 1.4 in Chapter One).

Pasture cover is the average pasture mass on the farm (kg DM/ha) at a particular point in time (Milligan et al., 1987). It is calculated by multiplying the pasture mass on each paddock by the paddock area to obtain the total pasture on the paddock and summing this value across all paddocks. This total, divided by the effective grazing area, gives the average pasture cover (Milligan et al., 1987; Parker, 1992). Average pasture cover reflects the difference between pasture growth and pasture consumption, and is a function of stocking rate and livestock performance, as well as environmental conditions. A knowledge of average pasture cover values at critical times of the year (e.g. at calving/lambing) is useful when planning pastoral systems (Milligan et al., 1987; Gray and Parker, undated). Pasture cover should be maintained within certain limits (1000-2500 kg DM/ha under New Zealand conditions) to support subsequent growth and to keep a reasonable level of quality (Hodgson, 1990). The pasture cover associated with a feed plan will indicate if desired levels of pasture allowance or post-grazing pasture mass for planned pasture intakes can be achieved. Thus, pasture cover should be regularly monitored because it is an effective indicator of how a grazing plan is working out (Milligan et. al., 1987).

Supplementary feeds can be introduced in a feed budget on the basis of their feeding value relative to pasture. The derived 'pasture equivalents' allows different types of supplementary feed to be standardised. Pasture conservation to control pasture surpluses, and transfer feed into periods of deficit, can be shown by a feed removal from the system (Milligan et al., 1987). This feed can be re-entered into the budget later in the planning period by deducting storage and feeding out losses. Because the application of nitrogen fertiliser increases pasture growth, it can be considered a form of supplementation, and is treated as feed input in feed budget calculations.

If pasture production is likely to exceed animal demand, the emphasis in feed budgeting is to manipulate the balance between grazing and conservation (included deferred grazing) in order to control sward conditions (Holmes, 1980; McCallum, 1991; McCallum et al., 1991). Conversely, when feed demand is likely to exceed feed supply, feed planning should be used to ration limited pasture supplies through grazing management in the most effective way (Hogdson, 1990). If a deficit is detected, the cost of supplementing animals should be evaluated against the effect of lowered production by reduced feed intake. If a surplus is detected, the effect of increasing feed intake or using the surplus in another way (e.g. conservation, buying stock) should be evaluated (Milligan et al., 1987; Hodgson, 1990). In addition, feed budgets can be used to plan the timing of livestock sales and purchases, and the feeding supplements (Milligan et al., 1987; Hodgson, 1990). Pasture cover and animal performance should be monitored at least monthly to detect if pasture cover and animal production values differ from those forecasted in the feed budget. This provides an objective basis for adjusting existing management policies (e.g. hay/silage feeding, selling/drying-off animals) (Milligan et al., 1987; Hodgson, 1990).

Because of the time needed to execute calculations, such as those outlined above (particularly when several classes of stock are involved and with different sets of pasture growth rate data), computers provide a cost-effective way to simplify and speed up the feed budgeting process (Milligan et al., 1987; Hodgson, 1990; Parker, 1992; Crawford and Gray, undated).

2.3. Computer Models as a Decision Support Tool.

2.3.1. Introduction.

Agricultural systems are complex and dynamic. To gain an understanding on how they function and how they can be manipulated requires the use of a range of techniques. This understanding will help researchers and farmers to plan and control food and fibre production (Spedding, 1976).

Computer models as an aide to understanding agricultural systems were developed and promoted during the 1960s and 1970s (Rickert, 1988). A model is an abstraction of existing knowledge about a system. The latter comprises components, a boundary, inputs and outputs, and interactions between these items (Speeding, 1988). Models are used in systems research to explain complex relationships between components in a logical way. There are several types of models. They may start as mental or verbal models, and afterwards be transformed into a diagrammatic or mathematical form. During this process, an improved comprehension of the system is obtained, and areas within the system where knowledge is incomplete are diagnosed (Ebersohn, 1976). Thus, assembling a model helps to identify where gaps in knowledge exist. Furthermore, they also indicate where the greatest opportunity for future performance gains are likely to be made, by allowing forecasts to be made of how the system is likely to operate under varying circumstances (Brockington, 1979; Penning de Vries, 1977; Spedding, 1988; Rickert, 1988; Seligman, 1993).

At the early stages of model development (1960s and 1970s) great expectations were held about the capabilities of simulation modelling in agricultural science. Many of these have yet to be realised because of the difficulties in modelling the complex relationships (mainly non-linear) that exist in agriculture and the absence of experimental data to describe many fundamental input-output relationships present on farms (Parker et al., 1994). Current expectations about the impact of modelling in grassland science or in management of the grassland resource are probably more realistic (Seligman, 1993) and have been assisted immensely by the development of computer technology.

A biological simulation model enables a preliminary assessment of the effects of new conditions or new techniques on system responses to be made. Furthermore, it provides a means to analyse system behaviour and therefore the ability to distinguish between sensitive and stable properties of biological systems. However, computer models cannot predict the future; supplant experiments designed to discover such things as biochemical pathways, ecological processes and site-specific system responses to manipulation; or substitute subjective assessment and value judgements that enter into many critical management decisions (Seligman, 1993).

2.3.2. Purpose of Modelling.

Models help the user to gain an understanding of a particular aspect of a real object by simplifying reality. An essential element in their construction is a degree of abstraction of particular features of the object modelled (Brockington, 1979; Spedding, 1988; Penning de Vries, 1987).

In farm management research many simulation models have been developed to quantify outputs from alternative strategies for resource use or the application of technologies to enhance production in pastoral systems. These vary from simple spreadsheet models to larger simulation models such as STOCKPOL (McCall, 1993). They can be used to make predictions that save money, time and work. While simulation models cannot completely substitute for field experimentation, they can be used to explore relationships that cannot be explored in any other way bacause expense is prohibitive or where non-destruction or non-disturbance is essential. The most common objective of management models is to investigate the effect of short-or long-term management options on output characteristics of the system (Brockington, 1979; Bywater and Cacho, 1994). Other applications of modelling are to help in the processes of problem identification and problem definition, assist the organisation of thinking and hypothesis formulation and facilitate the setting of research priorities (McCall, 1984; Korver and Van Arendonk, 1988). They can also produce outputs to act as a standard against which comparisons with the real world can be made, and provide a means to communicate and test thoughts and ideas (Stuth et al., 1993). Finally, but not least, they can be used to make predictions about system performance.

2.3.3. Different types of models.

Brockington (1979) classified models into four categories according to their function and capabilities:

i) Input/Output versus Mechanistic: The main feature of an Input/Output model ("Black box model") is that output changes are shown without describing the processes (physical or biological) by which these changes occur. Conversely, a mechanistic model represents the changes in outputs due to the effect of physical or biological processes (output variations are predicted for changes to production).

ii) Simulation versus Optimisation: The main goal of optimisation models is to look for the best possible answer given specific objectives and constraints about elements and processes within a system (e.g. Linear Programming). Simulation models are designed to provide an understanding of system performance for general purpose applications. In an overall system study, investigation and description of system behaviour is an essential prerequisite to devising optimum management strategies. Simulation analysis will therefore often precede the application of optimization techniques.

iii) Static versus Dynamic: A major feature of systems containing living components is that they are time-dependent. Consequently, it is impossible to describe them adequately without reference to the time dimension. Such systems are represented by dynamic models. In contrast, static models represent situations where changes occur at one point in time (Anderson, 1972). Feed budget models are dynamic.

iv) Deterministic versus Stochastic: Deterministic models have only one predetermined consequence for a given set of controlling conditions; they do not consider variation or risk. Stochastic models include the inherent variability associated with biological phenomena, which makes these models more suitable for describing biological systems than deterministic models. Despite this, deterministic models have dominated the field of simulation modelling in agriculture, including feed budgeting, primarily for two reasons. First, the data available for model construction is usually not complete; and second, variability is more difficult to model than a single (often average) situation. Therefore, it may be inappropriate to attempt to build complex stochastic models, when an inadequate base of quantitative data is available.

2.3.4. Strengths and weaknesses of modelling.

Mathematical models may avoid the need for large and expensive field experiments, with consequent savings in money and time. However, users of models (farmers, researchers, advisors, consultants, policy makers, extension agents) must appreciate the limits of modelling, which are created mainly by the complexity of the systems that they are trying to represent (Seligman, 1993). Dent and Thornton (1988) outlined some theoretical difficulties associated with the use of models. First, the levels of variability in the real system over long periods, and the variability generated through simulation, are usually unknown. Second, in most cases models are built by using data and information generated from experimental stations. Production levels obtained from these stations are rarely equal to those obtained on-farms, because of, among other reasons, differences in the resource base of the farmer (e.g. presence or absence of pests, diseases and nutrients; different soil and climate conditions; and differences in the timing of management decisions). Therefore, differences between experimental and commercial production levels need to be considered in model development and use.

A suitable agricultural production model should have some measure of portability between alternative sites (Dent and Thornton, 1988). This implies a structure based mainly on causal mechanisms. Total portability, while a desirable feature of an agricultural model, is not likely to exist, mainly because the data from which the model parameters are estimated and never measured in a totally specified environment (Dent and Thornton, 1988).

2.3.5. Model evaluation.

Model evaluation is an important factor within the whole modelling process. It includes both verification and validation (Wright, 1971; Anderson, 1974; Baker and Curry, 1976).

Verification involves checking that the model is performing all the calculations correctly (e.g. calculation accuracy, incorporation of factors in different equations). Validation is the procedure used to assess whether the model adequately mimics the behaviour of the system under study. This is often done by running the model with an independent set of data and comparing the model output with actual outcomes. Models can be validated at the overall system level and the component level by using empirical statistical tests, rational logic, or the degree to which the model meets its intended objectives. A combination of these approaches may be used to validate a model (McCall, 1984).

2.3.6. Summary.

Models have been used to summarise and understand the knowledge that exists for a particular system. They can be used to explain complicated structures, gain understanding of those structures, and identify areas where existing knowledge is weak. Additionally, they can be used to identify future opportunities and analyse the response of a system to a series of predetermined changes. Models can be used to identify farm specific management packages, and to predict production levels for alternative input combinations (McCall et al., 1994). Additionally, such responses can be simulated to estimate production variability and hence the risk associated with alternative packages. A model is also independent of seasonal conditions or the availability of measurement equipment that often slow the progress of field trials (Dent and Thornton, 1988).

Computers enhance the possibilities for modelling by increasing the speed of calculations and storing data for future retrieval and manipulation. Nevertheless, the use of models in agriculture still has limitations, both because of the complexity of the relationships between components of an agricultural system and their inability to completely substitute for experiments on some biological processes. The usefulness of models in farm management arises from their role in extension and simplifiying real-life events. Their 'diagnostic' features allow the analysis of alternative farm management options in terms of likely outcomes and other system effects. There are a range of model types that differ in their characteristics and objectives, and this enables models to match the particular needs of the analysis required.

2.4. Decision Support Systems (DSS).

Decision support systems are about 25 years old and have proven themselves by providing businesses with substantial savings in time and money (Mittra, 1986). Keen and Scott-Morton (1986) defined a DSS as "...interactive computer-based systems, which help decision makers utilise data and models to solve unstructured problems". Mittra (1986) provided a similar definition, "...computer based information system that help a manager make decisions by providing him or her with all the relevant data in an easily understandable form...". While both definitions suggest that DSS are computer-based, this not need be the case. A manual set of decision rules that systematically enable a farmer to work through a decision could be regarded as providing decision support. Therefore, a more appropriate definition of DSS would be:

A set of systematic decision rules to help a manager use all relevant data to work through a decision. This set of rules could be incorporated in an interactive computer-based information system to assist the decision-making process by providing data in an easily understandable form.

Two main characteristics of decision support systems can be identified: they incorporate both data and models and they are designed to help managers in their decision process for semi-structured (or unstructured) tasks [an unstructured problem is one in which none of the three phases of the problem is structured (intelligence, design and choice)] (Keen and Scott-Morton, 1978). Decisions where some, but not all, of the phases are structured are called semi-structured; they support rather than replace managerial judgement; and their objective is to improve the effectiveness of the decisions, not the efficiency with which the decisions are being made (Mittra, 1986).

Some characteristics and benefits of decision support systems were listed by Turban (1988). These included: the ability to support the solution of complex problems; fast response to unexpected situations that result from changes in inputs; the ability to test different strategies under different configurations quickly and objectively; new insights and learning, and facilitated communication; improved management control and performance and hence cost savings; more objective decisions and improved managerial effectiveness. The DSS may provide support for individuals and/or groups.

Computer models can be used as decision support tools. The ability of a decision-support system (DSS) to help to solve problems depends on the precision and accuracy of the model's possible solutions to the farmer's dilemmas and the accessibility and user-friendliness of the DSS system.

2.5. Spreadsheets for designing farming systems.

Spreadsheets are tabulated worksheets that allow the manipulation and calculation of numerical data. These devices can be used to calculate farm feed supply and demand, financial budgets and livestock inventories. They can be used to simulate grazing systems (Rickert, 1988, Wright, 1992), and are a useful tool to help managerial decision making (Rae, 1994). Also, they are relatively simple to use and very powerful, because they can perform many repetitive calculations quickly and accurately, and often have build-in statistical, mathematical, and logical functions that can be used for model construction. Most are capable of displaying graphics that can be used to summarise the feed budgeting outcomes for a farm.

Learning to use these computer devices can be achieved in a fraction of the time required to learn a programming language. Therefore, they provide an 'easy' way to construct computer models (Rickert, 1988; Wright, 1992; Mumford and Holt, 1993). Furthermore, spreadsheet models can now represent the basic biological and managerial principles that were previously associated with more sophisticated system models (Rickert, 1988).

