Improved Farming Systems for the Central Chaco of Paraguay: Some case studies

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Abstract of a thesis submitted in partial fulfilment of the requirements for the degree of M.Appl.Sc.

Improved Farming Systems for the Central Chaco of Paraguay: Some Case Studies.

By M.A. Gonzalez Amarilla

This study is about developing improved farming systems for the Central Chaco region of Paraguay. The improved systems must not only be more efficient, but also sustainable in the long run without depleting the resource base.

The Paraguayan economy relies heavily on agricultural production. An important farming community in the Central Chaco of Paraguay was chosen for this study. Three typical farms in the area of study were used to develop a database that was, subsequently, used to develop a linear programming model for a typical farm. This model was used to study and test how different factors impact on the farming systems. Furthermore, an assessment was made of how technological and managerial alternatives could improve the farming systems

This was the first attempt to study farming systems in Paraguay from a system perspective and, as such, data availability was limited. This study is expected to stimulate further research. The study showed that a dairy farming system is more profitable at current market conditions. Within this system, improvements in farm productivity will occur if seasonal calving is utilized.

Use of supplements during the dry season is also recommended. It is more profitable to buy at least 25% of replacements rather than to rear own replacements. Moreover, the introduction of legume mixtures in the system will not only improve the overall performance but also improve the sustainability of the farm system. A leucaena hedge row system is the most promising technological innovation among the explored alternatives

Research results also confirm the need for farmers to have an emergency plan on hand if drought strikes. Overall, this research has proved that linear programming can be successfully utilized to gain an insight into the farming system behaviour and should be considered for further studies in the area of study.

Key words: f*arming systems, modelling, Central Chaco, system approach, mixed farming, Mennonites, Paraguay, Linear programming, dairy farming.*

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Marco Gonzalez

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Chapter 1

NATURE AND PURPOSE OF THE RESEARCH

1.1 Introduction

Overall, farm productivity in Paraguay is low relative to Western standards, (N. Duarte, 2003; Heikel, 2003), and the country displays some of the lowest yields in all of Latin America[1]. There is extensive room for improving both yields and farm systems efficiency.

This study is about developing better farming systems for a particular area in Paraguay using a mathematical model. This Chapter contains an introduction to the research problem, the objectives and the methodology chosen for the study. Furthermore, it contains a description of the resources of the three case study farms utilized for developing the mathematical model and the outline of this thesis.

1.2 The importance of improving primary production

Improving primary production efficiency is particularly important in Paraguay as agricultural products represent 60% of the total exports (FAO, 2002), and more than 25 % of the total GDP of the country. Figures 1.1 & 1.2 contain the details. Furthermore, over the last twenty years the country has shown an economic growth rate of only 0.1 % per year, which is far behind the rest of the continent (FAO, 2002). This was due, in part, to two important factors: unfavourable climatic conditions in the country and a decline in the price of traditional agricultural products in international markets (Figures 1.3 to 1.6) (http://www.paraguaygobierno.gov.py, April 20, 2004; FAO, 2002).

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[1] http://reference.allrefer.com/country-guide-study/paraguay/paraguay65.html, 20th May 2003

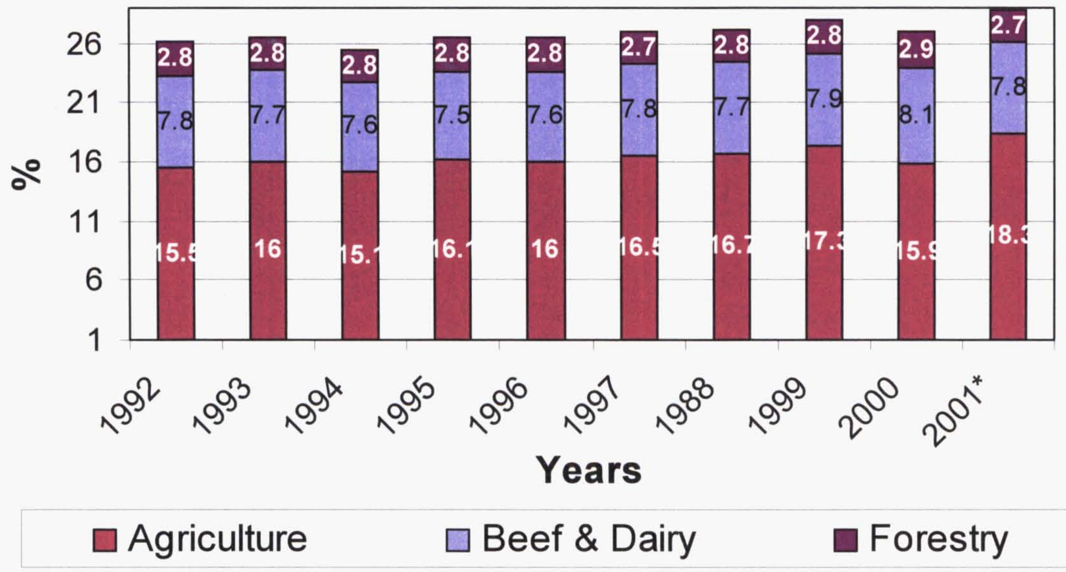

Figure 1.1 Paraguay's agricultural production as a % of the total GDP (MAG, 2002)

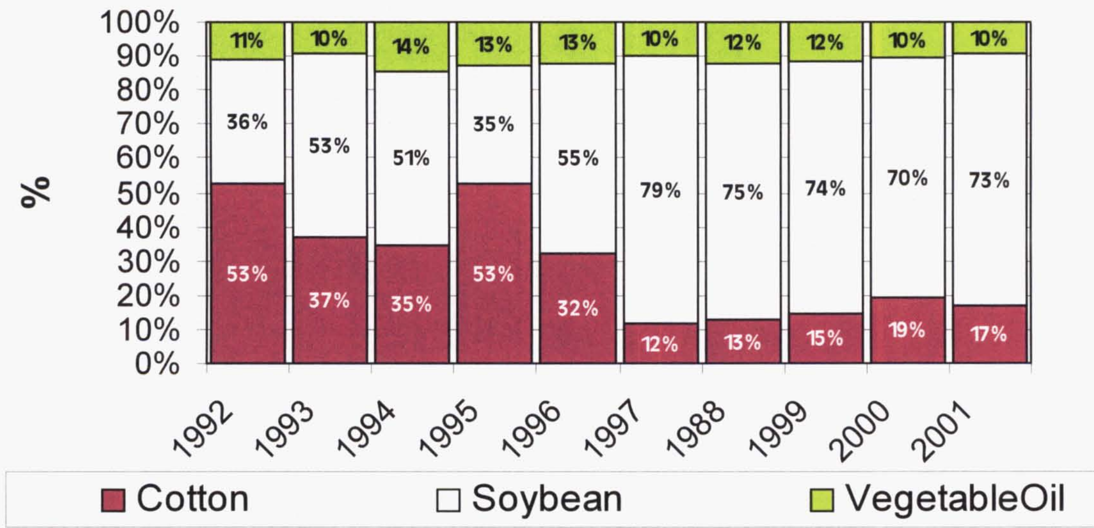

Figure 1.2 Paraguay's agriculture exports as a % of total agriculture export value (MAG, 2002)

The decline in agricultural prices has been especially dramatic in Cotton, which is one of the most important traditional agricultural products, representing 53 % of agricultural exports in 1992, but just 17 % of the total agricultural exports by 2001 (Figure 1.2). The price has shown a significant drop from 1995, with prices in 2001 being 50 % lower than in 1995 in real terms. (Figures 1.1 to 1.3) The same phenomenon has occurred to some extent with oil seed, beef and milk prices. (FAO, 2002)

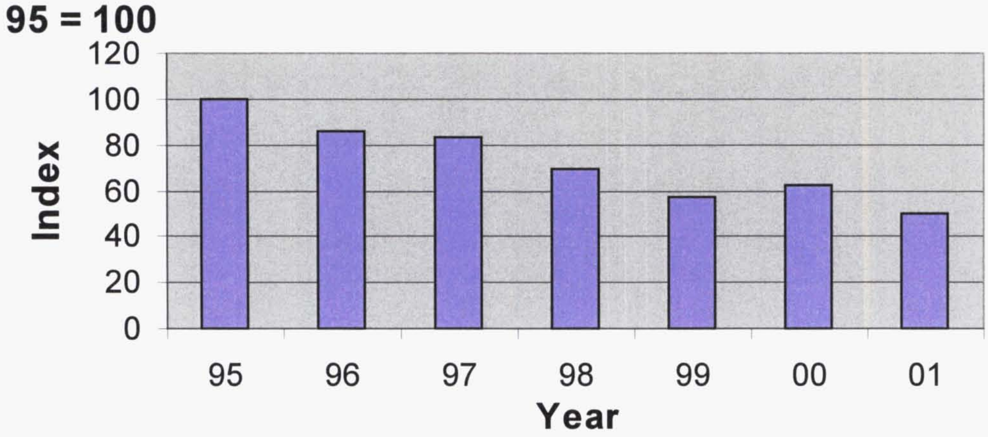

Figure 1.3 Cotton price index from 1995 to 2001. Source: adapted from FAO, 2002.

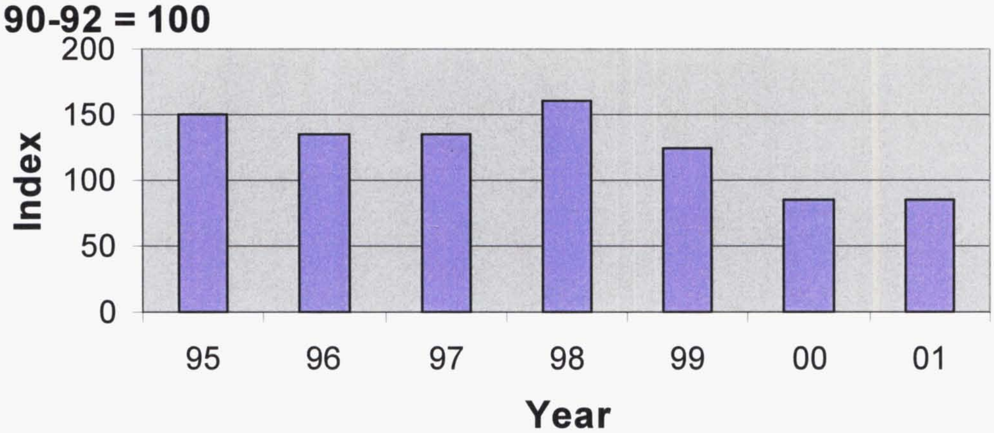

Figure 1.4 Oil seed price index from 1995 to 2001. Source: FAO, 2002

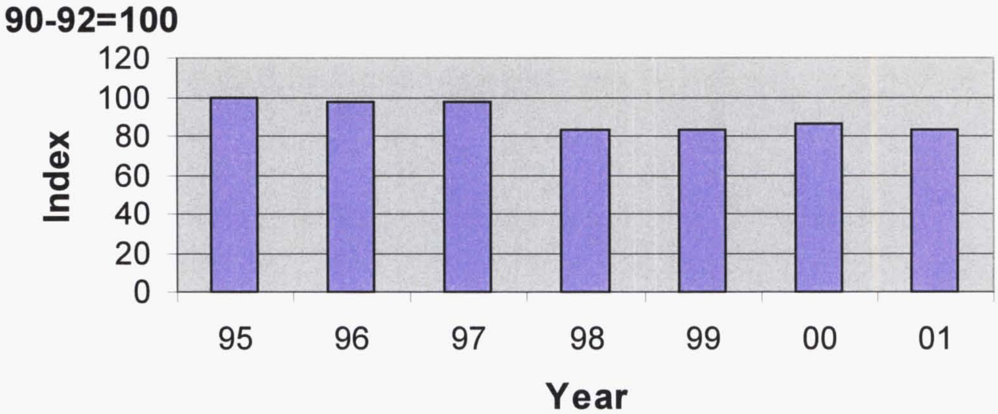

Figure 1.5 Beef price index from 1995 to 2001. Source: FAO, 2002.

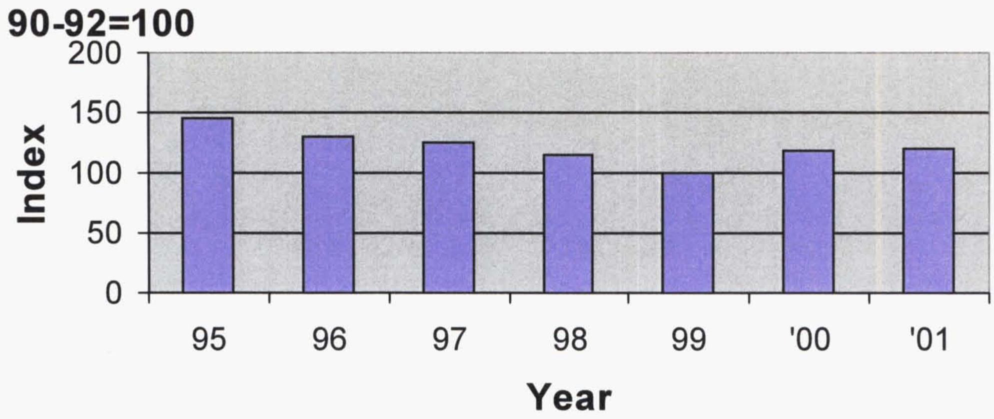

Figure 1.6 International milk price index from 1995 to 2001. Source: FAO, 2002

Because of the important role that agriculture plays in the national economy, the Paraguayan government has made supporting the agricultural sector a priority for the period from 2003 to 2008.

1.3 The Research Problem

It has been argued that the poverty and slow development of the country have their origins in the inefficient use of resources such as land and labour (N. Duarte, 2003; Heikel, 2003). There is a large amount of labour available but without access to land, technical assistance and credit facilities. As a result, the country has very low farm productivity compared to Western standards. More importantly, a factor severely threatening economic growth is the depletion of Paraguay's rich endowment of natural resources through unsustainable exploitation. For instance, timber reserves have been exhausted and the once rich topsoil of the eastern border region is now severely eroded (USAID, 2003).

As the price of agricultural products is determined on the world market, and future price rises are very uncertain, productivity growth is the only factor directly under the control of the farmer that could increase profitability.

There are two important, but often conflicting, problems arising in the farming communities. One is related to the need to improve productivity and the other is to assure sustainability. This research will explore how to improve productivity in a farming system, without depleting the resource base, by putting restrictions on possible practices to maintain fertility.

The problem this study will address is the same problem that constitutes the central concern of all agricultural production economics, that is, to find the most efficient production pattern and resource use in order to satisfy a given set of goals and objectives. (Barnard, C. & Nix, J., 1973)

If farm resources could be devoted to a single line of production, a large part of the planning process would be rendered unnecessary. However, the fact that resources can usually be used in alternative enterprises constitutes the nub of planning.

It is widely recognized that the need to plan arises from three basic factors:

1. individuals have different goals and objectives;
2. the production means available can be put to many different uses;
3. the means available to satisfy these wants are in scarce supply.

Clearly, it is very difficult to consider all these possibilities through empirical experimentation; so it is necessary to develop conceptual models to explore rational choices.

These will rely as far as possible on quantitative research, but due to the lack of data, it is necessary to draw on conventional wisdom, the observed successes and failures of farmers and, in some situations, informed intuition.

1.4 Objectives of the Study

The general objective of this research is to identify farming systems that will improve farm productivity in the Central Chaco of Paraguay which, in turn, will lead to poverty alleviation in the region through employment generation, the identification of technologies for a sustainable increase in food production, and the protection of the environment through better management of natural resources. Thus, the present study aims to identify optimal farm systems which ensure economic viability and ecological sustainability. Specifically, the objective is to develop a whole farm system model for a typical farm in the Central Chaco, and use this to experiment with different variables (technological, climatic, social and cultural).The research will explore optimal farming systems for the given set of resources and constraints.

It will involve comparing the optimal farming systems with the current systems, analyzing the ranges over which the optimal solution remains unchanged, finding further opportunities for improving the farming system and, finally, serving as a guide to farm advisors and farmers.

Different research outcomes developed both locally and elsewhere will be used in the model. The study will create a precedent for using a systems approach to the region. This may well stimulate further research in the area.

Furthermore, the study will explore which farming systems are more resilient to climatic and market changes.

Within these overall objectives this study aims to:

1. determine the optimal farming systems for farms with different soil type ratios,
2. predict the effect of changing the seasonality of livestock production in order to match periods of high energy demand with periods of high feed supply in order to reduce the cost of production and increase profitability,
3. explore the effect of changing output prices and their effect on the optimal solution,
4. foster further research in the area and on the topic.

1.5 Method of Study

The present analysis, like many farm management exercises, tends towards being normative in concept. Courses of action to be followed for clearly defined objectives, restrictions and constraints will be determined. The results will indicate the most profitable course of action under specific conditions (Thomson, 1974).

The decision problems could be resolved using simple partial budgets or marginal analysis of new production lines introduced into the current farming system. However, the solutions would be restricted due to the difficulty of doing hundreds of partial budgets. In addition a simple partial budget does not lead to a better understanding of the farming system as a whole. A whole farm system model is more suitable because it is possible to consider many variables at the same time, while matching the goals and objectives of the decision maker.

A mixed crop and beef model is required for this study, with different sub-systems taking into account all the variable components as well as their interrelationships. Implicit in a holistic approach are the awareness of system dynamics and the principle of ***"Ceteris imparibus"*** which means that if there is one change in the system everything else is also affected, though we may not always know exactly how.

A farm system comprises a series of resources, activities and constraints which interact with each other. Such a model complements empirical work because only a few farm prototypes can be tested experimentally, while a much larger number and a larger spectrum can be examined numerically and models allow a better specification of the tradeoffs between conflicting goals. (Van Leeuwen, 2001)

Linear Programming (LP) is a planning technique that can be used to provide normative answers to economics problems that include an objective, alternative methods or processes and resource restrictions. Further advantages of this planning technique include the fact that it provides considerable understanding of the nature of the general decision making problem. Software required to implement LP is readily available. This can generate different scenarios according to the decision-maker's preferences, interests or changes in resource availability or output prices. Finally, LP provides considerable insight into the nature and structure of the real world farm decision-making problem. However, this technique does have its limitations. These include the deterministic nature of the model, the essential postulate of linear relationships between variables, and the implicit assumption that the linear objective function of the model represents management objectives accurately (Nuthall, P., 198?).

These limitations do not prevent the use of this method for this study. Furthermore, the solving routines are very efficient in contrast, to say, a free form system simulation model which is very much more time consuming to develop and use. Where the relationships are complex, however, system simulations might be the only choice, but in this case it is expected a LP model will be relatively realistic.

Finally, a linear profit objective function is acceptable as profit maximisation is a means to an end for family satisfaction (Heady, O., 1952). In addition, the use of the profit motive enables non-financial objectives to be evaluated in financial terms. Money acts as a common denominator in making decisions (Barnard C. and Nix, J., 1973).

Consequently, a model of a typical farm from the Central Chaco was constructed using data collected from the area of study through interviews with farmers, researchers, farm advisers and consultants, together with data available in the literature.

1.6 The Case Study Farms

For the purpose of this study three case study farms where selected to both develop and validate the model. The criteria for farm selection were based on the farmer's willingness to participate in the research, the farm's representativeness within the area of study and availability of data.

1.6.1 Location

The three case study farms are located in the Central Chaco of Paraguay with one case study belonging to one of the three big agricultural cooperatives present in the area of study.

1.6.2 Area

The farm's total effective area, including leased land was, on average, 236 hectares ranging from 119 hectares (Case study 2) to 381hectares (Case study 1).

1.6.3 Climate

Climatic data for the Central Chaco as a region is applicable to all three case study farms. However, because of the irregular rainfall distribution within the region important differences can be expected for the effective rainfall between farms (Dürksen personal communication, 2005).

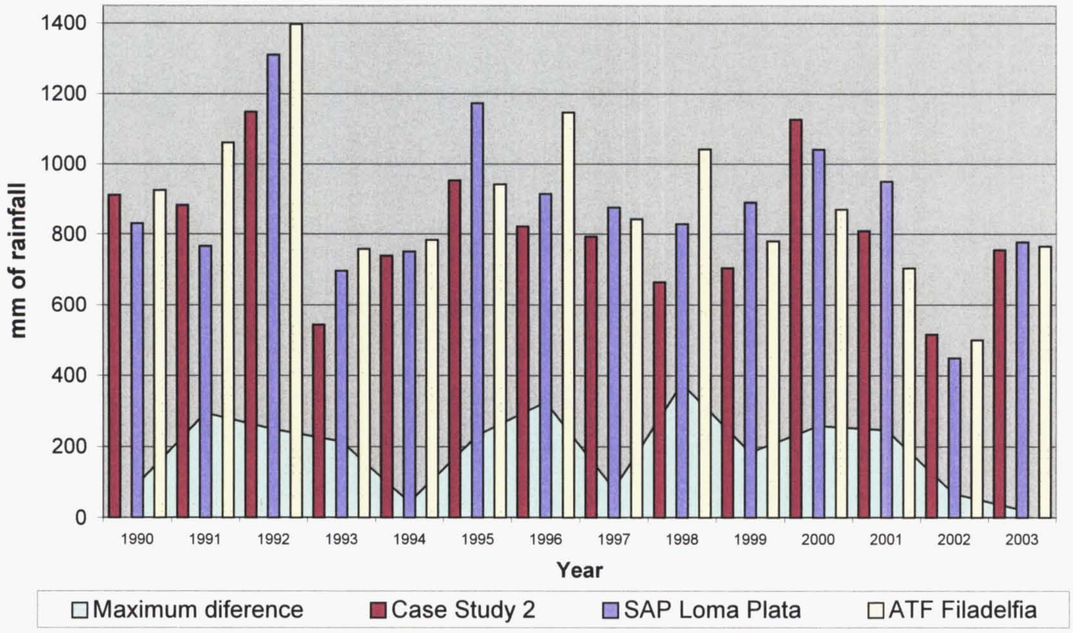

Figure 1.7 Effective rainfall records from two meteorological stations in the region contrasted with on-farm records from Case study 2, from 1993 to 2003.

According to Figure 1.7, the rainfall difference in the area of study can be as much as 350 mm between these three places, but for the year 2003 the difference is very small and, as such, we could expect the same pasture or crop yields in the three locations. However, when comparing the rainfall distribution per trimester between Case study 2 and ATF Filadelfia the close similarity for the year 2003 disappears, as shown in Figure 1.8

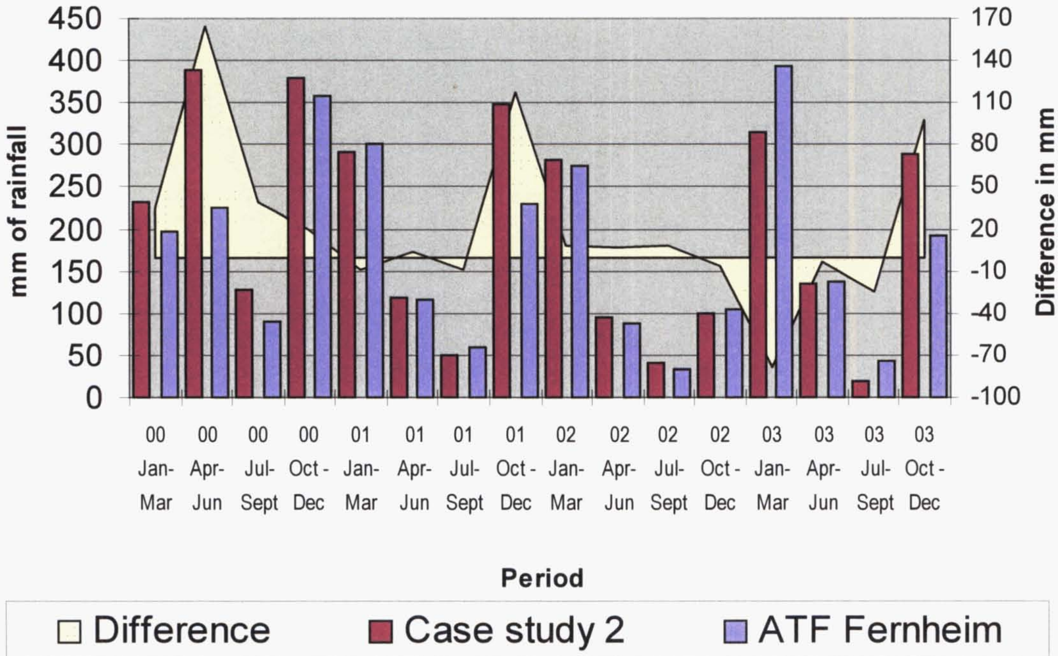

Figure 1.8 Comparison of Rainfall per trimester from January 2000 to December 2003 Source: data collected in the area of study.

1.6.4 Soils

The soil type in the Central Chaco is classified as Campo (light) and Monte (heavy) soils. Farmers are familiar with this classification and develop their farming systems according to the particular ratio of these soils present in the farm. Figure 1.9 shows the soil type ratio for the three case study farms.

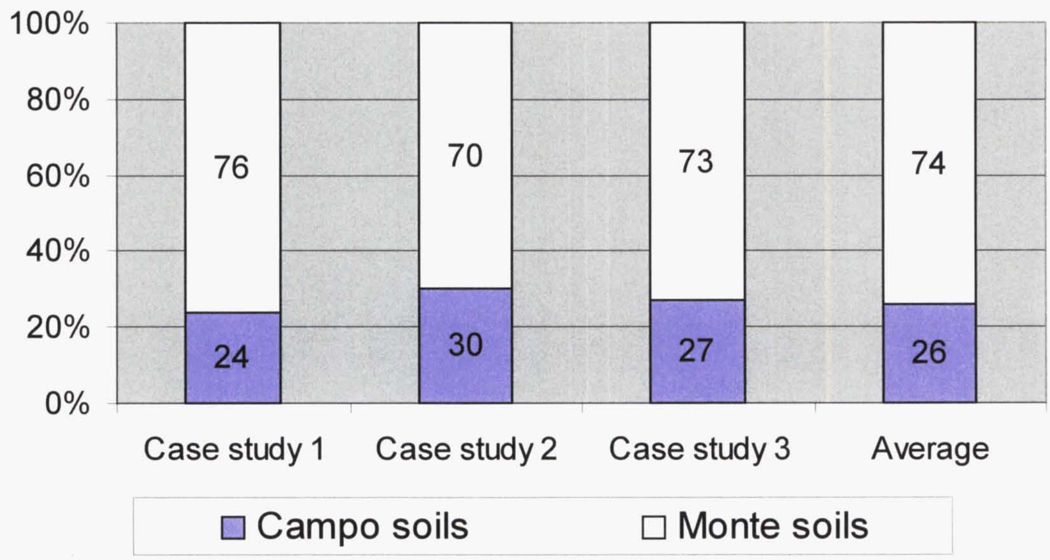

Figure 1.9 Soil type ratio for the three case study farms

1.6.5 Management

The three farms are managed either by the farmer alone (Case study 1) or the farmer with his wife (Case studies 2 & 3). The most important criteria for farm selection were based on availability of data and the farmer's willingness to share information. This is particularly true in Paraguay where farmers are protective of their personal data. These two factors are more likely to be found in farms that have good management, keep good farm records and are open to new ideas. The managerial skills of the three case study farm can be considered as above average for the region and this factor could be a limiting factor when interpolating their results to other farms in the area. However, as the objective of this study was to develop improved farm systems the use of above average data to validate the model can be considered acceptable.

The three case study farmers keep in close contact with the extension services of their respective colonies. For instance, one farmer (Case study 1) is the president of a farmers' discussion group. On the other hand, another farmer (Case study 2) is an artificial insemination technician, and his livestock is well known for their improved genetic merit. In addition he has a part time job as an electrician maintaining the local power supply network. Finally, the other farmer (Case study 3) is a part time officer of the extension service of his colony and has a degree in Agronomic Engineering.

1.7 Thesis Outline

Chapter 2 contains a description of Paraguay's agricultural sector and farming systems in general as well as the farming systems in the Central Chaco. Chapter 3 contains a description of the structure of the linear programming model developed for this study, excluding the nutritional sub-model which is described in Chapter 4. Chapter 5 contains the procedures used to evaluate the model and Chapter 6 gives the results of the different experiments carried out with the validated model. Chapter 7 contains a summary of the conclusions, implications and limitations of the study as well as suggestions for further improvements of the model and further research.

Chapter 2

PARAGUAY AND ITS AGRICULTURE

2.1 Introduction

To place the research problem into perspective it is important to describe Paraguay's farming systems, climate, resources and constraints. This chapter describes Paraguay including its location, physical features, economy and farming systems in general. It also describes the Central Chaco, the area selected for study. This includes its location, population, Climate, water resources, soils, and farm systems.

"Paraguay is a country with valuable resources, such as favourable climate, water, roads, land and labour force but it is still poor" (Heikel, 2003). Despite this, Paraguay is one of the poorest economies of the region, a place shared only with Bolivia and Haiti (Ciciolli, 2003).

2.2 Location

Paraguay is a landlocked country located in the southern Hemisphere between the parallels 19° 18' and 27° 31' S and the meridians 54° 15' and 62° 38' W. Its neighbours are Brazil and Bolivia in the North, Brazil and Argentina in the East, Argentina in the South and Argentina and Bolivia in the West.

The total land area of the country is 406,752 km^2 and it has a farming area of about 24 million ha. The country is divided by the Paraguay River into two major geographical regions with distinct topography and geology. These two regions are the Eastern region or "Oriental" and the Western region or "Chaco".

The Eastern Region has an area of 156,827 km^2. It has an undulating landscape of rolling hills with abundant rainfall ranging from east to west with 1,700 mm close to the frontier with Brazil and 1,200 mm close to the Paraguay River.

The "Chaco" has an area of 246,925 km^2. It is an extensive semi-arid to sub-humid alluvial plain with sediments from the Andes with a gentle slope to the Paraguay River.

Paraguay's population was estimated to be 6,036,900 in July 2,003 with 46 % of the population living in the countryside. The Eastern Region contains 98% of the population of the country. The population growth was estimated as 2.54% per year in 2,003 (World Fact Book, 2003).

Figure 2.1 Map of Paraguay with political division, main cities, rivers and routes. Source: UN, 2004.

2.3 Physical Features

The Eastern region is wet with moderate changes in temperature. There are no significant differences between the north and the south. In contrast with this, the Western region has a climate that ranges, from east to west, between tropical humid and tropical dry.

2.3.1 Rainfall

In the Eastern region the rainfall ranges from 1,270 mm near the Paraguay River to 1,900 mm close to the Parana River. In contrast, the western region or "Chaco" has periods of floods alternating with very dry seasons. Rainfall is concentrated during the summer period (October to March) and the dry season occurs during the winter period (April to September). The rainfall ranges from 400 mm near the frontier with Argentina and Bolivia in the west to 1,000 mm near the Paraguay River in the east.

2.3.2 Frost

Frost can occur throughout the country. In Asuncion, the capital city, the main temperatures are in the winter 18°and 24° in the summer (AQUASTAD, 2002).

2.3.3 Water resources

The water resources of the country have been calculated to be about 18,000 m^3 per inhabitant per year of potable water (N. Duarte, 2003).

There are two main hydrological catchments in the country. The largest one is the Paraguay basin that covers all the western region (246,845 km^2) plus two thirds of the Eastern Region (106,907 km^2) covering 87 % of the total area of the country. The remaining area of the country belongs to the Parana basin (52,998 km^2). Within this basin there are at least four rivers with important potential for hydro power generation (AQUASTAD, 2002).

Irrigation

Irrigation has been a poorly developed activity in Paraguay. According 1998 data the estimated irrigated area in Paraguay was 67,000 ha, of this 20,000 ha were used for rice and the remaining area for sugar cane, strawberries, tomatoes, vegetables and some orchards. In the Eastern Region irrigation water has been obtained mainly from surface water (rivers and streams). In this region there are situations of water scarcity related to the uneven rainfall distribution that calls for supplementary irrigation.

On the other hand, the climate and isolation of the Western Region have limited agricultural development in that region. Although the region has some areas with potential for agriculture, the scarcity of both surface and underground water sources is probably the most limiting factor to increasing its productivity (AQUASTAD, 2002).

2.4 Economy

Agricultural activities directly involve 36 % of the active population and contribute 28.8 % of the GDP of Paraguay (MAG, 2002). Moreover, the agricultural sector produces 90 % of the countries exports and more than 50 % of the added value in industrial activities comes from agro-industries (MAG, 2002). It has been estimated that more than 50 % of the total economy involves unrecorded informal production. There is a lack of transparency and, as a consequence, it is difficult to judge the real performance of the economy and this undermines the analysis of markets and other needs of the agricultural sector (Ibarra & Nunes, 1998).

Paraguay is among the poorest countries of the world, a place that in America is shared only with Bolivia and Haiti. Approximately 36% of Paraguayans live below the poverty line and rural Paraguay is particularly poor. (USAID, 2003; World Fact Book, 2003).

According to official data from 1999 the number of people living in the countryside in poverty was 1,100,000, or 41.3% of the rural population. Moreover, within this group more than 25% live in extreme poverty condition and survive on less than one American dollar per day (Ciciolli, 2003; World Bank, 2004). Inequality is also high in Paraguay relative to other countries in the region, the wealthiest 10 percent consume 90 times what the poorest 10 percent consume, one of the most inequitable ratios in the world (World Bank, 2004).

2.5 Farming systems in Paraguay

2.5.1 Background

Farming systems in Paraguay are characterized by a high proportion of family farms; the last available data (GTZ, 1994) shows that from the total number of farms in the country (310,000), corporations represent only 1 % percent while individual producers represent the remaining 99 % of the farms. Figure 2.2 contains data showing that in 1996 67 % of all farms were mixed farms; 25 % percent were cropping and the remaining 8 % percent livestock farms. As in other parts of the world, Paraguayan farmers use mixed farming systems to diversify production and minimize risk (Glatzle & Stosiek, 2001).

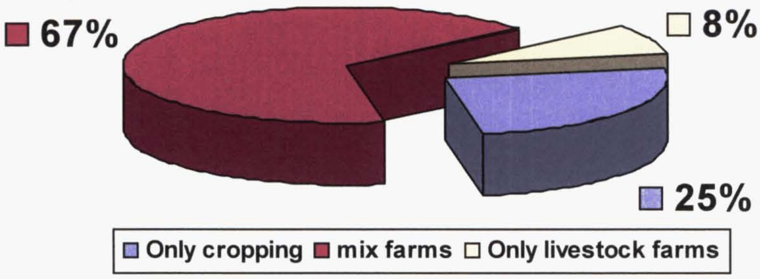

Figure 2.2 Percentages of different production systems in Paraguay. Adapted from Glatzle and Stosiek, 2001

Producers with more than 1,000 hectares represent 1 % of the number of farms, own 70 % of the farm land and 60% of the livestock population. Moreover, this group contributes more than three quarters of the agricultural exports of the country (Glatzle & Stosiek, 2001).

Paraguay has in its rural population a mosaic of different minorities (native Indians, groups of settlers of Brazilian, German or Japanese origin and foreign investors) who differ significantly in the production systems used, the production levels and organizational structures. Indigenous Paraguayans live predominantly by subsistence agriculture on communally owned land and show little affinity to livestock husbandry. In contrast, colonist Paraguayan farmers and, more recently, immigrate groups of producers are strongly market orientated developing mixed farming systems on privately owned land (Glatzle & Stosiek, 2001).

The organizational structure of Paraguayan farmers and foreign investors is relatively weak. However, almost all emigrant settler communities are organized into marketing co-operatives. Among them are the so called "Colonies" of Mennonites, a religious community of German origin, which settled in Paraguay mainly during the first half of the past century. These colonies exert a strong impact on national markets in special sectors such as dairy and beef products (Glatzle & Stosiek, 2001).

2.5.2 Cropping production systems

Cropping farming systems in Paraguay have been characterized as being reliant on a very narrow range of cash crops including cotton, soybean, sugar cane and maize.

Continuous use of the conventional tillage system and a lack of regular fertilizer application to replace the nutrients has produced soil erosion and depleted fertility levels in many traditional cropping areas. Consequently, many areas of the country that have been under cropping systems during the past three or more decades now have poor soils and, mainly, do not produce profitable crop yields.

2.5.3 Ruminant Livestock Production Systems

Cattle production for meat and milk is by far the most important livestock sector. Permanent housing for ruminants is a rarity with the animals being ranched on natural and improved tropical pastures. Tethering is common among smallholders and landless peasants. Even in intensive dairy systems, milking cows cover part of their feeding requirements on pastures near milking pens. (Glatzle & Stosiek, 2001)

Improved pasture establishment in Paraguay has a short history but has reached remarkable levels in the last two decades. The first record of an introduced improved pasture in Paraguay comes from the early nineteen fifties when an US American agricultural advisor to the Mennonite colonies in Central Chaco, Robert Unruh, introduced buffel grass (*Cenchrus ciliaris*) (Glatzle, 1999). Later, a number of other introduced pasture plants gained commercial importance and were multiplied on a national level (Glatzle & Stosiek, 2001).

Stocking densities on range, bush land and sown pastures vary from about 10 ha per head for cattle (in Alto Paraguay Province) to 0.2 ha per head (in the Central Province) depending on the agro-ecological conditions, feed and supplement availability (Glatzle & Stosiek, 2001)

Beef Production.

Beef produced in the country comes largely from all grass systems with concentrate use being negligible. Steer fattening in feedlots has shown marginal profitability (Glatzle and Stosiek, 2001)

Traditional beef production in Paraguay shows a low productivity due to a number of reasons, including low pregnancy rates, long inter-calving periods, lack of seasonal calving, incidence of reproductive diseases, and nutritional deficiencies in energy, protein, vitamins and trace elements. Furthermore, all this results in heifers replacements being reared slowly (thus, reducing their useful life). There are also deficiencies in farms' facilities (MAG2004).

Recently, however, a growing number of cattle farmers are regularly achieving higher productivity, as shown in Table 2.1 where traditional systems are compared with modern systems in the Chaco region.

The improved herd productivity results in almost twice as much liveweight (lw) from a unit of fodder energy consumed, as well as increased production per unit of area. Improved pasture establishment results in better land use efficiency as long as the production system is ecologically sustainable (Glatzle & Stosiek, 2001).

Table 2.1 Comparison of traditional and modern production parameters of beef cattle herds on grazing lands in the Chaco.

Production Parameters	Production systems	
	Traditional	Modern
Calving rate	50%	90%
Calf mortality rate	25%	5%
Adult mortality rate	10%	1%
Fattening period till 450 kg LW (months)	48	28
Proportion of cows in the herd	38%	34%
Production Indices:		
Culling rate	7%	28%
Energy efficiency (kg LW/ GJ ME)	2.8	5.3
Liveweight production (kg LW ha/year) from ME consumed:		
2.5 GJ of ME ha/year (native bush land)	7.1kg lw/ha/year	13.3kg lw/ha/year
25 GJ of ME ha/ (sown pasture)	71 kg lw/ha/year	133 kg lw/ha/year

Source: (Glatzle & Stosiek, 2001)

The base of the national beef herd comes from the "criollo breed", derived from Spanish and, later, British cattle importations. These animals are well adapted to the local conditions but besides their high fertility they are otherwise low in production. However, in the last 20 years commercial farms have received an increasing influence from Brahman and Nellore (*Boss indicus*) genes which has replaced the criollo breed. These cows are used in crosses with European breeds, such as Herefords and Angus (*British Boss taurus*), Charolais, Gelvieh, Fleckvieh and Limousine (*Continental Boss taurus*) in order to obtain an industrial cross with the advantages of the hybrid vigour (Glatzle & Stosiek, 2001).

Milk Sector

Forty percent of all the farms own dairy cows (on average 3.6 per farm), but only 25 % send their milk through processing systems. The remaining 75 % are either subsistence oriented or depend on local markets for fresh unprocessed milk or home made cheese (Glatzle and Stosiek, 2001).

Considering all the farms that produce milk in the country the national milk production shows poor productivity (Glatzle and Stosiek, 2001). However, if only the commercial dairy farms are compared, there are many specialized commercial dairy farms that are achieving remarkably high production levels (Table 2.2) through improved management, genetics and nutrition.

Table 2.2 Milk production parameters in Paraguay comparing the national average with data from a commercial farm and a Mennonite Cooperative in the Central Chaco.

Parameter	National average	Guarapi Farm (Commercial farm in the Eastern Region)	Menno Colony (Commercial farm in the Central Chaco)
Heifers' age at first service (months)	36	20 – 24	24
Calving interval (days)	450-500	380 – 400	400
Lactation length (days)	< 180	305	305
Production (kg milk/cow/year)	650	4500	2500

Source: Molas et al. 1996

The national dairy herd shows a 4 % yearly growth rate (MAG,2004). While Jerseys and dual purpose breeds such as Brown Swiss are present; the large majority of commercial dairy herds are based on Holstein Friesians. Genetic improvement is achieved mainly through artificial insemination, which is practiced within co-operatives and on big farms (Glatzle and Stosiek, 2001).

Silage sorghum is the most popular cultivated forage for dairy enterprises. Also, Cameroon grass (*Pennisetum purpureum*) is used for silage by smallholders in the Eastern region. Grain sorghum and maize are used in concentrates, mixed with by products obtained mainly from oilseeds (cotton and soybean). Finally, a typical emergency feed is sugar cane, grown on a small area on many farms and harvested in the dry season. (Glatzle and Stosiek, 2001)

Commercial milk production has developed only where efficient and reliable collection and processing plants have been built. This is the case in the Central Province (around the capital city, Asuncion) with around 1,000,000 inhabitants, in Caaguazu and Alto Parana Provinces (Eastern region) and in the Central Chaco (Western region).

2.6 Milk and beef consumption and exports

The processed national milk consumption (in 2000) is unsatisfactory, being 83.9 kg per head per year. This is less than 60 % of the 150 kg per head per year recommended by the FAO. Imported milk represents up to 13 % of the national consumption of commercialized milk. Dairy exports are still insignificant and come exclusively from the Central Chaco dairy industry (Glatzle & Stosiek, 2001).

On the other hand, beef provides more than half the total meat consumed in Paraguay and consumption per head per year is high compared to international standards. Beef exports represent around 5% of the total production of the country but it varies from year to year as it is highly dependant on the sanitary conditions of the country in relation to the occurrence of foot and mouth disease

The following section will focus on the Central Chaco of Paraguay, which is the area selected as the case study for this research because it comprises one of the most successful commercial farming communities in the country. They are well organized in cooperatives and have a strong impact in the national markets and economy.

2.7 The Central Chaco

At present, the country is experiencing a high population growth, which the traditional settlement areas of the eastern region cannot support. The development and colonization of the Chaco is therefore the declared objective of the Government of Paraguay. With the fragility of the ecosystem of the Chaco considerable effort is going into achieving a sustainable development (von Hoyer, M. and Godoy, E., 1998).

2.7.1 Location

The Central Chaco (Figure 2.3) is located 470 km northwest of the capital city Asuncion and has a population of 50,600 (1999). The most dynamic urban centres of the region are the three colonies, Menno, Fernheim and Neuland. These Colonies have an estimated population of 30,000 people (2002) and their sanitary and educational facilities are among the best in the country

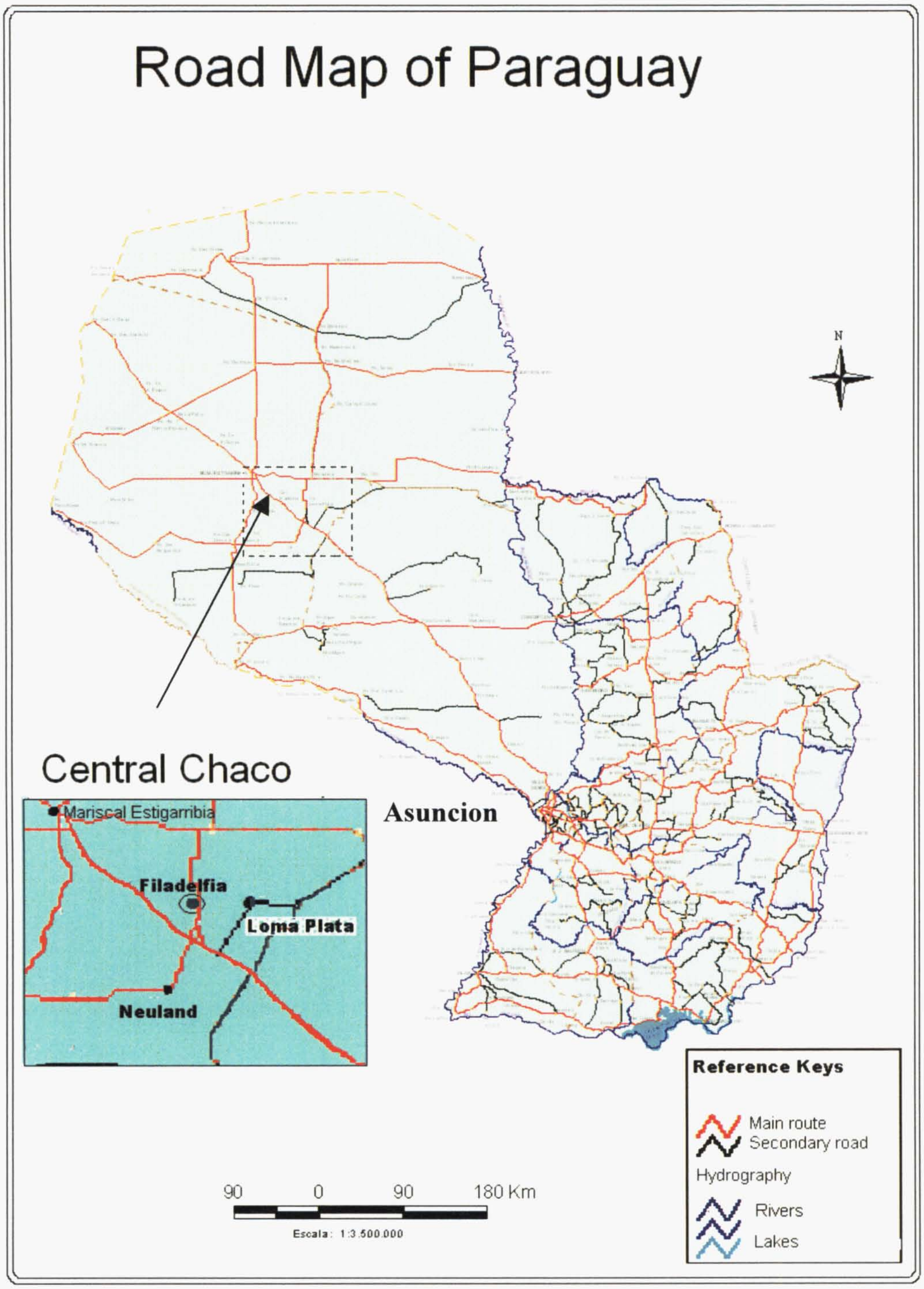

Figure 2.3 Location of the Central Chaco within Paraguay. Source: MOPC, 2004

The area has a flat topography, and the altitude ranges between 140 and 160 m asl. This area is an agricultural region within the "Gran Chaco" region which extends into Argentina and Bolivia as well.

2.7.2 Population

The area is populated by three different ethnic groups. These include indigenous people who belong to more than a dozen of different tribes, the Mennonites who are of European origin and then the group called Latin Paraguayans who are people who migrated to the zone from the Eastern region of the country.

Table 2.3 Population trends in the Central Chaco.

Projected population change in the Central Chaco					
Ethnicity	Population		Annual growth rate	Distribution	
YEAR	1999	2015	1999-2015	1999	2015
German-Paraguayans	14,400	19,758	2.0%	28%	23%
Indigenous-Paraguayans	25,500	47,761	4.0%	50%	56%
Latin-Paraguayans	10,120	16,240	3.0%	20%	19%
Others	580	796	2.0%	1%	1%
Total:	50,600	84,565	3.3%	100%	100%

Source: Association of Mennonite colonies of Paraguay, 1999 (cited by Desde el Chaco Org, 2003).

The Mennonites

The Mennonite colonies in the Central Chaco offer a notable exception to the country's low farm productivity (Glatzle & Stosiek, 2001). When the Mennonites first arrived in 1926, the Central Chaco was a virtual desert and, as a result, the pioneers suffered hardship for at least a generation until this semiarid region was made productive. These pioneers converted the Central Chaco into the major supplier of food for the entire Chaco and made it self-sufficient in almost every crop. Their success was generally attributed to their dedication, cooperative structure, superior farming techniques, and access to foreign capital (Von Hoyer & Godoy, 1997).

As a positive consequence of this continuous socioeconomic development in the Central Chaco, the GDP per head was equal to 8,000 US$ in 2001 whereas in the rest of the country it was just 1,510 US$ (El Gran Chaco.com, 2003), 13 Jun 2004)

These farmers have based their farming systems on mixed farming involving some cropping, extensive dairy and beef production

For Paraguay as a whole these colonies produce:

- 55% of sorghum (MAG, 2002)
- 50% of processed milk.((Glatzle & Stosiek, 2001)
- 20% of the beef production (Cabrera, Stosiek, Glatzle, Shelton, & Schultze, 2001)
- 21% of the sesame seed production (MAG, 2002)
- 15% of the Ground nut production (MAG, 2002).
- 12% of the Castor bean production (MAG, 2002).
- 11% of the dairy herd (MAG, 2002)
- 7% of the beef herd (MAG, 2002).
- 1% of the Cotton production (MAG, 2002).

Table 2.4 the most important products in the three colonies of the Central Chaco

Colony	Agriculture	Livestock	Agro industry	Other
Menno	Cotton Ground nut Seed production (gatton panic)	Beef Dairy	Beef Leather Dairy products Vegetable oils	Genetics (semen)
Fernheim	Cotton Ground nut Sesame seed	Beef Dairy	Beef Dairy products Vegetable oils	Genetics (semen)
Neuland	Cucumber Sesame seed	Beef Dairy	Beef Leather Processed food (pickled cucumbers and snacks)	

Source: Adapted from www.proparaguay.org, 2004, 20th Jun 2004

Within this farming community, agro-industries such as dairy, beef and vegetable oil industries have flourished (see Table 2.4). Economic indicators show that there is a trend in the region for the agro-industries to increase in order to add value to agricultural products. Success of this farming community has attracted people from other areas of the country, with many who came being indigenous people.

2.7.3 Climate

Introduction

The region has a continental climate, characterized by extremes and is edapho-climatically similar to Central Queensland and northern areas of South Africa (Cabrera et al., 2001).

Rainfall

The mean annual rainfall (58 years average) is 862 ± 230 mm. The Central Chaco has periods of flood alternating with very dry seasons. Rainfall concentrates (80 %) during the summer period (October to March) with the dry season (20 %) occurring during the winter (April to September). Rainfall data for the Central Chaco is shown in Figures 2.4 & 2.5. The average annual evaporation rate is between 1,400 mm and 2,000 mm.

The Central Chaco has a sub-humid climate, but as the rainfall distribution is strongly seasonal (Figure 2.4), there may be periods of 50-150 days where potential evapotranspiration is far in excess of precipitation during the dry season. In areas with similar climatic conditions it has been suggested that year-round crop production is possible with irrigation (James D., Hanks J. and Jurinak J., 1982).

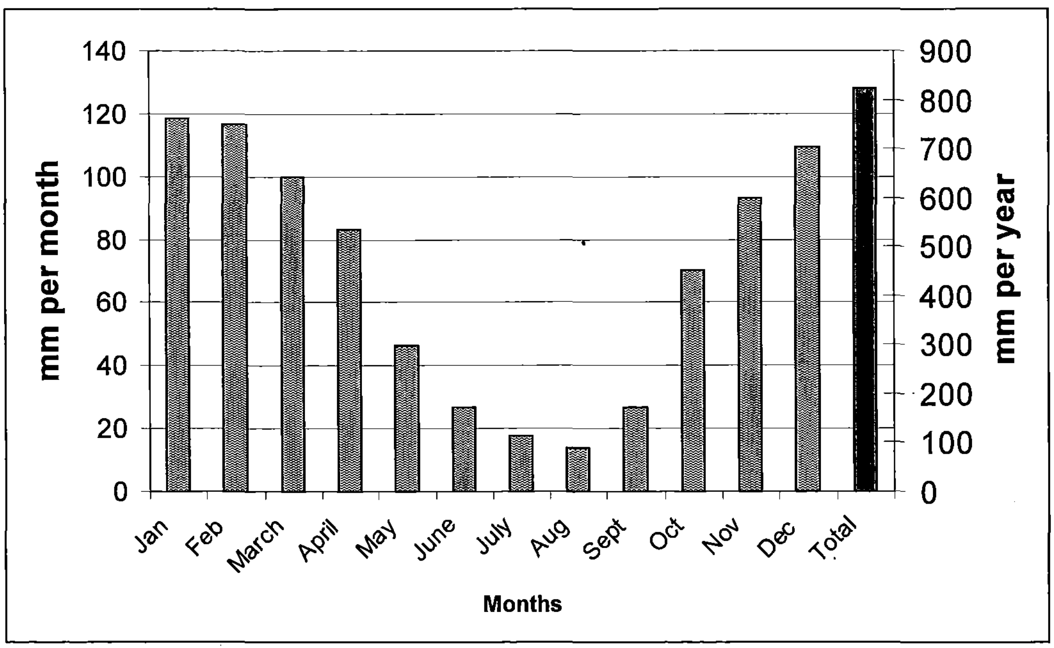

Figure 2.4 Rainfall monthly distribution in the Central Chaco. Average from 1953 to 2003 Source: ATF, 2004

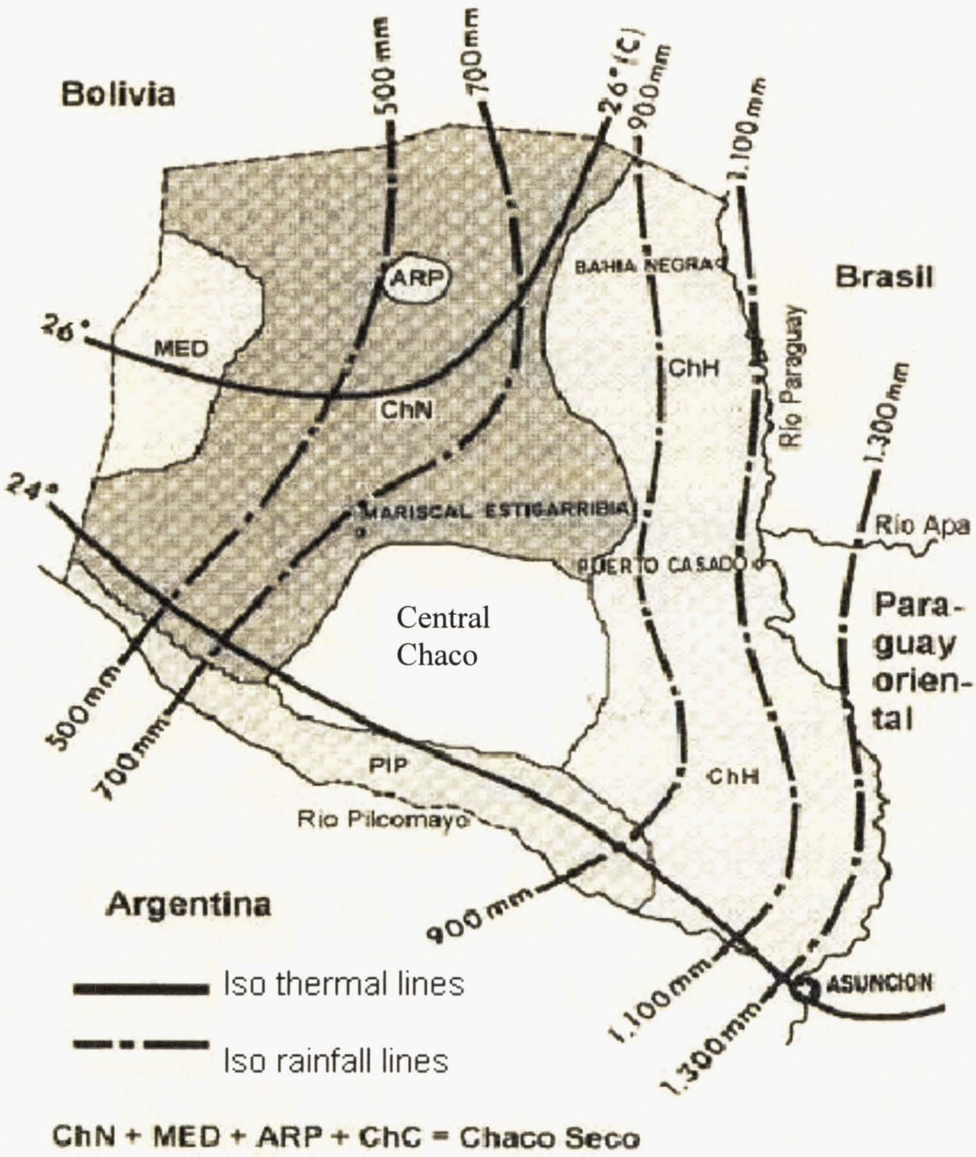

Figure 2.5 Average temperature and rainfall for the Chaco. Source: Glatzle, A. & Stosiek, D., 2001

The climate characteristics of the Southern America region generate strong inter-seasonal and inter-annual differences in water resources. These are aggravated by meteorological phenomena such as "El Niño".

Temperature

The average temperature for the Central Chaco is around 25 degrees Celsius and is shown in Figure 2.5. Extreme temperatures can reach below 0 degrees in the winter and above 40 degrees in the summer (www.desdelchaco.org.py , 10 May, 2004).

Wind

Wind is predominantly north-westerly and usually reaches speeds of 40 to 70 km per hour. It can produce serious eolic erosion during the dry season and increases the evaporation rate during summer period.

2.7.4 Water resources

The most limiting factor to the development of the Chaco is the water supply as there is a large deficit of water in terms of quantity, quality and reliability of supply. The Central Chaco does not have any permanent surface water courses, and underground water in the region is usually not suitable for human or animal consumption (saline and/or with high nitrate content). Thus, the water supply in the Chaco depends to a great extent on the volume and frequency of rainfall, which is usually erratic. Currently, many farms and are not self sufficient with respect to water and require a periodic input of water from external sources. Figure 2.6 shows the area in the Western Region where aquifers do not exist that can be used as a source of drinking water (shaded).

Figure 2.6 Area in the Chaco region that lacks underground water sources (Shaded). Source, Weins, F., 2000

Three methods are used to obtain drinking water in the Central Chaco (Von Hoyer & Godoy, 1997).

Rainfall harvesting: Rainwater is being collected from house roofs and drained into underground cisterns from where it is pumped into a raised water tank. Water then is piped into the house. A cistern of 25,000L per person is recommended. This collection system requires a fairly large and rigid roof area plus electricity for the pump. Therefore it can only be used for town or farm houses.

Water wells: In a few areas of the Central Chaco groundwater occurs at shallow depths (3 to 13 m below ground surface) in fine grained sands. The groundwater is generally saline with the exception of a few specific localities where fresh ground water lenses are encountered which are recharged by the annual rains. The lenses are generally small and thus sufficient only for the supply of homesteads and small settlements. Over pumping leads to the intrusion of the surrounding saline water.

Surface water storage: Extensive areas of the Central Chaco are covered by loams and sandy clays. These are also the areas where only saline groundwater is encountered. Here rain water is collected in "tajamares" (man made depressions in the lower part of the properties). These structures are at least 2 m in depth to prevent high evaporation loss (1500 mm per year) and have a storage capacity in the range of 10,000 to 20,000 m^3.

Many environmentalists are concerned about the sustainability of the growing dairy industry in the Central Chaco because it is very demanding of water, which is already currently limiting. Thus, water will be needed to be brought in from other areas of the country. (Guanes, R., per. communication 2004)

The government of Paraguay is undertaking a project that will divert water from the Paraguay River and pump it through a pipeline to the Central Chaco where the water will be distributed to different communities. Although the main objective of the project is to supply water for human consumption, the proposed project includes 1,000 m^3 per day of water available for drip irrigation plus 2,500 m^3 to 4,500 m^3 per day of recycled water that will be available for irrigation of non consumable crops (cotton, castor beans, seeds, etc). The cost of this water is still to be assessed (MOPC, 2004). This project will temporarily solve the water scarcity in the Central Chaco. However, there is still the question of how much water can be taken from the Paraguay River to cause minimum environmental effects (Guanes, R., per. Communication 2004).

Water demand in the Central Chaco has increased 500% in the last 25 years, reaching 40,000 m^3 per day in 2000 (Table 2.5). Water consumption in the Chaco (33 – 85 litres per head per day) is low in comparison with the national average (250L per head per day) and the international average (124 litres per head per day). The demand is higher than that but water use is constrained by the availability of water (Desde el Chaco, 2003). Water demand increases 7% per year in the Central Chaco mainly because of an increase in the demand from the agro-industries and people that migrate into the area (Wiens, 2003). Figure 2.7 shows the expected increase in demand for the period 2002 to 2015.

Table 2.5 Demand for drinking water in the Central Chaco (2000).

Consumers	m^3/day	Population	Cow numbers
Households	2,773	50,600	
Industry	736		
Commercial	294		
Services	654		
Sub-total	4,457		
Agriculture (livestock)	35,500		700,000
Total =	40,000		

Source: Weins (2003)

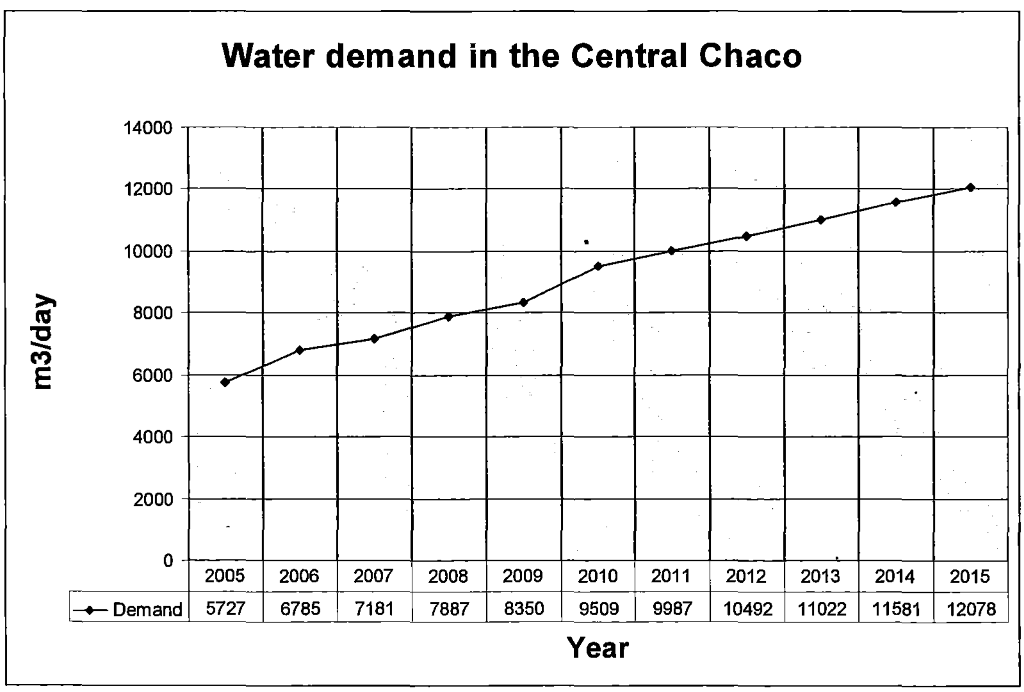

Figure 2.7 Future water demand projection in the Central Chaco for the period 2005 to 2015 (without the agricultural demand) Source: Wiens (2003.)

2.7.5 Soils

The Central Chaco is located in an inland delta of an ancient river. The soils are deep sedimentary soils from the Andes with a texture that ranges from very sandy to very clayish. These soils can be divided into so called (Sandy) "Campo" soils and (Loamy) "Monte" soils. (Amberger, A., 1988)

The predominant surface texture is loamy with a tendency to sandy loam, and these have good drainage properties. The soils in the Central Chaco are geologically young and because of that they are generally rich in nutrients, especially phosphorus. However, they are usually deficient in iodine and have toxic levels of molybdenum which produces a secondary copper deficiency. (Neufeld & Glatzle, 2001))

"Campo soils"

The problems of the Campo soils are mainly on the physical side. A very good aeration of surface soil together with high temperatures leads to a rapid decomposition of organic matter and, therefore, a low water holding capacity. With intensive soil cultivation the risk of wind erosion becomes a very severe problem (Amberger, 1988). Table 2.6 contains the main characteristics of this type of soils.

Under the semiarid conditions of the Central Chaco, Campo soils have favourable hydraulic characteristics because of their good drainage which allow a fast infiltration rate, which keep water in the root zone of pasture and trees plants and reduces loses due to evaporation. Moreover, they allow good root penetration, guaranteeing easy plant access to the stored water.

Table 2.6 Main Characteristics of "Campo" type soil.

Characteristic	Amount
Sand	50 – 80%
Silt	20 – 25%
Clay	1 – 5%
Ca and Mg saturation	60 – 65%
Organic Mater	0.5 to 0.7%
Total N	0.04%
pH	5.6 to 6.8
Electrical conductivity	Low

Source: Amberger, A., 1988

Regosol

The soil type "Campo" is mainly of the Regosol type. This type of soil has more than 50% of fine sand, clay content ranging from 5 to 15% and gross silt little developed. This soil has high infiltration rate and from medium to low fertility level (Table 2.8) (Barboza, Hoffman, & Medina Netto, 1995; Neufeld & Glatzle, 2001).

Agriculture has developed in the region mainly on eutric Regosols, but because of their continuous use with poor agronomic husbandry they have lost some of their natural fertility. However, although Regosols are susceptible to eolic, chemical and physical deterioration they can be used under sustainable management and can be rehabilitated following degradation (www.fao.org, 12 June 2004).

Arenosol

This soil has alluvial and/or eolic origins. It has more than 80% of sand and less than 5% of clay. It has low organic matter and nutrient content (Neufeld & Glatzle, 2001).

"Monte" soils

These soils make up the greatest part of the area of study; they have been used mainly for pasture and sorghum production. Table 2.7 contains the main characteristics of this type of soil.

Table 2.7 Main characteristics of typical "Monte" type soil.

Characteristic	Amount
Sand	30 - 50%
Silt	20 – 30%
Clay	15 – 15%
Ca and Mg saturation	60 – 65%
Organic Mater	0.7 to 1.5%
Total N	0.15%
pH	Above 7
Electrical conductivity	Increases with depth

Source: Amberger, (1988)

Luvic Xerosol group

The most common soil in the Central Chaco region is the Luvisol or "High Monte", with a texture that ranges from silt to clayish (Table 2.8).

The main feature of this type of soil is a horizon of increasing clay content between a depth of 30 to70 cm. These soils have a neutral to slightly alkaline pH; they are rich in nutrients such as phosphorus, magnesium and potassium. These soils are typically used for livestock production on improved pasture (Dürksen, 2004; Thorsten, 2004).

Cambisol

Cambisols are also within the "Monte" type soils, they are rich in silt (Dürksen, 2004), have medium fertility and have medium salinity (Table 2.8) (Barboza et al., 1995). The main difference between Luvisols and Cambisols is the absence of a horizon of clay accumulation. This soil usually has a fragile structure that forms a hard pan when exposed to the impact of strong rains in the absence of vegetable cover (Neufeld & Glatzle, 2001).

Solonetz

This soil is particularly common in the eastern limit of the area of study forming a belt from north to south and characterized with a shallow saline water table (less than 0.6m depth) and saline temporary lagoons. Local research has provided a better understanding of this problem and has identified improved management practices to minimize, or prevent the risk of salinity build-up as well as methods of soil reclamation (www.inttas.org., 2 May 2004).

The relatively high sodium content of this soil distinguishes it from the Luvisols. This soil is usually yellow-brown, is alkaline and has inadequate drainage (Table 2.8). Native trees very common on this soil include Palo Santo (***Bulnesia sarmientoi***) and Viñal (***Prosopis ruscifolia***) (Neufeld & Glatzle, 2001).

Table 2.8 Typical analysis result of soils present in the Central Chaco.

Soil type	Texture			pH	Ce 1:2	MO	p	ca	MG	K	NA
	Sand	Silt	Clay	H2O	mS/m	%	ppm	Mval/100			G
Luvisol	31	28	41	6.8	0.3	2.6	78	7.1	3.1	1.4	0.2
Solonetz	15	29	56	7.3	2.7	2.9	73	8.9	3.2	1.3	2.2
Cambisol	35	37	28	6.6	0.2	2.2	59	2.0	1.6	0.7	0.3
Arenosol	92	5	3	6.1	0.1	0.5	1	1.1	0.4	0.2	0.01
Regosol	78	15	7	6.7	0.1	1.3	11	2.8	0.5	0.3	0.1
Gleysol	2	34	64	5.7	0.3	1.4	2.3	6.3	3.2	1.6	0.6

Source: (Neufeld & Glatzle, 2001)

Summary

In general the soils of the Central Chaco have adequate to high natural fertility and a pH neutral to slightly alkaline. The Campo soils are in general poor in organic matter content and, therefore, have a low water holding capacity and nitrogen content. On the other hand, the Monte type soils are usually rich in phosphorous and with adequate levels of nitrogen and organic matter.

In areas where the water table is shallow, deforestation and mismanagement has resulted on land being lost from production and the risk of further areas being lost due to salinity build up is high.

2.7.6 Beef and Dairy

All beef produced in the Central Chaco is reared on an all grass system with minimum or no supplementation. Beef usually receives roughage supplements during the dry season (grass hay and sorghum silage). Also, a common practice is to provide a mineral supplement plus urea during the dry season. Finally, during drought events whole sugar cane produced in the eastern region is purchased by cattle farmers in the Central Chaco and this enable them to maintain their breeding herd.

On the other hand, dairy production usually relies on bought in concentrates such as pellets, grains (sorghum and maize) and agricultural by products (soy meals, Cotton seeds, Cotton meal, Ground nut meal, molasses, Cotton hulks, etc) as well as roughage supplements including sorghum silage, pasture hay and sugar cane. However, pasture still represents the most important and cheapest feed supply.

In the Central Chaco maximum energy conversion efficiency from *Panicum maximum* cv Gatton and *Cydnodon niemfuencis* pastures by grazing steers (into animal liveweight per ha) was attained by a stocking rate of 1.8 animal units[2] per hectare. However, the long term ecological optimum stocking rate recommended for the Central Chaco is from 0.8 to 1.2 animal units per hectare. (Glatzle and Stosiek, 2001). These values are for animals reared exclusively on grass with no supplementation and with continuous grazing. On the other hand, using strategic supplementation and a rotational grazing management a higher stocking rate could be possible which could improve productivity per unit of area without compromising the long term sustainability of the system (Kellaway & Harrington, 2004).

2.7.7 Crops

Agricultural land in the Central Chaco represents only 2.48 % of Paraguay's total crop area of 13,244 km^2. However, it represents 90 % of the crop area in the Chaco region. Most of

[2] Animal unit (AU) = steer of 400 kg liveweight.

the cultivation began after 1943; and the crop area doubled between 1956 and 1981 (Rivero, 200?).

Although agriculture had been the main source of income for the region from the 1920s to the 1980s, it now comprises no more than 6% of the total production of the area. This is due to the combined effect of a decline in product prices (Cotton and vegetable oils), and adverse climatic conditions (drought). As a response, farmers have moved strongly towards dairy and beef production (http://www.chortitzer.com.py; http://www.neuland.com.py, 10 May 2004).

Until now conventional tillage systems have been the basis of the cropping system. However, conservative tillage systems have started to be used and around 10% of the total area is currently under this system. The difficulty of finding a good green cover for the dry winter is the major limiting factor that prevents this management technique from being widely adopted (www.neuland.com.py, 10 May 2004).

Technicians from the agriculture extension services in the region have been researching new crops and technologies (INTTAS, 2004b), and although they have identified many potential lines of production and new technologies, farmers are still uncertain about optimal farming systems for their resources, goals and objectives. How much of their resources should be committed to each of the possible components of their farming systems?

The main agricultural crops currently produced in the area include Ground nuts *(Arachis hypogaea L)*, Cotton (*Gossypium hirsutum L., Malvaceae*), sorghum (*Sorghum bicolor (L.) Moench*) and Castor bean (*Ricinus communis L.*) (www.neuland.com.py; www.desdelchaco.org.py; Chortitzer.com.py, 20 May 2004).

Common crop rotations in the area include Gatton Panic (seed) with sorghum and ground nut with sesame seed (www.neuland.com.py, 20 May 2004).

2.8 Summary

In the above section the main features of the area of study have been outlined. It has been shown that the Central Chaco region has a very sensitive ecosystem, in which climatic and geological conditions are very distinctive. The water availability has been identified as the most limiting factor for development of the area. Also, important ecological problems threatening the sustainability of the region were identified. These include wind erosion, salinity build up in soils and water, and the soils' fertility depletion due to mismanagement.

Finally, there are increasing socio-economic problems arising from the increasing population of the area which increases the demand on water and new employment opportunities.

The farmers are facing increasing pressure to increase the productivity of their farming systems without hampering their sustainability in the long term. This is to ensure sustained development of the region. Consequently, it is important to study the current farming system in the area in order to identify opportunities for improvement.

Chapter 3
MODEL DEVELOPMENT

3.1 Introduction

In previous chapters background information about the Paraguayan agricultural sector and the Central Chaco, in particular, was presented. The current chapter includes a detailed description of the steps involved in the development of a linear programming model of a typical farm in the Central Chaco of Paraguay that was built in order to answer the research question. The nutritional sub-model is described separately in Chapter 4.

The linear programming development required four stages, namely: identification of information required for model development, information gathering, model construction and model evaluation.

3.2 Identification of information required

This stage involved an extensive literature review of research in the field. These articles provided guidance on the likely matrix structure that would be required to represent the farming systems. Areas of the farming system where gaps in the knowledge were more likely to appear were also identified. Finally, different approaches in dealing with the difficulties of representing farm systems with linear programming were identified and a decision was taken on the most suitable technique. For instance, the problem of variability in energy concentration between different sources of feed was investigated. This prevents, for example, direct substitution of high energy feed by low energy feed because of the problem of feed bulkiness. A decision was made to group the feed sources according to their energy concentration, and to calculate the animals' energy requirements using the quantities of these different quality feeds. Once the basic structure of the matrix was developed the next step involved collecting the required data.

3.3 Information Gathering

This comprised a multi-pronged approach including a literature review, consultation with researchers, animal and plant scientists, farm advisors, farm consultants and commercial farmers, in order to build up a database. This was used to calculate the coefficients required in the construction of the lineal programming model to ensure its adequacy and reliability.

Information was gathered both in New Zealand and in the area of study. Data collection in Paraguay was undertaken between November and December of 2004. It included semi-structured interviews with the three case study farmers and interviews with researchers, extension officers, agronomists and veterinarians from the area of study. These interviews provided data required in each specific area of expertise.

Many difficulties were encountered at this stage because of a lack of information on some aspects that might be important for analyzing the interrelationships between the many components in the farm system, including many input-output coefficients as well as many efficiency ratios. This was expected. Difficulties in finding adequate research data for developing a linear programming model are common (Dent, Harrison, & Woodford, 1986). Some data was recorded in a way that could not be used directly in the linear programming model, for example, and it was impossible to adjust other data to meet the modelling requirements, yet other data did not exist, possibly because its potential importance has been, as yet, unnoticed. For instance, there is no published work on the amount of feed available in different periods of the year for the Leucaena-Gatton panic hedgerow system. This system is being promoted by the extension services and research centres in the area of study.