Spreadsheet models are particularly suited to developing quick exploratory models that allow the range of probable outcomes from likely changes in the system to be assessed. The outputs from a simple spreadsheet model can be used as the basis for further discussion, analysis and experimentation (Rickert, 1988; Mumford and Holt, 1993).

While the principles of modelling different spreadsheets are similar, there are some differences in the programming language that each of the software packages use. The basic tool in computer spreadsheet programming is the creation of formulas to perform the mathematical functions of a given model. This obviously implies the *a priori* existence of a mathematical model that represents the problem to be addressed (e.g. a feed budget with its two main groups of elements: animal demand and feed supply). Once the spreadsheet is constructed, the model is set to do "what if....?" calculations by changing one or more inputs (e.g. animal demand by changing from bulls to calves, or feed supply by applying nitrogen fertiliser). This is done by using response functions, which indicate how one variable responds when the level of another variable is changed (Rae, 1994). Sensitivity analysis allows the effects of uncertain input values (e.g. pasture growth) to be explored.

A relevant feature of computer spreadsheet packages is that they can be used in combination with other software packages such as databases, linear programming packages, and risk analysis packages (Cunha, 1995). This further enhances the scope of spreadsheet applications in agriculture.

2.6. Farming Systems Research (FSR).

Socioeconomic circumstances can greatly influence the rate of development of farming systems. In most of the tropical regions of the world, rapid development of agriculture is required if food shortages and poverty are to be alleviated. The adoption of new technology to achieve this development change is more likely to occur when farmers themselves understand the need for change within the context of their own socioeconomic interests and capabilities. The development of methods to recognise these socioeconomic interests and capabilities is the core of Farming Systems Research

(FSR) (Byerlee et al., 1982; Simmonds, 1985). FSR therefore seeks to promote technological change farming in a socially acceptable manner (Byerlee et al., 1982; Simmonds, 1985), and to encourage farmers to adopt new technology quickly but effectively. Inherent characteristics of FSR are (Norman, 1978; Byerlee et al., 1982; Dent and Thornton, 1988): holistic analysis involving inter- and multi-disciplinary approaches to understand the activities of the farmer; a small-farmer orientation; focus on solving problems specified by the farmer; and the use of interactive feedback from farmers to modify further research activities. The processes of FSR are dynamic.

There are three broad types of FSR (Byerlee et al., 1982; Simmonds, 1985): FSR *sensu stricto*, on-farm research with a farming systems perspective (OFR/FSP), and new farming systems development (NFSD). FSR *sensu stricto* involves the description, analysis, and classification of farming systems as they are. This includes the technical, economic, and social circumstances of the systems being analysed. With OFR/FSP a farming systems perspective (FSP) is used to define the on-farm research (OFR) needed for development to progress. It assumes that changes should be adjusted to the circumstances of their users and that on-station experiments cannot substitute for farm experience. In contrast, NFSD aims to generate revolutionary change, by creating radically new systems.

There are four general stages to FSR: diagnosis, design, testing, and extension and monitoring (Dent and Thornton, 1988). During the diagnostic stage existing production systems are examined to identify constraints to improvement. This provides the basis for the design phase where potential improvements are identified. The most promising improvement(s) are then tested under local farming conditions. Information from the on-farm evaluation is then passed on to other farmers for further evaluation.

Advantages of the FSR approach to farm analysis have been described by Norman (1978), Byerlee et al. (1982) and Simmonds, 1985. First, the farm is considered in relation to the agrotechnical, economic, sociological, managerial and cultural variables that are inherent or interact with the farm as a unit. Second, the analysis identifies the diversity between farms and farmers, and this allows recommendations to be adjusted to the various categories of farm systems. Third, defining the problems that are relevant to farmers, and testing potential solutions to these at the farm level, is stressed. It is believed that the emphasis on these factors increases the efficiency of both agricultural research and extension, although evidence documenting that this is the case is not yet strong.

2.6.1. Farm systems research and modelling.

Among other things, the technology development process must consider the farming system environment into which the technology is to be adopted. This means that apart from specific goals, such as to increase production and enhance farmer lifestyle, technology developers need to consider the whole farm system (with its biological and socioeconomic features), if the technology is to be effectively adopted (Seligman, 1993; McCall et al., 1994).

Basic research generally looks for a comprehension of how the individual components of a system work rather than how they fit together and influence each other. Systems research tools such as dynamical systems modelling can help to achieve the latter (Wake, 1992; McCall et al., 1994).

While there have been some successful direct applications of basic research to the whole farm system, most of the results from component experiments exceed real farm performance (Sheath and Bryant, 1984; Brougham, 1973; Height, 1979; Bryant, 1990). This is because feedbacks may not be operating in component experiments where variable factors that may limit production are usually controlled to allow the factor of interest to be measured (McCall et al., 1994). Component analysis in animal production should therefore be planned in the context of constraints to real farm production systems. Farm system models have a role in linking component and field system research. Furthermore, they could help to define priorities by assessing the relevance of the constraints to on-farm performance, along with their role in helping to understand the association between component results and the process of developing improved farming systems (McCall et al., 1994).

FSR provides a suitable framework for the application of biological models. These allow technology to be assessed within a whole farm context. Interactions between the various farm activities during the whole year are included in the assessment, alongside an understanding of the managerial and social implications for the farmers and their families of change induced by the introduction of technology (Dent and Thornton, 1988).

Time and other important resources are required to adapt technology to a particular farm. Testing technology packages that involve livestock often takes a long time because of the length of their reproductive cycles. It is therefore usually impossible to evaluate several modifications of a livestock technology package for different situations (e.g. due to soils, or climatic conditions). Simulation models have the potential to overcome such problems, because of their ability to speed up the process of design and testing (see Section 2.3.2).

An acceptable production model for small farmers from tropical regions must consider the multiplicity of possibilities and data shortages characteristic of these regions. It must be sensitive not only to climatic and soil types, but also to management practices and farm resource availability (Dent and Thornton, 1988). It is difficult to meet these requirements in a developing country, and detailed whole farm models may have limited practical applications. Furthermore, the need for quick, economical feasible solutions is greater than that for precise, optimal decisions. Conventional farm management procedures are often just as able to discern what is feasible and what is not in these circumstances. This suggests that the possible usefulness of sophisticated models with high data inputs in FSR is low. However, when effects are spread over time, or when substantial changes to farming systems are sought, modelling may have a more significant role. For example, numerical models may be the only available way to assess the possible consequences, several years ahead, of relatively small changes made now (Simmonds, 1988). Overall this, and the lack of farm experimental data, suggests that initially relatively simple, user-friendly, decision support models are likely to have the greatest impact in FSR. 'Simple' prototype models are inexpensive and quick to build (e.g. on spreadsheets) but still allow the sensitivity of output from major system variables to be assessed. Furthermore, this prototyping modelling approach allows continual improvements to be based on feed back from field testing.

2.6.2. Farming Systems Research applied to Central Veracruz State.

A theoretical framework is required for the analysis of systems. The framework should be able to respond to the requirements of the analysis, which are determined by the interests of the researcher and the features of the system under analysis. Farming Systems Research (FSR) provides a framework to analyse and understand the socioeconomic circumstances of small farmers and their relationship with the adoption of new technology to improve their farm system. The characteristics of FSR that make it relevant to the present study are it: is based on inter- and multi-disciplinary cooperation; is directed towards finding solutions to problems specified by the farmers themselves; considers the farmer's environment when proposing solutions to the problems specified; and uses farmers' feedback in a dynamic way. Within the framework of FSR, biological models can be used to evaluate technology within the whole farm context (both biological and socioeconomic) inexpensively and quickly. The likely impact of a given technology can be quantified in physical and economic terms, along with the risk involved. The four stages of FSR: diagnosis, design, testing and extension and monitoring, allow the whole process of technology adoption to be followed through to ensure technology is applicable to farmers under their circumstances. This is consistent with the purpose of this study, which is concerned with evaluating the applicability of New Zealand's knowledge and techniques for improving farm productivity and efficiency in Central Veracruz State, Mexico.

2.7. Conclusions.

In pastoral-based systems, managing the balance between feed supply and demand is a key determinant of system performance and efficiency. Thus, feed planning techniques (both formal and informal) are very important in achieving the goals of pastoral farmers. Feed planning tools can be used to evaluate the possible consequences of alternate plans for the future. Furthermore, their output provides a standard against which actual system performance can be compared to determine whether and when modifications to the plan are needed.

A feed budget is a model (abstraction) of a pastoral farming system and presents a summary of the relevant data necessary to determine the best allocation of feed resource to achieve target levels of animal production. Thus, it can also serve as a decision support system, because the output provides information to assist the decision maker with grazing decisions.

Spreadsheets provide speed and accuracy in doing calculations for a feed budget, and are relatively simple to use, powerful, and inexpensive. The use of spreadsheets does not require a special knowledge of programming techniques that other kinds of software often require. Furthermore, spreadsheet models can be used as a basis for formulating prototypes from which more complex models can be developed. They also allow the decision-maker to analyse the performance of the current system, and undertake sensitivity analysis, and can be used in combination with other kinds of software such as databases, linear programming and risk analysis packages. This makes the scope of spreadsheet models very wide. It was concluded that they provide a suitable method for developing a prototype model for designing pastoral farming systems in Central Veracruz State. This process is described in the following Chapter.

Chapter Three.

Case Study: Technical and financial feasibility of improving grazing systems in Central Veracruz State, Mexico.

3.0. Introduction.

In this Chapter the method used to analyse the physical and financial feasibility of some New Zealand pastoral farming techniques in Mexico is described. First, a description of the model and its sub-models are presented. Second, a description of the "traditional" average farm in Central Veracruz State which was used for the modelling case study along with some preliminary analyses of possible changes to the traditional farming system are reported. This includes a comparison of the alternative "improved" systems with the "traditional" system, using model outputs for herbage utilisation and gross margin per hectare.

3.1. Method.

A series of linked spreadsheet models were developed to analyse an "average" farm in Central Veracruz State run under the traditional system of livestock management (see Section 1.2). This provided a basis from which alternative farming systems could be compared. Modifications to the "traditional" system were oriented towards improving pasture utilisation, by changing the pattern of livestock production from year-round calving to seasonal calving in order to improve the match between animal demand and herbage supply. Modifications to the traditional production system were assessed with the model, and the likely advantages/disadvantages of the alternative systems were measured in three main areas: animal performance (milk and calf production), pasture utilisation (the ratio of herbage production to herbage consumption) and financial performance (gross margin analysis). Inadequate data, particularly for pasture production, restricted the analysis. Nevertheless, the principles of how improved pastoral farming systems could be designed are illustrated, and importantly key areas for data collection and farm monitoring are identified.

3.1.1. Spreadsheet model.

Model features and organisation.

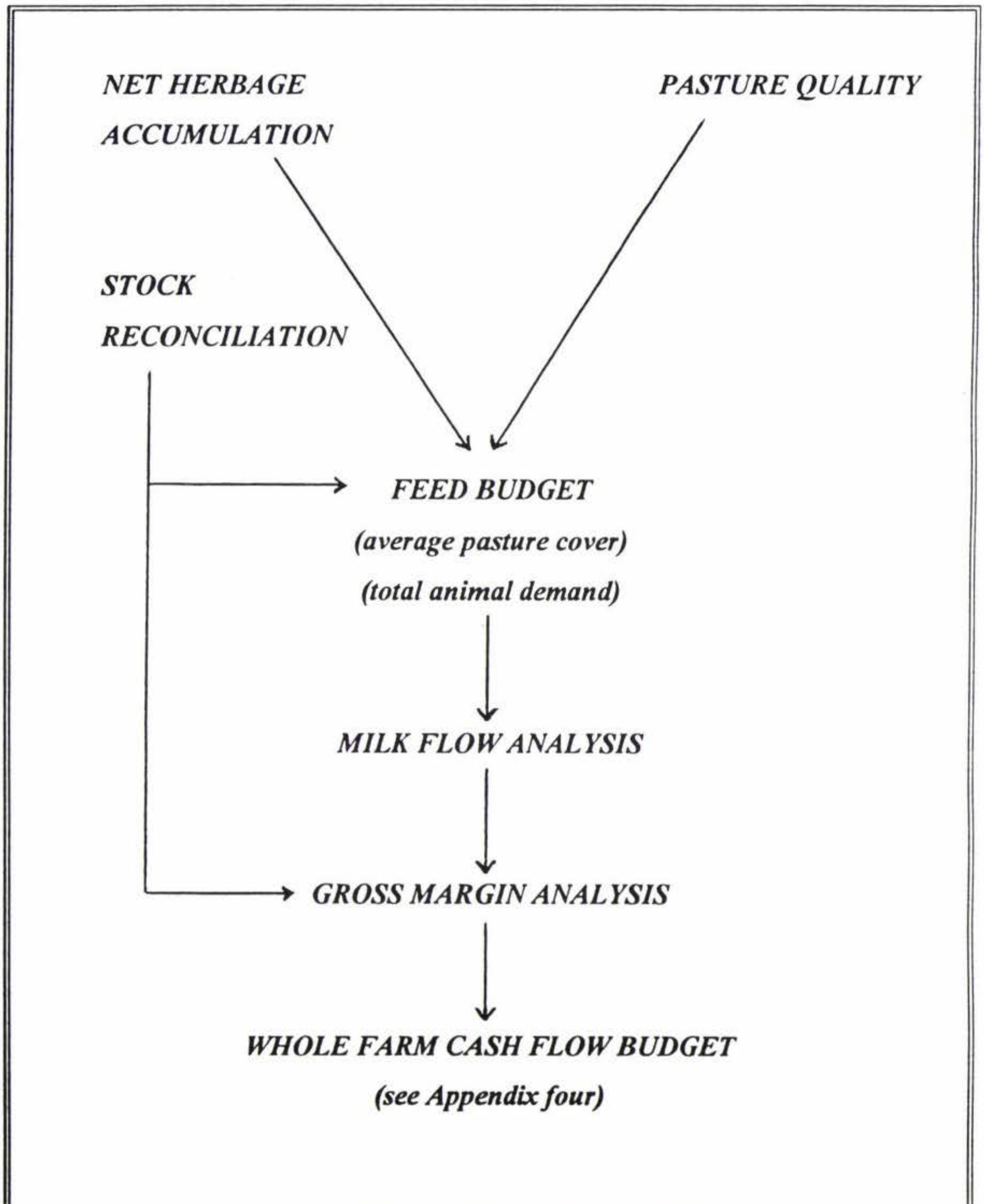
The model to analyse pastoral systems in Central Veracruz State comprised six linked sub-models (Figure 3.1), each build on a spreadsheet page. The sub-models are: *Stock Reconciliation*, *Feed Budget*, *Milk Flow Analysis*, *Gross Margin Analysis*, *Net Herbage Accumulation*, the *Monthly Milk Production*, and *Pasture Quality*. The sub-models, which are described in detail below, provided a basis for representing the practices and situations on Central Veracruz State farms (see Chapter One), and therefore a framework for analysing changes to the farming system. An average size farm (90 ha), which is described fully in Section 1.3.2, was chosen as a case study for the model. For a more in-depth description of the models see Appendix I.