3.4 Model Construction

"The construction of a system model can be even more insightful than the outcomes of the model. Understanding the system is what is valuable, not just numerical answers" (Hardaker, 1994).

Model construction began with designing the model in matrix form. Then the variables, inter-relationships and constraints that were judged necessary for representing the farm system with sufficient accuracy were incorporated. During this phase several versions of the model were constructed and tested, each subsequent version incorporated an increased level of complexity.

Some activities were included only for validation purposes. The addition of an activity that provides free labour during various period of the year was included, for instance, in order to represent the labour provided by farmers' children in of some of the case study farms.

The final version of the model includes 239 activities and 187 constraints. The full model can be found in Appendix I. A detailed description of the model structure follows.

3.5 Model description

The model is a deterministic linear programming model of a typical farm in the Central Chaco. It is assumed to be debt free and represents a single year production cycle divided into four three monthly sub-periods. The system is assumed to be in a steady state. As such, livestock and feed inventories at the start and the end of the year are made equal through livestock and feed reconciliation rows. The model selects a cropping pattern and level, calving date, level of production and a best feeding pattern that maximises the objective function.

The model comprises the following sub-models:

Crop production, labour use, cashflow reconciliation, a nutritional sub-model and livestock production sub-model as well as a tax calculation sub-model.

3.5.1 The Objective function

The objective function was defined as farm surplus after taxes and living expenses, which is the difference between the sum of all productive activities gross margins less total variable costs, living expenses and the calculated imputable income tax. Costs considered include hired-labour, feed not included in the gross margin calculations and living expenses. It is represented by the following equation:

$$\text{Max EAT} = \sum_{i=1}^{16} x_jC_j + \sum_{i=17}^{42} x_jC_j + \sum_{j=43}^{65} x_jC_j + \sum_{j=66}^{75} x_jC_j + \sum_{j=7}^{107} x_jC_j + \sum_{j=108}^{121} x_jC_j + \sum_{j=122}^{124} x_jC_j$$

$$+\sum_{j=125}^{126} x_jC_j + \sum_{j=127}^{135} x_jC_j + \sum_{j=136}^{147} x_jC_j + \sum_{j=148}^{152} x_iC_i + \sum_{j=153}^{160} x_jC_j + \sum_{j=161}^{165} x_jC_j + \sum_{i=166}^{188} x_jC_j$$

$$+\sum_{j=189}^{206} x_jC_j + \sum_{j=207}^{214} x_jC_j + \sum_{j=215}^{238} x_jC_j + \sum_{j=239}^{239} x_jC_j$$

Where:

j=1 – 16	dairy cows
j= 17 – 42	cropping activities
j= 43 – 65	pasture activities
j= 66 – 75	beef cattle activities
j= 76 – 107	rearing dairy calves activities

j= 108 – 121	selling beef activities
j= 122 – 124	selling milk activities
j= 125 – 126	selling supplements (hay and grain) activities
j= 127 – 135	selling replacements (beef and dairy) activities
j= 136 – 147	buying supplements (pellets, grain, mixes)
j= 148 – 152	buying beef cattle activities
j = 153 – 160	buying dairy cattle activities
j = 161 – 165	Hiring labour activities
j = 166 – 188	feeding supplement activities
j = 189 – 206	feed transfer activities
j = 207 – 214	water supply activities
j = 215 – 238	lending and borrowing activities
j = 239	income tax activity.

Subject to:

$$\mathbf{bi \geq \sum x_j a_j}$$

Where:

for i = 1 – 13, bi ≥ 50 land constraints periods for Campo soils

for i = 14 – 25, bi ≥ 150 land constraints monthly periods for Monte soils

for i = 26 – 28, bi ≥ 1 labour constraints three periods

for i = 29, bi ≥ 1maximum fixed labour constraint

for i = 30- 41, bi = 0 cash flow constraint monthly periods

for i = 42, bi income tax calculation constraint

for i = 42-46, bi ≥ 0 high quality feed constraint four feed periods

for i = 47-52, bi ≥ 0 inter-temporal feed transfer constraints

for i = 53 – 56, bi ≥ 0 medium quality feed constraint four feed periods

for i = 57 – 60, bi ≥ 0 low quality feed constraints four feed periods

for i = 61 – 63, bi ≥ 0 high quality legume reconciliation constraint three feed periods

for i = 64, bi ≥ 0 forage sugar cane reconciliation constraint

for i = 65 – 67, bi ≥ feed sugar cane upper limit constraint three feeding periods

for i = 68, bi ≥ grain storage reconciliation constraint

for i = 69 – 72, bi≥ 0 feed grain reconciliation constraints four feeding periods

for i = 73 – 76, bi ≥ 0 feed grain upper limit constraint four feeding periods

for i = 77, bi ≥ 0 hay shed reconciliation constraint

for i = 78, bi ≥ 0 silage reconciliation constraints

for i = 79 – 90, bi ≥ 0 water constraints monthly periods

for i = 91 – 97, bi ≥110000 water inter monthly transfer constraint four periods

for i = 98- 109, bi ≥ 0 beef reconciliation constraints for different categories of animals for i = 110 – 173, bi ≥ 0 dairy activities reconciliation constraints for different types and categories of animals

for i =174 – 177, bi ≥ 0 dairy finishing activities for four types of animals in two different culling dates

for i = 178 – 181, bi ≥ 0 milk tank reconciliation constraints for four selling periods

for i = 182 – 183, bi ≥ 0 soils fertility reconciliation constraint for two types of soil

for i = 184, bi ≥ 0 market constraints

for i = 185 – 187, bi ≥ 0 financial constraints for borrowing in two periods and for lending in one period

3.5.2 Livestock activities

Traditionally, the farming system in the Central Chaco has been a mixed farm with some dairy, some beef and some cropping. This occurs for many reasons which include: the farmers' personal preference, limited capital for investment, risk aversion through diversification, scarcity of reliable and skilled labour supply and, most importantly, lack of infrastructure (roads and electricity outside the Mennonite colonies). Consequently, both beef and dairy activities were included in the model and although dairy may appear as the optimal farming system it would not be applicable to all the farm units of the area of study for the reasons mentioned above.

Breeding cows

The most common breeds in the area of study are three breed composite animals (Brahman-Hereford-Charolais or Brahman-Hereford-Santa Gertrudis). However, in the last few years new composites, such as Montana®, are gaining popularity (Neufeld, E. personal communication 2004).

The performance level achieved in the area of study according to different references and the values adopted for the construction of the farm system model are included in Table 3.1

Breeding cows have a dual role in producing calves and managing pasture. These roles must be balanced at strategic times to maximize the benefits of having a breeding herd. Cows assist with control of pasture quality in summer. They provide a feed buffer in winter, through weight loss, while cleaning up poor quality feed (Fleming, 2003). In addition, in semi-arid conditions such as the Central Chaco, they can be used as a financial buffer when drought strikes. Selling trading stock and keeping breeding stock diminishes the cost of re-stocking once the drought has finished.

Table 3.1 Beef production performance in the Central Chaco

Parameter	%	Reference
Calving percentage	75 to 90	Glatzle, 2004
	80%	Case study 1
	95%	Case study 3
	90%	**Model assumption.**
Mortality rate of calves	=<5%	Glatzle, 2004
	5.8%	Case study 1
	5%	Case study 3
	5%	**Model assumption**
Adults mortality rate	<1% to 2%	Glatzle, 2004
	2.5%	Case study 1
	2%	Case study 3
	2%	**Model assumption**
Age at first service	24 to 34 months	Glatzle, 2004
	15 to 18 months	Case study 1
	18 months	Case study 3
	15 months	Model assumption
Replacement rate	15 to 20%	Case study 1 and 3
	20%	**Model assumption**

Calving date in the area of study is from July to September. Heifers are sometimes mated in autumn at 18 months of age and then again in spring of the next year. This management aims to increase their calving rate in the next year at the expense of having a longer first inter-calving period. A summary of the management calendar used in the area of study is included in Table 3.2

Table 3.2 Breeding beef management calendar

Category	Period	Reference	Comments
Calving date	July to September	Case study 1	All herd
	June to September	Case study 3	
	July to September	Glatzle, A., 2004	
	March to April	Glatzle, A., 2004	Only heifers
	Beginning of September	**Model assumption**	**All herd**
Weaning date	March to April	Glatzle, A.	200 to 250 kg liveweight
	April to May	Case study 1	250 to 260kg liveweight
	Eight months of age	Case study 3	250kg liveweight
	End of April	**Model assumption**	**230 and 250 kg liveweight**

Breeding cows' liveweight ranges between 400 and 500 kg depending on breed, whereas bulls have a 700 kg liveweight, on average (A. Glatzle, personal communication, August 31, 2004).

Finishing beef activities

On improved pastures steers and heifers are usually finished in 22 months (Case study 1); 24 months (Case study 3) and 28 months (Glatzle, personal communication, August 31, 2004) at 400 to 450 kg liveweight. These animals are finished without concentrate feeding. Nevertheless, during the dry season a non protein nitrogen supplement plus a limited amount of hay and silage are usually used. This model includes two finishing activities for steers and heifers, respectively. The liveweight curve used for these activities is shown in Table A. 2.

Dairy activities

Dairy production in the area of study is a year round supply system. Inter-calving periods are usually longer than 365 days. Although effort is put into achieving a smooth milk supply pattern throughout the year, there is a natural trend in the dairy herd to calve in the second half of the year. This is related to feed availability nine months before, during the rainy season.

If production efficiency is being sought a dairy cow should provide one lactation each year of her useful life (twenty four months of age onwards). Although an inter-calving interval longer than 12 months is the average in the local herd in the Central Chaco, there are still animals that continuously match the criteria of productive efficiency with lactation intervals of less than or equal to twelve months.

Long inter-calving dates can be directly related to nutritional factors in the form of a poor condition score at calving. Several studies have shown the cardinal importance of good cow condition at calving as a determinant of the subsequent reproductive and productive performance of the animal (NRC, Kellaway & Harrington, 2004; 2001). If body reserves are low at the beginning of lactation milk production will suffer, because a greater proportion of nutrients will be directed toward replenishing reserves rather than to milk production. In addition, low body reserves will delay the return of oestrus. This, in turn, will delay the conception date, and thus prolong inter-calving intervals (Pereira, 1998).

For the purpose of this study all dairy cow activities included in the model represent cows that calve every year at the same trimester. The inclusion of these activities is based on the objective of devising optimal improved systems. Utilizing longer inter-calving periods would prevent the model from approximating a steady state scenario on a yearly basis.

Because the nutritional sub-model includes only four sub-periods it was decided to explore only four potential calving dates. These are shown in Table 3.3.

Table 3.3 Potential calving dates to explore

	Dairy A	Dairy B	Dairy C	Dairy D
Calving date	1st of January	1st of April	1st of July	1st of October

The dairy herd in the Central Chaco comprises mainly American Holstein and American Holstein with Brahman crosses. These animals have ≥550 kg average liveweight. Jerseys and double purpose breeds such as Grey Swiss and their crosses with Brahman, Angus and Hereford are also present in the dairy herd, but to a lesser extent. These animals are usually lighter (450 kg liveweight) than American Holsteins and their milk production is usually lower than animals with a high proportion of American Holstein.

The average milk yield per lactation in these farm systems ranges between less than 3,000 L per lactation to more than 5,000 L per lactation. Farmers usually aim to have cross breed dairy animals. Despite having a higher milk yield, pure Friesian calves, other than replacements, must be finished on farm as currently there is no market for weaners. This is because pure animals are more difficult to finish on whole grass systems under the hot semi-arid environment of the Central Chaco. Thus, they require either longer rearing periods, or the provision of supplementary feed in order to finish them at the same age as cross breed animals.

In order to include these different categories of animals in the mathematical model two different yield levels and two different body weights were combined with the four calving dates giving 16 possible combinations. To simplify the model, the combinations were limited such that both typical and achievable situations in the Central Chaco could be represented with a minimum of cow activities.

In order to select the cow activities special attention was paid to the issue of heat stress in dairy cows. There is considerable literature on the adverse effects of high temperatures on dairy cows impacting on their lactation (with negative effects on milk yield and composition), and adversely effecting growth, and reproduction (Collier et al, 1982). The feed intake of Holstein-Friesians cows begins to decrease at ambient temperatures above 26°C. In days where the maximum temperature is above 32°C cows do no effective grazing at all between the morning and afternoon milking (R. Cowan, Moss, & Kerr, 1993).

In a thermo-neutral environment, which is approximately 5-20°C for Holstein-Friesian cows, the energy demands of walking are between 1.2 MJ and 6MJ/km on a horizontal plane. There is a rapid increase in the energy demands when animals are walking under heat stress, particularly if they are high producing (R. Cowan et al., 1993).

Considering the deleterious effect of heat stress on dairy cows, a decision to remove the cow activity calving at the first of January (Dairy A) was taken. December to March is the hottest period of the year, and animals in their last period of pregnancy are more susceptible to heat stress (Butterworth, 1989). Moreover, this cow activity has the largest energy requirement during the dry season (see Figure 3.1) which would require large amounts of supplements to be fed, thus increasing the cost of production.

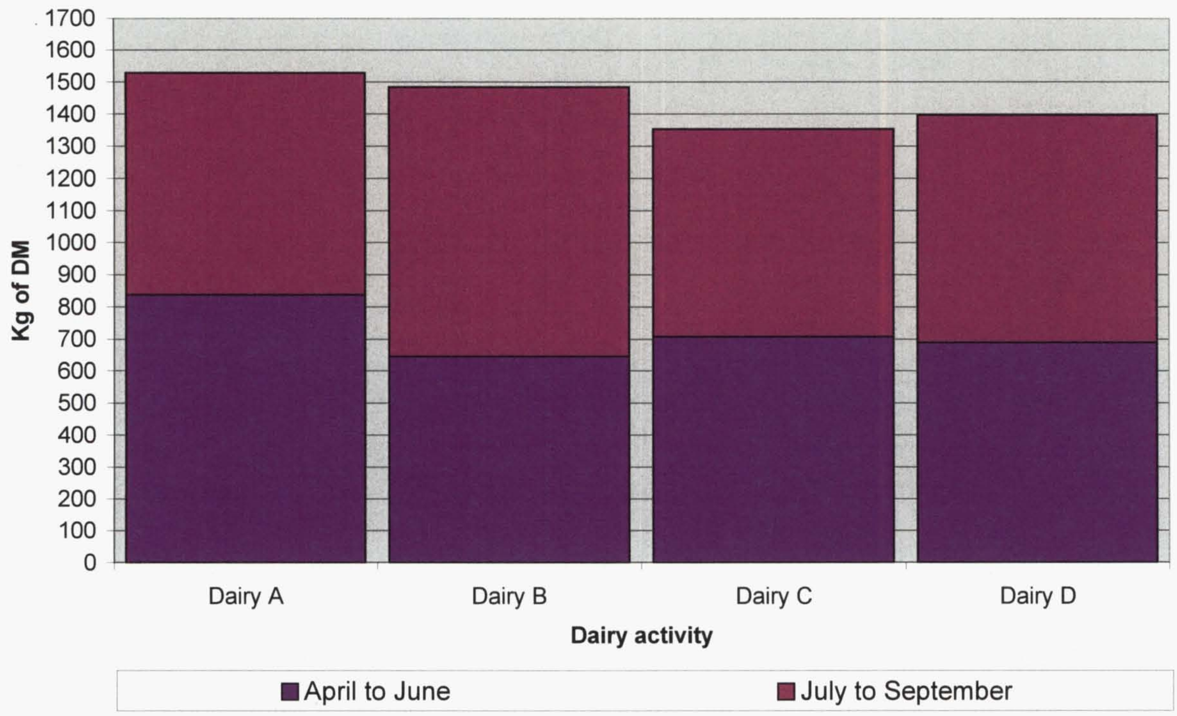

Figure 3.1 Medium quality feed demand during the dry season for dairy cows calving in different dates. Source: demands estimated with AFRC, 93

Cows calving at the first of April (Dairy B) were also removed. They require the largest amount of medium quality feed during the second half of the dry season when pasture production (which is the cheapest source) is limited, hence, increasing the cost of production.

Cows calving in the second half of the year (Dairy C and D) are more likely to better match the pasture growth pattern in the Central Chaco (see Figures 3.1 & 3.2) In fact, it replicates what currently happens in the area of study.

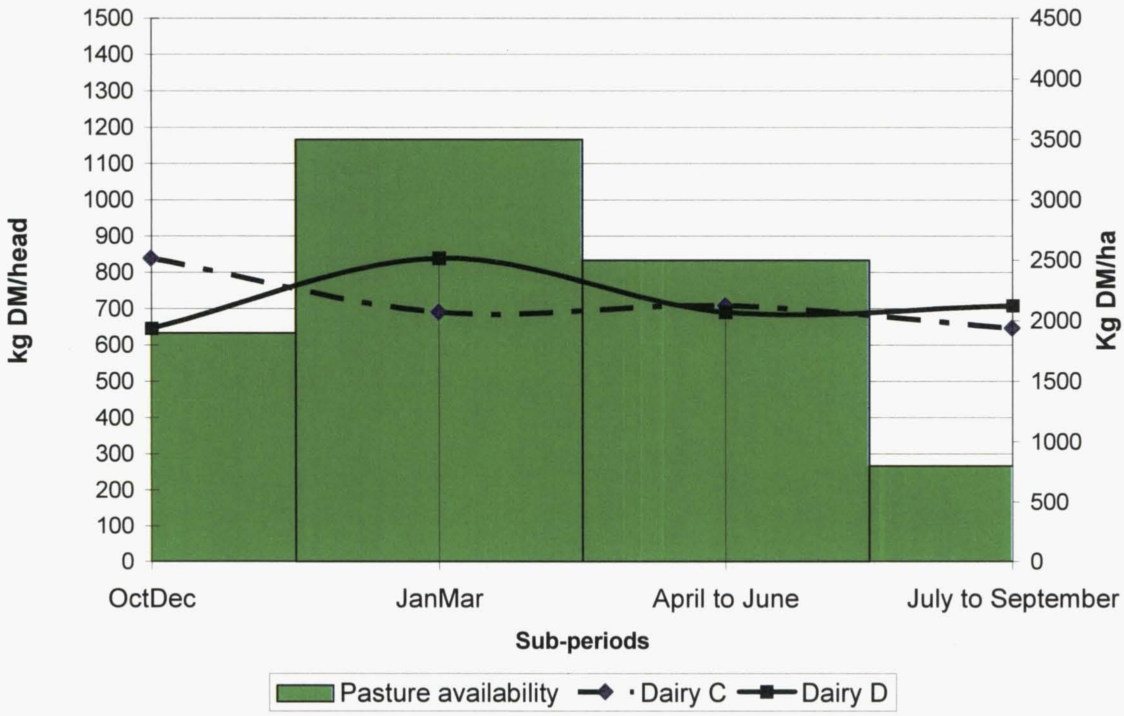

Figure 3.2 Medium quality feed requirement for cows calving during the second semester compared to pasture on offer in different periods of the year

Finally, cows calving in July and October were included in the mathematical model as their energy demands better match the grass production pattern in the area of study. It is likely that a more efficient pasture utilization will be achieved with cows calving on these dates.

Comparing cows calving in July and October it was clear that those calving in July have some advantages. Mating time is during the spring in the dry season when heat stress is less likely to occur. In contrast cows calving at the beginning of October will be mating in December. Heat stress is more likely to occur and this will jeopardise heat detection and, consequently, conception rates. Cows calving in the second half of the dry season also have high supplement requirements during the first trimester of lactation. Pasture production is at the lowest level at this time, so feed will have to be transferred from a period of feed surplus in the form of hay and silage, and / or winter crops. After this first trimester the energy demand of cows calving in July follows that of the pasture supply pattern (see Figure 3.2). Consequently, eight dairy cow activities were included in the model and their main features are summarized in Table 3.4.

Table 3.4 Dairy activities included in the model

Dairy activities	Description
Dairy1C	450 kg cow calving in July producing 3,000 L per lactation
Dairy1D	450 kg cow calving in October producing 3,000 L per lactation
Dairy2C	450 kg cow calving in July producing 4,500 L per lactation
Dairy2D	450 kg cow calving in October producing 4,500 L per lactation
Dairy3C	550 kg cow calving in July producing 3,000 L per lactation
Dairy3D	550 kg cow calving in October producing 3,000 L per lactation
Dairy4C	550 kg cow calving in July producing 4,500 L per lactation
Dairy4D	550 kg cow calving in October producing 4,500 L per lactation

A series of assumptions were required regarding these different dairy activities. For instance, Dairy 1 and Dairy 2 represent cow activities of low and high yielding cows, respectively, with a small body frame (Jersey, some Friesian and crossbreed cows). Then, Dairy 3 and Dairy 4 represent cow activities of low and high yielding cows, respectively, with large body frames (some double purpose breeds, Holstein-Friesians and Friesian crosses).

Currently, calves from Dairy 2 and Dairy 4 must be finished on the farm because there is not market for weaned animals. In contrast calves from Dairy 1 and Dairy 3 can be sold at rising one year as there is market for these types of animals on beef finishing farms (S. Harder, personal communication, December 2, 2004).

It is clear that finishing all calves on farm imposes limitations on the number of dairy cows that can be run per farm. Since growing cattle compete with dairy cattle for the limited pasture available. Thus, it can be argued that a more profitable option would be to get rid of the dairy calves during the first week of life in order to fully utilize the effective grazing area for productive dairy cows and to rear only the required replacements. Consequently, activities that provide the option of selling calves at price equals zero during the first week of life were introduced into the model.

All dairy activities have their respective associated activities such as weaning activities, rearing replacement and finishing activities. Also, an allowance has been made to include the possibility of selling pregnant heifers but with an upper limit. Moreover, all dairy activities have their corresponding reconciliation rows in order to ensure a steady state situation. All non replacements dairy animals were assumed to be finished for beef at twenty four months of age. Appendix A.3 shows the expected liveweight curve for these activities.

Dairy replacements can be reared on farm or bought in. However, there is always concern about the breeding and productive quality of purchased animals. This is because, currently, there are no individual recording schemes in place in order to assess their genetic merit. Thus, an upper limit of 25% was allocated for the activity buying dairy replacements of total replacements required

Milk production activities

Although calving date has a major influence on the pattern of milk production, this is mainly as a result of nutritional factors (seasonal variations in feed quality and availability). These seasonal variations are more evident under a totally grazing system such as in New Zealand but less obvious under a system that relies on a certain amount of supplementary feed, which can correct potential imbalances in the diet. Consequently, and to simplify the specification of cow activities, the lactation curves from similar productive potential cows were assumed to be the same for different calving dates. The formulation of the nutritional sub-model ensures that cows are provided with sufficient nutrients to achieve the specified lactation yields.

Milk production, milk consumption (by suckling calves) and milk selling activities where linked through the "milk tank" three monthly reconciliation rows.

3.5.3 Crop activities

Cropping activities have been calculated using real data collected in the area through interviews with researchers, farm advisors and farmers.

Every cropping activity represents a different crop and/or cropping techniques as well as the use of contractors or own machinery. For the purpose of this study machinery availability was considered not limiting.

Machinery costs were calculated using data provided by Harmut Bergen, farm advisor from the extension service of Neuland Coop Ltd and the detailed cost calculations are shown in Appendix C. All tractor costs are based on a tractor type MF275 which is the most popular tractor in the region because it can be used for most of the tasks involved in cropping and pasture production activities.

The different cropping activities included in the model are presented, below

The soil type of the farm determines the varieties of crops, rotations and yield expected for each crop.

Campo soil type represents about 15% of the total area of the Central Chaco. It offers a wider variety of cropping options compared to "Monte" type soils.

The summer cropping options include ground nuts, sesame, cotton, grain sorghum, forage sorghum, castor bean, sugar cane and maize. While the winter cropping options include only oats for forage. From all these options cotton, ground nuts, grain sorghum, and sesame are the main cash crops in the area. In contrast Monte soils are mainly suitable for pasture and sorghum.

Castor beans

Castor beans are well adapted to local conditions, but their current market price is very low. It is usually grown in degraded soils as a soil conditioner. Its leaves and seed hulls are rich in phosphorus and its deep root system aerates compacted soils.

Castor bean seeds contain about 90 % of ricinoleic oil content, which is industrialized and processed into more than 400 products such as paints, lubricants, etc. The by product, expeller, is an organic fertilizer rich in phosphorus, nitrogen and potassium (MAG, \, 2004 #41). Castor beans have a cycle length of 150 to 180 days with an expected yield for the Central Chaco of 545 to 1,000kg/ha (C, Rodas, personal communication, November 23, 2004; F. Eitzen, personal communication, December 14, 2004).

A minimum or no tillage system is recommended (MAG, \, 2004 #41) The ideal sowing date is from October to November and the recommended sowing rate is 6 kg per ha (C. Rodas, personal communication, November, 2004).

Two to three weedings during the first two months of the growing cycle are recommended, because weeds are not tolerated during establishment. Harvesting must occur when one third of the pods are dry, the remaining pods can be dried on the ground. Ripening of pods occurs in three waves with the first one about 145 days after sowing, the second around 158 day and the last around 178 days after sowing.

Castor beans must not be grown in the same paddock for two years in a row, a rotation with a green covers and/or cereals is recommended (MAG, 2004). Appendices D.1.1 and D1.2 contain the gross margin calculations for this activity using own machinery and using contractors, respectively.

Cotton

Cotton represented the most important source of income for the region in the past. However, its production has declined progressively during the last decade due to a continuous decline in prices of this commodity in international markets. Tables D.3 & D.4 contain the estimated gross margins for Cotton activities using own machinery and using contractors, respectively.

Groundnuts

Groundnuts represent an important crop in the Central Chaco and there are varieties for oil production and for confectionary. Originally, oil varieties were preferred but lately varieties for confectionary are more popular as they are directly exported to Germany. Ground nuts can be grown with conventional, minimum and no-tillage systems.

Ground nuts can be grown exclusively on Campo soils. Expected ground-nut yields in the Central Chaco ranges from 1500 to 1800 (Dück, personal communication, 2004) up to 2000kg/ha (Bergen, personal communication, 2004). The expected price for confectionary Groundnuts over 2004-5 was expected to be between $0.35 to $0.42 and up to $0.47/kg. The price depends on the quality of the product and this, up to a large extent, depends on climatic conditions during the growing period (Dück, personal communication, 2004).

A simple comparison between gross margins has shown that no-tillage systems are not profitable under local conditions, and considering that minimum tillage systems are already effective preventing wind erosion, it was decided to exclude the no-tillage ground nut activity. Therefore, the model includes Ground nut production activities for conventional and minimum tillage systems with the option of using either the farmer's own machinery or contractors. All the Groundnuts activities gross margin calculations, including the no-tillage system not included in the model, are shown in Tables D5 to D9.

Sesame seeds

Sesame seeds has become the most popular crop in the Central Chaco in the last few years because it is adapted to local conditions (drought tolerant), there is an absence of pests and diseases, and the fact that most of the production cost occurs at harvesting when there is certainty about the expected yield of the crop. This helps the decision about carrying out with the harvest. Finally, it has a high price per volume of product which is valuable relative to the freight cost (H. Baez, personal communication, December 10, 2004)

Sesame seed can be harvested mechanically or manually, thus both types were included into the model. Furthermore, the option of using contractors was included as well. The detailed gross margin calculations for all these four activities are shown in Tables D.12 to D.15. Sesame seed yields ranges from 350 to 400 kg for mechanical harvesting and from 150 to 800 kg per hectare for manual harvesting (A. Dück, personal communication, 2004)

Sorghum

Sorghum is a cereal well adapted to the rain fed conditions prevailing in the area of study. Shorter hybrids are preferable because tall varieties are usually damaged by the strong wind during the growing period. Sorghum can grow in Campo and Monte soils, and both grain and silage yield from sorghum grown on Monte soils are always higher due to its higher natural fertility.

Yield is the first consideration in growing summer forage crops, and the various forage sorghum cultivars are capable of producing a high yield of dry matter quickly. Sorghum produces higher DM yields under drought conditions than maize (Minson, Cowan, & Havilah, 1993) and can yield 20 to 30 t/ha of total forage fresh matter (30%DM) on Monte soils in the Central Chaco (Bergen, 2004)

While, forage sorghum is mainly used for silage making and later to be fed to dairy cattle, grain sorghum is fully used by the local mills for livestock feed production. Tables D.16 to D.19 contains the calculated gross margin for grain sorghum and forage sorghum for Campo and Monte soil type.

The nutritional values of sorghum silage and grain sorghum are discussed on pages 75 & 83

Maize is not well adapted to the local rainfall pattern and, thus, is a risky crop. The area under maize is usually negligible. Therefore, it was not included in this study.

Oats

The only winter cropping option is oats (white and black). As black oats are the most popular crop (INTTAS, 2004), there was more data available related to its management, expected yield and nutritional value under local conditions. Therefore, this was the activity selected to be included in the model.

Black oats provide high quality feed during the driest part of the year and is a popular feed resource for dairy farms in the Central Chaco (Cabrera, personal communication, 2004).

Table 3.5 displays the nutritional value from black oats grown in the Central Chaco and Tables D.10 & D.11 contain the gross margin calculations for this activity using own machinery or contractors.

Black oats are sown in April and expected yield is 2.8 tonnes of DM/ha with variations of ± 100kg of DM/ha. (A. Cabrera, personal communication, 2004). Grazing, or harvesting starts in July.

Table 3.5 Black Oats nutritional value.

Nutritional value	
ME MJ/kg of DM	Crude Protein in %
8.677±697	17±2

Source: Cabrera, 2004

For the purpose of this study a 80 % utilization rate was assumed for the oat activity. This high utilization rate was considered achievable assuming that it will be consumed by lactating dairy cows under rotational grazing.

3.5.4 Pasture activities

The quantity and quality of the pasture can not be improved further than the most limiting soil factors where they are growing (Dürksen, 2004). Under local conditions in the Central Chaco, grass protein content was found to be correlated to soil fertility level where the grass was grown. Grass energy content was found not to be correlated to soil texture or fertility level (Glatzle, 1999)

It is difficult to define a typical pasture production curve for an area with such a wide variation of rainfall in terms of quantity and distribution (Baez and Dürksen personal communication, 2005). However, consulting research data from the area some guidelines can be obtained (Figures 3.3 & 3.4).

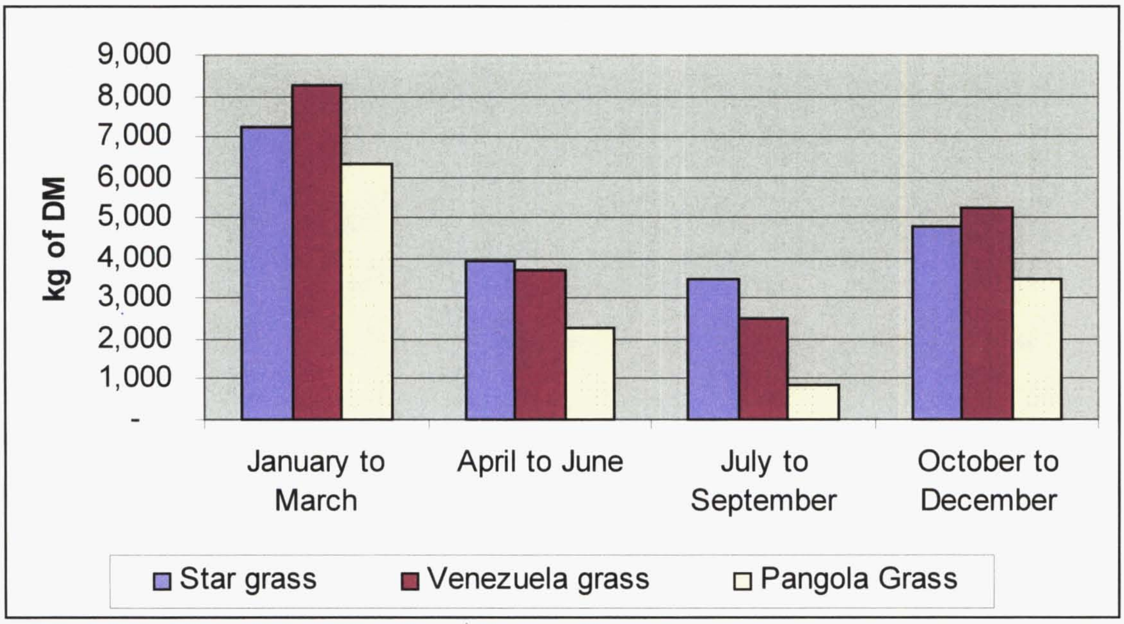

Figure 3.3 Total DM production of some improved pastures in the Central Chaco per periods. Source: Glatzle et al, 1995

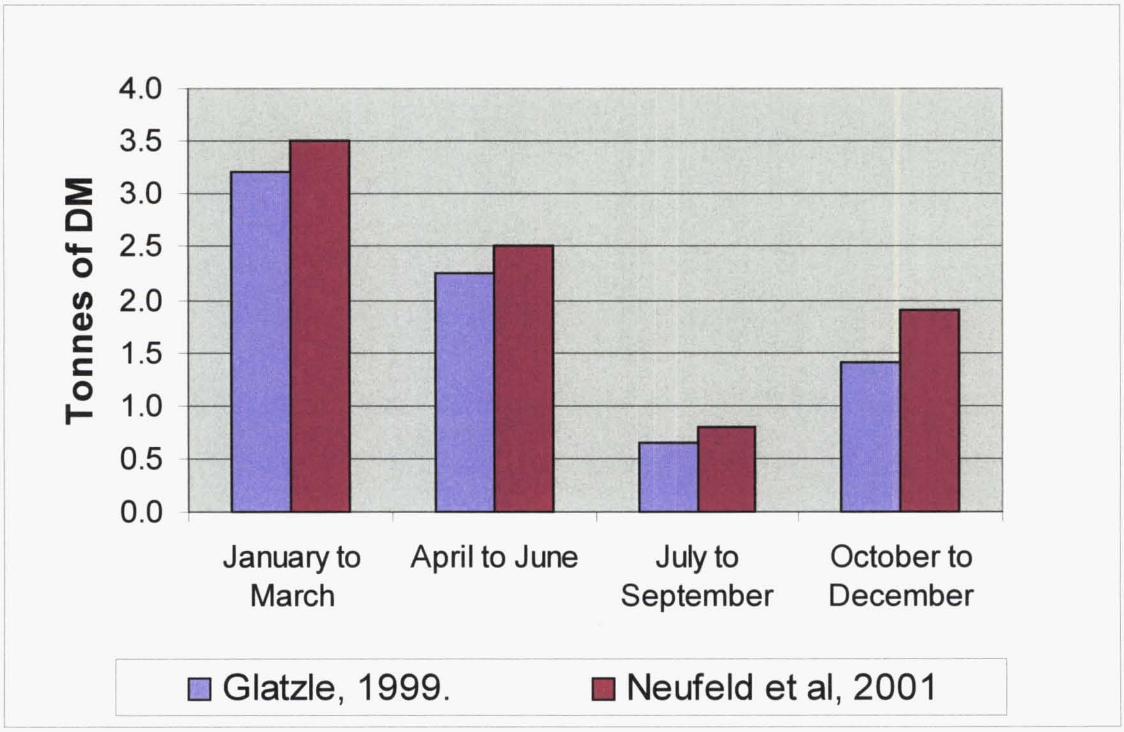

Figure 3.4 Pasture on offer per periods in the Central Chaco of Paraguay. Source: Glatzle, 1999; Neufeld & Glatzle, 2001)

Unfortunately, the data displayed in Figure 3.4 does not identify the grass species under consideration, nor the number of samplings used for the trial nor the years when the trials where made. Furthermore, both research data shows very similar values so that could be argued that they relate to the same trial.

In the Central Chaco, the costs associated with pasture maintenance (weed and soil compaction control) represent between 20% (Neufeld, E. et all, 1994) and 35% (F. Eitzen, personal communication, December, 2004) of total variable cost and are the major costs in cost of beef production per ha. According to Dürksen T., (2004) controlling woody weeds on pasture in the Central Chaco is a complex issue.

Because the woody weeds are a chronic problem, it is more practical to control them rather than eliminate them (Schonwalder, 1996) In addition, many weeds are emergency forage for livestock in periods of drought (Dürksen, 2004; Glatzle, 1999; Thorsten, 2004)) Overall, the most effective way of controlling weeds is through good grazing management. (Good stocking rate, periodic weeding and soil conditioning, pasture re-sowing, etc) which allows grass to regenerate fast enough to suppress weed invasion. For the purpose of this study it was assumed that the farmer applies good grazing management and weeding control includes a combination of manual, chemical and mechanical methods (Dürksen, 2004). This has been included in the calculation of pasture maintenance costs. The main scrubby and herbaceous weeds in the Central Chaco are shown in Appendix H.

"Campo" type pasture

The light sandy soils are called "Campo". On these soils typical improved pastures grown include Pangola grass (*Digitaria decumbens*), Star grass (*Cynodon pnemfuensis*) and Sabi grass (*Urocloa mozambizensis*) (INTTAS, 2004).

From these the most popular and wide spread is Pangola grass (Digitaria spp). This pasture is well adapted to light soils in the Central Chaco, has a good DM production and does not have many pests and diseases. However, it must be planted using vegetative means as its seeds are often sterile.

In the last few years the research stations of the area have introduced new African varieties of Digitaria sp that produce viable seeds and their preliminary assessment looks promising (INTTAS, 2004)

Star grass under the local conditions of the Central Chaco can support up to two Animal Units/ha[3] with continuous grazing. However, its metabolic energy content decreases below maintenance requirement level (<5.725 MJ/kg DM) during the winter period (Cabrera et al, 2001). Another interesting feature of this type of pasture is its propensity to support pests such as cutting ants and grasshoppers (H.Baez, personal communication, 2004).