Description of the sub-models.

i) Stock reconciliation: This template describes herd composition (classes and numbers) at the beginning and end of the study period (one year), and within period livestock transactions (purchases, sales, births and deaths). It is initiated by entering a description of the number of animals at the beginning of the season (OPENING STOCK) by class (cows, steers and bulls) and subclass (calves, weaners, heifers, milking and dry cows, rising 2yrs, 3yrs and older, and breeding bulls), along with the calving percentage. It also shows how livestock numbers change through the year as a consequence of purchases, sales, births and deaths. This allows the final number of animals within each class and subclass at the end of the season to be derived. Furthermore, it shows the stocking rate for the farm at the beginning of the farming year, which is calculated by multiplying the number of animals in each livestock class by its animal unit (AU) conversion factor and by dividing the total number of animal units (AU) by the effective farm area. The usefulness of the *Stock Reconciliation* is due to the fact that the main source of farm income in Central Veracruz State is from the sale of milk and animals. Thus, data from this sub-model can be used to estimate livestock sales and purchases, milk sold (number of cows times litres per cow), and animal health costs (animal health costs per head times number of animals). Furthermore, the number of livestock on the farm, along with their class and physiological state, determines feed requirements (see Chapter Two, Table 2.1). The *Stock Reconciliation* sub-model is therefore directly linked to the *Feed Budget* and the *Gross Margin* sub-models (Figure 3.1.).

There is a basic set of data to be entered into the *Stock Reconciliation*. The first piece of information to be entered are the comments, where the particular conditions of the situation analysed are described. Information regarding the total area and the effective area should be entered as well. Next, the sub-model asks if male calves are left entire (as bull calves) or castrated (= steers). Because the sub-model assumes that half of the animals born on the farm are males, if the answer is yes (Y), then fifty percent of the animals born will be steers (castrated) calves. If the answer to this question is "N" for no, the model assumes that half of the calves born are left entire. The actual or assumed calving percentage should be entered. In the column named OPENING STOCK, numbers of the different classes of animals at the beginning of the season should be registered, along with the purchases, the natural increase (due to the ageing of animals), and the number of animals sold. The cell within the model corresponding to the natural increase for calves (cows, steers and bulls) is automatically calculated from the number of possible pregnant animals (the number of heifers plus the number of milking cows). The percentage of losses for each class should be entered as well. The number of deaths, killed (household consumption) and missing animals, the closing numbers by class, the total AU per subclass of animals, the total AU and the stocking rate are all calculated by the model.

Figure 3.1. The Central Veracruz State farm system model; sub-models and their inter-relationships.



ii) Feed Budget: The *Feed Budget* sub-model is the core of the model. The feed budget describes the monthly feed demand for each class within the herd, along with the feed supply (in the form of net herbage accumulation rate, expressed in kg DM/ha/day). A basic set of data needs to be entered to run the feed budget. As with all the sub-models described here, there is a section for comments to be entered at the top of the form. The month in which the year to be analysed will start is typed into cell B6. Data regarding the effective area, on a monthly basis, is automatically recorded in the *Feed Budget* template from the *Stock Reconciliation* template. The initial average pasture cover (kg DM/ha) at the beginning of the season should be entered. In the section named PASTURE MOVEMENTS, net herbage accumulation values for each month are inputted from the *Net Herbage Accumulation* sub-model (see description later in this Section). The average pasture quality, expressed in % CP/kg DM and MJ ME/kg DM) for each month of the year, were obtained from the values described in Chapter One (Section 1.2.3) and from the *Pasture Quality* sub-model, respectively. However, this can be modified as required. The total animal intake per day (kg DM/ha) is calculated by the ANIMAL INTAKE section of the sub-model, using the following formula:

$$\textit{Total animal intake} = \frac{\sum(\textit{No. of animals per class} \times \textit{Intake per head per day})}{\textit{Effective area}}$$

where the total animal intake and intake per head per day are both expressed in kg DM/ha and the effective area is expressed in hectares.

The daily difference between total animal intake and pasture growth rate plus supplementation is then calculated ("Difference per day"; kg DM/d).

Data regarding supplementary feed should be entered in DM equivalents for the month concerned. Extra pasture production due to nitrogen fertiliser(s) is also entered here assuming each kg of nitrogen applied results in 10.5 kg DM of additional pasture growth.

Herbage dry matter not consumed in one month is transferred to subsequent months. The Final Cover in each month is calculated by the following formula:

$$\frac{\textit{(Initial Cover + (Difference per day x No. days per month)} \pm \textit{Supplements)}}{\textit{Effective area.}}$$

Inputs for the ANIMAL INTAKE section of the model are: the number of animals per class, the initial liveweight (kg) for the first month of the season or for the month when the animals are introduced to the herd, and the expected liveweight gain for each class and month. From these data, animal intake per day and the final average liveweight for each month are calculated. Animal feed requirements by class and performance (liveweight gain per day) were obtained from AFRC (1993). For the sub-class "Milking cows", the expected milk yield (l/day) should also be entered. Therefore, the sub-model *Feed Budget* calculates intake per head per day using the following formula:

$$Intake/headday = \frac{\sum (EI\ per\ head \times f_p) + f_o}{EP_t}$$

where EI = energy intake requirements per head in MJ ME, f_p = fraction of energy intake coming from pasture, f_o = energy from other feeds, and EP = average energy content of pasture and other feeds.

iii) Milk Flow Analysis: The *Milk Flow Analysis* sub-model derives milk production for the herd on a monthly basis from the number of cows in early, mid- or late lactation. It shows the total number of cows per month, the proportion of milking and dry cows, the expected milk yield (litres) per month, and the total milk yield per herd per year. The milk produced is partitioned between household (family and workers) consumption, calf rearing, cheese production and milk sales. All values are expressed in litres per month. Days per month are entered directly from *Feed budget*. Total milk sales (in Mexican pesos) are shown on a monthly and annual basis, and are calculated by multiplying milk sales (l/day) by the price per litre of milk. Milk price is the only data inputted to this model, the remaining calculations are derived from the *Feed Budget* sub-model.

iv) Gross Margin Analysis: The objective of this sub-model is to calculate the gross margin per hectare for the systems under analysis. Gross margin analysis is often used by farm management specialists to evaluate and compare the profitability of alternative feed budget plans (Parker, 1992). The gross margin represents the difference between total revenue and the variable costs associated with the enterprise and/or the feed budget plan. Comments can be entered to describe particular features of the alternative system under analysis. Farm area, stocking rate, and livestock sales and purchases are derived directly from the *Stock Reconciliation* model. The *Gross Margin Analysis* template is divided into two main sections: VARIABLE COSTS and GROSS REVENUE. Under VARIABLE COSTS data for livestock purchases (classes, number, and price per animal), animal health and breeding costs per year, hay and silage making, hay purchases, forage crops, and other feed(s) bought, and fertiliser type, amount (tonnes) and costs per tonne applied are entered. The annual cost of fence maintenance should be calculated and entered as well. The value of livestock purchases per class and per year, total feed costs, cost of fertilisers and total variable costs are all derived by the model.

In the GROSS REVENUE section, cattle sales (class, number, price per head) and sundry income (price per kg of cheese sold, number and price per unit of sundry income items) are entered. Total revenue per cattle class, volume of milk sold per year, milk revenue, cheese production (using data from *Milk Flow Analysis*), and revenue obtained from sundry items are calculated by the model. The Gross Margin per hectare is automatically calculated by using the following formula:

$$Gross\ Margin\ (\$/ha) = \frac{(Total\ revenue\ (\$) - Total\ variable\ costs\ (\$))}{Effective\ farm\ area\ (ha)}$$

v) Net Herbage Accumulation.

The *Net Herbage Accumulation* template uses data from the *Feed Budget* model to estimate monthly values of net herbage accumulation. Total animal intake values are automatically entered, and these allow the calculation of pasture production (kg DM/head/month) using the following formula:

$$TAI_i = \sum_{n=1}^{i=12} TAI_d \times d_i$$

where TAI_i = total animal intake (kg DM/ha) in month i, TAI_d = total animal intake per day (kg DM/ha) in that month and d_i = number of days in month i.

Estimated values of monthly farm utilisation of pasture are entered. These values, along with those estimated for pasture lost through senescence and decay, were derived from the conditions described in Section 1.2.3, and from rainfall and temperature data for Central Veracruz State. The estimated monthly pasture production (EPP_i) was calculated using the formula:

$$EPP_i = \frac{TAI_i \times 100}{EFU_i}$$

where EFU_i = estimated farm utilisation (%) of the herbage produced for month i.

Total annual utilisation (TAU, kg DM/ha/yr) is the proportion of annual herbage production consumed by the animals, and is calculated by the following formula:

$$TAU = \frac{\sum_{i=1}^{n=12} TAI_i \times 100}{\sum_{i=1}^{n=12} EPP_i}$$

Initial runs with the feed budget showed a large discrepancy between the pasture data figures reported in Figure 1.5 (Chapter One), and the typical farm stocking conditions and animal performance described in Section 1.2.3. Pasture growth rates (PGR) therefore had to be estimated subjectively, as outlined above. The *Net Herbage Accumulation* sub-model calculates likely pasture production (estimated pasture growth rates, EPGR) using the following formula:

$$EPGR_i = EPP_i \times d_i$$

The Net Herbage Accumulation formula derived from that described in Section 1.2.3, was as follows:

$$NHA_i = \sum_{i=1}^{n=12} EPGR_i - D_i$$

where NHA_i = net herbage accumulation for month i and D = kg DM lost in the i month through senescence and decay.

vi) Pasture Quality.

This sub-model was constructed to derive the metabolisable energy value (ME MJ) per kg of dry matter (DM) for a given composition of pasture. This overcame the lack of data regarding the amount of ME supplied by pasture at particular times of the year. Data inputs are the amount of crude protein, crude fibre, ether extract, nitrogen-free extract and digestibility coefficients. These were obtained from Göhl (1981). The quantity of each of the elements described above (in g/kg DM and kcal/g) is calculated in kcal and MJ for each component of the pasture as follows:

$$M/D_i = \frac{4.32(CP_i \times DC_{CP}) + 3.59(CF_i \times DC_{CF}) + 7.73(EE_i \times DC_{EE}) + 3.63(NFE_i \times DC_{NFE})}{239}$$

where for pasture specie i, M/D_i = the amount of ME in MJ/kg DM, CP_i = crude protein, CF_i = crude fibre, EE_i = ether extract, and NFE_i = nitrogen-free extract, and DC = digetibility coefficient for each of these elements. The ME constants for CP, CF, EE, and NFE were 4.32, 3.59, 7.73, and 3.63, respectively. It was assumed that 1 MJ was equivalent to 239 kcal (Göhl, 1981).

3.1.2. Case farm.

Traditional (average farm situation, 56% pasture utilisation):

The farm modeled represented an hypothetical 90 ha milk and beef production farm. It has an effective area of 88 ha (with the remaining 2 ha used for the house and other purposes). The present system is based on an all year round calving pattern. For the purpose of the analysis June was choosen as the beginning month of the year to make comparisions between the "traditional" and two improved systems. The stocking rate of the farm is 1.3 AU per hectare.

Assumptions.

An average calving percentage of 58 was assumed. This is the average for Central Veracruz State (Table 3.1 and Chapter One Section 1.2). Annual livestock transactions are described in the *Stock Reconciliation* sub-model (see Appendix I). The herd composition is shown in Table 3.2. Because of inadequate pasture production data the *Net Herbage Accumulation* sub-model was used to derive net herbage accumulation values for the farm. To do these calculations, it was assumed that the rainy season started in May-June and finished in October (see Section 1.2.2). Significant amounts of pasture accumulate within the rainy season, and it is assumed that this was associated with high losses of pasture through to senescence and decay. These losses are represented in the model as occurring from December to May. Herbage losses are more evident when the rainy season starts (May), and for this reason net herbage accumulation values from December-May are negative (Figure 3.2). There are neither supplements nor fertiliser inputs for this system.