[3] One Animal Unit (AU) = steer of 400kg liveweight

Sabi grass is a relatively newly introduced variety which has adapted well to well drained soils, it tolerates drought but not temporary flooding (Harder, S. personal communication, 2004).

Pure Pangola pasture has been selected to represent "Campo" pastures because of its popularity and availability of local data regarding its management, expected yield and nutritional value. The detailed gross margin calculation for the activities including this type of pasture are shown in Table F. 1

Improved pasture is obtained by associating Pangola with legumes which are sown in five metre bands. An average legume content of 26% on a green matter basis can maintain the sustainability of a grazing system (Cadish, Schunke, & Giller, 1994) These legumes include *Alysicarpus vaginalis* and *Estylosantes hamata* var. oxley (Drought resistant).

Pangola grass is sown by hand with sticks of Pangola grass which are buried one each 5X5 m. One labour unit can plant 2 ha/day. The sowing period is February-March and the paddock must be shut until January of the next year. Table F. 3 contains the calculated gross margin for this activity.

Table 3.6 Costs of legumes used in "Campo" type soils

Legume species	Sowing rate	Cost/kg ($)	Cost of seed per ha ($)
Alysicarpus v.	100 g/ha	$46.66	$4.67
Estilosantes H. Oxley	300 g/Ha	$29.16	$0.87

Source: S. Harder, personal communication, 2004

"Monte" type pasture

Pasture production on "Monte" type soils comprises mainly Gatton panic (*Panicum maximum var Gatton panic*) and, to a lesser extent, Buffel grass *(Cenchrus ciliaris)*. In the past Buffel grass was dominant but in recent years Gatton panic has taken over most of the "Monte" area on pasture due to its better performance and persistency.

For the purpose of this study the pasture activity is based on the Gatton Panic growth pattern and nutritional value. It has been argued that differences in yield and nutritive quality between improved grass species is negligible and that differences are more a function of the soil where the pasture grows than a specific characteristic of the grass species (Glatzle, 1999).

Well maintained panicum maximum type pastures can remain productive for an indefinite time (Glatzle, A. personal communication, 2004). However, for the purpose of this study a 20 year useful lifetime was adopted under the theory that after 20 years (which include several drought events) some major intervention would be required in order to upgrade the genetic quality and/or vigour of the pasture, and to combat weed invasion.

Table F. 2 contains the gross margin calculation for "Monte" type pasture activities.

Leucaena

Leucaena (*Leucaena leucocephala*) is a browsing legume which increases liveweight gain of cattle in tropical and subtropical areas around the world. However, cattle consuming diets with more than 30% of leucaena can suffer a hypothyroid condition, causing a decline in feed intake and bodyweight gain. The potential toxicity of leucaena is related to the presence of mimosine, a non-protein amino acid. Ingested mimosine is metabolized in the rumen to (DHP)4, which is a potent goitrogen (Quirk, Bushell, Jones, Megarrity, & Bulter, 1988). Microbial degradation of DHP prevents leucaena toxicity. Cultures of DHP degrading bacteria (***Sinergistes jonesii***) have been imported from Australia and introduced in the Central Chaco by INTTAS. The inoculation can be realized either orally or ruminally, only 10% of the herd is required to be dosed as the bacteria spreads naturally between animals in the herd.

In Central Florida edible percentages of approximately 50% of total DM yield for leucaena cut five-times a year have been reported, whereas in Costa Rica edible percentages of about 90% of total DM production for Leucaena cut every eight weeks have been reported (Mullen, Gabunada, Shelton, & Stûr, 2003).

Leucaena var. Cunningan has excellent grazing tolerance and from well established "pasture" Liveweight gains can be expected to exceed 1 kg/head/day, which greatly exceeds that obtained from herbaceous grass/legume pastures in similar environments. Moreover, it has been used successfully as a supplement for sugar cane diets, for molasses based diets and for milking animals on pasture (Saucedo, Alvarez, Jimenez, & Arriaga, 1980).

The metabolic energy (ME) of leucaena is high (up to 12.1 MJ/kg DM) relative to that of tropical grasses (Humphreys, 1994).

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[4] 3hydroxy-4(1H)pyridine

A leucaena hedgerow system was developed in Australia and introduced to the Central Chaco in the last decade. It consists of single, or double, rows of leucaena planted at high density (5 to 10 plants per linear metre) every five to six metres and with improved pastures (Gatton panic and/or Buffel grass) between the rows.

Leucaena is established on improved pastures using a sowing rate of 2.5 kg of scarified seed per ha (Harder, 2004). Once established it can deliver sustainable high productivity. This has been shown in Australia where the oldest leucaena / grass systems have been grazed for over 30 years and remain productive (Glatzle and Báez, 2002). It is relatively easy to maintain a suitable grass – legume balance as the two components are separated spatially (Shelton, 2001). The mixture provides an insulation against the worst effects of droughts, provided conservative stocking rates are employed. This arises due to the deep rooted character of leucaena enabling it to produce high protein sprouts during dry periods (Shelton, 2001). The system also control run-off during heavy precipitation and has excellent infiltration rate, thus, minimizing soil erosion. It also, increases the utilization of water stored in the soil profile, hence, diminishing the risk of salinity built up by water table rises. Furthermore, it has a considerable tolerance to saline soils (Glatzle and Baez, 2002) and fixes between 600 and 800 kg of carbon per ha per year.

The legume component remains green throughout the year, providing good quality feed and the partial shade provided by the leucaena during the dry season protects grass from excess irradiation, reducing evapotraspiration. It also, reduces the heat stress of grazing animals, so increasing their grazing time during hot weather.

However, the system also has some limitations such as a long establishment period and a requirement for improved managerial skills in order to prevent the legume component from growing too high preventing livestock browsing. Furthermore, cutting ants (Atta spp) and termites are economically important pests. A severe attack of cutting ants in the establishment phase can cause a complete failure.

There is a lack of data regarding the expected yield from hedgerow systems, therefore some best estimates are required in order to assess the likely impact of the introduction of this system into the farming systems in the Central Chaco. The only available data on expected yields of leucaena in different period in the Central Chaco is shown in Table 3.7

Table 3.7 leucaena yield at high density stands with four cuts per year in the Central Chaco.

Variety :	Cunningan				
Total production/ ha (kg of DM)	17,304.5				
Date of cut (cut at 20 & 50 cm high)	March	June	September	December	Total
% of leaves per period	52%	50%	52%	50%	
% of total forage as kg of DM per period	50%	35%	2%	13%	1.00
Total production of forage (kg DM)	4,499	3,028	180	1,125	8,832
ME/kg of DM	6.6	6.5	7.2	7.1	
Crude Protein as % of DM	24%	24%	30%	28%	

Source: Cabrera & Glatzle, 96. Ensayo de variedades de Leucaena

Hedgerow systems have lower leucaena density, and therefore, lower DM yield per unit of area can be expected by the legume component of the system. However, two factors must be considered in assessing the likely yield. First of all, the yield reduction is not expected to be linear because in the hedgerow systems the competition between trees for water, nutrients and light is not likely to be as strong as in a high density stand and, secondly, higher leucaena yields have always been obtained by browsing trials when compared with cutting trials (Pauw, Kruger, & Van staden, 1994).

This pasture activity annual yield was approximated using data from grazing trials in the Central Chaco. Unfortunately, the research data does not cover a 12 month period. Thus, accuracy can not be sought in predicting the total annual yield. Consequently, a decision was made to explore different possible scenarios varying this activity yield. They were, then, used for the last experiment of this study. Source: S. Harder, personal communication, November, 2004

Table F. 4 contains the calculated gross margin for this pasture activity.

3.5.5 Labour

Fixed labour force has been calculated after allowing time for holidays, weekends, sickness and overhead labour requirements such as repairs and maintenance, fencing, etc. (Tyler, 1964) The assumptions and calculations used for fixed labour supply are shown in Tables 3.8 & 3.9

Table 3.8 Assumptions used for the fixed labour supply calculation

	Overhead tasks assumptions	Leisure time assumption
January to March	two working days per month	0.5 day per week
April to September	four working days per month	0.5 day per week
October to December	two working days per month	0.5 day per week

Source: Case study 1 & 3

Table 3.9 Fix labour availability calculation

Period	Fixed labour supply (man day units)	Overhead tasks (man day units)	Leisure time (man day units)	Total fixed labour available (man day units)
January to March	75	6	6	63
April to September	150	24	12	114
October to December	75	6	6	63
Per year				240

Because of the isolation of the Central Chaco from other areas of the country, and the difficulty of obtaining a reliable permanent labour supply among the local population, most of the labour supply available in the area of study comprises indigenous people, who prefer temporary jobs. Consequently, apart from the labour provided by the farmer himself/herself, farmers in the Central Chaco rely completely on hired labour.

Hired labour in the Central Chaco is usually provided with on farm accommodation, and a basic health insurance. Workers are paid at a daily basis according to the availability of jobs. For instance, if there are no tasks available the employee is not paid for that day, even though he/she can remain on the property.

This creates a special situation that could be called 'permanent hired labour', which is a type of employment not protected by legislation as yet. Workers do not have holidays and can be dismissed at anytime. This leaves the employee disadvantaged and unprotected, however, discussing this issue goes beyond the scope of this study.

The seasonality of rainfall governs the labour demand in different periods of the year. The demand for labour is at its highest during the rainy season. This is mainly related to the cropping activities. This fluctuation in demand affects labour costs. For the purpose of this study the labour activities are reconciled using three time periods.

By law the minimum cost of hired labour per day is \$7.70[5] (33,000 Gs). However the reality in the area of study is that labour cost ranges between \$5.83 to \$9.33 (25,000 Gs - 40,000 Gs) per day depending on the season and employee qualification (A, Dück personal communication, 2004).

Table 3.10 Labour cost assumptions used in the model

Labour cost per day	(G)	(\$)
Labour January to March	40,000	9.33
Labour April to September	30,000	7
October to December	40,000	9.33

Source: Case study 1

3.5.6 Borrowing and lending activities

The farmers have good credit facilities available provided through their cooperatives. For the purpose of this study the farm is assumed to be debt free. Also, for the cash flow sub-model monthly borrowing and lending activities were included. These represent the opportunities for increasing the working capital through borrowing money and that of saving money when no other more profitable option is available for the farmer.

3.5.7 Income tax

Law number 2,421/04 "Administrative and taxation policy realignment", and decree number 4305/04 that regulates the cited law, regulate the income tax policies in Paraguay.

All farms with an effective area equal to, or larger than, 100 ha are subject to paying IMAGRO, which represents the income tax under Paraguayan taxation policy. Income tax calculations are based on expected incomes and not on real accountable results. The expected income is calculated based on the productive potential of the farm according to government estimates and a 2.56% tax rate is applied to this expected income which is calculated and paid at the end of December. An approximation to the government taxable income estimate per ha for the period 2004-2005 for the Central Chaco is shown in Chapter 5 section 5.2 and the detailed calculation can be found in Appendix E

[5]NZ\$1= 4,286 Gs.

However, the government is facing continuous pressure from international organisations in order to correct its continuous financial deficit and this includes the introduction of income taxes for farmers based on real account balances. Consequently, for the purpose of this study it was considered important to calculate income tax based on real farm performance in order to approximate the likely effect of this on the farm system's final profit.

Chapter 4
LIVESTOCK NUTRITION SUB-MODEL

4.1 Introduction

This Chapter contains a detailed description of the nutrition sub-model, which comprises a feed demand and supply, as well as water demand and supply components.

Feeding standards are traditionally calculated to achieve the maximum stock performance level which, in many situations, might not be economically sound (Kearl, 1982). The NRC and ARC standards are regularly used as guidelines for ration formulation, although, both standard systems seem to be inadequate for application in grazing situation (Pittroff & Wothmann, 2001).

The feeding standard used in this linear programming model is based is the AFRC, 1993 Energy and Protein Requirements of Ruminants. These feeding standards were selected because its equations take into account the diminishing response curve that can be expected with increasing feeding level, which is more realistic than the traditional approach of linear responses to increases in feeding level.

4.2 Feed Demand component

The feed demand component includes the energy and water requirements for eight dairy cow activities, sixteen dairy finishing activities, eight rearing dairy replacement activities, one breeding cow activity, two bull activities, six beef finishing activities and one rearing beef replacement activity

All feed demands were calculated per category on a daily basis, and then added up to the three monthly periods used in the mathematical model. The level of accuracy that could be reached by approximating the demand component of the model is dramatically constrained by the availability and accuracy of the feed supply component of the model plus the lengths of each time period considered in the model.

Feed demand has been calculated based on the premise that in ruminant production animal production is largely a function of energy intake and its availability to the animal (Thomson, 1974). However, the voluntary intake of non-lactating ruminants is depressed when the diet contains less than about 7% crude protein (Minson 1990). It is suggested that critical levels must be higher for lactating animals. The crude protein content requirement for an adequate beef and milk production under the semi-arid conditions of the Central Chaco has been estimated to be 13% of the total diet (Glatzle, 1999).

The feed demand component was calculated based on the assumption that protein content was not limiting in the farm system. However, it must be kept in mind that protein deficiencies may arise under certain circumstances such as:

1. when cows rely heavily on tropical grasses for their protein requirements. Under this scenario dietary protein is low and insufficient amino acids are absorbed, the energy in the forage appears to be diverted away from milk and into liveweigth gain (Minson, D., Cowan, T. and Havilah, E., 1993). This is not the case in the Central Chaco as protein supplementation is always provided to lactating animals;
2. in calves up to six months old. In this category of animals crude protein should be mainly in the form of true protein, as the calves are still not fully ruminants. The best way to ensure that feed protein is efficiently used is to supply it in the form of feed protein, escaping rumen fermentation which passes directly to the abomasums for acid digestion. Younger, lighter weaned calves require higher dietary crude protein levels and need more of their protein as undegradable true protein Moran, 2002);
3. in replacement dairy heifers, there is also evidence suggesting that insufficient protein intakes would produce excess fat deposition in the developing udder which can reduce the potential for that udder to produce milk in later life (Moran, 2002).

To ensure that these categories will meet their requirements, special allowances have been made. These include including non-protein nitrogen supplementation during the dry season in their gross margins calculations, when protein deficiency is likely to occur, and the use of an upper limit to the use of concentrates with low protein content. It has been argued that the introduction of legume based pastures into the farming system may be an effective way to prevent this deficiency (A. Glatzle; H. Baez and A. Cabrera, personal communications, 2004).

4.2.1 Dry matter appetite prediction

Animals eat surprisingly similar amounts of DM no matter what type of feed is offered. Maximum intakes are directly related to liveweight in growing calves at the rate of 2.5 to 3.0 % liveweight per day. This can increase to 4 % or even 5 % in high-producing dairy cows.(Moran, 2002)

The intake of nutrients of the grazing animal depends on a complex interaction of a number of factors, which can be categorized into three main groups. See Figure 3.5.

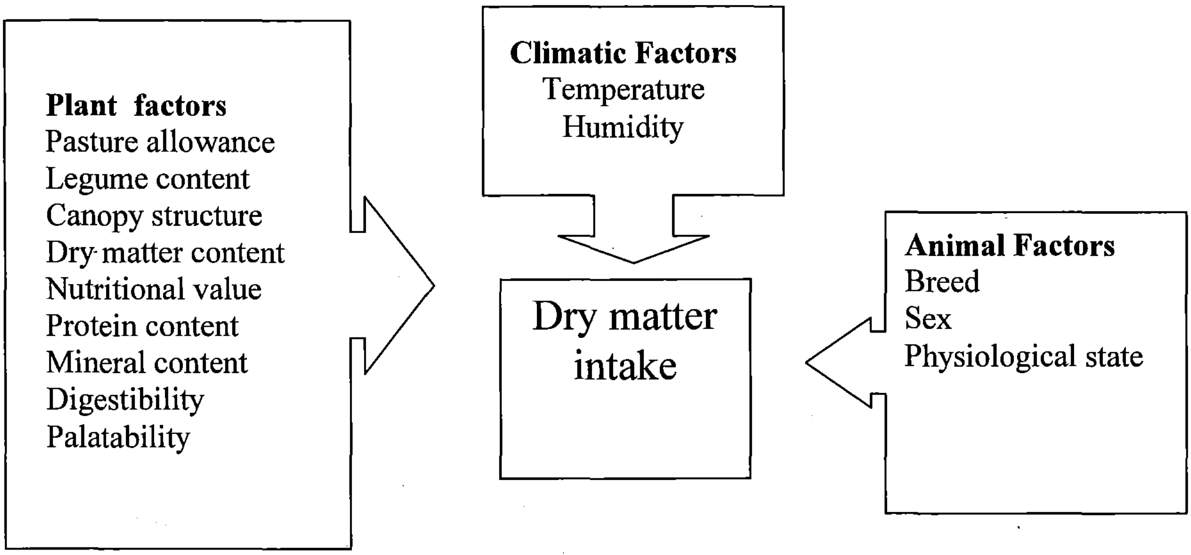

Figure 4.1 Factors affecting dry matter intake. Source: Adapted from Butterworth, 1985

Maximum daily dry matter intake for lactating beef cows was assumed to be 3.5% of liveweight and reduced to 3% of liveweight in dry cows. Maximum daily intake predictions for growing beef and dairy cattle were approximated according to the equation developed by Kearl, 1982 for livestock under tropical conditions. The equation is:

total dry matter intake = 0.105*Lw 0.75*(0.0833+0.85-ME)-0.1666*ME2

Where:

LW is Liveweight in kg.

ME is Metabolizable energy content of the feed in Mega calories.

For predicting the dry matter intake (excluding concentrates) of lactating dairy cattle the equation VH1 of Vladiveloo & Holmes (NRC,2001) was adopted.

DMI (kg/d) = 0.076 + 0.404C + 0.013W - 0.129n + 4.12log10(n) + 0.14Y

Where: C is kg DM of concentrate

W is liveweight,

Y is milk yield in l, and n is the week of lactation.

4.2.2 Dairy cows

Dairy cow energy requirements were calculated using the AFRC (1993) equations, The maintenance requirement was calculated including a daily activity allowance that assumes four kilometres walked, fourteen hours standing and nine position changes.

It has been proved that the ME (metabolizable energy) actually available to the animal is reduced significantly at high levels of feeding (Kearl, 1982) due to the increased outflow rate, and reduced retention time in the rumen (AFRC, 1993), This was taken into account when calculating the energy demand.

Because milk is a high quality feed that is digested efficiently in the abomasum, its energy value to the calf is considerably greater than that of solid feeds digested in the rumen. More than 90% of the gross energy in milk ends up as ME compared to only 50-60% of the gross energy in hay and concentrates(Moran, 2002 #37).

The energy requirements for growth increase with age and weight but also vary with the energy content of the feed. High energy feeds, such as milk and concentrates, are used more efficiently for growth than are low energy feeds, such as medium quality pasture or hay. Because the maintenance ME requirement is constant for a given liveweight, the faster an animal grows, the higher the proportion of the total ME intake available for growth. Calculations of energy requirements for milk-fed calves differ from those for calves with developed rumens. Because solid feed digested in the rumen are only used about half as efficiently by the growing calf as milk digested in the abomasum. However, the energy in milk costs up to four times more than that in concentrates, making early weaning onto solid feeds considerably cheaper than milk feeding.(Moran, 2002 #37)

Table 4.1 shows that the ME intakes for 1.0kg/day gain are only about 33% higher than those to achieve growth rates of 0.5kg/day but about double those for maintenance. This table also represents the required ME content of any ration to achieve growth rates of 0.5 or 1 kg/day. (Moran, 2002 #37)

Table 4.1 Requirement of weaned calves for metabolizable energy (ME), rumen degradable protein (RDP) and undegradable dietary protein (UDP) at different liveweights and for different growth rates

		Liveweight in kg		
		80	140	200
Maximum intake Kg/day		2.4	3.6	4.8
ME requirements (MJ/day)				
Maintenance (M) + 0.25kg/day gain		15	23	30
M + 0.5 kg/day gain		18	27	36
M + 0.75 kg/day gain		22	32	42
M + 1.0 kg/day gain		26	38	48
Minimum dietary ME content (MJ/kg DM)				
0.5 kg/day gain		9.2	8.9	8.7
1.0 kg/day gain		12.9	11.9	11.5
Crude protein requirement (g/day)				
0.5 kg/day gain	RDP	170	250	330
	UDP	130	120	110
1.0kg/day gain	RDP	240	335	430
	UDP	200	180	150
Minimum dietary crude protein content (%DM)				
0.5 kg/day gain		12.5	10.3	9.2
1.0 kg/day gain		18.3	14.3	12.1

Source: prepared by Webster, 1984 cited by Moran, 2002.

4.2.3 Beef cattle

Since climatic factors can not be changed, the objective must be in improving the match between feed supply and demand, which relies upon changes in the seasonality of livestock production.

The advantages of compensatory growth in beef cattle are widely recognized. Although it is regularly used as a management tool in the area of study, it was not included here under the principle that with high feed conversion efficiency the faster the animal grows and the more efficient the feed available is utilized. The liveweight curve used for different beef activities are shown in Table A. 2

Breeding cows

Cows in good condition in April can safely lose up weight to 15% of their liveweight from autumn to about four weeks before calving, without penalising calf production. This pattern of weight loss does not matter, it can be steady during the winter or rapid at times. Ideally, cows should gain liveweight during the last four weeks of pregnancy, to avoid metabolic problems (Fleming, 2003)

Good post-calving nutrition is usually easy to achieve if the calving date coincides with the start of the spring pasture flush. This will help to reduce the period of anoestrus and increase the calving rate.

Culling cows are sold after weaning with a minimum of 460 kg of liveweight. There is a very small market for replacements, thus, farmers finish for beef all non replacements heifers (Dück, A., Bergen, H., 2004 personal communication 16th December 2004).

For this study beef cattle requirements were calculated for cows with 450 kg average liveweight. The energy requirement was calculated utilizing equations from the AFRC (1994), and the intake limit was assumed to range from 3.5 % of bodyweight during peak of lactation to 3 % of body weight at calving and after weaning. An expected liveweight curve was approximated utilizing data collected in the area and experts advice (See Figure 3.6).

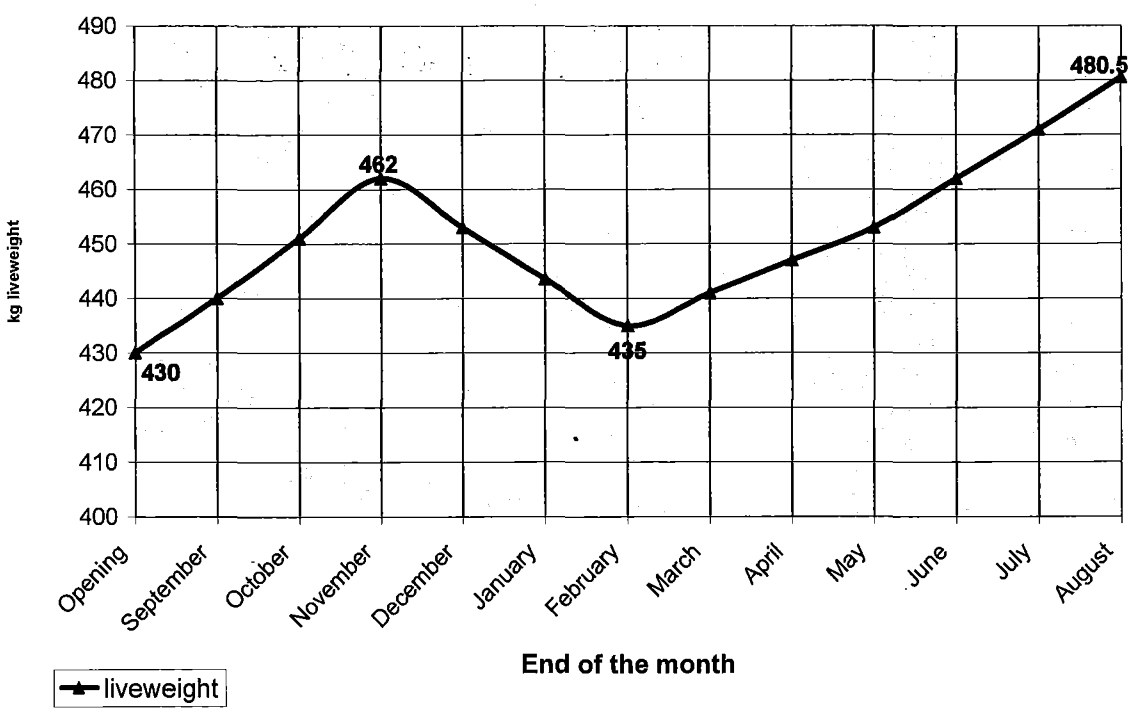

Figure 4.2 Liveweight pattern used for the breeding cow energy requirement calculation. Adapted from (AgResearch, 1996)

Maintenance requirements were calculated assuming an activity allowance of 1.6 km walked, twelve hours standing and six position changes. The same activity allowance was utilized for the energy requirement calculation for beef and dairy growing animals and bulls, but not for milking cows.

The expected milk production was used to calculate the energy requirement related to this metabolic activity. Total milk production of beef cows was approximated, as in

Lintwinczurk & Krol, 2002, using the expected weaning liveweight for milk production calculation.

Total milk yield = LBW * 1700/WA

Where:

LBW = liveweight of the calf at weaning in kg[6].

WA = age of calf at weaning in days.

The milk yield at the beginning of the lactation was assumed to be 7.8 l which is similar to values obtained by Holmes et al. (1968) analyzing the milk yield of *Bos Taurus, Bos indicus* and crosses under grazing conditions, values ranged from 7 L for Hereford cows to 9 l for Afrikander cross cows, with Brahman cows giving a value of 7.9 L. The lactation curve was approximated, as shown in Figure 3.7.

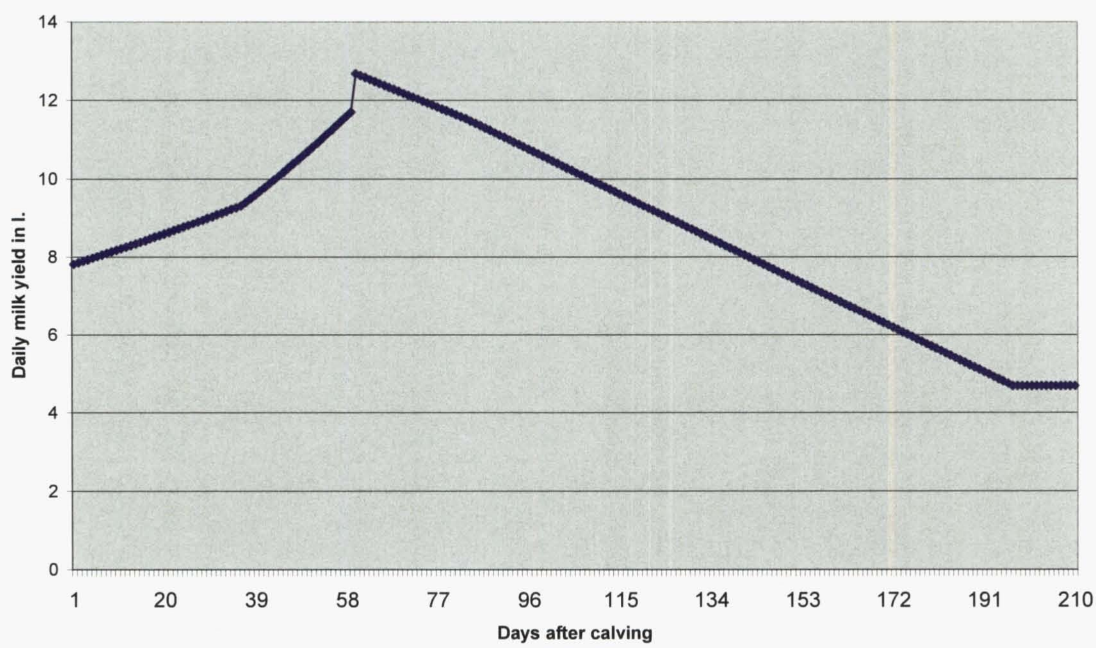

Figure 4.3 Expected milk production curve for beef cows. Source: Adapted from Holmes et al, 1968 and Lintwinczurk & Krol, 2002

It has been argued that 60 % of the liveweight gain for weaned calves is the direct effect of milk supply (Litwinczuk & Krol, 2002). Thus, assuming an average calving liveweight of 35 kg and a weaning liveweight of 240 kg, there is 205 kg of liveweight gain during the 210 days of lactation and only 84 kg can be assumed to be the direct effect of grass consumption. Then, assuming 9.916 MJ per kg of liveweight gain as the requirements for liveweight gain for the ruminant calf (Joyce, 1971) we can approximate the amount of

[6] Liveweight at weaning was assumed to be 230kg for heifers and 250kg for steers.

medium quality feed (9.25MJ/kg of DM) required for the suckling calf to be 90 units of medium quality feed. Then this amount was allocated subjectively between the second trimester and the last month of the suckling period as shown in Table 4.2.

Table 4.2 Feed demand calculation of suckling beef calves.

liveweight gain(kg)	Total ME required (MJ ME)	Medium quality feed content	Amount of Medium quality feed required in (DM kg)	
			Second trimester	Last month
84	833	9.25 MJ/kg DM	54	36

The annual energy requirement for a 450 kg liveweight cow was set at 28.512GJ of ME. Adding the required pasture allowance for the suckling calf (see Table 4.2) the total energy requirement was 29.344 GJ which is slightly higher than the 28.5GJ ME per year that has been argued as the energy requirement for breeding cows under local conditions in the Central Chaco (Glatzle, 1999),but it can be considered acceptable. The details of energy requirements calculations are shown in Appendix A. Table 3.10 shows the result in summarized form.

Table 4.3 Calculated feed requirement for a breeding beef cow calving in September

	Medium quality feed (9.25MJ ME/kg DM) in Kg DM	Low quality feed (7.5MJ ME/kg DM) Kg DM
January to March	54	960
April to June	36	879
July to September	455	851
October to December	648	663

Bulls

Beef and dairy bulls have on average 700 kg of liveweight in the Central Chaco (Glatzle, 2004). They spend most of the time at maintenance level except before and during the mating season when provisions must be made in order to ensure that good quality feed is available so they can perform to their genetic potential. Annual replacement rate is 33% and the bull to cow ratio is usually 1 to 30.

Two bull activities were included in the model. They represent exactly the same type of bull but they have different energy requirements during the dry season. This was in order to explore if a weight loss during the first period of the dry season would be more desirable than the weight loss during the second period of the dry season.

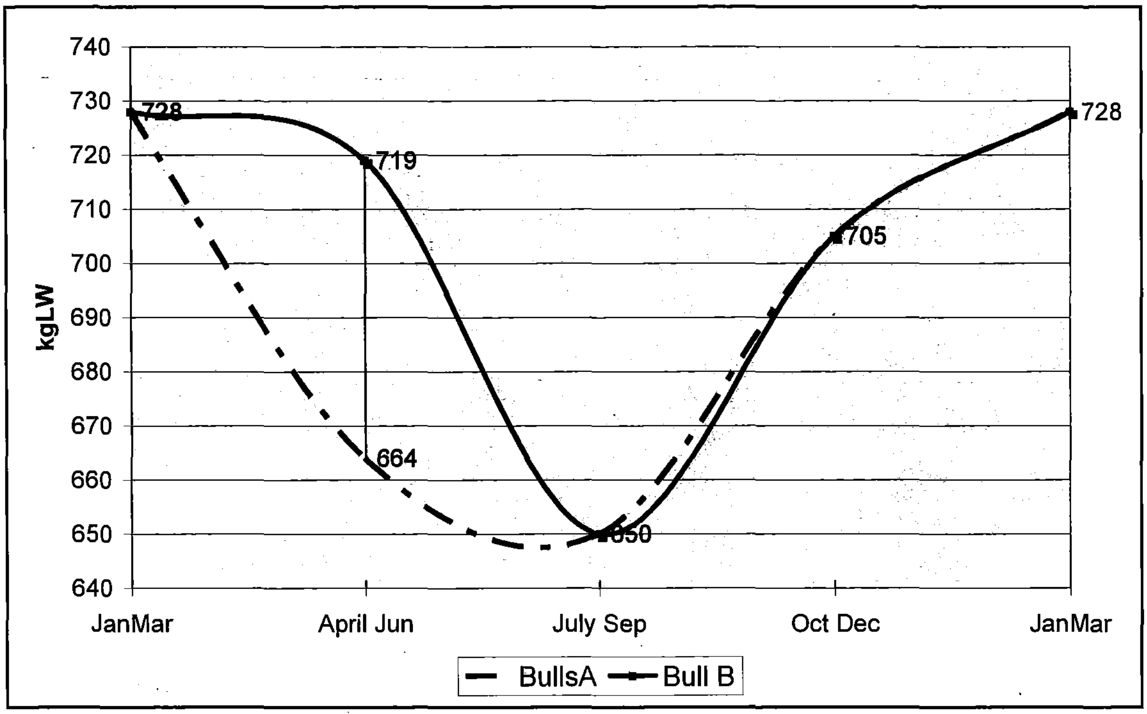

Figure 4.4 Liveweight pattern of bull activities included in the model

As "the performance of growing and finishing cattle is largely determined by the voluntary feed intake" (AFRC, 1993), it is important to assess this correctly.

Bull calves can be sold as weaners at 250 kg average, or they can be reared until 450 kg of liveweight between 18 and 30 months of age. For the purpose of this study, only two finishing steer activities were included these represent the possibility of finishing the steers at a fast rate in 18 months and at a slower rate at 24 months of age both at 450 kg liveweight.

Steers can also be bought in the market and an upper limit was imposed on the amount of weaner steers that could be obtained at standard prices and extra steers can only be purchased by paying a premium price.

Heifers that are not kept for replacements are usually finished for beef. Selling pregnant heifers is a rarity because the market is very risky. In fact, farmers prefer buying adult pregnant cows than pregnant heifers (Glatzle and Dück, personal communication, 2004).

Heifers can be traded as weaners or finished on farm. There are two finishing activities included in this study to represent the possibility of finishing heifers at a fast rate in 18 months and at a slower rate at 24 months of age, both at 230 kg liveweight.

Finishing heifers and replacements heifers are usually reared together during the first year. They are treated differently, after selection, during the second year. Thus, the model uses only one activity for rising one year heifers but two different activities for rising two year heifers in order to differentiate replacements from finishing heifers.

Replacements heifers are assumed to be mated at fifteen months of age in order to have their first calf at the age of two years. This is only achieved by the top farmers in the area of study but, considering this study aims to find improved systems in a steady state scenario this was judged proper.

4.3 Feed Supply components

The feed supply component includes different types of grazed pasture, grass hay, sorghum silage, sorghum grain, concentrates, and oats as a special crop. Feed inventories are assumed to be in equilibrium which was ensured by means of feed transfer activities.

For this study the feed supplies were divided into three categories according to their Energy density (MJ ME/Kg DM) (Table 3.11). This is a common practice to deal with the problem of feed bulkiness and intake limits that must be managed by the linear programming model (Crotty, 1979; Nuthall, 198?; Thomson, 1974).

High quality feed has an average metabolizable energy content of 11 MJ per kg of DM. This group comprises concentrate feeds, grains, pangola with legumes (January to March) and leucaena leaves (October to June)

Leucaena leaves show a wide variation of metabolizable energy content ranging from 6.5 (Cabrera & Glatzle, 1996) to 12 MJ/kg DM (Humphreys, 1994). However, sustained daily liveweight gains of above 1 kg achieved by animals browsing leucaena hedgerow systems support the inclusion of this feed as a high quality feed.

Medium quality feed has an average metabolizable energy content of 9.25 MJ per kg of DM. To this group belong all pasture types included in the model during their young stage of growth plus sorghum silage, sugar cane and Oats.

Low quality feed has an average metabolizable energy content of 7.5 MJ per kg of DM. To this group belong all those pasture types included in the model during the period July to September. This is based on local research data that shows that pasture quality in the Central Chaco maintains a relatively high quality value until the arrival of the first frost. After this, the senescence rate increases rapidly and this process can even be accelerated by small rainfall events that usually happens during this period (Neufel & Glatzle, 2001) Another pasture production included here is 10% of the Gatton panic yield during the period January to March. This represents the area shut off for seed production during the first two months of the year which becomes available after this period but with a low nutritive value due to its advanced stage of maturity. Finally, another activity that was included in this group of feed includes hay, which could be harvested in November, March or April.

Table 4.4 Feed category groups used for this study

Category	Average metabolic energy density MJ/kg DM	Type of feed	Observed metabolic energy content MJ/kg DM[7]
High quality feed	11	Sorghum grain Concentrate formula Concentrate pellets Leucaena from October to June Pangola with legumes from January to March	12 11.6 11.8 7.5 to 12 10
Medium quality feed	9.25	Pastures from October to June Leucaena from July to September Sugar cane Silage Oats	7.8 7.5 to 12 9.4 9.5 9.5
Low quality feed	7.5	Hay Pasture from July to September	7.1

Variation in the quantity-quality of pasture yield has shaped farming practices, and farmers have developed different strategies to cope with this variation, such as flexibility of slaughter date, changing stocking rate and feeding supplements.

Because livestock production in the Central Chaco is dependent on pasture grazed in situ, feed budgeting is primarily concerned with the manipulation of the animal requirement pattern to get maximum utilization of the pasture grazed. Feed budgeting implicitly assumes that the supply and demand parameters are known. These demand parameters were derived as explained in Section 4.2.

After the establishment of appropriate pasture growth rates it is necessary to consider the amount of this pasture that is consumed by the grazing animal and to modify this as a percentage of the feed ingested.

[7]Source: Butterworth, 1989, FAO, 200?, INTTAS database, 2004, Kearl, 1982

4.3.1 Factors affecting pasture usage

It is the utilization of available pasture that is the true constraint on animal production. However, there is little formal information about pasture utilization under tropical conditions.

Unlike conserved fodder (e.g. hay), not all pasture can be used by livestock as some is not accessible to the animals and some is unpalatable. Further losses occur due to tramping and senescence. Most importantly, a minimum residue must be maintained if the pasture is to continue producing on a sustainable basis, this is known as proper use (Hocking & Mattick, 1993).

Three correction factors are needed to adjust for grazing efficiency, losses and proper use. However, with little or no research substantiating these correction factors, estimates remain subjective.

The lack of research on pasture utilization measures under tropical and sub-tropical conditions makes the estimation of satisfactory measures throughout the year very subjective.

Most studies come from Africa and India and they use a single multiplier that combines corrections for the dry matter on offer and the utilization rate. Edible forage representing from 30 to 40% of total dry matter available (Cossins, 1988 #138)(Le Houerou & Hoste, 1977). Van Wijngaarden (1985) proposes a proper use of 45 % of available dry matter during the dry season, finding that at higher utilization rates the grass cover is reduced in the subsequent season.

In South America, pasture utilization rates of 25 to 30 % are expected under commercial farm conditions (de Oliveira, 1997) This can be supported by the finding that if maximum intakes are expected the feed on offer must be twice to three times the daily intake requirement of the animal(Matthews, 1994).

Pasture utilization is likely to have seasonal variations as a response to changes in feed availability and stocking rate. For instance, higher utilization rates can be expected during the winter months (Holmes et al., 2002) and lower during the summer months as grass growth exceeds utilization capacity. While increasing the stocking rate may increase pasture utilization it can decrease total pasture production and pasture persistency (Glatzle, 1999).

Higher utilization rates can be achieved during periods of surplus through shutting paddocks for hay production in order to reduce the grazing area, which increases temporarily the stocking rate (Crotty, 1979). On the other hand, higher utilization rates can be achieved through supplementation combined with an intensive rotational grazing (Kellaway & Harrington, 2004).

The lack of research in the area of study on pasture and browsing utilization measures makes the estimation of satisfactory measures throughout the year very subjective. However, the greatest error arises from the use of a single utilization figure at any one period for all types of livestock. In reality, stock on a maintenance diet are forced to utilize greater amounts of feed on offer than stock being fattened (at increasing utilization rates nutritional value of the total diet decreases as the proportion of leaves in the total diet decreases at the expense of less nutritional components of the sward). This source of error was, however, unavoidable due to the lack of more accurate data.

Forage supply varies greatly from year to year and in different periods within a year according to rainfall quantity and pattern of distribution.

Table 4.5 Utilization rate assumptions (%) used for grass and scrub legume

Period	Grazing	Browsing
January to March	25%	70%
April to June	45%	80%
July to September	45%	80%
October to December	30%	80%

Table 4.5 shows the utilization rates assumed for this study. The onset of the rainy season is usually delayed until mid November and sometimes even until mid December, therefore high utilization rates are still likely to occur during October and November. Grass supply usually reaches its highest levels from December to April. Therefore, lower pasture utilization is likely to occur during January to March. Moreover, high temperatures during this period of the year make heat stress likely to constrain feed intake. During the dry season availability of feed is likely to become limiting. Thus, higher utilization rates can be expected.

There is no data in relation to utilization rates for browsing legumes, thus, utilization rates have been very subjective and based on the following facts:

1. Leucaena has high palatability and it is often preferred to the grass grown in the vicinity;
2. proper management will keep the plant at an animal's reachable height;
3. as the trees are in rows minimum losses due to tramping can be expected;
4. as the shade provided by leucaena reduces solar radiation, intake depression due to heat stress is likely to be lower in animals grazing a hedgerow system than that in animals grazing open grassland.

For semi-arid conditions such as prevalent in the area of study a high utilization rate means more than 40% of available feed (McCosker, 2000). High levels of grass utilizations were not explored in this study, as the quality grouping of feed adopted for this model assumes that selective grazing occurs. Also, in the course of aiming for high levels of utilisation through the sequences of good and bad seasons, the pasture became degraded.

4.3.2 Grazed Pasture

Energy contents above 8 MJ/kg of DM in pasture grown in the Central Chaco are common and provide excellent grazing. However, if it falls below 6 MJ/kg of DM the grass will only be sufficient for maintaining liveweight.

Table 4.6 Differences in crude protein and metabolizable energy content of different grass species in the Central Chaco of Paraguay, Glatzle, 1999

Species	ME in MJ/kg DM	% of Crude Protein
Buffel grass (Cenchrus ciliaris)	7.5	12.5
Brizhanta (*Brachiaria*)	8	10.5
Estrella (Cynodon pnemfuensis)	7.5	12.5
Gatton (Panicum maximum)	8	14
Pangola (Digitaria spp)	8	5.5
Mixtures	7.5	12

The metabolic energy content does not change significantly between different species and the difference in the crude protein content between grass species reflects more the soil type than the true difference between the species being compared (Table 4.6).

Table 4.7 Typical pasture production curve in the Central Chaco according to Glatzle, 1994, p104

	February	May	August	November	Average
Yield in tDM/ha	3.2	2.25	0.65	1.4	1.875
ME in MJ/kgDM	7.75	7.18	7.75	7.75	7.6075
Crude Protein in gr/kg	10.5	10	15.05	13.5	12.2625

Table 4.8 Typical pasture production curve in the Central Chaco according to Neufeld, E. et al., 2001, p83-84

	February	May	August	November	Average
Yield in tDM/ha	3.5	2.5	0.8	1.9	2
ME in MJ/kgDM	7.8	7.1	7.65	7.65	7.55
Crude Protein in gr/kg	11	11	15	12.5	12.125

Tables 4.7 and 4.8 show typical production curves for pasture grown in the Central Chaco according to published references. For the purpose of this study the more recent reference was adopted to calculate feed supplied by the "Monte" type pasture activity.

In the Central Chaco the average stocking rate is about 0.8 UA/ha (Dück, 1995; Glatzle, 1999). On improved pastures maximum levels of livestock productions were obtained with a stocking rate of 1.8 AU/ha. However, this value exceeds the recommended long term ecological optimum stocking rate for this area, at 0.8 to 1.2 AU/ha (Glatzle & Stosiek, 2001).

Ideal stocking rates for pasture depends on two main factors. First, it depends on the specific conditions of the pasture under consideration in regard to ground cover, weed persistence, and soil compaction. (Neufeld et al. 2001). Secondly it depends on the grazing and feeding management system used (Kellaway & Harrington, 2004).

Table 4.9 Ideal stocking rate for different pastures in the Central Chaco under continuous grazing and without supplementation

Pasture species	Stocking rate AU/ha[8]
Panicum maximum var. Gatton panic	1.1 to 1.4
Cynodon spp	1.4 to 2.0
Panicum maximum var. Tanzania-1	1.7

[8]One Animal unit = 400kg of liveweight.

Source: Neufeld, E. et al, 2001 and Cabrera et al, 2001.

The ideal stocking rate displayed in Table 3.16 was obtained by considering several factors. These include: production factors (high liveweight gain rate and high pasture production per ha), ecological factors (pasture persistence over time) and economic factors (an estimated 30% safety margin under the stocking rate that achieves the maximum production per ha) (Neufel & Glatzle, 2001).

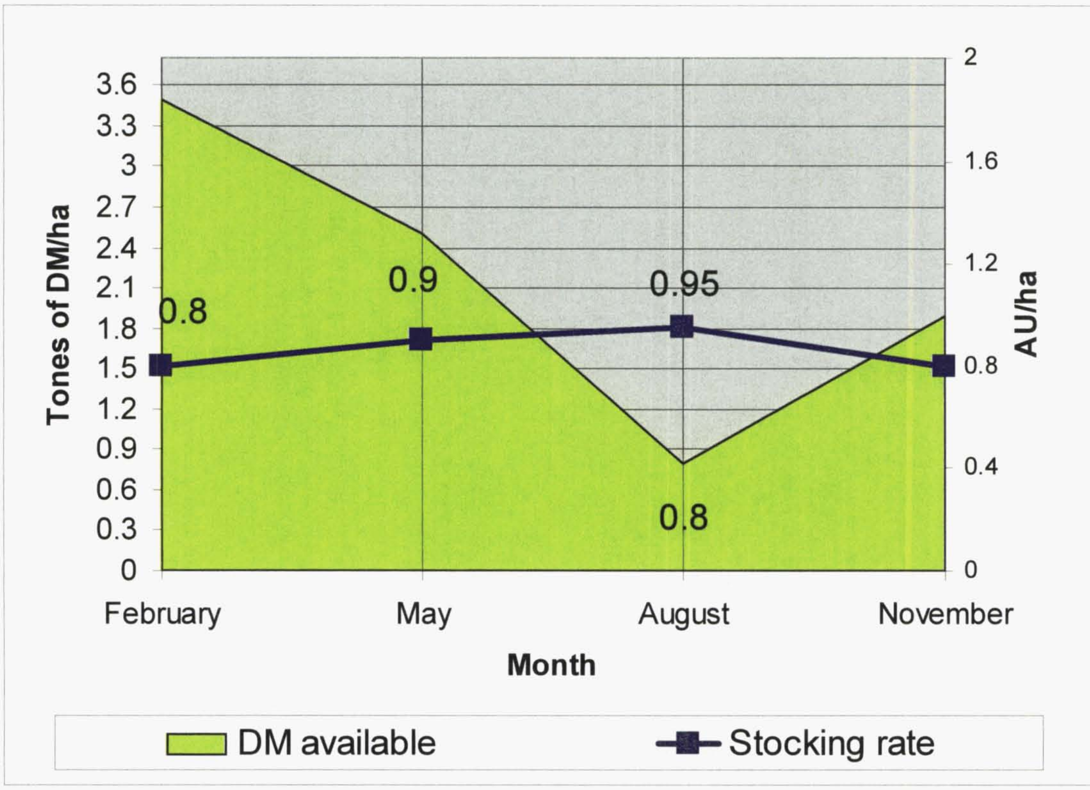

Figure 4.5 Forage availability per periods and stocking rate in the Central Chaco. Source: Neufeld, E., 2001

Figure 3.9 displays a typical grass production pattern compared with the stocking rate pattern for beef farms in the Central Chaco.

4.3.3 Conserved forages

Farmers are increasingly facing the need to supply a significant quantity and quality of product on a specified date. This is difficult to manage in many grazing systems (T. Cowan, 2000). With the demand to use natural resources more efficiently to meet quality assurance targets, and to ensure animal welfare, as well as facilitate sustainable land management practices, it can be argued that each of these goals is easier to achieve in a system that has a high reliance on conserved crops (T. Cowan, 2000).

The most common methods of forage conservation include hay and silage making. They allow inter-temporal transfer of feed from periods of surplus to periods of deficit. Another method used for inter-temporal feed transfer is deferred grazing or standing hay (Neufel & Glatzle, 2001). This method is included in the model by means of inter-temporal feed transfer activities. There is little written about the losses in quality and quantity that occurs during these inter-temporal activities. However, feed transferred as standing hay always has a lower nutritive value than hay itself (Crowder & Chheda, 1982).

Silage and hay are the most common supplements utilized in the area of study. Quality of silage and hay varies widely in relation to the species utilized and appropriate technology used for their preparation and storage (T. Cowan, 2000; Crowder & Chheda, 1982; Molas, 1998). Responses of 0.73 L of milk per kg DM of hay or silage used in a dairy feeding program can be expected (T. Cowan, 2000).

Silage

The quality of silage of tropical grasses is relatively low without the use of expensive additives (T. Cowan, 2000). In contrast, maize and sorghum can yield good quality silage and, therefore, are the preferred options under tropical conditions. In contrast to sorghum, maize is not well adapted to the rain fed conditions in the Central Chaco and, as such, is considered a risky crop. Thus, sorghum appears as the preferred crop for silage production in the Central Chaco. Expected nutritional values for different types of silages are shown in Table 4.10.

There are several methods for silage production and storage. Bunker silage is most commonly used in the area of study. Silage is usually fed individually on the dairy shed or in feeders. Losses in dry matter and nutritive value during silage preparation and storage normally range from 15 to 20% (Molas, 1998).

Table 4.10 Typical nutritional value of silage in the Central Chaco

Silages	Crude Protein in %	Metabolizable energy in MJ/kg DM
Sorghum silage pH 3.8 to 4.4	6.6-8.2	3.6 - 11.8
Maize silage, pH 3.8	7.8	11.6
Gatton Panic silage pH 4.4 to 4.6	6.9 - 7,0	7.4 – 9.6

Source: Cabrera de Rotela et al, 1995

Hay

Grass hay has better feeding value than the standing hay left in the field, it is an easy way of conserving forage for the dry season, easy to produce, transport and distribute in the farm. In addition, it can be a source of additional income. *Panicum maximum, Cenchrus ciliaris, Cynodon spp and Digitaria decumbens,* when grown under good fertility conditions and carefully managed, offer opportunities for making hay of acceptable quality. (Crowder & Chheda, 1982)

The area used for hay production is shut for one and a half to two months. Usually farmers use contractors for hay making. Hay can also be sold or bought. However, quality is always a concern and the demand is limited.

Drying efficiency is high when the potential evapotranspiration is higher than 5 mm per day (JICA, 1995). Under these conditions a minimum of one day and a half is needed to reduce grass moisture content from 80% to less than 15%, which is required to obtain and preserve good quality hay. Average losses of dry matter during hay making and storage are estimated to be around 25-30% and may be greater with adverse weather. (Crowder & Chheda, 1982). For the purpose of this study dry matter loses were assumed to be 25%.

Table 4.11 Typical hay nutritive values of different improved grasses in the Central Chaco

Species	DM%	Protein%	ME in MJ/Kg DM	Source
Gatton panic	90 - 95	3.1 - 13.6	5.3 - 8.2	Inttas, Database, 2004
Gatton panic		7.0 - 11.4	5.5 - 7.2	Cabrera et al, 1994
Buffel grass		6.1 - 7.3	5.7 - 7.5	Cabrera et al, 1995
Cynodon plestostachyus	95.1	5.0	7.4	Inttas, Database, 2004
Digitaria eriantha var Pangola	94 -96	1.5 - 12.64	7 - 9.2	Cabrera et al, 1995

Paraguayan research shows an average hay utilization rate of 83% (JICA, 1995) Hay is usually made in the area of study at any time between November and May. Hay yields range from 12 to 15 round bales[9] per ha. As pasture utilization rates varies in different periods and is always lower than 50%, total feed available per period was used to calculate the amount of DM that was required per bale (350kg) unit.

[9] One round bale = 350 kg fresh matter

Table 4.12 DM requirement of Hay making activities in different periods

	January to March	April to June	October to December
Average Pasture available per period[10] (kg DM/ha)	4,900	2,388	2,698
Average Pasture utilized per period (kg DM/ha)	1,225	1,075	809.4
Average yield per ha (bale units)	12	6	6.7
Amount of medium quality feed required per bale (Kg DM)	101	179	120

4.3.4 Feed transfer

Inter-temporal and inter-quality grouping transfer activities

Feed that is not consumed during a given period can be transferred up to the next period with some losses in quality. These transfer activities represent the common practice of keeping some area of the farm shut during certain periods of the year to utilize it later. Since concentrates can be readily brought into the farm at any given period of the year the inter-temporal activities do not use concentrates such as grain or pellets.

The degree of quality losses that can be expected are very subjective. It has been assumed that quality losses are expected to be higher than the loss that occurs during feed transfer as hay. A problem often faced is the selection of the optimal solution of large amounts of feed that is transferred as standing hay. This means that the expected pasture growth for that area of grass in the next time period is not likely to accrue and, as a consequence, the model will show that there is more feed available during the period that receives transferred grass than there should be. In addition, the quality of this pasture will be the same as if it was new grown pasture. This is not the case in reality. This problem can be avoided by using high levels of quality losses and limiting the maximum amount that can be transferred from one period to the next (Crotty, 1979 #5).

For the purpose of this study the nutritional sub-model has only four three monthly periods. The feed values are averaged for that time period. The length of these time periods prevents the model from transferring feed of a certain quality group to the same quality group in the next period because quality losses are likely to occur before their utilization in the next period. High quality feed can be expected to lose quality at a higher rate than low quality feed (Crotty, 1979).

[10] Average DM yield for Gatton panic and Pangola type pastures (model assumption) combined.

Six inter-temporal transfer activities have been included into the model. Because feed supply is the lowest in the period July-September it is unlikely that any feed surplus will occur during this period of the year, so feed that is not fully utilized during this period is lost by senescence. See Table 4.13 for the assumptions on the losses in feed through transference adopted for this study.

Table 4.13 The L.P. Sub-tableau outlining the inter-temporal feed transfer activities

		Medium Quality feed			
		January-March	April-June	July-September	October-December
High quality feed					
October-December	1	-0.85			
January-March	1		-0.85		
April-June	1			-0.85	
		LOW QUALITY FEED			
Medium Quality feed		January-March	April-June	July-September	October-December
October-December	1	-0.90			
January-March	1		-0.90		
April-June	1			-0.90	

Inter-quality transfer activities

These activities represent the possibility of using a feed of higher quality to supply energy of a lower quality feed within the same sub-period being considered. Table 4.14 shows the LP sub-tableau outlining the inter-quality feed transfer activities. An upper limit was used to prevent digestive disorders that might arise when large amounts of concentrates are fed

Table 4.14 The L.P. Sub-tableau outlining inter-quality feed transfer activities

		Medium Quality feed[11]			
High quality feed		January-March	April-June	July-September	October-December
October-December	1	-1.189			
January-March	1		-1.189		
April-June	1			-1.189	
		Low Quality feed[12]			
Medium Quality feed		January-March	April-June	July-September	October-December
October-December	1	-1.233			
January-March	1		-1.233		
April-June	1			-1.233	

4.3.5 Sugar Cane

Although sugar cane is a popular feed source for the dry season for dairy farms in the Central Chaco, most of it comes from the Eastern Region of the country with the associated high cost of freight. In addition, quality is always a concern. (Funk, A. Personal communication, 2005).

Sugar cane can be successfully produced at least in the south and east part of the Central Chaco (A. Cabrera and T. Dürksen personal communication, 2005). However, its production is not extensive among the farming community (H. Baez and A. Funk, personal communication, 2005). Some of the reasons for this low adoption of production include the fact that improved management developed in the area of study has not been adopted and that there is not availability of improved quality sugar cane stock (A. Cabrera, personal communication, 2005). Thus, very often farmers who grow sugar cane with traditional

[11] This is 11 MJ/9.25MJ = 1.189
[12] This is 9,25MJ/7.5MJ = 1.233

management and poor quality stock soon become disappointed by the low yields achieved when drought strikes.

Some of the advantages of forage sugar cane production include its high dry matter productivity per hectare and its nutritive value, which is only slightly affected by the age of the plant even at advanced stages of maturity. Its use is therefore very flexible and easier than for other herbages (Fernandes et al., 2001).

Under tropical conditions, whole sugar cane-based systems have proven to be technically and economically a very attractive solution for small and average dairy or dual purpose farms, where areas for fodder are limited (Chenost & Sansoucy, 1991)

Sugar cane has special characteristics such as the presence of two opposite types of forage components: structural carbohydrates of low and slowly digestible energy (fibre) and soluble carbohydrates (sucrose) that rapidly fermentable. On the other hand, its nitrogen (N) content is very low. However, the deficient nutrients in sugar cane can be easily provided by locally produced or available feed resources such as fermentable N through green fodder or urea and unfermentable N (by-pass N") by legumes such as *Leucaena leucocephala* and/or by oil cakes such as Cotton seed cake.

In the Central Chaco a special cropping system has been developed for sugar cane in dairy farms. It is hand planted in rows on the flats with a density of 4m x 1m, using about 800 kg of seeds per hectare (Cabrera personal communication, 2005). Seed cane is cut just before planting at a length that includes three or four-budded sets of no more than 450 mm in length. The crop is harvested every year from June to August (Baez, 2005) or November (Cabrera, 2005). Harvest can be completely mechanized or by hand. The crop is allowed to ratoon (regenerate) three to four times before it is replanted. With successive rattoning plant population, vigour and yield decline and it becomes more susceptible to pests and diseases (Glyn, 2004) The decision to replant is based on the premise that it is time to replant when the cumulative loss in revenue (in this case DM yield/ha), over a series of successive ratoons, when compared to the income generated by planting cane, is equal to the replanting costs (Bakker, 1999),

Good land preparation is required in order to ensure a continuous good performance for the crop throughout its useful life and the consequences of bad land preparation can not be corrected by any other managerial measures before replanting (Glyn, 2004) Thus, for the purpose of this model land preparation includes the use of a heavy disking once followed by two light diskings (Cabrera, 2005 personal communication). Consequently, weed control is an important part of this crop management and experiences around the world show that proper weed control can increase yields up to four times (Glyn, 2004) Recommended weed control measures include using a break crop and crop rotation to alter the dominant weed spectrum, hand weeding and mechanical inter-row weeding. Finally, pests such as cutting ants and termites also represent a problem in the Central Chaco.

Studies have shown that fertilizer applied to drought-stressed sugar cane will not help yields. However, by improving the organic matter content of the soil the water holding capacity of the soil and more nitrogen can be available to the plant (Bakker, 1999). A common practice in dairy farms is to apply cow manure back to the field in order to return nutrients and to increase the organic matter content of the soil. This is particularly important in a cut and feed system.

Table 3.22 shows the expected sugarcane yield in the Central Chaco

Table 4.15 Expected sugar cane yield in the Central Chaco

Weather	DM yield in Tonnes per Ha.
Good years	30
Dry years	25

Source: A. Cabrera, personal communication, 2005.

The calculated gross margins for this activity both using own machinery or contractors are shown in Tables D.20 and D.21.

In the linear programming model, sugar cane activities are linked with feeding sugar cane activities in different periods of the year though corresponding sugar cane reconciliation rows, which ensures that the maximum amount of sugar cane used in any given time is not more than the sugar cane available in that period.

Feeding sugar cane involves harvesting the sugarcane from the field and chopping it to about 20 mm. This process must be done just before feeding to prevent nutrient loses due to oxidation. Data regarding expected losses during feeding was not available and, after consulting to researchers in the area, a subjective value of 5% was considered appropriated for this model.

4.3.6 Concentrates

Tropical pastures are, on average, energy deficient. Feeding concentrates can not only allow high levels of production but also, combined with increasing stocking rate, can increase pasture utilization (Kellaway & Harrington, 2004).

Advantages of feeding concentrates include:

1. an increase in stocking rate, which allows increased production per hectare and per cow. Also, increased stocking rate increases pasture utilization as cows utilize a larger proportion of what is grown. Thus, there is a reduction in the cost per tonne of pasture eaten;
2. supplement feeding promotes good development of young livestock that has not reached yet its mature size. This increases its appetite and milk production potential in the current and future lactation;
3. cows fed supplements achieve a better condition score. This increases their ability to reach their milk yield potential and reduce their open days;
4. when milk prices are high feeding supplements can increase net milk income;
5. feeding supplements when feed availability is low can increase lactation length. And can assist in allowing recovery of pasture growth. and
6. appropriate supplementation can correct deficiencies due to seasonal variation in the nutritive value of tropical pastures.

On the other hand there is the disadvantage of the substitution effect, concentrate feeding cause a decrease in pasture intake if pasture availability is not limiting. However, by increasing stocking rate this can be prevented or, at least, diminished (Kellaway & Harrington, 2004).

Farmers in the Central Chaco usually supplement their dairy cows according to yield production using a ratio that ranges from one kg of concentrate every three to four litres of milk produced. Interestingly, a feature of this type of supplementation strategy, in comparison to flat rate supplementation, is the achievement of a higher milk peak yield at the expense of lower milk yield in late lactation due to compounding effect in late lactation when supplementation is linearly reduced with decreasing yields (Broster & Thomas, 1981).

Grain

The most common grain available in the area is locally produced grain sorghum. Maize produced in the eastern region of the country is also available and, depending on the season, can be the cheapest option.

For the purpose of this study sorghum grain was utilized because it is readily available, locally produced and can be grown 'on farm'. This is based on the principle that "sustainable agriculture involves the maintenance of exports in the long term without requiring increasing external inputs" (Glatzle, 1995)

The protein content of grain sorghum is variable and depends on soil fertility and seasonal conditions (Minson et al., 1993). The nutritional value of typical grain sorghum grown in the area of study is shown in Table 3.23.

Grain sorghum has an average of 10% crude protein content. (Kearl, 1982) However, local data (Table 3.23) shows lower protein levels in the area of study. This can be related to the fact that most of the cropping land in the Central Chaco has depleted soils after years of mismanagement.

Table 4.16 Average nutritional value of grain sorghum

Grain	DM content	Based on DM	
	%	Crude protein in %	Metabolic enegy in MJ
Sorghum	88	9.8	12

Source: Silva, (INTTAS database), 2004

Although bird damage is a big issue with this crop, new improved varieties are usually bird proof. This has been achieved through selection of varieties with higher levels of tannins in the grain. These tannins repel birds but also might reduce the digestibility of the grain, hence reducing its nutritive value.

Concentrate (Pellets)

There are several companies that produce pelletized concentrate feeds. Quality and prices are usually very similar from the different sources and selection is based mainly on personal preference.

Table 4.17 Nutritional value of commercial pellets in the area of study

Products	DM %	Crude Protein in % of DM (minimum)	Metabolizable energy in MJ/kg DM	Reference
Dairy concentrates (Pellets)	90	18	11.82	Inttas database, 2004
Dairy concentrates (Pellets) Trociuk ®	89	19	11.55	Wlosek, personal communication, February 15, 2005
Dairy concentrate Loma Plata	89	20	12	Klassen, personal communication, December, 2004

Pellets have the advantage of increasing the feed intake, decreasing wastage, and ensuring that vitamins and minerals are present in the diet at the specified amount. However, they are usually more expensive than 'on farm' fromulas.

Oil cakes

These constitute the largest source of supplementary protein. The assessment of their potential use as protein supplement will be based on the degree of degradability of their nitrogen in the rumen.

Ground nut and Cotton cake are readily available in the area of study. However, their availability varies from year to year in response to changes of vegetable oil prices in international markets. In the last few years these prices have been low, therefore the availability of these supplements is limited.

As they represent a source of foreign exchange and of high quality protein for human and non ruminant animals, their use as protein supplement for ruminants should be considered against the local availability of legumes and or legume trees.

Table 4.18 Chemical composition of some protein supplements in the Central Chaco. Source: Silva (INTTAS database), 2004

Products	DM %	Crude Protein in % of DM(minimum)	Metabolic energy in MJ/kg DM
Soybean cake (Expeler)		58.3	12.877
Sunflower cake (Expeler)		33.2	9.727
Ground nut cake (Expeler)		51.8	12.906

On farm formulas

It is common for farmers to make on farm mixes in order to decrease the cost of concentrate feeding. The ingredients vary widely according to availability and price variations. These formulas are not intended to substitute completely the commercial feed but to decrease its percentage in the daily diet (H. Bergen, personal communication, December, 2004).

A feed formula provided by one of the case study farms was include in this study in order to assess its impact on profitability. Table 4.19 shows the composition and cost calculation of this formula combined with the pellet concentrate in the proportion suggested by information collected in the area of study.

Table 4.19 Formula 1 Ingredients' composition

	Cotton seed	Cotton hulls	Molasses	Dairy concentrate	Urea
Price per kg	450	290	750	804	4050
Fresh weight	2	3	0.5	4	0.09
% of dry matter	92.0%	90.0%	73.0%	89.0%	99.0%
Energy in MJ/kg DM	16.359	8.117	12.468	12	0
Crude Protein in g/kg DM	236	236	31	200	2850
Dry matter weight	1.84	2.7	0.365	3.56	0.0891
Total ME per kg DM	30.101	21.916	4.551	42.72	0

Source: Case study 3

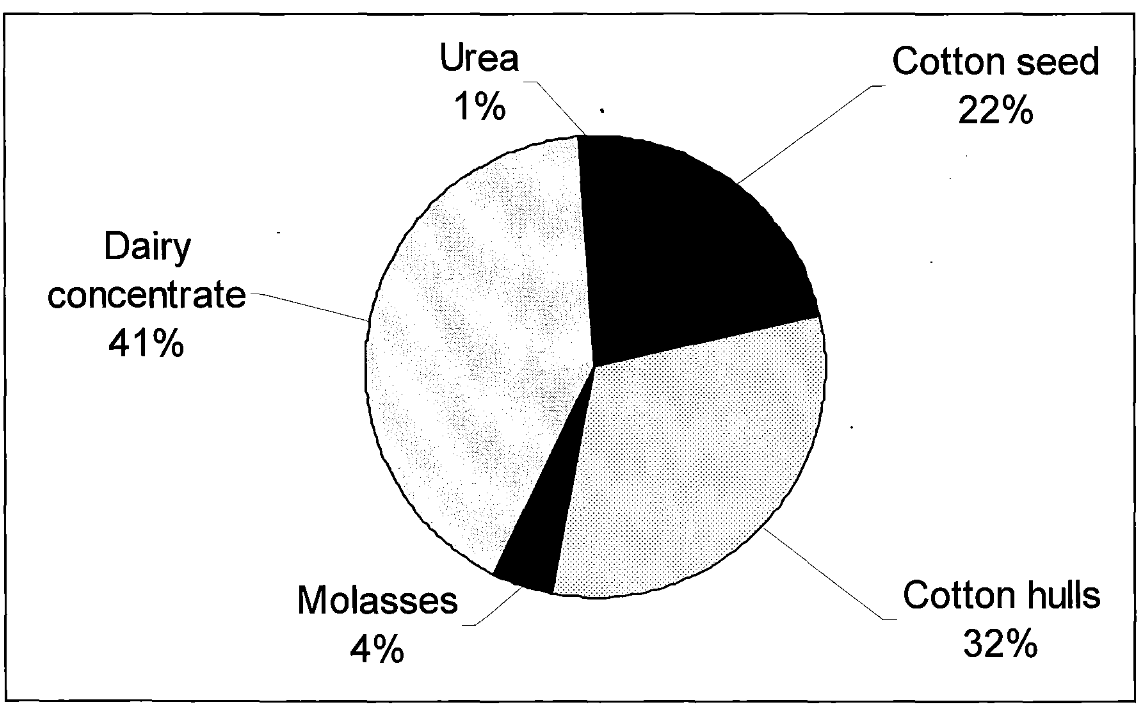

Figure 4.6 Formula 1 composition on a dry matter basis.

Figure 3.10 displays the composition of Formula 1. Molasses is a popular source of energy and is the preferred carrier of urea when this is fed as a non protein nitrogen supplement. Molasses is high in energy but low in nitrogen. Used in small amounts it can increase the palatability of roughages such as hay, straw and aged grass increasing their voluntary intake (Butterworth, 1989).

At current market prices feeding one kg DM of Formula 1 is $0.01 cheaper than feeding the commercial product alone. Appendix E contains the current market prices of the ingredients.

4.4 Water requirements

Matching water requirements is equally as important as matching feed requirements. A feed deficit will primarily result in livestock underperformance but a water deficit, even for short periods, could result in livestock deaths. Also, an interdependency between water and dry matter intake exists, whenever the intake of one is reduced the intake of the other is affected.(Kearl, 1982).

Because, in the Central Chaco, there are neither permanent rivers or streams, nor good aquifers, water availability relies heavily on the amount and pattern of rainfall. Some farmers depend completely on rainwater collected in artificial ponds constructed in the lower parts of their properties, whereas others use water from shallow wells that have thin layers of drinkable water on top of very salty water. This upper layer is seasonally recharged with the rains. In addition, some farmers use infiltration ponds that increase the amount of water that reaches this layer.

In any case water supply is at its maximum in the second half of the rainy season and it is at its minimum at the beginning of the rainy season, or even before.

Water stored in open ponds is continuously lost by evaporation and, in general, only one third of the water stored is effectively used. On the other hand, water stored in the shallow aquifer on top of salty water has lower quality with the advance of the dry season, until a point when it is not drinkable any more.

It was concluded sensible to include a water reconciliation sub-model where water needs and supplies could be approximated in order to explore how this seasonal water availability affects the optimal solution.

4.4.1 Water Demand

Milk fed calves will suffer from the absence of water if they are exposed to heat stress. Also, as soon as they start eating solid feed, particularly dry feeds like hay or straw, calves require regular access to fresh water(Moran, 2002 #37)

Weaned calves can drink up to 25 litres/day on hot summer days (Moran, 2002 #37)

As a guideline for the Central Chaco, a water allowance of 60 L per Animal Unit (400 kg liveweight) per day must be budgeted. Also, considering the high evaporation rate of the region it is recommended to have 55 m3 per animal unit/year of water storage capacity. In the water troughs in the paddocks it is recommended to have 20 L of water per animal unit (AU=400 kg liveweight) at any given time (Neufeld, E. et al., 2001)

It has been suggested that non lactating animals need between 3 and 8.5 L of water for each kg of dry matter consumed (Glatzle, 1999). These amounts should be increased by approximately 50% for pregnant animals during the last part of the gestation period. Lactation requires an additional 0.87 kg of water for each kg of milk produced. These amounts are for temperate zones and must be modified for arid and tropical regions as ambient temperature affects an animal's requirement for water. However, there is some evidence that Indian breeds *(Bos indicus*) on the average, consume less water than the amount suggested above (Kearl, 1982).

NRC, 2001 recommend the use of the equation developed by Murphy et al, (1983) for free water intake prediction in lactating dairy cows.

Thus. for the propose of this model monthly water requirement was calculated usig the following equations .

For Dry animals:

MWR = (AVlw*/a *a*30)...........(1)

For lactating animals:

MWR= (AVlw*a*30) + (AVmilk*0.87)...........(2)

Where,

AVlw = Average liveweight for the trimester

a = is a constant represented by 60/400 (60 L of water per animal unit)

AVmilk = Average monthly milk production and, 0.870 which is a constant requirement of water per L of milk (Kearl, 1982)

Appendix I shows the calculated water demand for different categories in different periods of the year.

4.4.2 Water supply

The losses of stored water were subjectively approximated based on the fact that on average two thirds of the water stored is lost due to evaporation (Von Hoyer & Godoy, 1997).

The urgent need for research data has been highlighted in relation to the dynamic of water stored in artificial ponds under the local conditions of the Central Chaco (Duarte et al, \, 2003 #134). However, until now there are no data available in relation to the real losses due to evaporation and infiltration and only approximations in relation to the recharge rate were available (Giesbrecht, Harder, Thiesen, & Klassen, 2004).

A number of assumptions were required in order to approximate the typical farm water supply these include:

1. the storage capacity is 10,000 m^3 per farm unit (Case study 2);
2. the farm relies completely on surface water storage and the water contained in the water reticulation system is assumed constant, the collecting area is 1.5 ha;
3. the pond's surface area was approximated assuming 4m pond depth (Von Hoyer & Godoy, 1997) and using Total Water storage capacity = Area * Depth*0.22;
4. only 70% of the total rainfall is effective and from this only 60% can be used from the collecting area (40% is lost by evaporation and infiltration) (Giesbrecht et al., 2004) and
5. water collection efficiency for all rain falling on top of the ponds was assumed to be 99% assuming one percent was lost immediately by evaporation.

Chapter 5

MODEL VALIDATION

5.1 Introduction

This Chapter contains a description of the procedures used in validating this particular linear programming model.

Once the model has been developed it must be validated, or tested, to ensure it is a realistic portrayal of the farm system. This can be difficult to achieve, and can require further research and model development. Model "validity" is not an all or nothing concept, but may be regarded as lying in the range zero to unity (Thornley, 2001). The modeller's aim is to get as closer as possible to unity.

Mathematical models are representations of reality. As such, they are incomplete, and should not be confused with reality. However, the use of every mathematical model requires a certain degree of accuracy in order to have confidence in the outcomes obtained through using the model. The validation process becomes one of determining the model usefulness for the intended application(s) and/or range of applications. This chapter contains a description of the procedures used in validating this particular mathematical model.

Validation procedures can be tedious and time consuming (Pannell, Kingwell, & Schilizzi, 1996). However, it often leads to improvements in model programming, and can be valuable in allowing the researcher to obtain insights into the behaviour of the model, and the interpretation of model outcomes.

Finally, absolute validation can be only achieved by the adoption of the model outcome by farmers.(Thornley, 2001)

5.2 Description of the procedures used to validate the model

5.2.1 Model Verification

Verification includes all methods of criticizing a model. Verification of models is essential, although it can be rather subjective. Verificating the model with respect to the objectives of the research question is the first consideration (Thornley, 2001)

Verification of a deterministic model should begin at the level of the assumptions (lower level) and proceed to the predicted outcomes (upper level). Parameters should be determined by investigations at the level of the model's assumptions. Unfortunately, this is not always possible, and some "tuning" or "calibration" of parameters is usually needed. The fact that verification is not a wholly objective process creates problems between the authors of modelling manuscripts, and reviewers and editors, who often are not hands-on modellers and, therefore, lack the perspective which that brings (Thornley, 2001).

Verification consists of checking the mathematical and logical accuracy of the model with the objective of ensuring that it is consistent in all its underlying assumptions. This includes the prevention, identification and elimination of bugs. Bugs are errors in the structure of the model and can involve coefficients, constraints and/or activities (Pannell et al., 1996). They are usually detected during the model development and testing phase, but can also occur when the model is changed for a particular analysis. The more serious bugs are usually detected through infeasible solutions, unbounded solutions and unlikely model solutions.

The first two symptoms are easily identified in the output of the computer program, but unlikely solutions may require a high degree of attention and understanding of the system being modelled. The unlikely solution can be the level of an activity, the dual price of an activity, the level of slack for a constraint, or the shadow price for a constraint (Pannel et al., 1960). These values can be used not only to track bugs, but also to calibrate the model.

During the early stages of model development the most common bugs arise from mistyping signs, activity coefficients and activity names, and from constraints operating in the wrong direction. The number of bugs in a matrix increases rapidly with the size of the matrix, although a well maintained model decreases the number of bugs present as they are discovered over time. Seldom, however, are they completely eleiminated (Pannel, D. et al, 1996).