Crude Protein percentage (CP%) values for each month of the season were obtained from Aluja (1984). Values for metabolisable energy contents of the herbage produced were derived with the *Pasture Quality* sub-model, using the pasture composition data described in Section 1.2 (see Appendix V). CP% values would limit (less than 7%) annual production in May, June, August and September (ARC 1989). The lowest energy values occur in February and April, with the remaining months having a derived value of 9 MJ ME/kg DM (see Appendix I). These values were used as the basis for exploring two other systems of livestock production (Table 3.1).

A corollary of year round calving pattern was that the herd composition remained the same each month. Liveweight gain per day for each class of livestock were described earlier in Section 1.2.

Figure 3.2 Net herbage accumulation for the traditional farming system in Central Veracruz State.

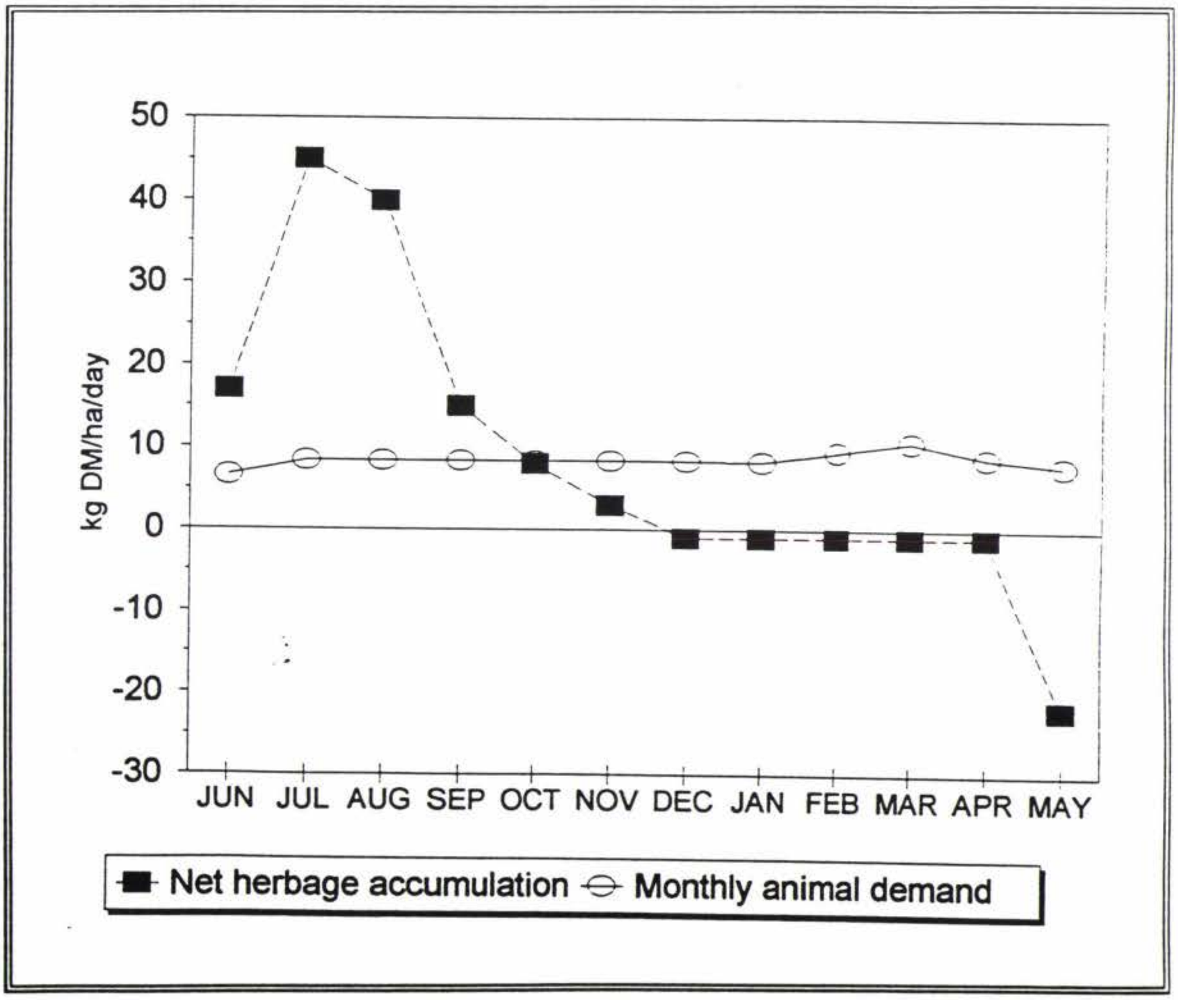


Table 3.1 Assumptions for the three farming systems explored with the model.

	Traditional	Improved I	Improved II
Production system	Milk and beef (calving all year round)	Milk and beef (seasonal calving: June)	Milk and calf (seasonal calving: June and July)
Stocking rate (AU/ha)	1.3	1.5	1.5
Calving date/spread	All year round	75% of the milking cows calve in June, the remaining 25% in July	55% of the milking cows calve in June, the remaining 45% in July
Calving percentage	58%	80%	80%
Weaning date	All year round when the calves reach @150 kg lwt)	March-April (calves @ 150 kg lwt)	March-April (calves @ 150 kg lwt)
Additional inputs	-	2 workers for milking	4 more workers for milking

Table 3.2. Assumed herd composition on 1 June for the three farming systems studied for Central Veracruz State.

Livestock Class	Traditional	Improved I	Improved II
Heifer calves	13	22	28
R1yr heifers	11	12	16
R2yr heifers	24	10	16
Dry cows	17	7	7
Milking cows	20	44	55
Bull calves	13	22	28
Weaner calves	11	19	0
R2yr and older	6	10	0
Breeding bulls	2	2	2
Animal Units	111	133	134

Improved farming system I (milk and beef production, seasonal calving, 78% herbage utilisation).

This farming system involves milk and beef production using a management system similar to that of the traditional system. The farm area of 90 ha includes an effective grazing area of 88 ha. June was the opening month for the year, when the rainy season starts, which means that net herbage accumulation values begin to be positive in that month. A seasonal calving pattern with 75% of the milking herd freshing in June and the balance in July was assumed. This provides milk production for 11 months of the year (see Appendix II). The stocking rate for this farm is 1.5 AU per hectare.

Assumptions.

An 80% calving percentage for this system was assumed (see Appendix II). This represents a 22% increase on the traditional farming system. It is assumed that this increase can be achieved through better pasture utilisation (which in this case is 78%), increased pasture quality (and pasture production) and consequently improved animal nutrition. This level of reproductive performance should be achievable (see Section 1.2). Tables 3.2 and 3.3 show that in comparison to the traditional system this system produces more calves and bulls (44 vs. 26 and 10 vs. 6 respectively), allows more cows to be milked and supports less dry cows (7 vs 17). Net herbage (and pasture production) accumulation values were assumed to be the same for this farming system as for the traditional farm from June to November (Figure 3.2) but differ from December onwards because of herbage losses through senescence and decay (see Appendix II). Predicted individual animal performance (liveweight gain and milk production per cow) is also superior to that of the traditional system (Figure 3.3). As for the traditional farming system, it was assumed that neither supplements nor fertiliser were used for the improved system.

Pasture quality values (CP% and MJ ME/kg DM) were kept the same as for the traditional system, despite the possibility that pasture quality could increase due to improved herbage utilisation.

Improved farming system II (milk and calf production, seasonal calving, 75% herbage utilisation).

In comparison to the two systems described previously, this system results in greater milk and calf production (see Appendix III). The farm would have a stocking rate of 1.5 AU per hectare if calving occurred in June (55% of herd) and July (45%). This would result in milk production for 11 months and improve the farm cashflow.

Assumptions.

The herd calving percentage in this milk and calf production system was assumed to be 80% (Tables 3.1 and 3.2). Annual pasture utilisation was 75%. It was assumed that all calves surplus to the heifer replacements required for the herd are sold as weaners. This results in reduced beef production but more pasture for the milking cows.

3.1.3. Comparative Analysis of the Systems Modelled.

Tables 3.3 and 3.4, and Figure 3.3 summarise the main features of the three systems analysed. The number of milking cows for the traditional system (20), compared to 44 and 55 milking cows respectively for the improved systems, was significantly lower. Herd size affected the number of weaners for sale, which increased from 5 animals for the traditional farming system to 34 animals for Improved Systems II (milk and calf production system). Changes in the number of milking cows, along with a better pasture utilisation, resulted in greater annual milk yields, and its pattern of production for each of the three systems analysed, with a difference of almost 50,000 litres per year for the milk and calf system (Table 3.3).

The distribution of milk by end use is shown in Table 3.3. Milk was allocated for household consumption, calf feeding, cheese production or sales. Calves could be fed better in the two improved systems, if the traditional practice of leaving a quarter or two for the calf is followed, simply because the milk yield per cow is greater. This can be translated into better calf liveweight gains (0.6 kgLWG/head/day from September to October when pasture availability is adequate) compared with 0.3 kg LWG/head/day for the traditional system.

Table 3.3 End uses of mlk produced by the three farming systems studied with the model.

	Traditional	Improved I	Improved II
Milking cows (head)	20	44	55
Weaner sales (head)	5	22	34
Total milk yield (l/yr)	40,740	72,931	90,270
Household	2,607 (6.4%)*	2,607	2,607
Calves	17,111 (42%)	30,631	37,913
Cheese production	2,607 (6.4%)	2,607	2,607
Sale	18,414 (45.2%)	32,965	40,802
Milk income ($/yr)	18,414	32,965	40,802

* The percentage of milk yield used for this purpose in the traditional system (see Section 1.2).

An increase in overall milk production not only means that there will be more milk available for household and calf consumption and cheese production, but also that there will be more milk for sale. The largest income from milk sales is produced by the Improved System II (milk and calf production) with 40,802 litres a year for sale, which in Mexican pesos (1 peso per litre) equates to 40,802 pesos a year, against 18,414 pesos for milk sales in the traditional system, and 32, 965 pesos for the milk and beef system (Improved I).

Figure 3.3 shows the liveweight change profile through the season for herds under each of the systems analysed. Liveweights were higher under the two improved systems and increased relative to the beginning of the year. This net increase in liveweight over the year suggests that the farm stocking rate could be further increased to ensure that the systems operated at a new status quo (i.e. opening and closing liveweights should be the same).

The liveweight gain profiles for replacement heifers were also improved through the modifications made to the traditional farming system. Heifers reached 384 kg and 439 kg at two years of age, respectively, for Systems I and II, compared with 301 kg for the Traditional System (see Appendices I, II and III). Larger replacement heifers should lead to a higher two year old calving percentage, and greater lifetime milk production. It would take 3-5 years for the full effect of improved heifer rearing to be reflected in overall herd performance.

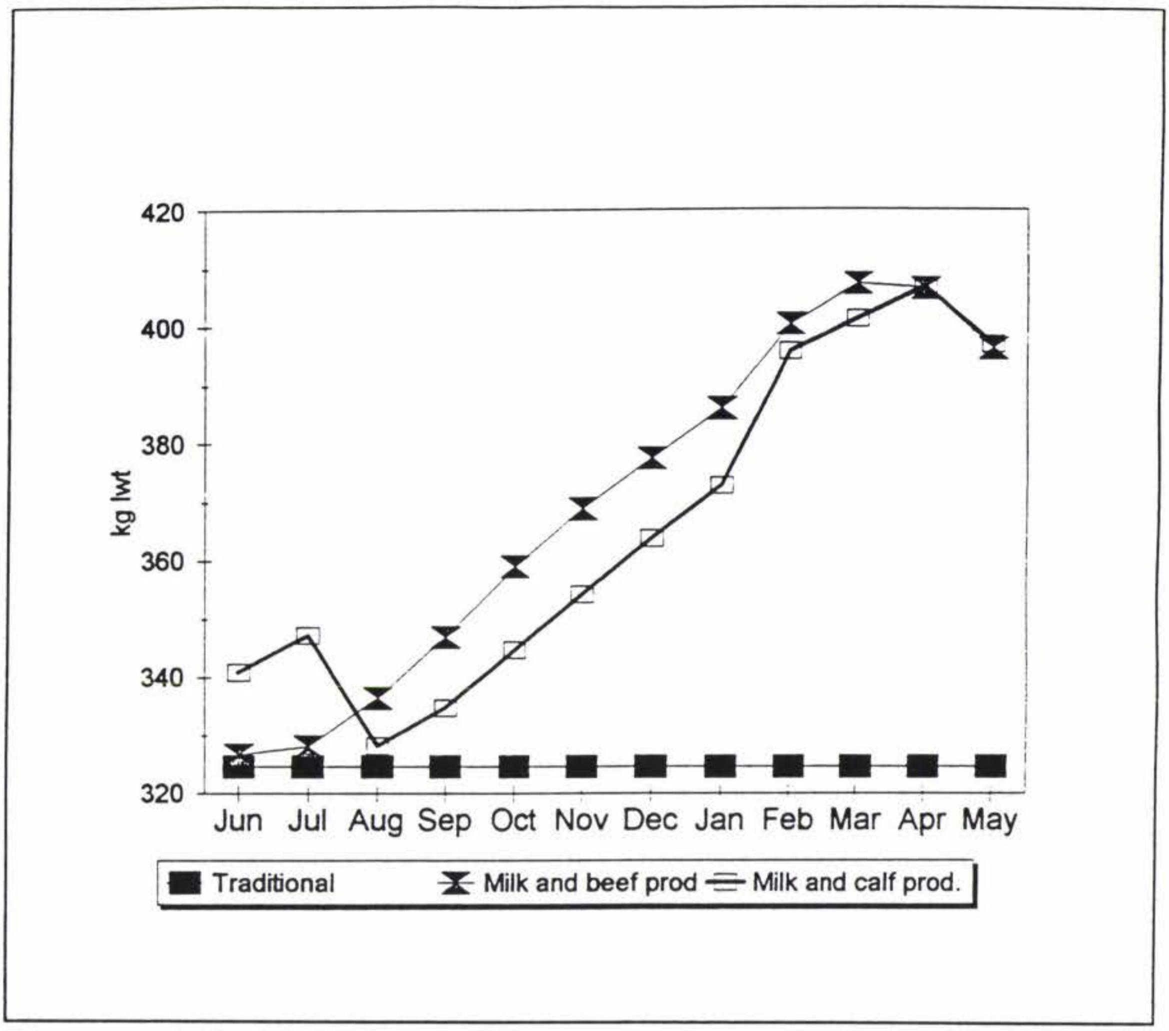


Figure 3.3 Animal liveweights through the year for the three systems analysed.