In this study the initial solutions were found to be unlikely. This led to an examination of the model and consequent improvements. A bug identified early in the testing phase was related to inter-temporal transfers of large quantities of pasture. These required some changes in some coefficients as well as the introduction of some upper limits of the amount of pasture allowed to be transferred.

5.3 Model Validation

Validity is not a property of the model alone, but of the model in relation to some application. Attempts to formally "validate" a mechanistic model are not generally conclusive, and neither is using mechanistic models as pseudo regression equations (Thornley, 2001).

A fundamental issue underlying the process of validation is subjectivity. The statement "the model was judged valid" can mean almost anything. In order to address this issue some authors have recommended a systematic approach to the validation process. This provides documentation of the model characteristics in relation to its strengths and weaknesses. This can be invaluable for users and those who must extract information from a model's results. (McCarl & Apland, 1986)

5.3.1 Validation by construct

The use of the validation by construct approach ensures, by assumption, that a real world outcome will be replicated. This is the most common type of LP model validation and involves analyzing the underlying assumptions utilized by the model to ensure that they are sound and sensible. A description of this procedure follows.

First, the list of assumptions and parameters included in the model was presented to researchers, producers and farm advisors in the area to be modelled in order to assess their correctness. They were later modified as required.

Subsets of the three case study farms were analyzed, comparing model outcome with the case study farms after fixing some of the activities at real world levels and leaving others unconstrained. Then the degree of association between model solutions and real world data were tested and a decision made regarding the validity.

Partial tests were used to approximate the feed utilization values. High utilization rates similar to those achieved under rotational grazing in temperate conditions were used at the beginning. This led to overestimates in the carrying capacity for tropical pasture. There was not local information in regard to pasture utilization under local conditions in the Central Chaco. For this reason a partial test was executed using references from other areas with similar climatic conditions. The pasture utilization rate in each period was calibrated until the stocking rates selected by the model were considered within the range expected under local conditions.

Weaknesses attributed to this type of validation procedure include the fact that a nominal examination of a model result may, typically, show that the results do not contradict the model builder's, user's and/or associated "expert" perceptions of reality. Also, simply constraining a model to ensure validation can result in the right answer for the wrong reason. However, validation by construct is a necessary precursor to any validation by result testing (McCarl & Apland, 1986).

5.3.2 Validation by results

This procedure consists of determining whether the model reproduces real world results with enough accuracy for the purpose of the model, and in this way assesses the predictive capability of the model.

The procedure involves rerunning the model several times while changing a few variables, in order to evaluate the correctness and accuracy of the model behaviour. These experiments include feasibility experiments and quantity, price, and coefficient change experiments. A successful validation was achieved but not without difficulties. The problems encountered when attempting to validate the mathematical model are discussed in the following section.

As each experiment generated too much detail to be included in this section, the only results included are the predictive experiments forecasting the optimal herd structure for the three case study farms utilized. The detailed model solutions for the three case study farm are shown in Appendix J.

In Figures 4.3, 4.4 and 4.5 predicted and observed livestock numbers for the three case study farms selected are compared. After these experiments the model was considered valid for the purpose of this study.

Case study 1

The predictive experiment carried out for the case study farm 1 provided acceptable association between predicted and observed activity levels as shown in Figure 4.3. This was only achieved, however, after several unsuccessful attempts.

In order to obtain an acceptable degree of association between predicted and observed values for case study 1, some calibration of the model was required. First, in the nutritional sub-model breeding cows' feed requirements were recalculated for cows averaging 500 kg lw by increasing the average cow's liveweight by 50 kg (from 450 to 500 kg lw). At first sight this liveweight change does not seem to be of importance. However, the maximum feed intake is related to bodyweight. This means a difference of 50 kg could change significantly the amount required of different categories of feed as shown in the table below.

Table 5.1 Calculated feed demand per category of feed and sub period.

		450 kg cow	500 kg cow
Medium quality feed (9.25MJ ME/Kg DM) in Kg DM	Jan Mar	54	54
	April June	36	36
	July Sep	339	235
	Oct Dec	561	232
Low quality feed (7.5MJ/kg DM) in Kg DM	Jan Mar	960	991
	April June	879	916
	July Sep	851	1144
	Oct Dec	816	1134

After introducing these new estimated requirements for the breeding cow activity the model was rerun. However, the solution was still underestimating breeding cow numbers, as shown in Figure 5.1.

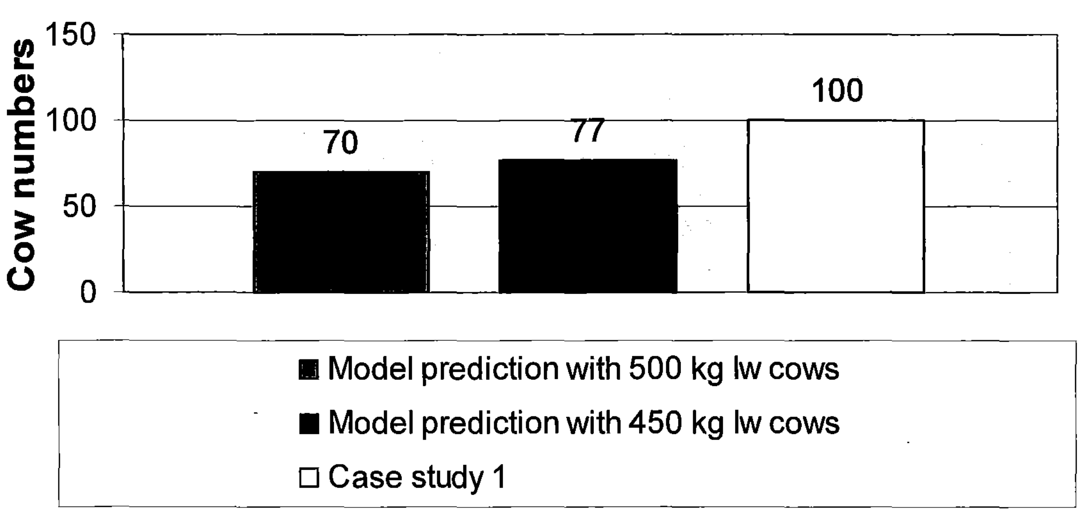

Figure 5.1 Observed breeding cow numbers compared with numbers predicted by the model for cows with different average liveweights.

After re-checking the matrix for bugs it was decided to report this issue to researchers in search of an explanation for the differences.

Hypotheses to justify the difference were formulated and the experts were asked to comment. These hypotheses included:

that the feed supply component was incomplete, as shelter belt browsing components were not included in the model. Thus, there is more feed available than expected in the system.

that the model does not account for different maintenance requirements. It has been argued that *Boss indicus* animals and their crosses have lower maintenance requirements than European breeds under tropical conditions (Butterworth, 1989; Kearl, 1982). Thus, the energy requirement for beef animals might have been overestimated as energy requirements were calculated based on tables developed with *Boss taurus* animals fed in metabolic chambers. However, the calculated requirement for breeding cows was close to values obtained by researchers in the area of study (Glatzle, 1999) as discussed in page 63

that the model does not accurately reflect mating age. The model assumes that all replacements are mated at 15 months of age, whereas the case study farm only mates a few replacements at that age usually waiting until 18 months of age. This increases the feed requirements of these animals compared with those mated at 18 months of age.

that the model does not include the possibility of selling livestock at a lower liveweight than 450 kg for steers and 400 kg for heifers. The inclusion of extra rearing activities with a different culling rate might save some feed that can be used by another category of livestock.

that the model does not include the effect of compensatory growth, which is a common managerial tool. However, the length of sub periods used for this study prevented the inclusion of this effect. The same overall liveweight gain or loss in a three monthly period could be achieved by several quite different feeding strategies.

that the model does not account for the large difference in pasture yield between farms. This could be due to irregular rainfall distributions within the area and / or differences in grazing management

After consulting with different experts the following explanation was chosen as the most likely explanation.

Average pasture yield figures are obtained after several years of data recording. Pasture yield in any given year has not only a strong relationship with rainfall in that given year but also to the previous years and to the grazing management. Also, it has a relationship with the age of the pasture and the procedure used in clearing the land and the pasture establishment.

The variable rainfall in the area of study and its patchy distribution can produce wide variations in pasture yield in any given year between farms located close together. Also, there might be differences in the grazing management between the case study farms under consideration. Dairy farms are more likely to suffer from overgrazing and have a higher average stocking rate than beef farms (Dürksen, T, personal communication, 2005). In the course of aiming for high levels of pasture utilization through sequences of good and bad seasons, the pasture becomes degraded.

Furthermore, beef cattle can be more easily traded at any time of the year and at any age from weaning up to their culling liveweight. This increases the flexibility of the stocking policy for this type of farm compared to dairy farms. It allows alleviation of pasture pressure under drought conditions through selling livestock more easily than dairy farms.

The conclusion was to parametrically increase the feed supply component (grass production activities) until the observed and predicted values showed an acceptable degree of association. In the final solution it was necessary to increase the feed supply coefficients in the pasture activities by 60% for all sub-periods compared to the value obtained by published references (Glatzle, 1999; Neufel & Glatzle, 2001). As shown in Figure 5.2.

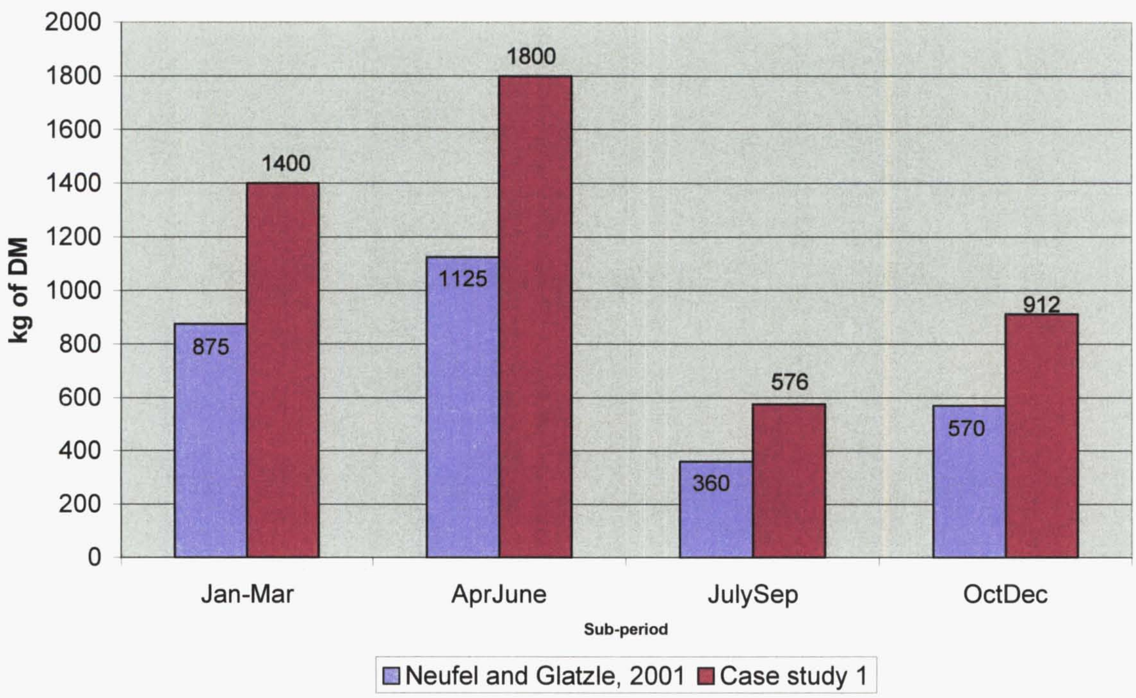

Figure 5.2 Gatton panic pasture feed supply (kg DM available feed per period) used for this case study farm compared with feed supply used for the other two case study farms

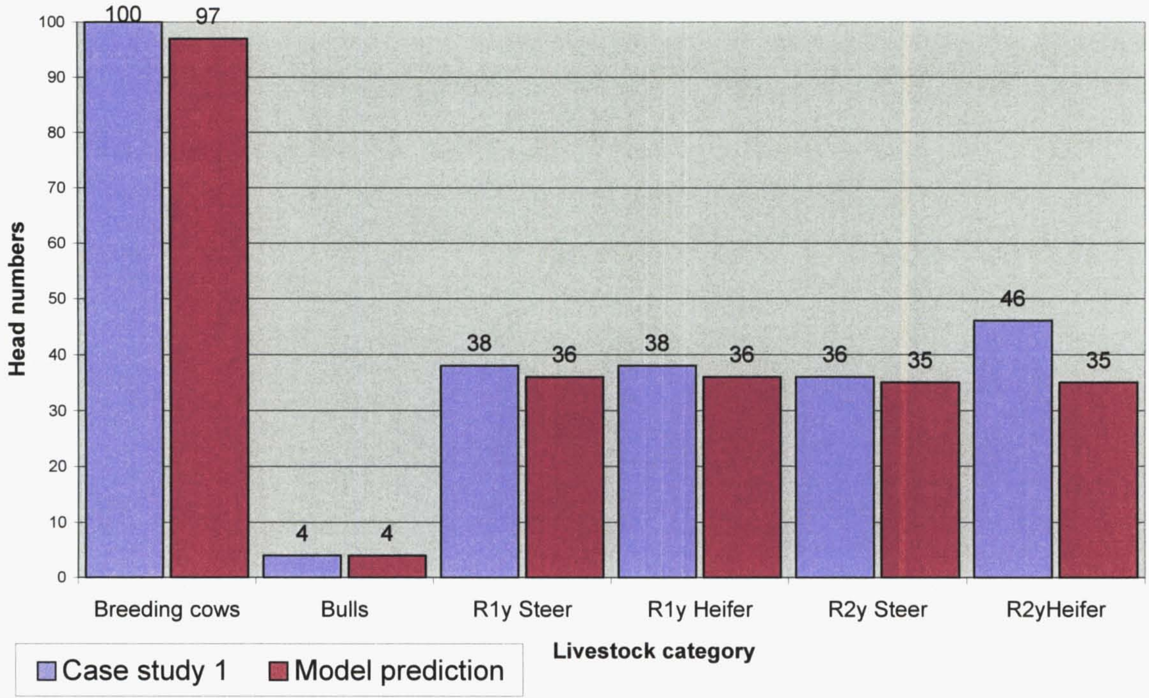

Figure 5.3 Livestock numbers predicted by the model contrasted by livestock numbers observed in the case study farm 1

Finally, with the pasture supply increased by 60%, predictive and observed values were considered to be adequate. As Figure 5.3 shows. When pasture supply is increased by 60% the breeding cow numbers predicted by the model were very slightly lower than the observed values. This difference seemed intuitively reasonable since farmers in the area of study, facing the risk of drought, are more likely to keep breeding stock and sell trading stock at a lighter liveweight, rather than sell breeding cows. This reduces financial pressure involved in restocking the farm once rainfall resumes (Baez, personal communication, 2005).

This farmer reported that sometimes he must sell his livestock at lighter liveweights. This can justify in part the underestimation of livestock numbers predicted by the model as it assumes a fixed liveweight pattern for culling livestock.

Case study 2

A prediction for case study 2 was run after fixing the land use activity levels at observed values and leaving the model to select the best herd structure for the current land use pattern. The final result is displayed in Figure 5.4.

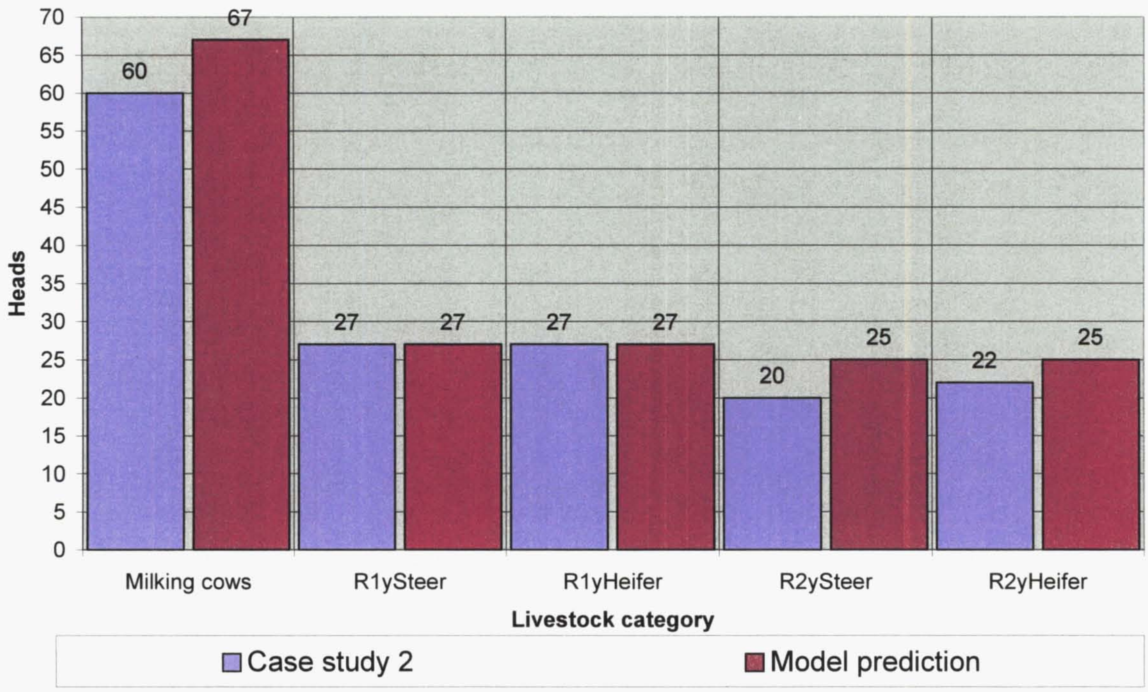

Figure 5.4 Livestock numbers predicted by the model contrasted by livestock numbers observed in case study farm 2

The result shows that seven extra dairy cows could be run by shifting from a year round system to a more seasonal calving pattern (calving all cows around July every year). This improves the match between energy requirements and pasture growth patterns. Differences in other categories of animals were not considered of importance because they only show that the farmer usually sells some livestock out of schedule whenever either an opportunity, or a special need, arises (R. Harder, personal communication, 2004)

Case study 3

In order to reproduce observed activity levels all feed supply activities were fixed at the observed value. This farm is currently undertaking a conversion from beef to dairy. Thus, beef and bull numbers were also fixed at observed values.

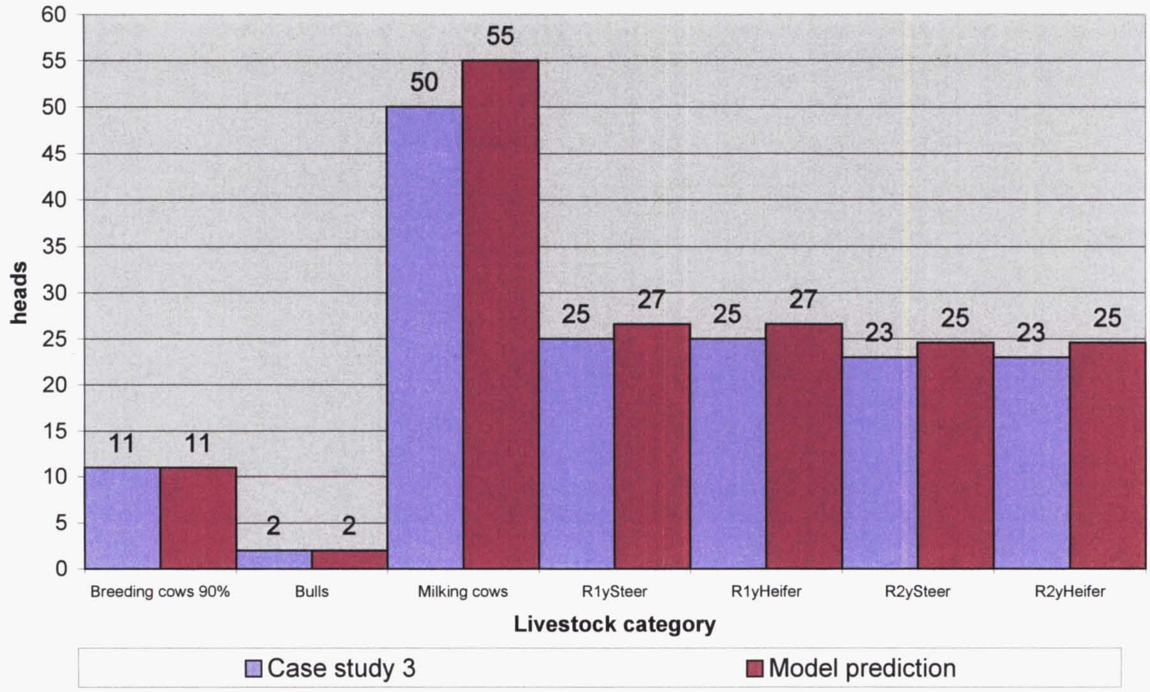

Figure 5.5 Livestock numbers predicted by the model contrasted by livestock numbers observed in the case study farm 3

As with case study 2, the total dairy cows under a steady state scenario is higher than the observed numbers. This is to be expected as the conversion to dairying will be a learning curve for the farmers. It is likely that the farm will operate under the optimal levels for a few years before fully exploiting its farm productive potential. Moreover, the farmer is not currently utilizing a seasonal calving pattern and inefficiencies in utilization of on farm grown pasture can be expected.

The degree of association between the observed and predicted values for the three case study farms was considered acceptable and, as such, the model was considered a valid portrayal of the farm systems being simulated.

5.4 Validation Discussion

The mathematical model has been constructed to simulate a steady state scenario. This is in order to explore which production system would be the most profitable in the long run but without compromising the resource base. This makes comparing the model outcome with the observed values of the case study farms subjective because, in reality, these case study farms are often not in a steady state scenario.

Also, the mathematical model assumes that profit maximization is the sole objective. This is a simplification of reality and rarely the case. Although further constraints have been used within the model in order to approximate other objectives, farmers' objective functions are often complex and dynamic.

Linear programming models provide answers to what should be (normative analysis), in contrast to describing what occurs in practice (positive analysis) (Heady & Candler, 1958). Farmers might not be working at their optimal level because of factors which might include, for example, carry over effects of past droughts (the last two years have been particularly dry in the area of study) or market changes. For instance, foot and mouth disease was detected in Paraguay in 2003 and, as a result, the access beef had to all high value markets was lost for more than one year (Dürksen, 2005).

The accuracy of a model as a whole will be determined by the least accurate data. This mathematical model was formulated using, whenever possible, published research data. Where this was not available estimates of input/output coefficients were obtained from professionals and later they were validated by the case study farmers, whenever possible. However, there were some coefficients that were neither possible to obtain from the case study farms nor from research data. These were approximated using best estimates based on empirical results and sometimes just on reasoned guesses which were later validated by consulting with experts in the respective areas.

There were problems when trying to obtain the farm results using research data at a commercial level. This is particularly the case for the animal feed requirements and plant nutritional value standards used to calculate the nutrition sub-model. On one hand, the feed supply depends to a large extent on climatic conditions but also on the grazing management. Therefore, there is expected to be variation between farms under similar climatic conditions. Also, the feed demand is based on feeding standard calculated in metabolic chambers using "*Bos Taurus*" animals under controlled environmental conditions. "*Bos Indicus*" and Cross-breed animals, under grazing conditions in the Central Chaco, could have quite different feed demands compared to the calculated demands used for this model.

The mathematical model assumes a linear relationship in all the resources used, which can be held within certain limits. However, in reality, there are many factors outside the structure of the mathematical program which influence the behaviour of the components of the farming system in ways difficult to approximate accurately.

The area under study is located in an ancient inland river delta that determines the soil type distribution. In the Central Chaco sudden changes of soil types within short distances are the rule and usually the "Campo type" soil (which represents about 15% of the total area under study) is scattered within areas of "Monte soil" type. This implies that inefficiencies can be expected when cropping areas are increased as extra cropping land is usually not located in the immediate vicinity. On the other hand, this feature represents an advantage in an area where the rainfall distribution is very irregular and has a patchy distribution. As the cropping land is scattered within a larger area there are more chances that some rainfall will be intercepted by the cropping area than when only a single large area is under cropping.

Livestock have regular access to natural shelter in every paddock of the farms. These are native bush shelters, and these also represent a source of extra feed which can be especially important during critical periods of the year. These are native bushes rich in leguminous species which are a good source of protein, although they usually have low palatability. Furthermore, there are many species which have edible fruits and pods which are readily eaten by the livestock and represent a feed source not included in the model because of lack of data. 0 shows the main native trees and bushes that provide forage during different periods of the year.

5.5 Summary

For a model to be valid, it does not need to reflect reality in all aspects. A model is always incomplete and, therefore, usually does some things well and other things not so well or not at all. (Thornley, 2001)

A linear programming model uses linear equations to represent a bio-economic system. The accuracy and predictability of this model were evaluated through verification and validation. Partial tests and predictability experiments were carried out with the model using data from three case study farms from the area of study. The degree of association between predicted and observed values was judged adequate. Consequently, it was concluded that the model was valid for its purpose.

Chapter 6

RESULTS AND DISCUSSION

6.1 Introduction

In this Chapter the results of different experiments undertaken with the model, in order to accomplish the research objectives outlined in Chapter 1, are described.

Experimentation proceeded in six stages. The first experiment explored the effect of utilizing different values for the fertility restorative level for pasture activities. This showed the economic effect of utilizing different pasture rotation lengths on the farming system and provided guidance on the optimal pasture rotation length. The second experiment explored the effect of soil type ratio on the optimal plan. The third experiment investigated the impact of reducing all the cropping and pastures production yields in order to simulate a drought scenario. Later, this optimal plan was forced into the model with coefficients for an average year in order to assess the opportunity cost of maintaining the optimal plan for drought years under average weather conditions. The fourth experiment simulated different milk and beef prices scenarios in order to asses the sensitivity of the farming system to these market changes. The fifth experiment explored the potential of forage sugar cane in the current farming systems. Finally, the likely impact of the introduction of pasture legume mixtures on the optimal plan was explored.

As each run of the model generated a detailed description of the optimal system and there is limited space to fully reproduce the results, they are presented in a summarized form, that includes only the critical data related to the objective of each trial. The detailed solutions are included in Appendices K to P

None of the sensitivity analyses have been included because the price range within which the objective function coefficient of a basic activity can vary without changing the optimal solution is based on nothing else changing. This also applies for the increase in a gross margin, or reduction of cost, necessary for a non-basic activity to become basic without affecting the value of the objective function. However, in reality, most of the objective coefficients are not completely independent, therefore, a change in one is often accompanied by a change in many other coefficients within the system.

6.2 Exploring the optimal pasture rotation length

There are gaps in the knowledge about the shortest period under pasture that would be required to replenish the fertility level in terms of the organic matter content for both Campo and Monte soils. Traditionally, the farm managers have increased productivity by developing unimproved land. In the last decades, however, most of the farms have completed the development of their total area. Consequently, they are facing, for the first time, the need for developing a sustainable system where land is rationally used in order to maintain and/or improve its production potential in the long-term.

Attempts at utilizing chemical fertilizers for replenishing nutrients in the Central Chaco have been both disappointing and uneconomical with current market prices(Glatzle, 1999). Therefore, the only option currently viable for maintaining the soils fertility levels in Campo soils is by means of proper management which includes the use of crop rotations and the introduction of leguminous crops and/or a pasture phase.

While leguminous crops replenish the soils' organic matter and nitrogen content, grass only pasture phase replenishes the organic matter content of soils previously under cropping. There is no local data available regarding the shortest period under pasture that would be required to replenish fertility levels for a new cropping phase. In addition, it has also been suggested that introducing a pasture phase in a cropping system may reduce the infestation of insect pest and or nematodes through interrupting their life cycle (Humphreys, 1994).

On the other hand, on Monte (heavy) soils, perennial pastures have been used for undefined periods with pasture renewal being a rarity (Baez, Glatzle and Dürksen personal communication). Using a cropping phase for pasture land has been suggested as an effective alternative form of weed control, especially against woody species. (Dück, 1995; Humphreys, 1994).

In the Central Chaco, there are contrasting positions between researchers in regard to pasture renewal. Some researchers support the theory that pasture can be maintained productive in perpetuity by means of seasonal changes in stocking rate and grazing management. Others believe that regular pasture renewal and intensive rotational grazing is the correct strategy for maintaining productivity on a sustainable basis (H. Baez, personal communication, July 7, 2005).

This set of experiments explored the likely effect of different lengths of pasture phase in the optimal solution under average rainfall conditions utilizing a hypothetical farm of a 200 ha effective area (25% Campo, 75% Monte soils).

Under good grazing management most of the expenses in pasture activities are related to pasture implantation, consequently, shorter pasture phases will have increasing average costs per year. In addition, because tropical pastures requires from nine to twelve months for establishment before they can actually be grazed, shortening the pasture phase length will reduce the feed availability per unit or pasture activity. As a result, there is a trade off effect between having more area available for cropping and increasing average cost and decreasing feed availability per area under pasture. These two features are displayed in Figure 6.1.

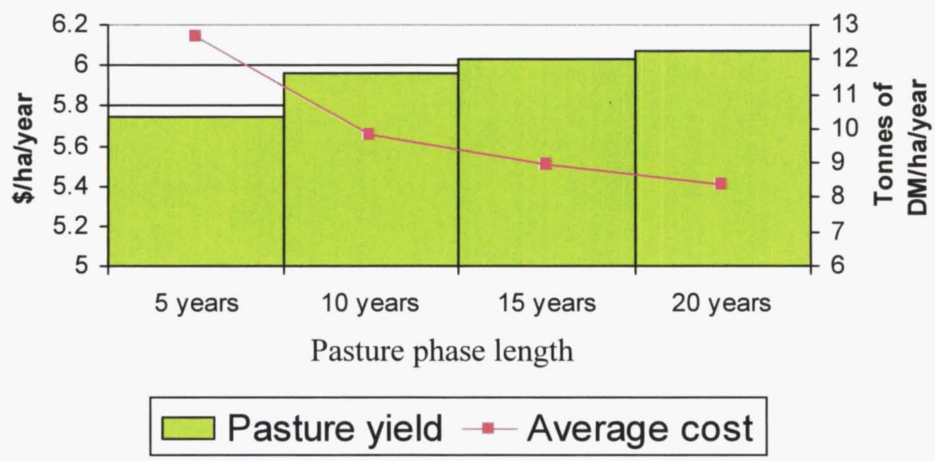

Figure 6.1 Pangola type pasture average annual cost $/ha/year and expected yield in Tonnes of DM/ ha/year under different rotation lengths

As there is no data available related to the fertility replenishing power of a pasture phase, some assumptions were required to assess the likely effect on the farming system of different values. These assumptions are summarized in Table 6.1

A summary of the results is shown in Figure 6.2 and Table 6.2, the detailed solutions for these optimal plans are included in Appendix K

Table 6.1 Rotation combinations explored

Rotations combinations	Description
A	A pasture rotation length of 20 years followed by up to three annual depleting crops
B	A pasture rotation length of 15 years followed by up to three annual depleting crops
C	A pasture rotation length of 10 years under pasture followed by up to three annual depleting crops
D	**A pasture rotation length of 10 years in Monte soils and a pasture rotation length of 15 years in Campo soils followed both by up to for three annual depleting crops**
E	**A pasture rotation length of 10 years in Monte soils and a pasture rotation length of 20 years in Campo soils followed both by up to three annual depleting crops**
F	A pasture rotation length of 5 years followed by up to two annual depleting crops
G	**A pasture rotation length of 5 years followed by one annual depleting crop.**

Figure 6.2 Surplus after taxes and living expenses assuming different pasture rotation lengths

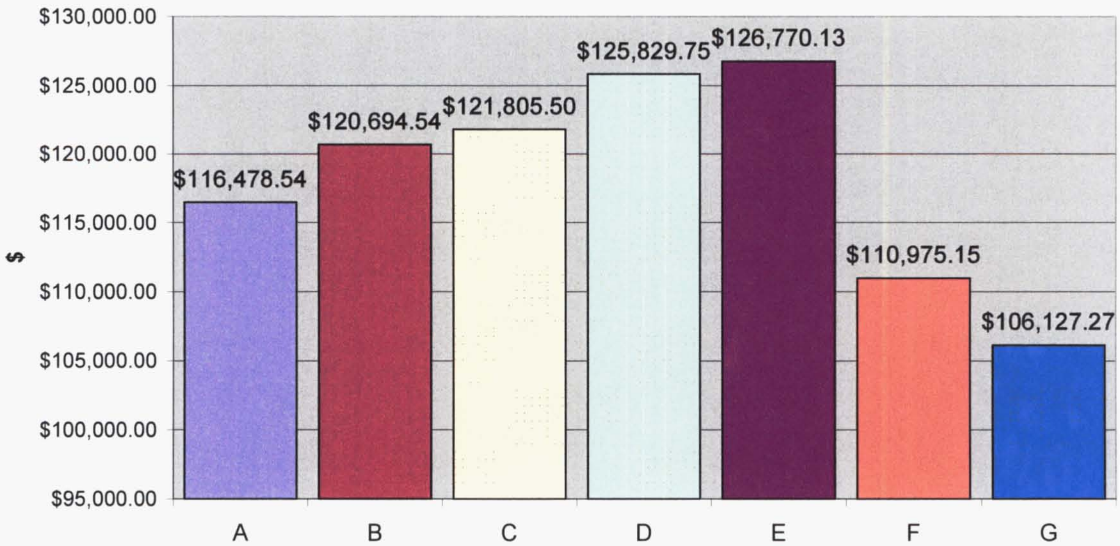

Table 6.2 Land use pattern and activity level under different pasture rotation lengths

–	Pasture rotation combination						
Activity	A	B	C	D	E	F	G
Pangola grass (Ha)	23	34	47	47	46.1	50	42
Gatton panic grass (Ha)	130	124	115	115	115	112	125
Silage (Ha)	34	35	38	38	38.5	38	33
Winter crop (Ha)	14	9	3	3	3.9	0	8
Ground nuts (Ha)	13	6.6	0	0	0	0	0
Dairy cows (Heads)	230	236	247	254	256	226	217
Total milk production (l)	925,992	958,295	1,000,041	1,021,860	1,031,202	918,493	886,955
MVP of Fertility balance in Monte soils	$2,706.56	$964.71	$1,118.05	$1,293	$1,258.86	0	0
MVP of Fertility balance in Campo soils	$545.24	$612.88	0	0	0	0	$0.41

From the results shown in Figure 6.2 and Table 6.2 the most profitable land use pattern requires a pasture phase of 10 years followed by three years of sorghum for silage in Monte soils and a pasture phase of 15 to 20 years followed by sorghum for silage and black oats for three years in a row in Campo soils. Rotations of five years are not recommended because the longer rotations are more profitable. The long rotation phase that the model chooses for pasture in Campo soils is common in the area of study. However, the short rotation phase for pasture in Monte soils is not currently used in the area of study. Local producers have proved that a rotation of 10 years is feasible on these soils but there was no available information to suggest that this rotation was more profitable than longer ones (H. Baez, personal communication, 22 June, 2005).

The marginal value products for rotation length on heavy soils show that decreasing, by one year, the rotation length from 20 to 19 would increase the farm gross margin by $2,706 and on light soils by $545.24. When considering a pasture rotation of 10 years for both types of soils the marginal value product of decreasing the rotation length for Monte soils has a marginal value product of $1,335 whereas, on Campo soils, the rotation length did not constrain the farm gross margin. However, the model assumed that by reducing one year the rotation length will decrease linearly yield and average cost which is not the case in reality. This must be remembered when assessing these values.

Thus, it can be argued that a pasture rotation of 10 year in Monte soils should be recommended for dairy farmers and that in Campo soils under current market prices a rotation between 15 and 20 years would be the most profitable strategy. Finally, results suggest that future research on optimal rotation length under different soil types in the Central Chaco should focus on between five and ten year rotations for Monte soils, and that under current market conditions the pasture phase in Campo soils in the optimal solution is driven by feed demand rather than by fertility constraints.

Optimal plans according to the soil type ratio

The fact that the soil ratios within different farms varies widely in the area of study, with old farms having sandy soils comprising up to about 80% of their total area while the newest farms having little or even no sandy soils (Funk personal communication, 26th April 2005), introduces the question on the optimal farm system for farms with different soil type ratios.

As it was explained in Chapter 2, Campo soils (sandy) have more cropping options when comparing with Monte soils (heavy) that are suitable for pasture production, grain and forage sorghum.

A hypothetical farm of 100 effective hectares was used for this experiment. This farm size was selected because farm size of the farm systems modelled range between 20 ha to 500 ha with an average of 100 ha. Also, 70% of the largest Cooperative (Chortitzer Ltd.) in the area comprises farms with about this average area (A. Funk, personal communication, 26th April 2005). Since the model uses linear relationships the optimal solution can be easily extrapolated to larger farms because the linear relationships are expected to held between the ranges of farm sizes present in the area of study.

In order to assess the impact of the soil type ratio several runs of the model were conducted by changing the soil type ratio from zero percent sandy soils up to 80% sandy soils. This covers the full range of soil type ratios found in the area of study (A. Fünk, personal communication, 26th April, 2005). In Table 6.3 the results obtained are shown in summarized form with the detailed solutions included in Appendix L

Table 6.3 Optimal plans for farms with different soil type "Campo"/"Monte" ratios. 30% Campo soil representing the average

	% of total effective area with Campo soil								
Category	0%	10%	20%	30%	40%	50%	60%	70%	80%
Surplus after tax and living expenses ($)	$30,617.65	$37,705.23	$44,297.98	$47,953.74	$49,920.74	$51,887.75	$53,723.79	$54,893.29	$56,062.79
Taxable income ($)	$50,732.23	$58,017.14	$63,921.66	$68,586.42	$70,618.27	$72,650.12	$73,543.61	$74,745.22	$75,946.82
Income tax ($)	$1,268	$1,450	$1,598	$1,715	$1,765	$1,816	$1,839	$1,869	$1,899
Surplus after tax and living expenses ($/ha)	$306.18	$377.05	$442.98	$479.54	$499.21	$518.88	$537.24	$548.93	$560.63
Difference compared to the typical soil type ratio (%)	-36%	-21%	-8%	0%	4%	8%	12%	14%	17%
Land Use in ha.									
Sorghum for silage Monte (ha)	14.4	16.1	17.5	16.2	13.9	11.5	9.2	6.9	4.6
Gatton (ha)	85.6	73.9	62.5	53.8	46.1	38.5	30.8	23.1	15.4
Pangola (ha)	0	10	20	27.3	32.1	37	41.2	45	49
Sorghum for silage Campo (ha)	0	0	0	2.3	5.1	7.8	10.8	14	17.2
Oats (ha)	0	0	0	2.3	5.1	7.8	10.8	14	17.2
Ground nuts (ha)	0	0	0	0.4	2.8	5.2	7.9	10.8	13.8

Table 6.3 (contd)

	% of total effective area with Campo soil								
Category	0%	10%	20%	30%	40%	50%	60%	70%	80%
Livestock numbers in heads									
Dairy cows calving in July	71	84	95	104	108	111	113	113	114
Dairy cows calving in October	26	24	23	21	21	20	20	20	20
R1 year replacements	10	12	19	20	21	21	21	21	21
R2 year replacements	10	11	18	19	20	20	20	20	20
Buying replacements	5	5	6	6	6	7	7	7	7
R1ysteer	6	5	0	0	0	0	0	0	0
Bulls	3	3	4	4	4	4	4	4	4
Total labour requirement	278	307	322	343	345	348	344	339	335
Total milk production (kl)	355.371	403.156	441.321	476.788	489.213	501.637	508.001	509.983	511.965
Milk production per ha (L/ha)	3,553.71	4,031.56	4,413.21	4,767.88	4,892.13	5,016.37	5,080.01	5,099.83	5,119.65
Difference in milk production (%)	-25%	-15%	-7%	0%	3%	5%	7%	7%	7%

Table 6.3 (contd)

	% of total effective area with Campo soil								
Category	0%	10%	20%	30%	40%	50%	60%	70%	80%
Feed supply									
Concentrate mix formula in tonnes of DM	154.502	172.906	181.524	202.416	210.962	219.508	223.203	224.061	224.898
Grain fed in tonnes	43.343	48.512	50.928	56.796	59.192	61.591	62.626	62.869	63.098
Silage fed in tonnes of DM	80.909	90.83	98.286	98.675	94.996	91.322	88.478	86.244	84.018
Hay fed in bale units (350 kg)	10	10	0	0	0	0	0	0	0
Marginal value product (MVP) Campo February	$0.00	$0.00	$1,057.50	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
MVP Camp March	$0.00	$411.71	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
MVP Campo April 2	$0.00	$0.00	$206.20	$561.08	$561.08	$561.08	$527.49	$527.49	$527.49
MVP Campo October	$1,203.78	$0.00	$0.00	$386.50	$0.00	$386.50	$379.25	$378.56	$0.00
MVP Campo Dec	$0.00	$757.27	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
MVP Monte Feb	$0.00	$666.75	$680.36	$0.00	$0.00	$0.00	$789.79	$789.79	$789.79
MVP Monte March	$666.38	$0.00	$0.00	$750.88	$750.84	$750.84	$0.00	$0.00	$0.00

Figure 6.3 Trends in farm surplus per ha, milk production and labour demand in optimal plans for farms with different soil type ratio (Campo:Monte)

The optimal plans show an almost linear increase of farm surplus in relation to increasing areas with "Campo soil" (Figure 6.3). Similar effects are expected with stocking rate and, up to certain extent, with labour demand. This is because "Campo" soils compared to "Monte soils" have more versatility allowing up to two crops per year and this increases its production potential.

Livestock numbers show a progressive increase with increasing levels of light soils. The optimal solution for farms with 100% heavy soils has a stocking rate of 1.7AU/ha and for farms with 80% sandy soils has 3AU/ha. According to the results, it can be argued that on average the total stocking rate of the farm increases 7% per 10% increase in Campo soils.

Man day units of hired labour increases from 278 man day units for farms with zero Campo soils", to 348 man day units for farms with a fifty–fifty soil type ratio, decreasing again with higher percentages on Campo soils. For instance, farms with 80% "Campo soils" use 335 man day units per year. The increase in labour demand from zero to 50% per cent Campo soils is due to a progressive increase in the stocking rate and the increasing use of double crops per year on Campo soils. The latter decrease in labour demand can be explained by a progressive decrease in silage fed per head with increasing percentages of sandy soils. This is a combined effect of the lower sorghum yields expected on sandy soils plus the extra medium quality feed provided by black oats for direct grazing.

Milk production shows a progressive increase with the increasing percentage of sandy soils in the property, ranging from 272 thousand litres for farms with 0% sandy soils up to about 370 thousand litres for farms with 60 and 80% of sandy soils, respectively.

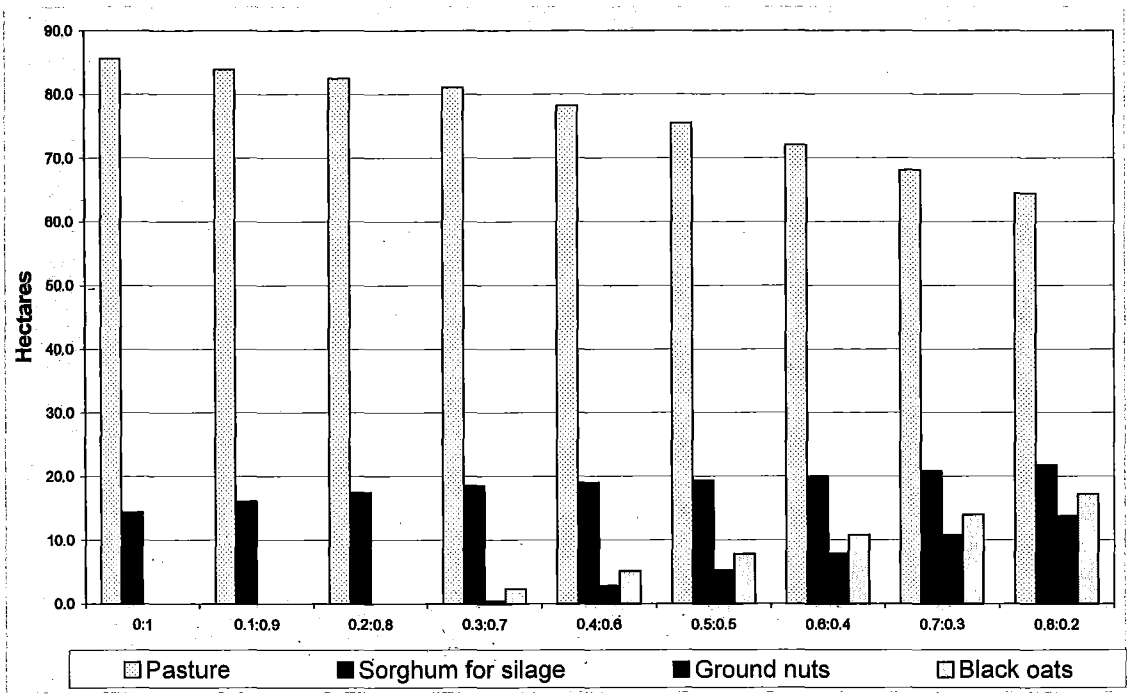

Figure 6.4 Land use pattern in optimal plans for farms with different soil type ratio (Campo:Monte).

As shown in Figure 6.4 the total area under cash crops increases with increasing area with light soils, from 0.4 ha of ground nuts for farms with 30% light soils up to 13.8 ha for farms with 80% light soils. Furthermore, the total area under pasture decreases progressively from 86% of the total area under pasture with 100% of the farm with heavy soils to 64% in farms with 20% of heavy soils.

Black oats for grazing are included in the optimal solution for farms with 30 - 80% of their area with Campo soils. Oat levels increase progressively from 2.3 ha for farms with 30% Campo soils to 17.2 ha for farms with 80% of light soils.

Table 6.4 Farm area (has) required to achieve similar surplus after taxes and living expenses under different soil type ratios

		Soil ratio = Campo : Monte								
		0:1	0.1:0.9	0.2:0.8	0.3:0.7	0.4:0.6	0.5:0.5	0.6:0.4	0.7:0.3	0.8:0.2
Campo soils	0	100	81	69	64	61	59	57	56	55
	10%	123	100	85	79	76	73	70	69	67
	20%	145	117	100	92	89	85	82	81	79
	30%	157	127	108	100	96	92	89	87	86
	40%	163	132	113	104	100	96	93	91	89
	50%	169	138	117	108	104	100	97	95	93
	60%	175	142	121	112	108	104	100	98	96
	70%	179	146	124	114	110	106	102	100	98
	80%	183	149	127	117	112	108	104	102	100

Table 6.4 shows what farm area would be required to achieve similar levels of surplus for farms with different soil type ratio. These results are in accordance with observed farm size trends in the area of study. The smallest production units are not only the oldest but, more importantly, those with a large proportion of Campo soils (> 60%). The newest units are larger units with little or no sandy soils. The minimum size established by Fernheim Ltd for new productive units is 220 ha to address this fact. (Dűrksen personal communication, 2004)

For a farm with no Campo soil to achieve the same level of surplus as a farm with 80% sandy soils it must be 83% larger in effective area. Also, for typical farms with 30% sandy soils they would need to be 17% larger than a farm with 80% sandy soils if a similar surplus level is sought.

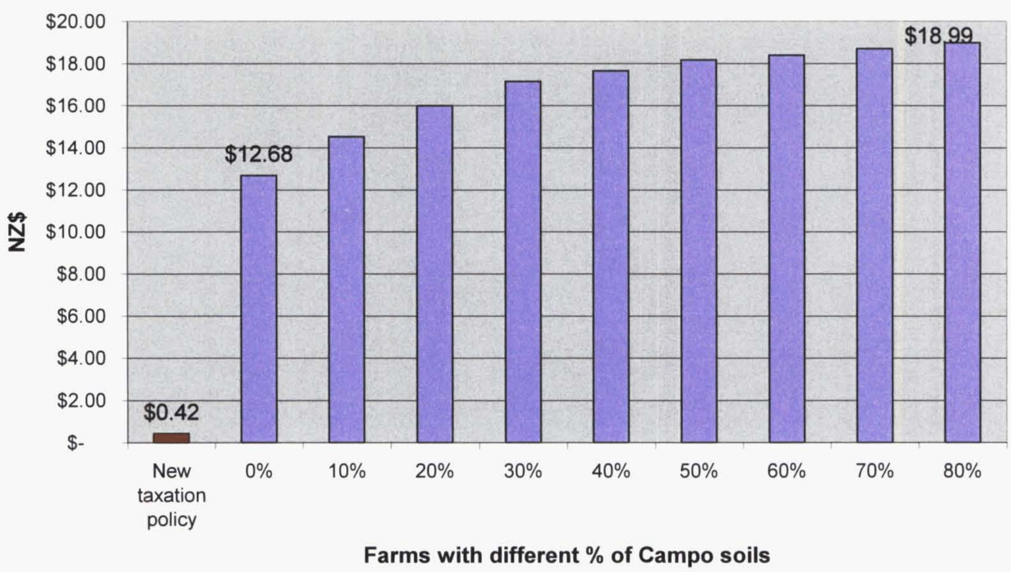

Figure 6.5 Income tax per ha estimated by the Paraguayan government for farms in the Central Chaco, contrasted to calculated taxable income for farms with different soil type ratio

Under the new taxation policy, which becomes applicable from December 2005 (Ley 2421, \, 2004 #126), the area of the Central Chaco is categorized as being on soil suitable for semi-intensive beef production ("Reglamentacion del articulo 4 de la ley No. 2421/2004," 2004). As such, the government estimated that taxable income for farms in this area will be around $16.33/ha (calculations are shown in Appendix G). The model results show that real taxable income per ha ranges between $401 and $640 per ha. Even though the real taxable income will be less than this once fixed costs and depreciation are included, they would not have a large impact on the final taxable income. Appendix N shows the fixed cost calculated for typical 200 ha farm units in the Central Chaco.

The findings of this set of experiments provide implications for policy makers with respect to planning for future sub-divisions. They must consider the difference in the productive potential of the land according to soil type. Furthermore, they have implications for the taxation policy because they not only show the wide variation in surplus potential for farms with similar size, but also with different soil type proportions. More importantly, it shows that income tax based on real account balances will be much higher than what is estimated by the new tax legislation.

6.3 Exploring the farm sensitivity to milk and beef price changes

Traditionally, the farms in the Central Chaco have been mixed farms with dairy, beef and cropping activities present in different proportions. However, under the current price scenario the optimal solution shows dairy farming as the most profitable. Since beef and milk prices are subject to price fluctuation in the international market it would be interesting to explore how changes in milk and beef prices would impact on this optimal plan.

Because the most intensive activity is dairying in the optimal plan, increasing milk prices will not change the optimal plan unless a more intensive dairy activity is made available. In contrast the likely effect of lower milk prices can be explored to assess the trade off effects between milk, beef and crop activities.

Milk prices are either seasonal or flat depending on the factory processing the milk. After running the model under both pricing schemes the model chooses the same optimal plan for both. Consequently, it was decided to carry on the experiments involving changes in milk prices assuming a flat pricing scheme.

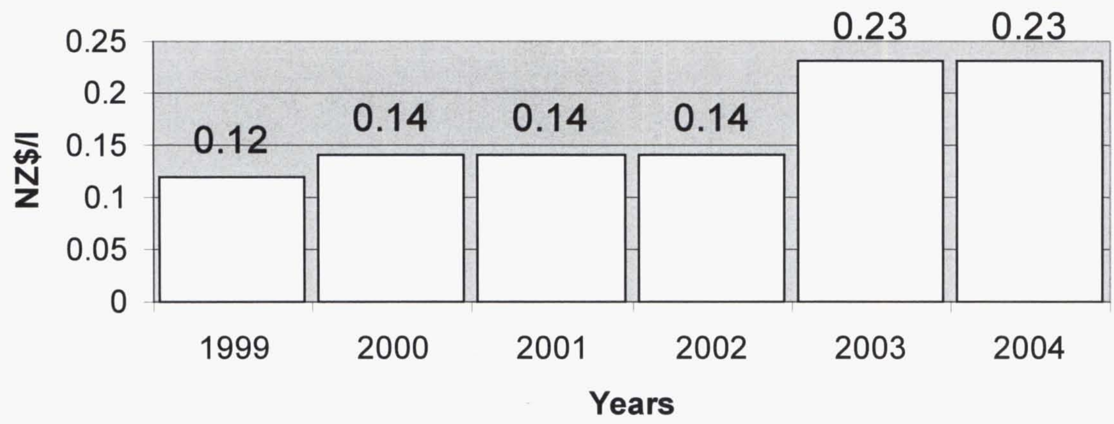

Figure 6.6 Milk payout NZ$/l in the Central Chaco period 1999 to 2004. Source: adapted from Kaetler, 2004

While milk prices have experienced a steady rise for the last six years, as shown in Figure 6.6, milk is a commodity and as such milk prices are likely to decrease in the long term unless demand increases. Moreover, neighbouring countries such as Argentina, Uruguay and Brazil have a competitive advantage due to a milder climate and stronger dairy industry. They constitute a permanent threat to the local dairy industry. Consequently, milk prices were parametrically decreased from current prices to the prices of the year 2000 which equals 60% of current prices. Milk price scenarios explored in this set of experiments are displayed in Figure 6.7. These five prices were combined with five different beef prices in order to explore scenarios with different price combinations.

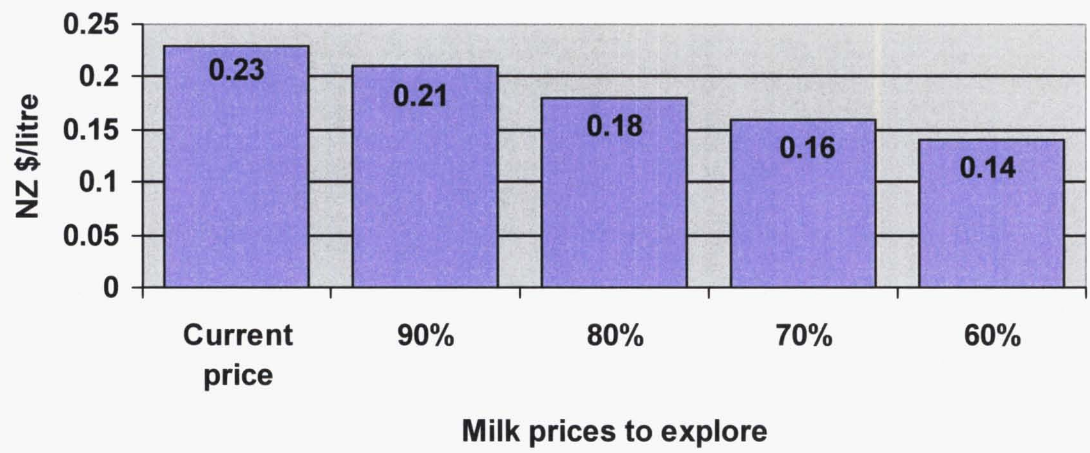

Figure 6.7 Milk prices scenarios as a percentage of current milk prices selected to be explored

Beef prices are subject not only to international prices and fluctuations in the exchange rate, but more importantly to the Foot and Mouth disease status (Glatzle & Stosiek, 2001). This status determines access to high value market access which, in turn, has a great impact on beef prices paid to farmers. Argentina, Brazil and Uruguay are also strong beef producers.

However, Paraguay has similar competitive advantages in terms of resources and climate. Therefore, it was believed appropriate to explore different beef price scenarios up to 130% the current beef prices. Current prices for different animals in the year 2004 are given in Figure 6.8

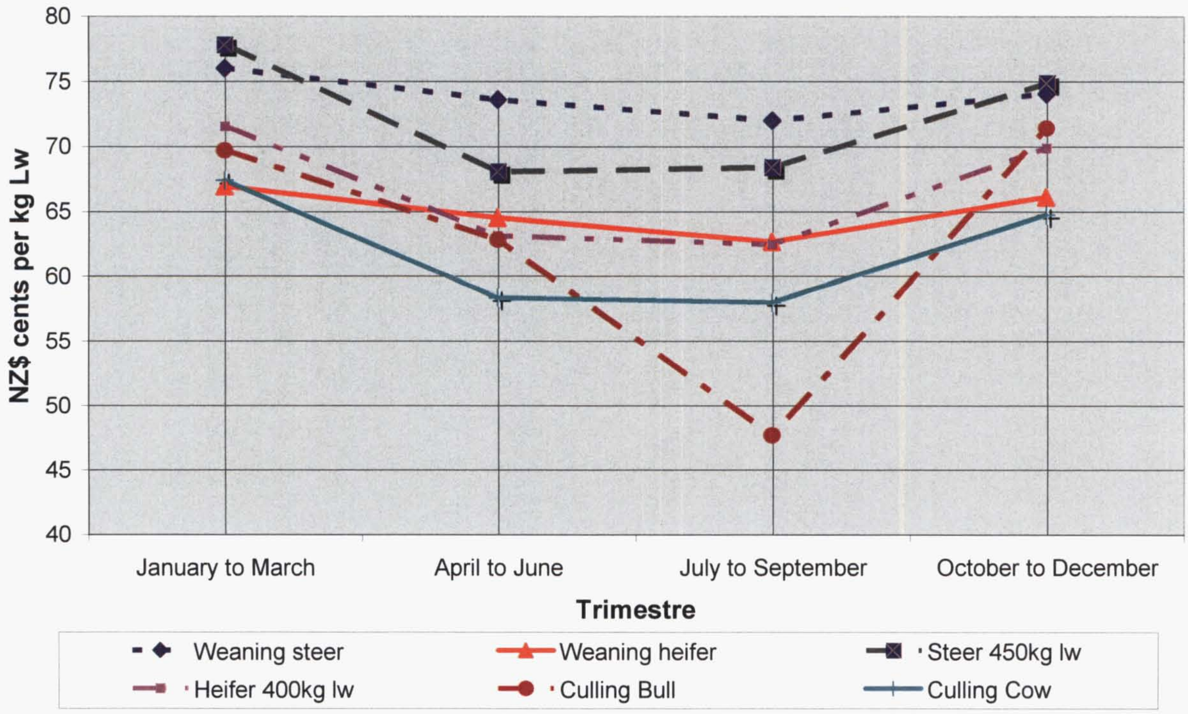

Figure 6.8 Average beef prices New Zealand cents/kg liveweight in different periods of the year 2004. Source: S. Neufel, personal communication, December 22, 2004

The seasonal variation in beef price is related to variations in the quantity and quality of beef available. For instance, the lowest prices are usually received during the dry season when the supply of animals surpasses the demand of beef at that time of the year. On the other hand, beef prices usually rise steadily from September to December due to a shortage of beef, both in quantity and quality. From January to March beef prices usually decrease slightly as more beef becomes available until April to June when beef prices decline even more as breeding farmers try to reduce their stocking rate for the dry winter season.

In order to explore different price scenarios the average beef prices per trimester and category were increased parametrically from current prices up to 140%. All coefficients affected by beef prices were recalculated and modified for each run. In total, for each run the change of 68 coefficients from 34 different activities was required.

It can be argued that because beef is less intensive than dairy it would be disadvantaged on 100 ha farms. Thus, for this and thee following experiments a hypothetical farm of 200 ha effective with 25% of the area on light soils was used.

Figure 6.9 contains the expected farm gross margin per ha in New Zealand dollars under different beef and milk price scenarios.

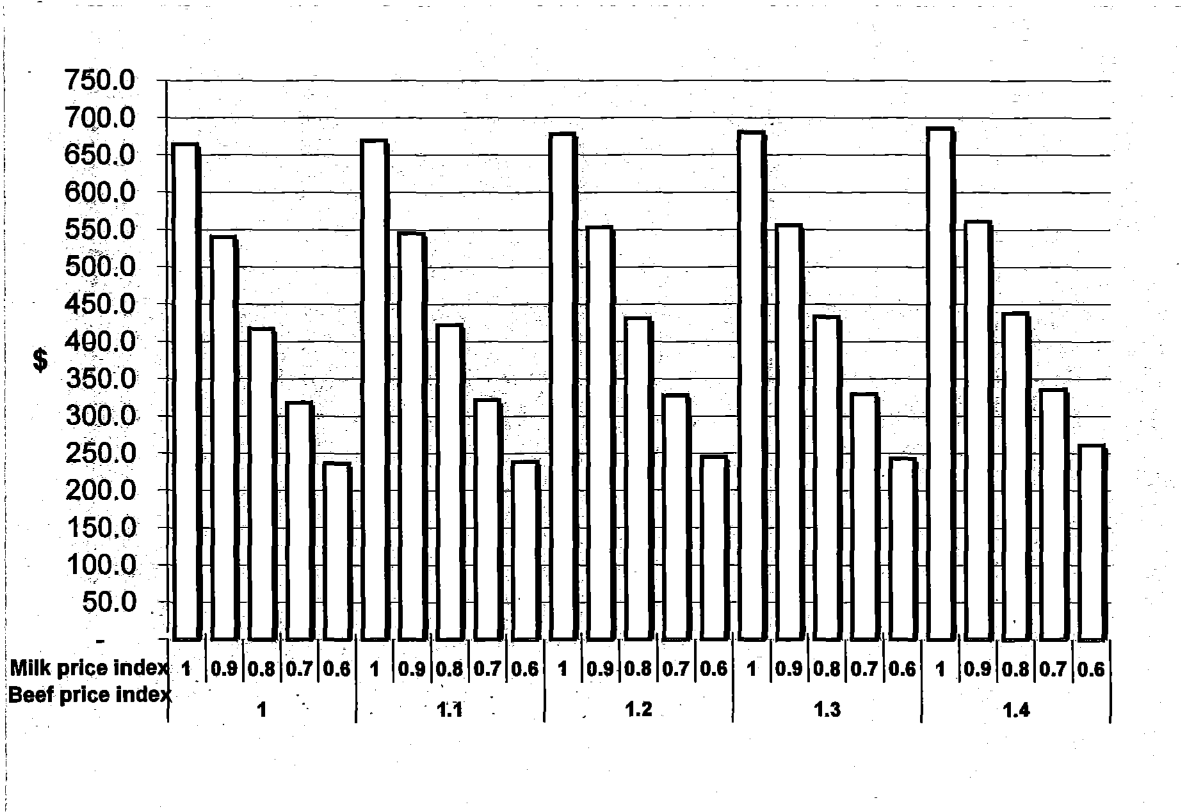

Figure 6.9 Total farm gross margin per effective ha in New Zealand Dollars under different beef and milk price scenarios

Under current beef and milk prices the optimal plan chosen is buying replacements up to the limit of 25% and 'selling' all non replacement calves at $0 price in the first week of life. This plan gives a total gross margin per ha of $664.3.

Under a scenario where the beef prices remains unchanged at current levels and milk prices drop to 60% of current levels the farm total gross margin per ha equals $236.1, which represents a 64.4 % decrease compared to the current scenario. On the other hand, under milk prices similar to the current prices and beef prices increased 40%, the optimal solution is the same plan selected for current market prices but the farm total gross margin is $685.6, which represents a 3.5% increase compared to the result of the same plan under current market prices.

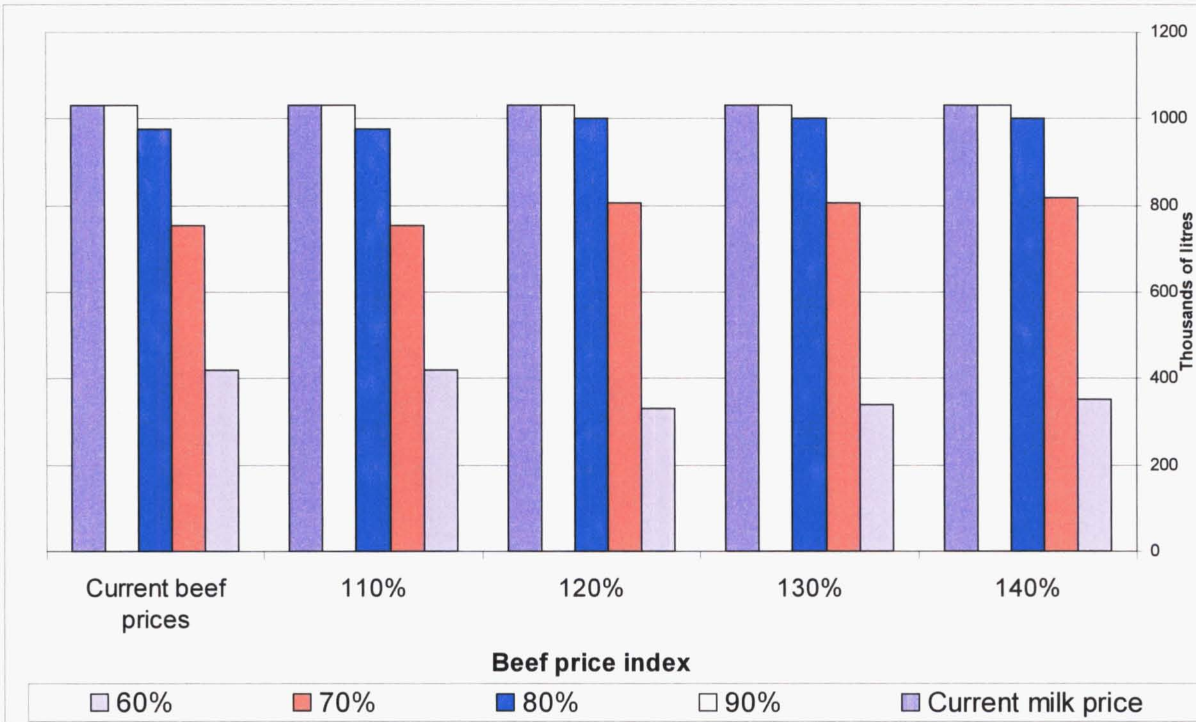

Figure 6.10 Milk production under different milk and beef prices scenarios

Similarly to the financial results, the physical results show that activity levels selected in the optimal plan under different milk and beef prices scenarios are more sensitive to changes in milk prices than to changes in beef prices. See Figure 6.10 & Table 6.5.

The milk production pattern remains unchanged under current and 90% milk prices combined with all the beef prices explored. However, with milk prices at 90% of current prices the optimal plan shows a slight increase with increasing beef prices. On the other hand, with milk prices at 70% of current market prices the milk production shows a steady increase with increasing beef prices. Finally, with milk prices at 60% of current prices the optimal plans show a decline in milk production when combined with beef prices up to 120% of the current price scenario, and will increase again slightly under beef prices at 130 to 140% of current prices. The milk supply change under different prices is a combined effect of changing dairy cow numbers and type. Under the lowest milk price scenario the model chooses to run a dairy herd of 67 high yielding 450 kg liveweight cows calving in July producing 4500 L per lactation as well as 34 low yielding 550 kg liveweight cow calving in October and producing 3,000 L per lactation. Appendix H.1 contains the detailed plans under different scenarios.

It could be argued that under lower milk payouts using double purpose cows would be more profitable than using a high yielding cow. However, the results discussed previously suggest that this may not be the case, since the model consistently predicts that even at milk prices 30% lower than current prices, and under all explored beef prices, the optimal strategy is to have high yielding cows calving only in July or in combination with a few calving in October.

In contrast, double purpose cows (550 kg liveweight and 3,000 L milk yield) were only included in the optimal plans for scenarios with milk prices 30 and 40% of current prices in combination with beef prices at 140% of current prices but, in these optimal plans, they only represent 11% and 33.6% of the total dairy herd, respectively.

Table 6.5 Output levels under different milk and beef prices scenarios

Beef Prices (Index)	Milk prices (Index)	Milk production (litres)	Ground nut (kg)	Sesame seed (kg)	Cotton (kg)	Finishing steers (heads)	Selling yearling heifer (heads)	Selling hay Bales (350kg)
1	1	1,031,000	0	0	0	-	-	-
	0.9	1,031,000	0	0	0	-	-	-
	0.8	978,000	0	3,900	0	-	-	-
	0.7	752,000	19,880	10,200	0	-	-	-
	0.6	420,000	35000	0	30000	-	-	244
1.1	1	1,031,000	0	0	0	-	-	-
	0.9	1,031,000	0	0	0	-	-	-
	0.8	978,000	0	3,900	0	-	-	-
	0.7	752,000	19,880	10,200	0	-	-	-
	0.6	420,000	35,000	0	30,000	-	-	244
1.2	1	1,031,000	0	0	0	-	-	-
	0.9	1,031,000	0	0	0	-	-	-
	0.8	1,001,000	0	3,900	0	-	-	-
	0.7	804,000	15,820	8,940	0	-	-	-
	0.6	330,000	35,000	0	30,000	18	9	290
1.3	1	1,031,000	0	0	0	-	-	-
	0.9	1,031,000	0	0	0	-	-	-
	0.8	1,001,000	0	3,900	0	-	-	-
	0.7	804,000	15,820	8,910	0	-	-	-
	0.6	341,000	35,000	0	30,000	34	-	316
1.4	1	1,031,000	0	0	0	-	-	-
	0.9	1,031,000	0	0	0	-	-	-
	0.8	1,001,000	0	3,900	0	-	-	-
	0.7	818,000	7,700	6,360	0	18	9	-
	0.6	352,000	35,000	0	30,000	54	12	245

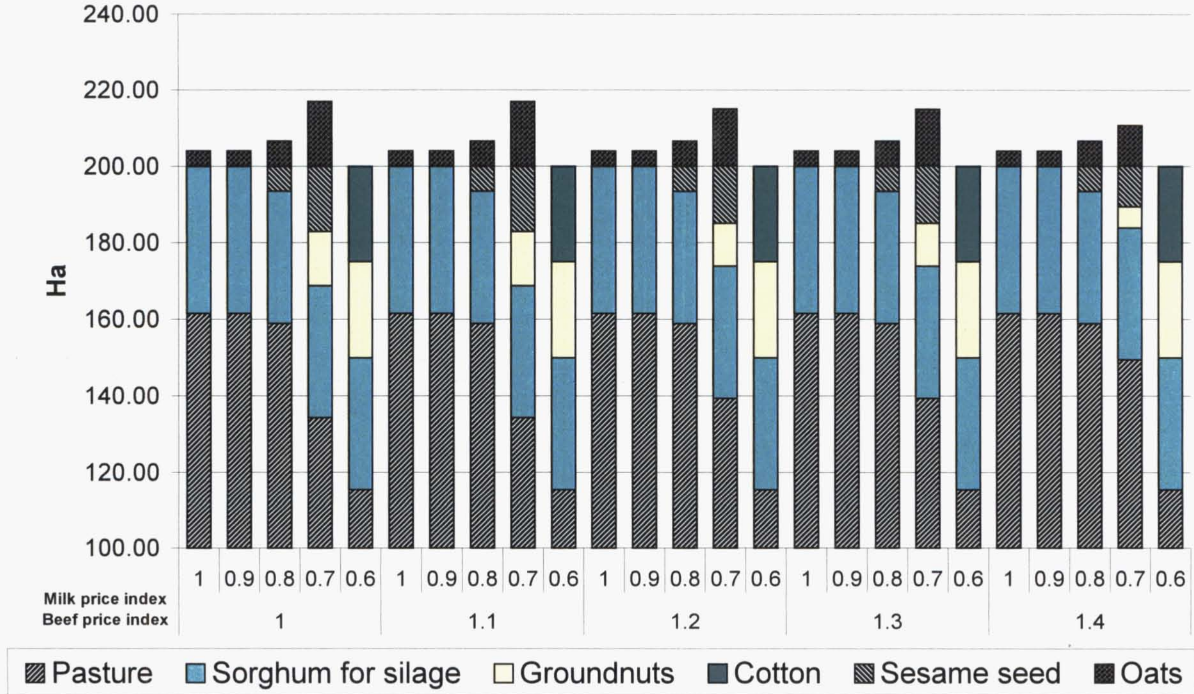

Figure 6.11 Land use pattern under different milk and beef price combination scenarios (has)

As shown in Table 6.5and Figure 6.11 land use is also affected by changes in milk prices but it was not affected by changes in beef prices within the range of prices that was explored (except for the scenario with milk prices at 70% and beef prices at 1.4% where it was affected slightly). The land use pattern selected for the optimal plan under the current price scenario remains unchanged with milk prices at 90% of current prices. However, changes in land use patterns start to appear with milk payouts lower than 90% of current prices. Agriculture becomes increasingly important under diminishing milk payouts with cash crops rising from utilizing 8 ha of effective area at current prices up to 50 ha with milk prices at 70% of current prices. Interestingly, the model chose an increasing area under winter crops and decreasing area for silage making under low milk price scenarios. This can be explained by the fact that the winter crop activity is associated with sorghum for silage activity at current market prices and at milk prices at 90% of current prices. In contrast, under lower milk prices the winter crop appears associated with sesame seed, which becomes optimal under those price scenarios.

In the last few decades large areas previously under cropping have been changed into pasture (Fernheim Cooperative, 2004; Neuland Cooperative, 2004). The model confirms that this is a reasonable move in response to market signals. According to the results, cash crops in the Central Chaco under current market prices are not included in the optimal solution and it is likely that if both beef and milk prices do not decrease, or crop prices do not rise, cropping will always be of a lesser importance for the region compared to milk and beef.

It is clear the practice of rearing all calves is counterproductive. The model was used to calculate the opportunity cost of the practice under different milk and beef prices scenarios. Figure 6.12 gives the results.

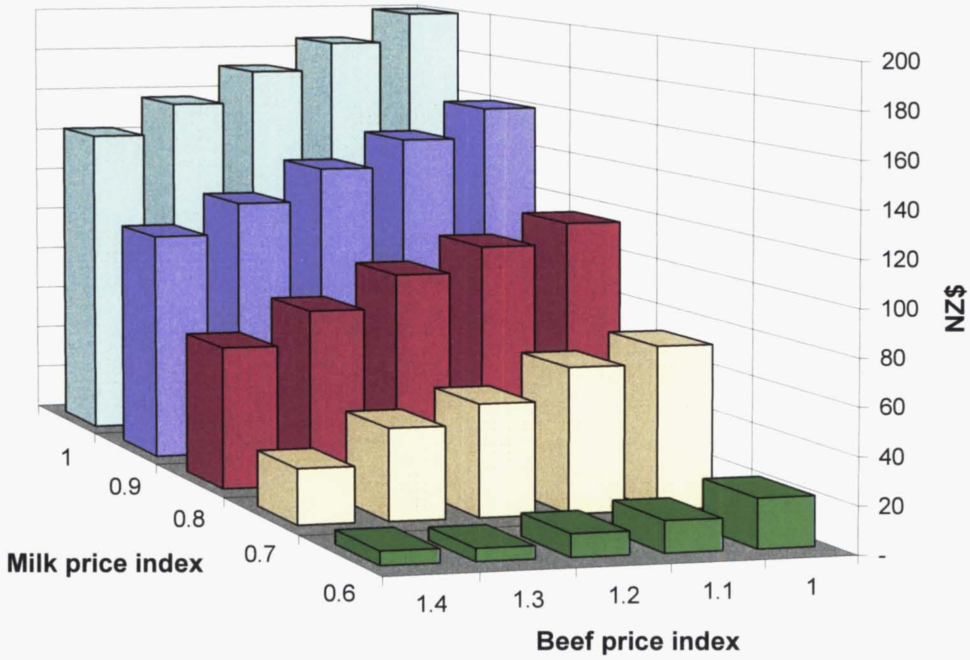

Figure 6.12 Opportunity costs of finishing all calves under different beef and milk price scenarios (Gross margin per ha)

As was expected, the opportunity cost is larger when milk prices are high and they decrease with lower milk payouts and increasing beef prices. More importantly, even at the highest beef price explored, it is still more profitable not to finish all the non replacement calves.