3.2. Discussion.

Table 3.4 illustrates the comparison of some of the physical and financial characteristics of the farming systems explored. From that table, the system with the highest herbage utilisation (78%) for milk and beef produced, (Improved I) is shown to be the most profitable and productive.

Table 3.4. Physical and financial characteristics of the three farming systems for Central Veracruz State estimated with the model.

	Traditional	Improved I	Improved II
Herbage utilisation (%)	57	78	75
Milk production (l/ha/yr)	209	829	1,026
Beef production (kg lwt/ha/yr)	74	130	125
Variable costs ($)	31,315	50,795	65,680
Gross revenue ($)	51,861	98,902	108,499
Gross margin ($/ha/yr)	233	547	487

Milk production per hectare for the Improved System II (milk and calf production) was 1026 l/ha/yr because of the greater number of milking cows (55) in this system. This contributed to a gross revenue of 108,499 pesos, more than twice that of the traditional system. Nevertheless, a greater gross margin per hectare was obtained for Improved System I (milk and beef production), because of the revenue obtained from beef (finished bulls from the milk and beef system were valued at 2,500 pesos against 870 pesos for weaners from the milk and calf system). However, the main reason why the gross margin for the milk and calf production system was lower than that of System I, was because of the workers needed to milk the additional cows farmed (55 against 44 for the milk and beef production system).

There is no doubt that the traditional livestock production system in Central Veracruz State is feasible, because that is the way the things have been done up until now. Nevertheless, these traditional farming systems do not utilise the pasture resource efficiently, as evidenced by the huge amount of material lost through senescence and decay (see Section 1.2 also). Therefore, it can be concluded that a straightforward way to improve the animal productivity of these systems is to increase pasture utilisation.

It is important however to remember that several assumptions were made for the three systems modelled, because of inadequacies in the data that were available, particularly in relation to the net herbage accumulation values and sward dynamics under grazing in a tropical environment. Because no data were available to illustrate what could happen within the sward under different grazing management systems in Central Veracruz State, it was assumed that pasture utilisation (78% for the milk and beef system and 75% for the milk and calf system) could increase both herbage quality and quantity (see Section 1.5). Nevertheless, the converse could be true if increased animal grazing pressure on the sward resulted in the more productive pasture species (i.e. those which have been introduced) being overgrazed. Consequently, both herbage growth and quality could decrease unless subdivision was put in place and properly used to control the frequency and severity of grazing.

The possibility of tactical applications of nitrogen fertiliser should be considered, mainly during the months when CP% values are low (May-June and August-September) in order to increase both pasture quality (CP%) and pasture growth. Nitrogen fertiliser is presently not widely used because of the low rate of return obtained. The need for an analysis of the likely return from nitrogen fertiliser application for the months mentioned above, and under conditions of better animal performance and improved pasture composition (with more legumes and introduced grass species), could be explored with the model.

The second important group of assumptions for the modelling study related to animal performance. As stated earlier, a big leap in calving percentage from the traditional system (58%) to the improved (80%) was assumed to be possible simply by concentrating mating into the months of October-November, when pasture quality and quantity are usually not limiting (Figures 1.3 and 1.4). While some adjustement to the equations used for calculating animal demand for a given level of performance could be made, the animal liveweight changes (which indicate the likely feasibility of an increase in animal performance, including calving percentage) seemed reasonable and consistent with the quality of pasture available at the time. Again, the lack of data regarding sward dynamics under different grazing management policies restricted the amount of analysis that could be done in relation to this factor.

To achieve improved pasture utilisation changes must to be made to grazing management methods. As stated in Chapter One, this could be facilitated by paddock subdivision through electric (or solar powered) fencing. This would not necessarily mean a large outlay of capital expenditure, if subdivision were planned for a flexible grazing management policy with two or three wire electric fences. A detailed analysis of the advantages/disadvantages of this practice should be done in the future.

An even cash flow throughout the year is important for farmers in the study region (see Chapter One). Both of the improved systems were designed bearing this factor in mind. Data presented in Appendices I and II, show that only one month will not have a cash income (May), because of the seasonal characteristic of the systems proposed. However, this would coincide with a low need for hired labour because cows are not milking at that time (which represents the largest cost for the systems). The increase in the gross margin per hectare for both improved farming systems can be used to plan for that period when the cash flow is either reduced (low number of milking animals in April) or nil (no milk production in May).

Lactation lengths have been reduced for both improved systems, which results in shorter calving intervals and improved condition score at calving. The number of dry cows has also been reduced in the improved systems, which represents a big advantage because a dry cow eats pasture without a financial return.

The calculated gross margin per hectare was highest for the improved system I (milk and beef production). This system has the additional advantage of having R2 yrs and older animals, which can be used as "buffer" against periods of pasture surpluses (feeding them better at that time to increase pasture utilisation) and deficits (rationing these animals and using their body reserves to overcome feed shortages).

In the milk and calf production system, the highest gross revenue was obtained (102,159 pesos), with most of this revenue coming from milk production. Nevertheless, it is assumed that a large proportion of this revenue was used to pay the extra workers needed to milk the extra cows. This suggests that revenue could be used instead to pay for a modern milk parlour. Such a capital investment could be funded from savings made by reducing labour for milking the cows.

3.3. Conclusions.

The changes to the traditional system proposed here represent an increase in pasture utilisation and consequently in animal production and profit. Additional inputs are mainly in the form of management (planning, implementation and control of the pastoral systems) and labour. Some other inputs likely to be used include nitrogen fertiliser, and improved animal genetics and capital investment into improvements such as fencing, a milk parlour and pasture species. The attitude of farmers towards risk should be considered when exploring the principles outlined above. In addition, the characteristics of the database necessary to operate the model should be considered, to ensure that appropriate field data are collected for its effective operation (and validation). The protocols for measurement of pasture, soil and animal parameters should be defined to ensure that the data requirements for farm system simulation models, such as the version described in this study, are met. In the following Chapter, the final conclusions and some recommendations regarding these and other topics explored up to this point are discussed.

Chapter Four: Conclusions.

Several important conclusions can be drawn from the analysis and comparison of pastoral farming systems in Central Veracruz State with those from New Zealand. First, climatic differences primarily determine the differences in pasture species, and therefore the potential pasture quality (Chapter One). The literature review and the modelling analysis suggested that more research emphasis should be placed on developing and establishing pasture species for tropical grazing conditions that have higher quality and a less pronounced seasonal pattern of growth. Particular attention should be paid to improving summer pasture production and pasture composition, in order to increase the protein content of the herbage consumed by animals.

Second, grazing technology in New Zealand; is well developed, with a higher level of farmer adoption of research findings and greater inputs (such as fertiliser and subdivision) than in Central Veracruz State. Research in New Zealand has attempted to find ways to overcome the seasonality of pasture production, and to maintain the viability of farming when no government subsidies are provided and there are long distances between New Zealand and its export markets (see Chapter One). An outcome of this is a dependence on pasture as the primary feed supply for animals and efficient pasture utilisation. A knowledge of sward dynamics under grazing, a well-developed database on pasture production, and an emphasis on the whole farm system have helped New Zealand to gain an international competitive advantage in pastoral-based systems. In order to improve pasture utilisation in Central Veracruz State, some aspects of New Zealand research should be copied to build a database of pasture and animal production at the farm level. These data can then be used to design more productive and profitable farming systems. This data collection process should take particular account of local farming conditions. The lack of fundamental information on pasture growth, and animal liveweight and milk yield data, seriously constrained the analysis of farming systems in the present study (Chapter Three). However, the spreadsheet model developed for Central Veracruz State did confirm the key parameters for which data should routinely be collected (e.g. pasture growth rate, pasture quality). Procedures for collecting these data are well-established.

The economic advantage of higher inputs of fertiliser, including the tactical application of nitrogen, in Central Veracruz State need to be analysed within a systems framework. Factors such as the best time to apply fertiliser and the conditions that make the practice economically feasible should be considered. The spreadsheet model would allow an initial analysis of fertiliser benefits for animal production to be undertaken.

The use of supplementary feeds such as agricultural by-products and crops, were not considered in this study. They are an alternative feed source to be explored, and are already being used to some extent by farmers in Central Veracruz State to overcome deficits in the pasture supply and to improve system sustainability. Again, the use of feed supplements should be analysed from the farming system perspective, and consider factors such as carry-over effects, quality parameters relative to those of pasture, and costs relative to the value of increased animal output.

The development of technologies suitable for farmers, and their characteristics must be considered when making recommendations on the way they should run their farms (Chapter Two). Thus, care should be taken to consider the farmer's attitude towards risk, and their aims and goals. Researchers must first diagnose local on-farm constraints, and design technologies that meet their needs and expectations. The establishment of farmer organisations to improve economic returns for animal, and other farm products, to farmers should be investigated. Efforts to increase the level of education of farmers should be intensified, because the adoption of improved technologies is positively associated with educational qualifications.

It can be concluded from the preliminary analysis of milk production systems in this study that the adoption of some of New Zealand's pastoral farming principles could significantly increase animal production and farmer's returns from pasture in Central Veracruz State. This is despite the deficiencies in the data used to construct the model. In particular, adopting a seasonal pattern of calving, reducing the number of non-productive animals, improving the rate of liveweight gain in herd replacements, and the calving percentage would all increase herd productivity, pasture utilisation (and quality) and profit. The modelling framework developed for the pastoral systems analysis has a lot of potential, and should be tested and further refined when new data are collected in Mexico.

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Appendices

APPENDIX I: Traditional Farming System.

ntral Veracruz State — **Feed Budget Submodel** — **A. N. Martinez-Garcia**

Comments: "Traditional" farm medium size (90 hectares) in Central Veracruz State

ert the number of the starting month in B6.

EFFECTIVE AREA:	88	88	88	88	88	88	88	88	88	88	88	88
INITIAL COVER:	700											
STARTING PERIOD:	6											
MONTH:	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
STURE MOVEMENTS												
t herbage accumulation (kg DM/ha/day):	17	45	40	15	8	3	-1	-1	-1	-1	-1	-22
Pasture quality (%CP/kg DM)	6	7	6	6	7	8	8	8	7	8	8	5
Pasture quality (MJ ME/kg DM)	9	9	9	9	9	9	9	9	8	7	8	9
Total animal intake/day (kg DM):	6.6	8.4	8.4	8.4	8.4	8.4	8.4	8.3	9.5	10.7	8.8	7.8
Difference/day (kg DM):	10.4	36.6	31.6	6.6	-0.4	-5.4	-9.4	-9.3	-10.5	-11.7	-9.8	-29.8
plements (kg DM or kg)												
Hay/Silage:												
Other:												
Nitrogen:	0											
FINAL COVER:	1011	2147	3127	3326	3314	3152	2861	2573	2280	1919	1625	701
MAL INTAKE												
Calves (No.)	11	11	11	11	11	11	11	11	11	11	11	11
Intake/Head/Day (kg DM)	3.0	4.6	4.6	4.6	4.6	4.6	4.6	4.6	5.1	5.8	5.1	4.6
Initial liveweight (kg)	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0
Liveweight gain/day (kg)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Final liveweight (kg)	96	96	96	96	96	96	96	96	95	96	96	96
R1yr Hfrs(No.)	11	11	11	11	11	11	11	11	11	11	11	11
Intake/Head/Day (kg DM)	4.2	6.5	6.5	6.5	6.5	6.5	6.5	6.5	7.3	8.3	7.3	6.5
Initial liveweight (kg)	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0
Liveweight gain/day (kg)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Final liveweight (kg)	171	171	171	171	171	171	171	171	170	171	171	171
R2yr Hfrs (No.)	24	24	24	24	24	24	24	24	24	24	24	24
Intake/Head/Day (kg DM)	6.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	10.1	11.5	10.1	9.0
Initial liveweight (kg)	290.0	290.0	290.0	290.0	290.0	290.0	290.0	290.0	290.0	290.0	290.0	290.0
Liveweight gain/day (kg)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Final liveweight (kg)	301	301	301	301	301	301	301	301	300	301	301	301
Milking cows (No.)	20	20	20	20	20	20	20	20	20	20	20	20
Intake/Head/Day (kg DM)	8.3	8.9	8.9	8.9	8.9	8.9	8.9	8.3	10.0	10.7	9.4	8.3
Milk yield/day (kg)	5.0	6.0	6.0	6.0	6.0	6.0	6.0	5.0	6.0	5.0	5.0	5.0
Initial liveweight (kg)	421.0	0.0										
Liveweight gain/day (kg)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Final liveweight (kg)	421	421	421	421	421	421	421	421	421	421	421	421
Dry cows (No.)	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0
Intake/Head/Day (kg DM)	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	6.6	7.6	6.6	5.9
Initial liveweight (kg)	470.0											
Liveweight gain/day (kg)	0.0											
Final liveweight (kg)	470	470	470	470	470	470	470	470	470	470	470	470
R1yr Steers(No.)	0											
Intake/Head/Day (kg DM)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Initial liveweight (kg)	0.0											
Liveweight gain/day (kg)	0.0											
Final liveweight (kg)	0	0	0	0	0	0	0	0	0	0	0	0
R2yr Steers (No.)												
Intake/Head/Day (kg DM)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Initial liveweight (kg)												
Liveweight gain/day (kg)												
Final liveweight (kg)	0	0	0	0	0	0	0	0	0	0	0	0
R3yr Steers (No.)												
Intake/Head/Day (kg DM)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Initial liveweight (kg)												
Liveweight gain/day (kg)												
Final liveweight (kg)	0	0	0	0	0	0	0	0	0	0	0	0
R1yr Bulls (No.)	11	11	11	11	11	11	11	11	11	11	11	11
Intake/Head/Day (kg DM)	3.9	6.5	6.5	6.4	6.4	6.4	6.4	6.4	7.2	8.2	7.2	6.4
Initial liveweight (kg)	186.0	186.0	186.0	186.0	186.0	186.0	186.0	186.0	186.0	186.0	186.0	186.0
Liveweight gain/day (kg)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Final liveweight (kg)	197	198	198	197	197	197	197	197	196	197	197	197
R2yr Bulls (No.)	6	6	6	6	6	6	6	6	6	6	0	0
Intake/Head/Day (kg DM)	5.9	6.2	6.3	6.5	6.6	6.7	6.9	7.0	8.0	9.3	0.0	0.0
Initial liveweight (kg)	280.0											
Liveweight gain/day (kg)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	
Final liveweight (kg)	291	303	316	328	340	352	364	377	388	400	0	0
R3yr Bulls (No.)	2	2	2	2	2	2	2	2	2	2	2	2
Intake/Head/Day (kg DM)	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.9	9.0	7.9	7.0
Initial liveweight (kg)	650.0											
Liveweight gain/day (kg)												
Final liveweight (kg)	650	650	650	650	650	650	650	650	650	650	650	650
TOTAL DEMAND/DAY:	6.6	8.4	8.4	8.4	8.4	8.4	8.4	8.3	9.5	10.7	8.8	7.8
DAYS/MONTH	30	31	31	30	31	30	31	31	28	31	30	31

Central Veracruz State | # Stock Reconciliation Submodel | **A. N. Martinez-Garcia**

Comments: "Traditional" average farm in Central Veracruz State

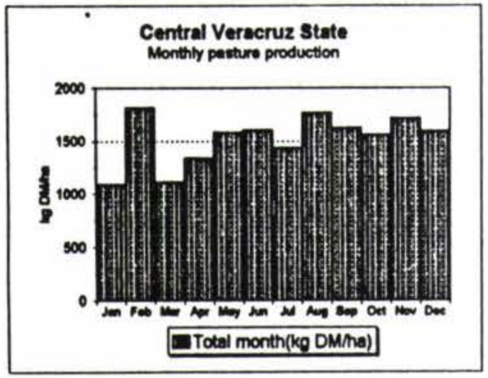
Farm Area (ha) 90 | **Effective area (ha):** 88 | **Stocking rate (AU/ ha):** 1.3

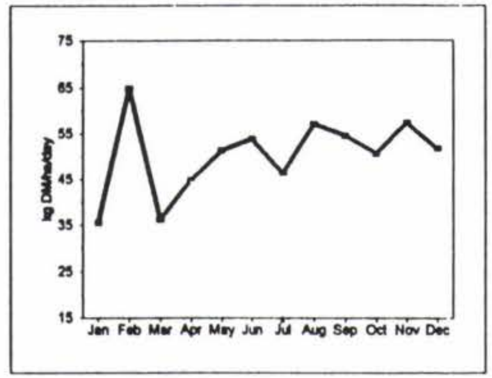
FARMER:

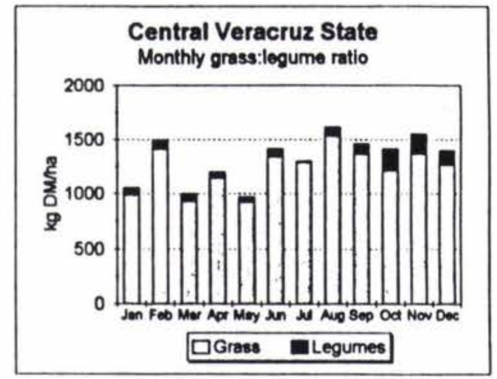
STOCK CLASS	OPENING STOCK	PURCH.	NATURAL INCREASE	SALES	DEATHS KILLERS MISSING	CLOSING	A.U's Conversion	TOTAL A.U.	LOSSES
DUAL PURPOSE CATTLE	Are Male calves left entire?("Y " or "N")			y			**DUAL PURPOSE CATTLE**		
	Calving %	58%							
COWS									
Calves			13		2				13.0%
Weaners	11				0	11	0.7	8	1.0%
Heifers	24				2	24	1.4	34	10.0%
Milking cows	20			8	1	20	1.6	32	3.0%
Dry cows	17			0	0	17	1.0	17	1.0%
STEERS									
Calves			0				0.7		13.0%
Weaners					0	0	0.7	0	1.0%
Rising 2yr					0	0	1.2	0	1.0%
3yr and older					0	0	1.8	0	1.0%
BULLS									
Calves			13		2		0.7		13.0%
Weaners	11			5	0	11	0.8	9	1.0%
Rising 2yr	6			6	0	6	1.3	8	1.0%
3yr and older	0				0	-0	1.8	0	1.0%
Breeding bulls	2				0	2	2.0	4	1.0%
TOTAL	91	0	26	19	7	91			
	Check		117			117	TOTAL	111	

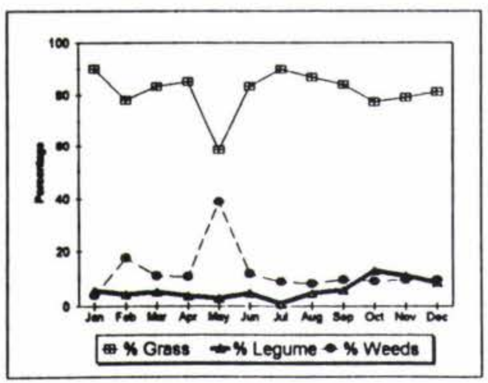
...PASTURE GROWTH RATES (kg DM/ha) IN CENTRAL VERACRUZ STATE, MEXICO (Source derived from Aluja, 1984)

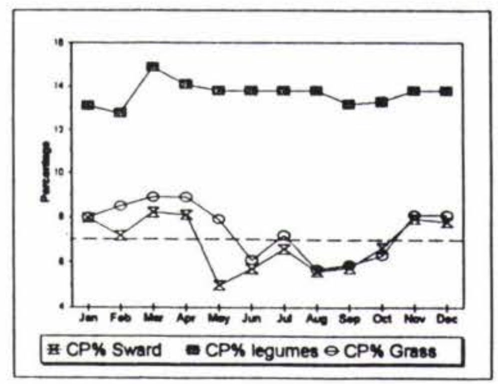
Month	%DM	Total month(kg DM/ha)	kg DM/ha/day	Grass	Legumes	%Grass	%Legume	%Weeds	CP% Grass	CP% Legume	CP% Pasture	D/M value (MJ ME/kg DM
Jan	22%	1,098	35	990	63	90	6	4	8	13	8	9
Feb	38%	1,815	65	1415	78	78	4	18	9	13	7	9
Mar	31%	1,120	36	934	59	83	5	11	9	15	8	9
Apr	39%	1,345	45	1146	52	85	4	11	9	14	8	9
May	26%	1,588	51	927	45	58	3	39	8	14	5	9
Jun	25%	1,612	54	1343	75	83	5	12	6	14	6	9
Jul	31%	1,438	46	1289	12	90	1	9	7	14	7	9
Aug	22%	1,767	57	1536	83	87	5	8	6	14	6	9
Sep	25%	1,631	54	1364	99	84	6	10	6	13	6	9
Oct	26%	1,566	51	1212	206	77	13	9	6	13	7	9
Nov	28%	1,719	57	1364	190	79	11	10	8	14	8	9
Dec	29%	1,599	52	1264	139	81	9	10	8	14	8	9
Total		18,298				81	6	13	8	14	7	9











ıtral Veracruz State **MILK FLOW ANALYSIS** A. N. Martinez-Garcia.

ıments: "Traditional" average farm in Central Veracruz State

K PRODUCTION	TOTAL	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
ıber of cows		37	37	37	37	37	37	37	37	37	37	37	37
Fresh cows (no.)		2	2	2	2	2	2	2	2	2	2	2	2
Already milking cows (no.)		18	18	18	18	18	18	18	18	18	18	18	18
Total milking cows (no.)		20	20	20	20	20	20	20	20	20	20	20	20
Dry cows (no.)		17	17	17	17	17	17	17	17	17	17	17	17
Total milk yield (litres)	40740	3000	3720	3720	3600	3720	3600	3720	3100	3360	3100	3000	3100
Household (6.4%; l/day)	2607	192	238	238	230	238	230	238	198	215	198	192	198
Calves (42%; l/day)	17111	1260	1562	1562	1512	1562	1512	1562	1302	1411	1302	1260	1302
eese production (6.4%; l/day)	2607	192	238	238	230	238	230	238	198	215	198	192	198
Sale (45.2%; l/day)	18414	1356	1681	1681	1627	1681	1627	1681	1401	1519	1401	1356	1401
Price per litre		$1.0	$1.0	$1.0	$1.0	$1.0	$1.0	$1.0	$1.0	$1.0	$1.0	$1.0	$1.0
Total sales ($)	$18,414	$1,356	$1,681	$1,681	$1,627	$1,681	$1,627	$1,681	$1,401	$1,519	$1,401	$1,356	$1,401

tral Veracruz State — **Gross Margin Analysis** — **A. N. Martinez-Garcia**

Comments:	"Traditional" average farm in Central Veracruz State	No. ha:	88	**Stocking Rate:**	1.3

	Variable Costs			**Total Costs**
tock purchases	Class	Number	Price/head	
				$0
				$0
				$0
				$0
				$0
		Total livestock purchases:		$0
r animal related costs			Animal health	$475
			Breeding costs	$0
l expenses				
	Hay & Silage making			$0
	Hay purchase			$0
	Forage crops			$0
	Other feed			$0
	Total feed costs			$0
liser	Type	Tonnes	$/tn/applied	
				$0
				$0
				$0
	Total fertiliser			$0
ur		No. of workers	Annual salary	Total
		4	$7,710	$30,840
ing				$0
		TOTAL VARIABLE COSTS		$31,315
oss Margin/ha =	$233			

	Gross Revenue			**Total revenue**
Cattle sales	Class	Number	Price/head	
	Cull cows	8	$1,596	$12,768
	Weaners	5	$870	$4,350
	3yr and older	6	$2,200	$13,200
				$0
				$0
			Total Cattle sales	$30,318
Milk revenue	Total l/milk sold/herd/yr			
	18,414			$18,414
Sundry income	Concept	Number	Price/unit	
	Cheese	261	$12	$3,129
				$0
				$0
				$0
				$0
				$0
				$0
				$0
				$0
				$0
				$0
			Total sundry income	$3,129
			TOTAL REVENUE	$51,861

APPENDIX II: Improved farming systems I - Seasonal calving, with high (78%) pasture utilisation, for milk and beef production.

ntral Veracruz State — **Feed Budget Submodel** — A. N. Martinez-Garcia

Comments: Improved farm medium size (90 hectares) in C.V.S.; seasonal calving (June), increased milk production; 78% pasture utilisation

ert the number of the starting month in B6.

EFFECTIVE AREA:	88	88	88	88	88	88	88	88	88	88	88	88
INITIAL COVER:	700											
STARTING PERIOD:	6											
MONTH:	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
STURE MOVEMENTS												
t herbage accumulation (kg DM/ha/day):	17	45	40	15	8	3	0	0	0	0	-1	-7
Pasture quality (%CP/kg DM)	6	7	6	6	7	8	8	8	7	8	8	5
Pasture quality (MJ ME/kg DM)	9	9	9	9	9	9	9	9	8	7	8	9
Total animal intake/Day (kg DM):	8.3	9.4	9.7	11.4	11.2	11.2	10.9	10.6	11.8	11.9	8.0	6.7
Difference/Day (kg DM):	8.7	35.6	30.3	3.6	-3.2	-8.2	-10.9	-10.6	-11.8	-11.9	-9.0	-14.0
plements (kg DM or kg)												
Hay/Silage:												
Other:												
Nitrogen:	0											
FINAL COVER:	961	2064	3004	3113	3015	2769	2431	2103	1773	1404	1133	701
MAL INTAKE												
Calves (No.)	32	40	40	40	40	40	40	40	40	40	21	21
Intake/Head/Day (kg DM)	1.9	2.3	2.7	3.0	3.2	3.4	3.5	3.7	4.3	5.1	4.7	3.9
Initial liveweight (kg)	30.0	0.0	0.0	0.0								
Liveweight gain/day (kg)	0.4	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.2
Final liveweight (kg)	42	56	71	85	99	111	122	133	143	154	165	171
R1yr Hfrs(No.)	12	12	12	12	12	12	12	12	12	12	12	12
Intake/Head/Day (kg DM)	4.4	4.7	4.5	5.7	5.6	5.5	5.5	5.6	6.5	7.6	6.5	5.4
Initial liveweight (kg)	171.0											
Liveweight gain/day (kg)	0.4	0.4	0.3	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.3	0.2
Final liveweight (kg)	182	194	204	222	237	249	260	271	281	293	302	308
R2yr Hfrs (No.)	10	10	10	10	10	10	10	10	10	10	10	10
Intake/Head/Day (kg DM)	5.5	6.3	6.1	7.7	7.3	7.0	6.9	7.0	8.0	9.3	7.9	6.6
Initial liveweight (kg)	308.0	0.0										
Liveweight gain/day (kg)	0.2	0.4	0.3	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.3	0.2
Final liveweight (kg)	314	325	334	352	368	380	391	402	412	424	433	439
Milking cows (No.)	33	44	44	44	44	44	44	44	35	25	10	0
Intake/Head/Day (kg DM)	9.0	9.0	9.6	11.8	11.1	11.3	10.7	9.8	9.9	11.4	9.9	0.0
Milk yield/day (kg)	6.0	6.0	7.0	7.0	6.0	6.0	5.0	5.0	5.0	5.0	5.0	0.0
Initial liveweight (kg)	439.0	0.0										
Liveweight gain/day (kg)	0.0	0.0	0.0	0.5	0.4	0.4	0.4	0.2	0.0	0.0	0.0	0.0
Final liveweight (kg)	439	439	439	439	453	466	479	491	497	497	497	0
Dry cows (No.)	19.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	16.0	26.0	41.0	51.0
Intake/Head/Day (kg DM)	6.1	8.6	5.7	5.7	5.7	5.7	5.7	5.7	9.7	7.8	6.8	6.1
Initial liveweight (kg)	497.0	439.0	0.0					0.0	497.0			
Liveweight gain/day (kg)	0.0											
Final liveweight (kg)	497	439	439	439	439	439	439	439	497	497	497	497
R1yr Steers(No.)	0											
Intake/Head/Day (kg DM)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Initial liveweight (kg)	0.0											
Liveweight gain/day (kg)	0.0											
Final liveweight (kg)	0	0	0	0	0	0	0	0	0	0	0	0
R2yr Steers (No.)												
Intake/Head/Day (kg DM)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Initial liveweight (kg)												
Liveweight gain/day (kg)												
Final liveweight (kg)	0	0	0	0	0	0	0	0	0	0	0	0
R3yr Steers (No.)												
Intake/Head/Day (kg DM)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Initial liveweight (kg)												
Liveweight gain/day (kg)												
Final liveweight (kg)	0	0	0	0	0	0	0	0	0	0	0	0
R1yr Bulls (No.)	19	19	19	19	19	19	19	19	19	10	10	10
Intake/Head/Day (kg DM)	3.8	3.9	4.2	4.3	4.6	4.6	4.6	4.7	5.3	6.2	5.6	5.0
Initial liveweight (kg)	150.0											
Liveweight gain/day (kg)	0.5	0.5	0.6	0.5	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4
Final liveweight (kg)	165	181	199	214	233	248	259	270	280	291	302	313
R2yr Bulls (No.)	10	10	10	10	10	10	10	10	10	10	0	0
Intake/Head/Day (kg DM)	6.5	7.1	7.2	7.9	8.1	7.8	7.4	7.5	8.6	9.3	0.0	0.0
Initial liveweight (kg)	313.0											
Liveweight gain/day (kg)	0.4	0.5	0.5	0.6	0.6	0.5	0.4	0.4	0.4	0.3	0.4	
Final liveweight (kg)	325	341	356	374	393	408	420	432	444	453	0	0
R3yr Bulls (No.)	2	2	2	2	2	2	2	2	2	2	2	2
Intake/Head/Day (kg DM)	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.9	9.0	7.9	7.0
Initial liveweight (kg)	650.0											
Liveweight gain/day (kg)												
Final liveweight (kg)	650	650	650	650	650	650	650	650	650	650	650	650
TOTAL DEMAND/DAY:	8.3	9.4	9.7	11.4	11.2	11.2	10.9	10.6	11.8	11.9	8.0	6.7
DAYS/MONTH	30	31	31	30	31	30	31	31	28	31	30	31

Central Veracruz State # Stock Reconciliation Submodel **A. N. Martinez-Garcia**

Comments: Improved farm system (seasonal calving pattern; 80%calving percentage, milk and beef production, more animals for sale; 78% p. utilisation)

Farm Area (ha) 90 **Effective area (ha):** 88 **Stocking rate (AU/ ha):** 1.5

FARMER:

STOCK CLASS	OPENING STOCK	PURCH.	NATURAL INCREASE	SALES	DEATHS KILLERS MISSING	CLOSING	A.U's Conversion	TOTAL A.U.	LOSSES
DUAL PURPOSE CATTLE	Are Male calves left entire?("Y " or "N")			y			**DUAL PURPOSE CATTLE**		
	Calving %	80%							
COWS									
Calves			22	7	2				11.3%
Weaners	12			2	0	12	0.7	8	1.0%
Heifers	10			0	1	10	1.4	14	10.0%
Milking cows	44			8	1	44	1.6	71	3.0%
Dry cows	7			0	0	7	1.0	7	1.0%
STEERS									
Calves			0				0.7		11.3%
Weaners					0	0	0.7	0	1.0%
Rising 2yr					0	-0	1.2	0	1.0%
3yr and older					0	0	1.8	0	1.0%
BULLS									
Calves			22		2		0.7		11.3%
Weaners	19			9	0	19	0.8	15	1.0%
Rising 2yr	10			10	0	10	1.3	13	1.0%
3yr and older	0				0	-0	1.8	0	1.0%
Breeding bulls	2	1		1	0	2	2.0	4	1.0%
TOTAL	104	1	43	37	8	103			
	Check		148			148	TOTAL	133	

tral Veracruz State **MILK FLOW ANALYSIS** **A. N. Martinez-Garcia.**

ments: Improved farm system; seasonal milking, 80% calving percentage; 78% herbage utilisation

PRODUCTION	TOTAL	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
ber of cows	[redacted]	51	51	51	51	51	51	51	51	51	51	51	51
Fresh cows (no.)	[redacted]	33	11	0	0	0	0	0	0	0	0	0	0
Already milking cows (no.)	[redacted]	0	33	0	0	0	0	0	0	0	0	0	0
Total milking cows (no.)	[redacted]	33	44	44	44	44	44	44	44	35	25	10	0
Dry cows (no.)	[redacted]	19	7	7	7	7	7	7	7	16	26	41	51
Total milk yield (litres)	72931	5940	8184	9548	9240	8184	7920	6820	6820	4900	3875	1500	0
Household (6.4%; l/day)	4668	380	524	611	591	524	507	436	436	314	248	96	0
Calves (42%; l/day)	30631	2495	3437	4010	3881	3437	3326	2864	2864	2058	1628	630	0
eese production (6.4%; l/day)	4668	380	524	611	591	524	507	436	436	314	248	96	0
Sale (45.2%; l/day)	32965	2685	3699	4316	4176	3699	3580	3083	3083	2215	1752	678	0
Price per litre	[redacted]	$1.0	$1.0	$1.0	$1.0	$1.0	$1.0	$1.0	$1.0	$1.0	$1.0	$1.0	$1.0
Total sales ($)	$32,965	$2,685	$3,699	$4,316	$4,176	$3,699	$3,580	$3,083	$3,083	$2,215	$1,752	$678	$0

tral Veracruz State — **Gross Margin Analysis** — **A. N. Martinez-Garcia**

Comments: Improved farm system, milk and beef production; seasonal calving, 80% calving, 78% herbage util.

No. ha: 88 | **Stocking Rate:** 1.5

	Variable Costs			Total Costs
tock purchases				
	Class	Number	Price/head	
	bull	1	$4,000	$4,000
				$0
				$0
				$0
				$0
		Total livestock purchases:		$4,000
r animal related costs				
			Animal health	$535
			Breeding costs	$0
expenses				
	Hay & Silage making			$0
	Hay purchase			$0
	Forage crops			$0
	Other feed			$0
	Total feed costs			$0
iser	Type	Tonnes	$/tn/applied	
				$0
				$0
				$0
	Total fertiliser			$0
ur		No. of workers	Annual salary	Total
		6	$7,710	$46,260
ing				$0
		TOTAL VARIABLE COSTS		$50,795
oss Margin/ha =	$502			

	Gross Revenue			Total revenue
Cattle sales				
	Class	Number	Price/head	
	cull cows	8	$1,668	$13,344
	weaners	18	$870	$15,660
	R2yr and older	10	$2,491	$24,910
	bull	1	$2,500	$2,500
				$0
			Total Cattle sales	$56,414
Milk revenue				
	Total l/milk sold/herd/yr			
	32,965			$32,965
Sundry income				
	Concept	Number	Price/unit	
	Cheese	467	$12	$5,601
				$0
				$0
				$0
				$0
				$0
				$0
				$0
				$0
				$0
				$0
			Total sundry income	$5,601
			TOTAL REVENUE	$94,980

APPENDIX III: Improved farming system II - Seasonal calving (June and July) for milk and calf production.

ntral Veracruz State	Feed Budget Submodel									A. N. Martinez-Garcia		
Comments:	Improved farm medium size (90 hectares); seasonal calving (June and July), milk and calve production; 75% herbage utilisation											
rt the number of the starting month in B6.												
EFFECTIVE AREA:	88	88	88	88	88	88	88	88	88	88	88	88
INITIAL COVER:	700											
STARTING PERIOD:	6											
MONTH:	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
TURE MOVEMENTS												
herbage accumulation (kg DM/ha/day):	17	45	40	15	8	3	0	0	0	-1	-3	-8
Pasture quality (%CP/kg DM)	6	7	6	6	7	8	8	8	7	8	8	5
Pasture quality (MJ ME/kg DM)	9	9	9	9	9	9	9	9	8	7	8	9
Total animal intake/Day (kg DM):	7.6	9.4	9.5	10.6	11.0	11.2	10.9	10.5	10.9	10.2	8.3	6.7
Difference/Day (kg DM):	9.4	35.6	30.5	4.4	-3.0	-8.2	-10.9	-10.5	-10.9	-11.2	-11.3	-15.0
plements (kg DM or kg)												
Hay/Silage:												
Other:												
Nitrogen:	0											
FINAL COVER:	983	2085	3031	3162	3071	2824	2486	2161	1855	1506	1166	702
AL INTAKE												
Calves (No.)	27	50	50	50	50	50	50	50	50	16	16	16
Intake/Head/Day (kg DM)	1.9	2.4	2.8	3.1	3.4	3.7	3.6	3.8	4.5	5.3	4.8	4.0
Initial liveweight (kg)	30.0	0.0	0.0	0.0								
Liveweight gain/day (kg)	0.4	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.2
Final liveweight (kg)	42	58	73	88	104	119	130	141	151	162	173	179
R1yr Hfrs(No.)	16	16	16	16	16	16	16	16	16	16	16	16
Intake/Head/Day (kg DM)	4.0	4.6	4.6	4.7	5.0	5.2	5.3	5.5	6.3	7.4	6.6	5.3
Initial liveweight (kg)	179.0											
Liveweight gain/day (kg)	0.2	0.4	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.2
Final liveweight (kg)	185	196	205	214	226	236	248	259	269	280	291	297
R2yr Hfrs (No.)	16	16	16	16	16	16	16	16	16	16	16	16
Intake/Head/Day (kg DM)	5.1	5.8	5.7	5.8	6.1	6.3	6.4	6.5	7.4	8.6	7.7	6.1
Initial liveweight (kg)	266.0	0.0										
Liveweight gain/day (kg)	0.2	0.4	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.2
Final liveweight (kg)	272	283	292	301	313	323	335	346	356	367	378	384
Milking cows (No.)	30	55	55	55	55	55	55	55	45	35	15	0
Intake/Head/Day (kg DM)	8.9	8.9	9.4	10.9	10.9	11.0	10.5	9.6	9.7	11.2	9.8	0.0
Milk yield/day (kg)	6.0	6.0	7.0	7.0	6.0	6.0	5.0	5.0	5.0	5.0	5.0	0.0
Initial liveweight (kg)	421.0	0.0										
Liveweight gain/day (kg)	0.0	0.0	0.0	0.3	0.4	0.4	0.4	0.2	0.0	0.0	0.0	0.0
Final liveweight (kg)	421	421	421	421	430	443	456	468	474	474	474	0
Dry cows (No.)	32.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	20.0	40.0	55.0
Intake/Head/Day (kg DM)	5.9	5.9	0.0	0.0	0.0	0.0	0.0	0.0	6.7	7.6	6.7	5.9
Initial liveweight (kg)	475.0							0.0	475.0			
Liveweight gain/day (kg)	0.0											
Final liveweight (kg)	475	475	0	0	0	0	0	0	475	475	475	475
R1yr Steers(No.)	0											
Intake/Head/Day (kg DM)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Initial liveweight (kg)	0.0											
Liveweight gain/day (kg)	0.0											
Final liveweight (kg)	0	0	0	0	0	0	0	0	0	0	0	0
R2yr Steers (No.)												
Intake/Head/Day (kg DM)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Initial liveweight (kg)												
Liveweight gain/day (kg)												
Final liveweight (kg)	0	0	0	0	0	0	0	0	0	0	0	0
R3yr Steers (No.)												
Intake/Head/Day (kg DM)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Initial liveweight (kg)												
Liveweight gain/day (kg)												
Final liveweight (kg)	0	0	0	0	0	0	0	0	0	0	0	0
R1yr Bulls (No.)	0	0	0	0	0	0	0	0	0	0	0	0
Intake/Head/Day (kg DM)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Initial liveweight (kg)	150.0											
Liveweight gain/day (kg)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Final liveweight (kg)	0	0	0	0	0	0	0	0	0	0	0	0
R2yr Bulls (No.)	0	0	0	0	0	0	0	0	0	0	0	0
Intake/Head/Day (kg DM)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Initial liveweight (kg)	280.0											
Liveweight gain/day (kg)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	
Final liveweight (kg)	0	0	0	0	0	0	0	0	0	0	0	0
R3yr Bulls (No.)	2	2	2	2	2	2	2	2	2	2	2	2
Intake/Head/Day (kg DM)	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.9	9.0	7.9	7.0
Initial liveweight (kg)	650.0											
Liveweight gain/day (kg)												
Final liveweight (kg)	650	650	650	650	650	650	650	650	650	650	650	650
TOTAL DEMAND/DAY:	7.6	9.4	9.5	10.6	11.0	11.2	10.9	10.5	10.9	10.2	8.3	6.7
DAYS/MONTH	30	31	31	30	31	30	31	31	28	31	30	31

Central Veracruz State | # Stock Reconciliation Submodel | **A. N. Martinez-Garcia**

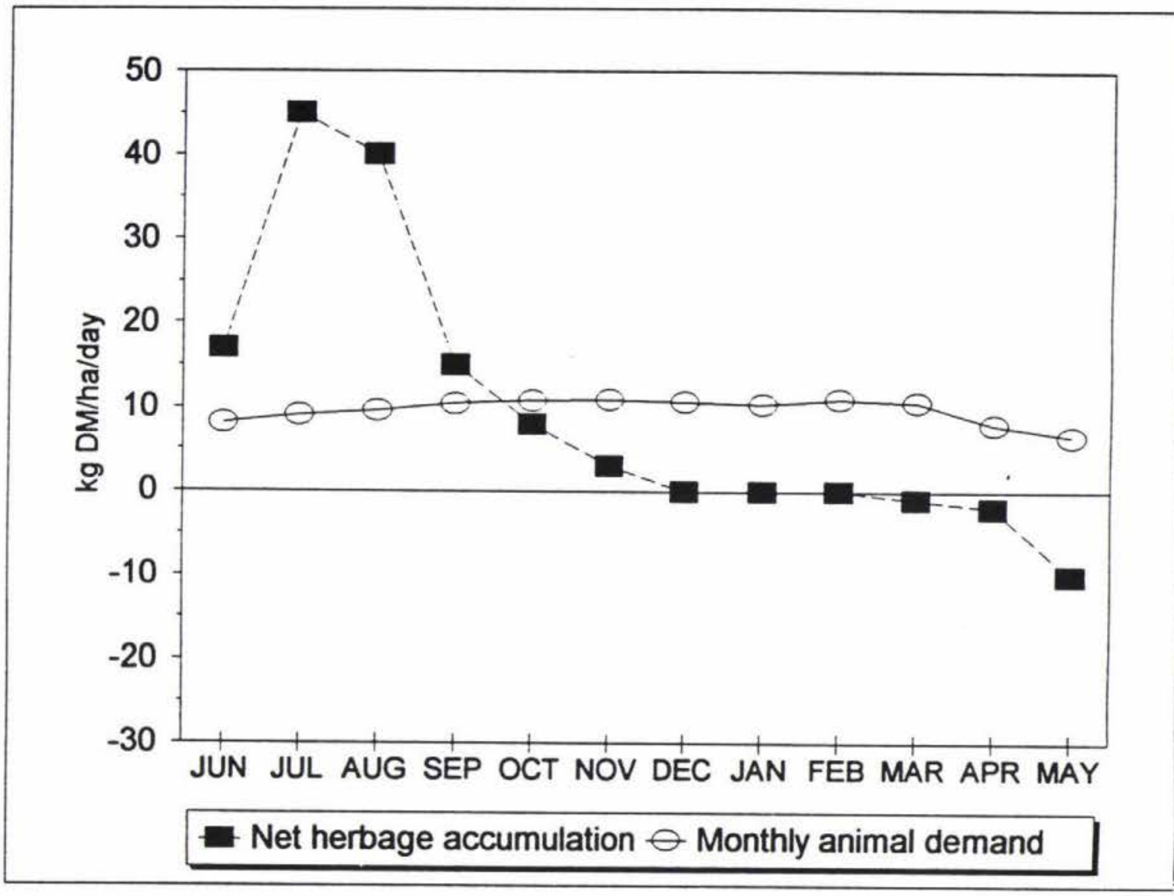
Comments: Improved farm; seasonal calving (June/July; 80%calving percentage, milk and calf production, 75% herbage utilisation

Farm Area (ha) 90 **Effective area (ha):** 88 **Stocking rate (AU/ ha):** 1.5

FARMER:

STOCK CLASS	OPENING STOCK	PURCH.	NATURAL INCREASE	SALES	DEATHS KILLERS MISSING	CLOSING	A.U's Conversion	TOTAL A.U.	LOSSES
DUAL PURPOSE CATTLE	Are Male calves left entire?("Y " or "N")			y			**DUAL PURPOSE CATTLE**		
	Calving %	80%							
COWS									
Calves			28	9	3				11.0%
Weaners	16			0	0	16	0.7	11	1.0%
Heifers	16				2	16	1.4	22	10.0%
Milking cows	55			14	1	55	1.6	89	1.0%
Dry cows	7			0	0	7	1.0	7	1.0%
STEERS									
Calves			0				0.7		11.3%
Weaners					0	0	0.7	0	1.0%
Rising 2yr					0	0	1.2	0	1.0%
3yr and older					0	0	1.8	0	1.0%
BULLS									
Calves			28	25	3		0.7		11.0%
Weaners	0			0	0	0	0.8	0	1.0%
Rising 2yr	0			0	0	0	1.3	0	1.0%
3yr and older	0				0	0	1.8	0	1.0%
Breeding bulls	2	1		1	0	2	2.0	4	1.0%
TOTAL	96	1	57	49	9	96			
	Check		154			154	TOTAL	134	

Improved farm, milk and beef, seasonal calving (June and July), 75% pasture utilisation



ıtral Veracruz State **MILK FLOW ANALYSIS** A. N. Martinez-Garcia.

ments: Improved farm medium size; seasonal calving (June/July); 80% calving percentage; milk and calf production; 75% herbage utilisation

‹ PRODUCTION	TOTAL	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
ber of cows		62	62	55	55	55	55	55	55	55	55	55	55
Fresh cows (no.)		30	25	0	0	0	0	0	0	0	0	0	0
Already milking cows (no.)		0	30	0	0	0	0	0	0	0	0	0	0
Total milking cows (no.)		30	55	55	55	55	55	55	55	45	35	15	0
Dry cows (no.)		32	7	0	0	0	0	0	0	10	20	40	55
Total milk yield (litres)	90270	5400	10230	11935	11550	10230	9900	8525	8525	6300	5425	2250	0
Household (6.4%; l/day)	5777	346	655	764	739	655	634	546	546	403	347	144	0
Calves (42%; l/day)	37913	2268	4297	5013	4851	4297	4158	3581	3581	2646	2279	945	0
ese production (6.4%; l/day)	5777	346	655	764	739	655	634	546	546	403	347	144	0
Sale (45.2%; l/day)	40802	2441	4624	5395	5221	4624	4475	3853	3853	2848	2452	1017	0
Price per litre		$1.0	$1.0	$1.0	$1.0	$1.0	$1.0	$1.0	$1.0	$1.0	$1.0	$1.0	$1.0
Total sales ($)	$40,802	$2,441	$4,624	$5,395	$5,221	$4,624	$4,475	$3,853	$3,853	$2,848	$2,452	$1,017	$0

ıtral Veracruz State — Gross Margin Analysis — A. N. Martinez-Garcia

Comments:	Imprvd. farm; seasonal calving (June/July), 80% calving percentage; milk and calf prod.; 75% hrbg util.	No. ha:	88	Stocking Rate:	1.5

Variable Costs

				Total Costs
ıtock purchases	Class	Number	Price/head	
	bull	1	$4,000	$4,000
				$0
				$0
				$0
				$0
		Total livestock purchases:		$4,000
ır animal related costs			Animal health	$0
			Breeding costs	$0
l expenses	Hay & Silage making			$0
	Hay purchase			$0
	Forage crops			$0
	Other feed			$0
	Total feed costs			$0
liser	Type	Tonnes	$/tn/applied	
				$0
				$0
				$0
	Total fertiliser			$0
ıur		No. of workers	Annual salary	Total
		8	$7,710	$61,680
ːing				$0
		TOTAL VARIABLE COSTS		$65,680

ːoss Margin/ha =	$415

Gross Revenue

				Total revenue
Cattle sales	Class	Number	Price/head	
	cull cows	14	$1,596	$22,344
	weaners	34	$870	$29,580
	bull	1	$2,500	$2,500
				$0
				$0
			Total Cattle sales	$54,424
Milk revenue	Total l/milk sold/herd/yr			
	40,802			$40,802
Sundry income	Concept	Number	Price/unit	
	Cheese	578	$12	$6,933
				$0
				$0
				$0
				$0
				$0
				$0
				$0
				$0
				$0
				$0
			Total sundry income	$6,933
			TOTAL REVENUE	$102,159

tral Veracruz State — **Net herbage accumulation submodel** — **A. N. Martinez-Garcia**

Month	Total animal intake (kg DM)		Estimated farm utilisation (% per month)	Estimated pasture production (kg DM/month)	Estimated Pasture Growth Rate (kg ha/day)	kg DM lost through senescence &decay	Net herbage accumulation (kg/ha/day)
	kg DM/ha/day	kg DM/ha/month					
JUN	6.6	199	90	221	7	5	2
JUL	8.4	259	40	649	22	1	21
AUG	8.4	260	30	866	29	1	28
SEP	8.4	251	25	1,005	34	2	32
OCT	8.4	260	45	577	19	3	16
NOV	8.4	252	55	458	15	6	9
DEC	8.4	260	70	372	12	8	4
JAN	8.3	257	100	257	9	8	1
FEB	9.5	265	95	279	9	8	1
MAR	10.7	330	100	330	11	7	4
APR	8.8	263	100	263	9	9	-0
MAY	7.8	242	100	242	8	8	0
al Annual		3,099	56	5,519			

l = 4.184 joules
J = 239 kcal.

Cassia laevigata

alculate ME :		Dry Matter		Digestibility	Digestible Nutrient		Total	Total
		%	g/kg	coefficient	g/kg	kcal/g	kcal	MJ
ıde protein)	CP	17.9	179	70.80%	126.732	4.32	547.5	2.3
de fibre)	CF	24.7	247	72.30%	178.581	3.59	641.1	2.7
er extract)	EE	6.2	62	72.30%	44.826	7.73	346.5	1.4
ogen-free extract)	NFE	41.1	411	73.00%	300.03	3.63	1,089.1	4.6
						Sum (ME/kg DM)	2,624.2	11.0

Central Veracruz State	Estimation of amount of MJ ME/kg DM per pasture specie						A. N. Martinez-Garcia	
Comments:								
Herbage specie:	Axonopus compresus (data from Gohl, 1981)							
To calculate ME :		Dry Matter		Digestibility	Digestible Nutrient		Total	Total
		%	g/kg	coefficient	g/kg	kcal/g	kcal	MJ
(Crude protein)	CP	9.4	94	48.00%	45.12	4.32	194.9	0.8
(crude fibre)	CF	34.8	348	31.00%	107.88	3.59	387.3	1.6
(ether extract)	EE	1.52	15.2	37.00%	5.624	7.73	43.5	0.2
(nitrogen-free extract)	NFE	44.02	440.2	30.00%	132.06	3.63	479.4	2.0
1 cal = 4.184 joules						Sum (kcal/kg DM)	1,105.1	
1 MJ = 239 kcal.						Sum (ME/kg DM)		4.6

APPENDIX VI: Framework for a whole farm cashflow model.

Central Veracruz State — **CASH FLOW BUDGET** — A. N. Martinez -Garcia

Comments:

PRODUCTION	TOTAL	Jun	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
AVERAGE No. OF COWS													
Litres/cow sold per day													
Cheese													
TOTAL MILK INCOME	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
LIVESTOCK	$0												
Cull Cows	$0												
Calves	$0												
Weaners	$0												
R1yr	$0												
R2yr and older	$0												
	$0												
OTHER	$0												
	$0												
Tax	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL INCOME	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
EXPENDITURE													
Livestock Purchases	$0												
Wages	$0												
Animal Health	$0												
Artificial Insemination	$0												
Herd Testing	$0												
Shed Expenses	$0												
Cash Crop Expenses	$0												
Contracts	$0												
Electricity	$0												
Feed	$0												
Freight	$0												
Fertiliser	$0												
Lime	$0												
Seeds	$0												
REPAIRS AND MAINTENANCE													
Milking Shed & Machines	$0												
Bldgs & Improvements	$0												
Plant & Machinery	$0												
Weed & Pest	$0												
FARM VEHICLE EXP (incl car)													
Fuel & oil	$0												
Car	$0												
Other	$0												
ADMINISTRATION													
Accounts	$0												
Tel / Mail	$0												
Other	$0												
Consultancy	$0												
Insurance (Farm)	$0												
Other	$0												
TOTAL FARM EXPENSES	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Mortgage (interest+ principal)	$0												
Rent / Lease	$0												
Taxation (To pay this year)	$0												
Personal Expenses	$0												
Life Insurance (personal)	$0												
Capital Items	$0												
Other	$0												
TOTAL EXPENSES	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
SURPLUS/DEFICIT	$0												
OPENING BALANCE		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
MONTHLY BALANCE		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
CLOSING BALANCE	$0												