These findings suggest that research should be done on alternative methods of rearing dairy calves. Furthermore, there might be opportunities for farms to specialize in rearing dairy calves. These farms could rear calves for veal production or could rear dairy replacements under a contract agreement with dairy farmers. This alternative might be a viable option for those properties which, due to lack of year round access or because they are located outside the current area of milk collection, can not intensify into dairy.

Currently, there is underutilized plant capacity in the killing work of the largest colony. The use of new born calves for veal and/or pet food production are alternatives that would increase the income generated by dairy activity.

Furthermore, for the purpose of this study it was assumed that all cow activities calve once a year and all empty cows are sent to the works. However, considering that in Paraguay year round dairy production is the rule, there are opportunities to sell these cows once they are in calf as dairy replacements for other farms. This would increase the gross margins from seasonal dairy activities.

Consequently, the results suggest farmers in the Central Chaco under current, and most of the price scenarios explored should, specialize in dairy production with a dairy herd comprised exclusively by high yielding dairy cows calving in July, with all non replacement calves given away during the first week of life. Buying at least 25% of cow replacements is more profitable than rearing their own replacements under all the scenarios explored. Also, under decreasing milk prices the recommended strategy is to decrease stocking rates rather than to change the type of cow.

6.4 Exploring the farming system behaviour under drought conditions

This set of experiments studied the impact of drought on the farming system and the economic implications of having an optimal drought strategy under normal climatic conditions.

Farmers in the Central Chaco face serious limitation imposed by the wide variations in effective rainfall. This unpredictable factor can change completely the outcome of the plan selected. There is no single recipe that could provide an optimal plan under different rainfall conditions. Thus, it was considered interesting to explore the optimal plan or plans under average dry years. This optimal plan was forced into the model, set up for average rainfall conditions, and this result was compared with the optimal solution in order to assess the opportunity cost of maintaining a drought optimal strategy through a normal year.

In order to simulate an average dry year all crop yield coefficients were reduced according to expected yield under such conditions See Figure 6.13. A series of assumptions were required. These included: 600mm average rainfall that represents 73% of the average rainfall of the area; pasture supply was reduced assuming a linear response to rainfall level; water supply was reduced linearly. Ground nut with conventional tillage was constrained to zero. Finally, hay prices were increased subjectively by 25% as the demand is expected to increase under drought conditions. Four different pasture rotation patterns were explored under drought conditions and they are depicted in Table 6.6.

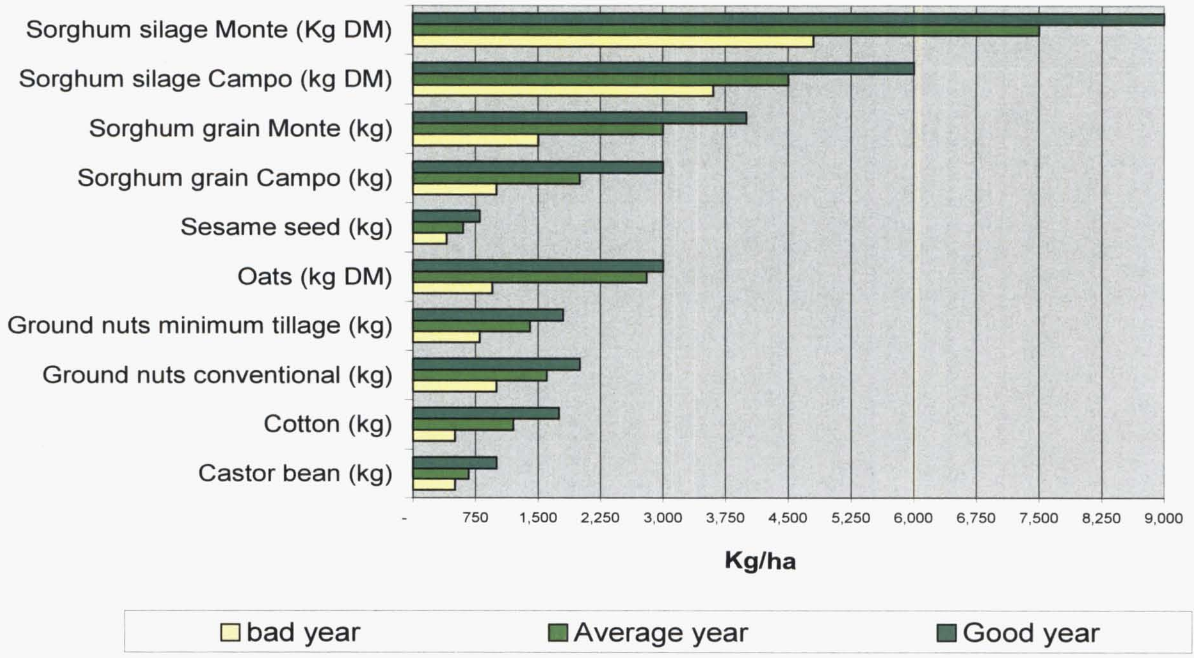

Figure 6.13 Expected yield variation for different crops in the Central Chaco according to rainfall level[13]

Table 6.6 Scenarios explored under drought conditions

Scenario	Rotation description
A	Gatton panic and Pangola rotation of 20 years followed by up to three annual depleting crops
B	Gatton panic and Pangola rotation of 15 years followed by up to three annual depleting crops
C	Gatton panic and Pangola rotation of 10 years followed by up to three annual depleting crops
D	Gatton panic rotation of 10 years and Pangola rotation of 15 years followed both by up to three annual depleting crops
E	Gatton panic rotation of 10 years and Pangola rotation of 20 years followed both by up to three annual depleting crops

The optimal plans utilizing different rotation lengths under drought conditions are shown in summarized form in Figure 5.14 and Table 5.7. Appendix 0 contains the detailed plans under these conditions.

[13] Source: case study farmers 2004, A. Cabrera, personal communication, January, 2005, and H. Baez personal communication April, 2005

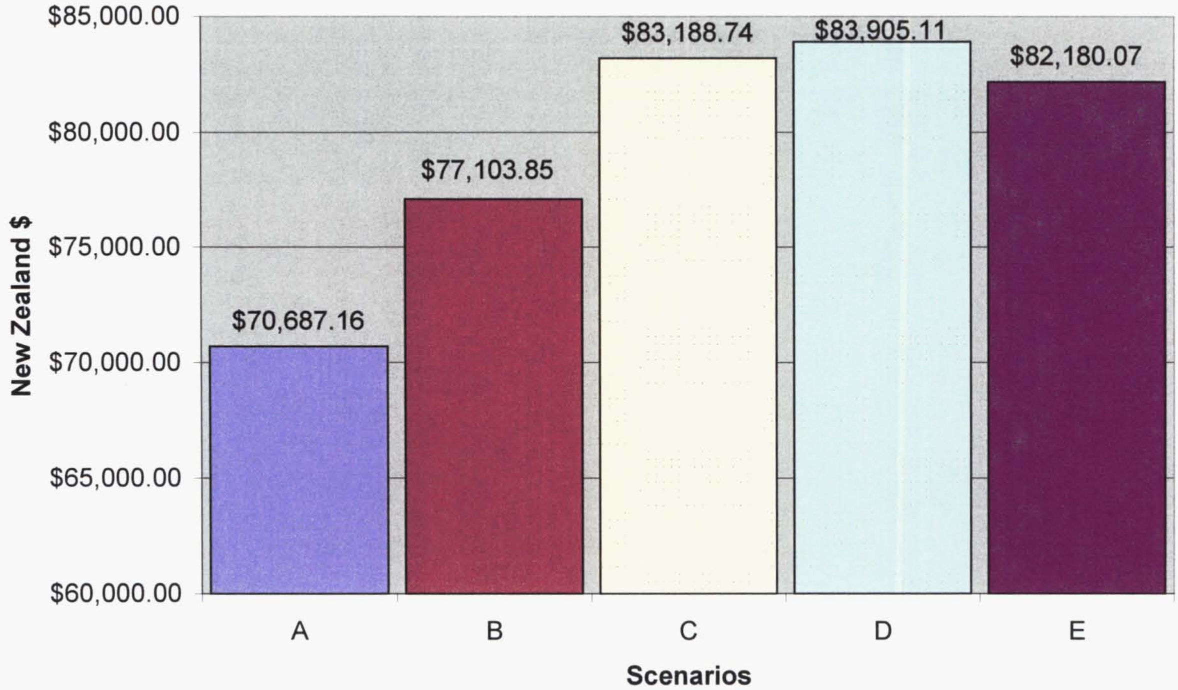

Figure 6.14 Farm surplus after taxes and living expenses for optimal plans under drought condition and different pasture rotation lengths

As shown above and in Table 6.7, rotations length of 10 years for Gatton panic and between 10 and 20 for Pangola were predicted as the most profitable. Between these three rotation combinations (C, D and E) the most profitable was a combination of 10 years Gatton with 15 years Pangola (D). It is interesting to note that cash crops are not included in any of these optimal solutions, which reinforces the hypothesis that livestock production will always prevail in the region because of the higher risk of rain fed agriculture (Glatzle, personal communication, 2004).

Table 6.7 Optimal plans under drought conditions with different pasture rotation lengths

Rotation Gatton: Pangola	20:20	15:15	10:10	10:15	10:20
Scenario	A	B	C	D	E
Farm surplus after tax and living expenses	$70,687.16	$77,103.85	$83,188.74	$83,905.11	$82,180.07
Total gross margin per ha	$462.47	$495.48	$519.53	$530.07	$521.25
Land use (ha)					
Pangola (ha)	16.1	41.7	41.2	41.7	47.6
Sorghum silage Campo (ha)	17.4	8.3	8.8	8.3	2.4
Gatton panic (ha)	130.4	125	115.4	115.4	115.4
Sorghum silage Monte (ha)	19.6	25	34.6	34.6	34.6
Ground nuts (ha)	16.5	0	0	0	0
Oats (ha)	17.4	8.3	8.8	8.3	2.4
Total labour required (man day units)	669	601	713	716	658
Livestock numbers					
Dairy cows	159	163	183	186	173
Bull A	0	0	6	0	0
Bull B	5	5	0	6	5
R1yheif	26	26	29	30	28
R2yheif	24	25	28	28	26
Total milk production (Thousands of litres)	640.873	655.442	738.557	747.244	698.079
Hay making (350kg bale units)	23	77	0	0	0
Sell hay (350kg bale units)	7	60	0	0	0
Buy hay (350kg bale units)	0	0	0	18	17

The next step involved forcing the optimal plans for farms under drought conditions into the model with coefficients for normal climatic conditions. This enabled assessing the opportunity cost of maintaining the drought optimal plan under average climatic conditions.

However, as expected the optimal plan for the average climatic scenario in drought year becomes infeasible. This shows that in order to survive a drought scenario the farmer will be required to choose between selling stock, or buying extra feed.

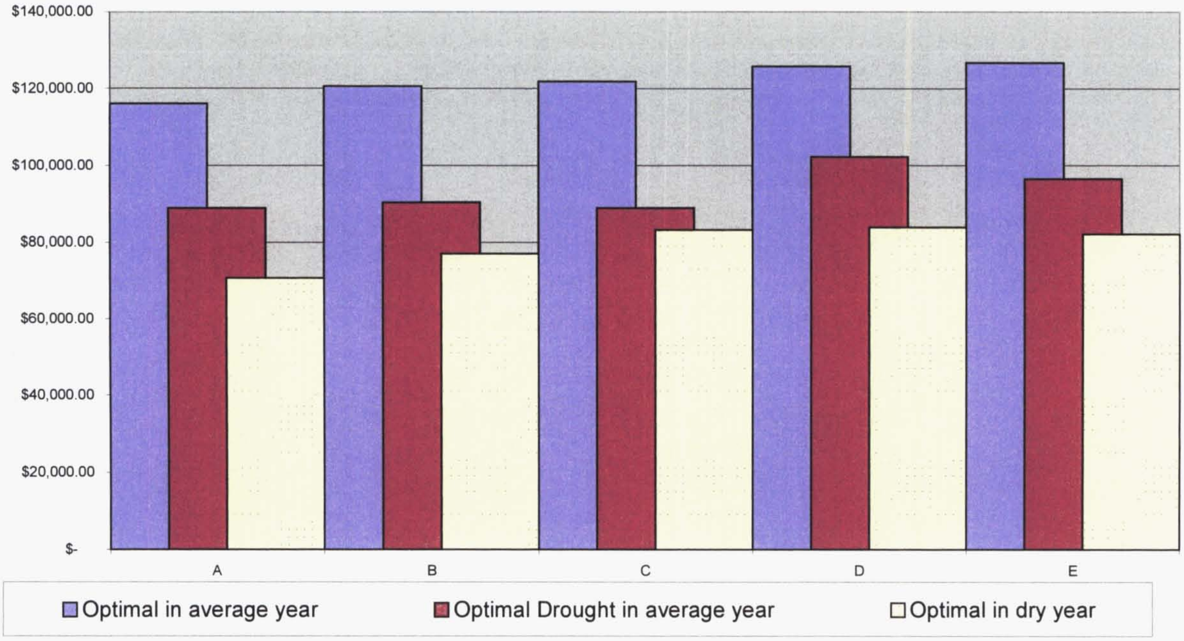

Figure 6.15 farm surplus after taxes and living expenses between the optimal solution for average climatic conditions, drought optimal plans under average climatic conditions and optimal plans under drought conditions.

Under normal conditions plan E appears as the most profitable as was already discussed in section 5.1. However, when comparing the optimal plan under dry years forced into the model for a normal year, plan D appears as the most profitable in both scenarios under drought and also when forced under normal conditions.

Comparing the optimal under dry conditions of all the plans with the same plan under normal conditions, the model predicted that plan C has the lowest income variability (6.5%), and plan A showed the highest income variability with 20.5%. It is interesting to note that the plan with the largest income variability is also the only one which includes some cash crop in its optimal plan.

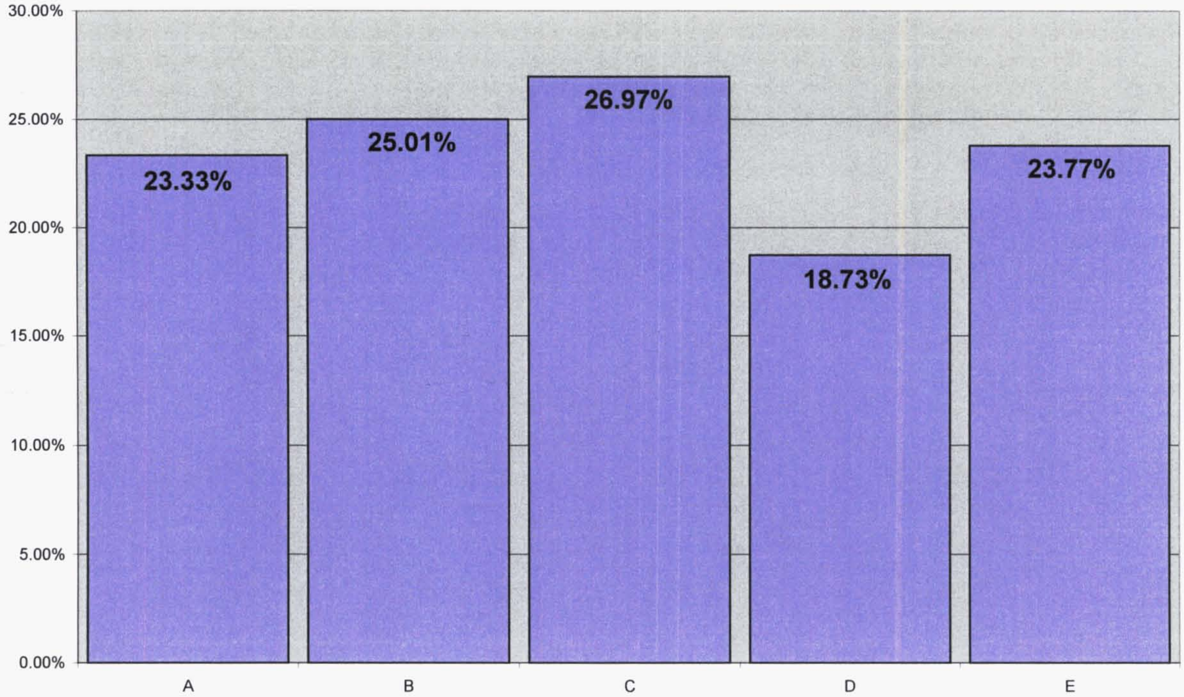

Figure 6.16 Opportunity costs of maintaining a drought optimal plan under normal climatic conditions compared to the optimal plan under these conditions

As shown in the figure above, the opportunity cost ranges from a 26.97% loss for plan C to 18.73% for plan D. The lower opportunity cost of plan D is because the drought strategy only decreases 26.8% the number of dairy cows of the optimal solution whereas the other plans the decrease in cow numbers from 30.9% (Plan A) to 34.5% (Plan C).The results are presented in Table 6.8.

Table 6.8 Optimal plans for normal years compared to optimal plans for dry years but under normal climatic conditions

	A		B		C		D		E	
	Optimal	Optimal Drought	Optimal	Optimal Drought	Optimal	Optimal Drought	Optimal	Optimal Drought	Optimal	Optimal Drought
Gross margin	$137,315.86	$109,260.41	$142,920.15	$111,084.77	$142,399.06	$109,225.94	$146,424.78	$122,361.67	$147,366.95	$117,007.39
Surplus after tax and living expenses	$115,986.93	$88,927.97	$120,531.34	$90,390.81	$121,840.44	$88,980.33	$125,834.91	$102,266.92	$126,770.13	$96,641.86
Surplus after tax and living expenses per ha	$579.93	$444.64	$602.66	$451.95	$609.20	$444.90	$629.17	$511.33	$633.85	$483.21
Difference		-23.3%		-25.0%		-27.0%		-18.7%		-23.8%
Land use pattern										
Pangola grass	25.3	16.1	37.1	41.7	45.8	41.2	46.3	41.7	46.1	47.6
Silage Campo	14.26	17.4	10.2	8.3	4.2	8.8	3.7	8.3	3.9	2.4
Ground nuts	10.5	16.5	3.7	0	0	0	0	0	0	0
Gatton panic grass	130.4	130.4	125	125	115.4	115.4	115.4	115.4	115.4	115.4
Silage Monte	15.58	19.6	25	25	34.6	34.6	34.6	34.6	34.6	34.6
Oats	10.5	16.5	10.8	8.3	4.2	8.8	3.7	8.3	3.9	2.4
Stocking rate AU/ha	2.1	1.6	2.2	1.5	2.2	1.5	2.3	1.7	2.3	1.5
Bulls	7	5	7	5	7	5	7	5	7	5
R1y replacements	37	25	39	37	40	26	41	30	41	28
R2y replacements	35	24	37	25	38	25	39	28	39	26
Dairy cows	230	159	244	163	249	163	254	186	256	173
Milk production per farm (Thousands of litres)	926,004.00	640,524.00	981,949.00	656,639.00	1,003,607.00	656,639.00	1,024,081.00	749,293.00	1,031,201.00	696,923.00
Milk sold per ha (Thousands of litres)	4,630.02	3,202.62	4,909.75	3,283.20	5,018.04	3,283.20	5,120.41	3,746.47	5,156.01	3,484.62

Table 6.8 (contd)

	A		B		C		D		E	
	Optimal	Optimal Drought	Optimal	Optimal Drought	Optimal	Optimal Drought	Optimal	Optimal Drought	Optimal	Optimal Drought
Bales of hay made[14] and sold	0	477	0	733	0	815	0	379	0	379
Bales of hay bought	0	0	23	0	0	0	0	0	0	0
Supplement feed use										
Total mix formula (tonnes of DM)	373.74	195.8	404.242	198.503	420.433	198.52	425.642	228.64	438.716	210.521
Total grain (tonnes)	104.86	54.94	113.42	55.69	117.965	55.69	119.43	64.16	120.329	59.1144
Total silage tonnes of DM	158.29	168.87	177.062	168.635	209.02	224.318	207.199	222.638	208.095	202.72
Total high value feed used per lt of milk sold (gr DM/l)	0.503	0.381	0.513	0.377	0.522	0.377	0.518	0.380	0.528	0.377

[14] Bale of 350kg.

6.5 Sugar cane experiment

As discussed in Chapter 4 section 4.3.5, under tropical conditions, whole sugar cane-based systems have proven to be technically and economically a very attractive solution for small and average dairy or dual purpose farms where areas for fodder are limited (Chenost & Sansoucy, 1991)

In the Central Chaco a special cropping system has been developed for sugar cane in dairy farms. However its adoption is still low. To explore the likely impact of introducing sugar cane as a regular forage crop in the farming systems of the Central Chaco the model was rerun introducing sugar cane activity under different yield assumptions (From 12.5 tn DM/ha up to 30 tn DM/ha). The model was then rerun with the sugar cane activity set at 6ha which is similar to current observed values (A. Cabrera personal communication, 2005).

The calculated gross margins for this activity both using 'own machinery' or contractors are shown in Tables D.20 and D.21.

An upper limit of 50% of total medium quality feed demand was allocated to feeding sugar cane to prevent dry matter intake depression that occurs when feeding diets with an high level of sugar cane content (de Souza Mendoca et al., 2004).

Sugar cane can be purchased at $0.07 per kg fresh matter. Assuming a 26% DM content gives $0.26 per kg DM. This is more expensive than even high quality feeds in the area of study such as sorghum grain ($0.14), or even commercial dairy concentrates ($0.21).

The optimal solutions under these different scenarios are shown in Table 6.9.

Table 6.9 Optimal plans under different sugar cane yields contrasting with observed values in the Central Chaco.

	Yield assumptions in tonnes of DM								Optimal plan at observed level
	12.5	15	17.5	20	22.5	25	27.5	30	
Total gross margin	$191,827	$196,962	$199,968	$202,653	$204,616	$206,083	$207,111	$207,915	$177,129
Surplus after taxes and living expenses	$157,152	$163,887	$167,570	$170,219	$172,155	$173,593	$174,621	$175,429	$151,069
Gross margin per ha	$959.14	$984.81	$999.84	$1,013.27	$1,023.08	$1,030.41	$1,035.56	$1,039.57	$885.65
Difference with observed value	4%	8%	11%	13%	14%	15%	16%	16%	-
Land use pattern									
Sorghum for silage Campo (ha)	4.6	6.2	6.5	5.1	3.7	2.6	1.8	1.2	6.1
Ground nuts (ha)	12.6	12.1	11.9	8.2	4.6	1.6	1.2	1.8	0
Sesame seed (ha)							1.2	2.7	0
Pangola 15 year rotation (ha)	0.6	4.6	5.7	13.5	21.2	27.7	29.3	29.3	37.9
Sugar cane (ha)	32.2	27.1	25.9	23.2	20.5	18.2	16.4	15.1	6
Oats (ha)	4.6	6.2	6.5	5.1	3.8	2.6	3	3.9	6
Sorghum for silage Monte (ha)	34.7	34.7	34.6	34.6	34.6	34.6	34.6	34.6	34.6
Gatton (ha)	115.4	115.4	115.4	115.4	115.4	115.4	115.4	115.4	115.4
Total hired labour (Man day units)	1768	1789	1814	1789	1757	1729	1727	1735	1334
Livestock numbers									
Rising one year replacement	59	60	61	61	61	61	61	61	52
Rising two year replacement	56	57	58	58	58	58	58	58	49
Dairy cow 450 kg lw producing 4500 L	365	377	379	379	379	379	379	379	326
Bull A	0	8	11	11	11	11	11	11	10
Bull B	11	3	0	0	0	0	0	0	0
Total silage	210.477	215.811	216.901	212.156	207.529	203.584	200.93	198.911	215.383
Total sugar cane fed in tonnes of DM	402.921	407.074	453.97	463.27	460.29	453.75	452.11	452.11	165

Table 6.9 (contd)

	Yield Assumptions in tonnes of DM								Observed level
	12.5	15	17.5	20	22.5	25	27.5	30	
Total concentrate feeding (tonnes of DM)	638.16	658.189	630.464	611.495	600.856	593.976	592.714	592.714	570.335
Total grain fed (tonnes of fresh matter)t	179.058	184.683	177.897	171.576	168.591	166.771	166.311	166.311	160.011
Hay buying	35	9	0	0	0	0	0	0	0
Fed hay	35	9	0	0	0	0	0	0	0
Use of high quality feed as medium quality feed	0	0	0	0	0	0	0	0	0
January to March	60.222	62.135	62.456	52.795	43.361	35.327	33.309	33.309	53.844
April to June	55.618	56.019	17.451	3.699	0	0	0	0	48.146
July to September	51.94	54.694	55.35	55.35	55.35	55.35	55.35	55.35	47.717
October to December	71.111	73.37	73.75	73.75	73.75	73.75	73.75	73.75	63.58
Total high quality feed used as medium quality feed (tonnes of DM)	238.891	246.218	209.007	185.594	172.461	164.427	162.409	162.409	213.287
Total milk production (thousands of litres)	1,470.915	1,517.649	1,525.498	1,525.498	1,525.498	1,525.498	1,525.498	1,525.498	1,315.141
Milk production per ha (l/ha)	7,355	7,588	7,627	7,627	7,627	7.627	7,627	7,627	6,575
Difference in milk production compared to observed values (%)	11.8%	15.4%	16%	16%	16%	16%	16%	16%	-
Marginal value product (MVP) Campo April2	$680.60	$540.66	$465.98	$361.64	$321.32	$314.65	$240.01	$240.01	$0.00
MVP Monte March	$824.12	$680.55	$603.97	$507.26	$460.21	$452.43	$379.17	$378.43	$688.01
MVP High quality feed January to March	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17
MVP Medium quality feed October to December	$0.38	$0.31	$0.28	$0.23	$0.22	$0.21	$0.00	$0.00	$0.25
MVP Medium quality feed July to September	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.18	$0.18	$0.00
MVP Low quality feed October to December	$0.07	$0.07	$0.06	$0.02	$0.04	$0.04	$0.03	$0.03	$0.00
MVP Sugar cane (tonne of DM)	$100.74	$69.77	$53.32	$38.73	$31.70	$28.13	$21.44	$196.58	$161.85
MVP Silage (tonne of DM)	$355.76	$296.41	$264.74	$220.48	$203.38	$200.55	$168.90	$168.90	$238.24

The model predicts that, with the current resource base, farm productivity will increase with increasing area under sugar cane. However, the optimal solutions for sugar cane with yields comparable to observed values are constrained by water availability in September and not just by the upper limit imposed to sugar cane feeding in all periods. The scarcity of water in September constrains the number of livestock included in the optimal solution, thus constraining the amount of sugar cane that can be used in the system. Thus, a larger area under sugar cane would be selected if either more water is made available. Sugar cane could supply more than 50% of the total medium quality feed demand.

The results show that, assuming sugar cane yields 25 ton DM/ha, 18.2 ha should be planted with sugar cane and this will increase the farm surplus per ha by 14%. If the expected sugar cane yield is 30 ton DM/ha, 15.1 ha should be planted with sugar cane, this will increase the farm surplus per ha by 16%.

Baez, H.,(personal communication, 18 May, 2005) reported that sugar cane could be used to provide up to 70% of the total roughage diet without intake depletion nor milk instability effects. However, for the purpose of this study a more conservative (50%) limit was considered correct. Milk production is expected to increase by 15.9% compared to observed values and the amount of feed bought in decreased by 50 g. per litre of milk sold.

Interestingly, if feeding sugar cane in October to December is constrained to zero, the optimal plan under different scenarios are quite similar to the observed values in the Central Chaco as shown in Table 6.10

Table 6.10 Optimal plans under different sugar cane yields without feeding sugar cane in October to December

Sugar cane yield (kg DM/ha)	12,500	15,000	17,500	20,000	22,500	25,000	27,500	30,000	Observed level
Eat ($)	131,172.88	133,045.24	134,504.66	135,687.85	136,901.53	137,791.94	138,732.89	139,532.30	138,261.38
Gross margin ($)	151,708.26	153,592.29	157,250.24	158,458.97	159,446.13	160,488.25	161,449.25	162,265.68	161,069.62
Difference with observed value	-5.81%	-4.64%	-2.37%	-1.62%	-1.01%	-0.36%	0.24%	0.74%	0.00%
Sorghum for silage Campo (ha)	18.7	19.6	20	20.5	20.6	19.7	20.14	20.5	21.25
Ground nuts (ha)	21.2	21.8	22	22.3	22.3	21.8	22.1	22.3	22.8
Sugar cane (ha)	10	8.6	8	7.2	7.1	8.5	7.8	7.2	6
Oats (ha)	18.7	19.6	20	20.5	20.6	19.7	20.1	20.5	21.3
Sorghum silage Monte (ha)	34.64	34.64	34.64	34.64	34.64	34.64	34.64	34.64	34.64
Gatton (ha)	115.36	115.36	115.36	115.36	115.36	115.36	115.36	115.36	115.36
Total hired labour (man day units)	1306.5	1321	1346	1356	1366	1381	1389	1395	1378
Rising 1 year replacements	46	46	47	47	47	47	47	47	48
Rising 2 year replacements	43	44	45	45	45	45	45	45	46
Dairy 2C	285	288	293	296	296	292	294	296	299
Bull A	9	9							
Bull B			9	9	9	9	9	9	9
Stoking rate AU/ha	3.6	3.6	3.7	3.7	3.7	3.7	3.7	3.7	3.8
Total silage (tonnes DM)	258.13	261.01	262.26	264.08	264.32	261.4	262.84	264.1	266.5
Sugar AprJune (tonnes DM)	90.31	92.68	95.79	97.3	113.02	111.54	112.28	112.91	114.2
SugarJulSep (tonnes DM)	34.73	36.85	44.98	46.37	46.52	100.06	101.55	102.82	50.8
Total sugar (tonnes DM)	125.04	129.53	140.77	143.67	159.54	211.6	213.83	215.73	165

Table 6.10 (contd)

Sugar cane yield kg DM/ha)	12500	15000	17500	20000	22500	25000	27500	30000	Observed level
Total concentrate formula (tonnes DM)	497.26	503.91	512.92	517.15	507.55	464.12	467.6	470.47	511.76
Total grain (tonnes)	139.5	141.39	143.9	145.09	142.37	130.21	131.2	132.017	143.64
Hay buying (350kg bale unit)	0	0	0	29	29	29	29	29	29
Fed hay				29	29	29	29	29	29
Buy replacement (%of total required)	25%	25%	25%	25%	25%	25%	25%	25%	25%
Use of high quality feed as medium quality feed									
January to March (tonnes DM)	46.942	47.573	48.401	48.803	36.43	35.05	35.742	36.329	37.526
April to June (tonnes DM)	41.975	42.539	44.702	45.073	45.113	0	0	0	43.577
July to September (tonnes DM)	41.601	42.16	41.745	42.092	42.129	41.577	41.854	42.089	42.568
October to December (tonnes DM)	55.43	56.175	57.153	57.627	57.679	56.922	57.301	57.623	58.28
Total high feed used as medium quality feed (Tonne DM)	185.95	188.45	192.001	193.595	181.351	133.549	134.897	136.041	181.951
Totalmilk (Thousands of litres)	1146.5	1161.8	1182.2	1192.02	1193.1	1177.4	1185.3	1191.9	1205.5

These results suggest that, currently, farmers might not be feeding sugar cane in the period October to December. The reason could be that they do not have enough sugar cane available for this period or that the quality of the sugar cane during this period is such that it is prevented from use as forage (H. Baez, personal communication, 2005)

To conclude, the results of this set of experiments show that there is potential for increasing the farm system performance by increasing the percentage of Campo soils under forage sugar cane. Furthermore, research on this specific forage are required for the area of study. In particular, it would be important to:

1. determine the exact upper limit below which no depression on voluntary intake is produced and maximum energy conversion efficiency is achieved;
2. determine the effects that other forage sources including grass legume mixtures, Leucaena hedge-row systems and sorghum silage could have in regard to the

undesirable depression on voluntary intake and cellulose digestibility that occur with high levels of sugar cane feeding;

3. import improved genetic material;
4. determine the best rotations and rattooning length;
5. determine the best harvesting and conservation systems.

6.6 Introduction of grass-legume mixtures in the farm systems

It has been argued that a strategy for improving the farm system productivity and sustainability would be the inclusion of legume species in pastures (Crowder & Chheda, 1982; Cadish et al., 1994). There have been several studies in the area of study and around the world that have shown that there is a potential advantage in including legumes in grazing systems. In the Central Chaco attempts to increase pasture yield with nitrogen fertilization have shown to be uneconomical because of the low moisture availability, high temperatures and high fertilizer costs (Glatzle, 1999).

Legumes not only fix nitrogen to the soil, which increases pasture and subsequent crop yield production, but also provide protein to the grazing animal, hence, improving productivity per unit of area. It has been argued that increased animal production from legume based pasture would eliminate the need for further deforestation (Mannetje, 1997).

Legume species adapted to the local conditions have been tested by the Central Chaco Research station during the nineties and, based on their experiences, general recommendations have been made. Herbaceous legumes are more adapted to sandy (Campo) soils whereas scrub legume *Leucaena leucocephala* is the best adapted legume species for heavy (Monte) soils (Glatzle, 2004).

The set of experiments carried out in this section were undertaken in two phases. Firs the effect of introducing companion legume for Pangola pasture was explored. Second, the effect of introducing the Leucaena-Gatton panic hedgerow system was explored.

Although there have been several trials comparing animal performance under pure and mix pasture in the area (Tables 6.11 & 6.12) there is no data available on grass-legume pasture yield per hectare during different periods of the year. Thus, some indirect approximations were required.

Table 6.11 Average liveweight gain per period without supplementation at a stocking rate of one animal unit per ha from a five year trial on Campo soils

	January to March	April to June	July to September	October to December	Total
Pangola-legume	101.528g	71.155g	34.335g	63.37g	270.39kg
Pangola	85.2985g	64.7525g	28.22g	59.3075g	237.58kg
%Difference	19.0%	9.9%	21.7%	6.8%	13.8%

Source: A. Glatzle personal communication, August 24, 2004.

Table 6.12 Liveweight gain per ha without supplementation from a grazing trial from 15/07/03 to 15/04/04

	Liveweight gain per ha
Gatton panic	211
Leucaena-Gatton Panic hedgerow system	476
% Difference	126%

Source: INTTAS, 2004.

The overall effect of introducing legumes in all grass pasture can be defined as the combined effect of more feed available, improved nutritional value of the forage and increased voluntary intake. For the purpose of this study it was assumed that the difference in liveweight gain was exclusively related to the availability of extra feed.

6.6.1 Pangola-legume

The estimated difference in feed available per period was approximated using the energy value of weight gain (AFRC, 1993)which, for a steer of 400kg lw, is 135.3MJ. This equals 18 units of low quality feed (7.5MJ/kg DM) 14.6 units of medium quality feed (9.25MJ/kg DM) or 12.3 units of high quality feed (11MJ/kg ME). According to Table 6.11 this will increase the amount of utilizable DM from 4,020 to 4,521 kg DM.

Table 6.13 Extra feed availability per period estimated utilizing the energy value of weight gain

Utilizing energy value of liveweight gain	January to March (High quality)	April to June (Medium quality)	July to September (low quality)	October to December (Medium quality)	Total
Difference in kg of liveweight gain	16.2	6.48	6.12	4.06	
Extra units of feed	199	95	110	59	501

According to Glatzle (1999) the yield of sorghum for silage improves to almost 40% if the previous cover was Pangola with legumes compared with a Pangola pasture alone (Glatzle, 1999). Thus, the coefficients of the sorghum for silage in Campo soils were modified accordingly. It was assumed that the first crop increased by 40% whereas the yield of the second and third subsequent crop remained unaffected.

As it can be argued that Pangola-legume mixtures can replenish fertility faster than Pangola pasture alone, the use of shorter pasture phases would be economically sound with more land available for cropping. Thus, five different activities representing five different rotation lengths under pasture were developed and used for this set of experiments. The estimated gross margin for these activities were derived from the gross margin displayed in Table F. 3.

Table 6.14 shows the result of forcing into the model the different rotation lengths and comparing them with the optimal that did not include legumes.

The results predict that longer rotations for Pangola-legume pastures are more profitable and rotation length was, indeed, constraining the optimal solution. The total milk production is expected to increase by 5.3% with a 20 year rotation length. Furthermore, the introduction of Pangola-legume pasture improves the total gross margin compared to the optimal solution without legumes by 5% with rotations of 20 years; 1.67% with 15 year rotations and by 0.61%with a 10 year rotation.

Table 6.14 Optimal plans for Pangola-legume with different rotation length compared to the optimal plan without legumes

	Pangola legumes 20 year rotation	Pangola legumes 15 year rotation	Pangola legumes 10 year rotation	Pangola legumes 8 year rotation	Pangola legumes 5 year rotation	Without legumes
Farm surplus after taxes and living expenses	$133,096.49	$132,087.70	$130,563.70	$129,242.87	$125,169.37	$126,751.80
Total gross margin	$154,507.05	$153,486.79	$151,945.46	$150,609.50	$146,489.02	$148,100.44
Gross margin per ha	$772.54	$767.43	$759.73	$753.05	$732.45	$740.50
Difference in gross margin per ha	4.33%	3.64%	2.60%	1.69%	-1.09%	0.00%
Land use						
Sorghum Campo (ha)	6.4	6.1	5.7	5.3	4.2	3.9
Pangola with legumes (ha)	43.6	43.85	44.28	44.66	45.78	0
Pangola (ha)	0	0	0	0	0	46.1
Oats (ha)	6.4	6.1	5.7	5.3	4.2	3.9
Sorghum for silage Monte (ha)	34.6	34.6	34.6	34.6	34.6	34.6
Gatton 10 (ha)	115.4	115.4	115.4	115.4	115.4	115.4

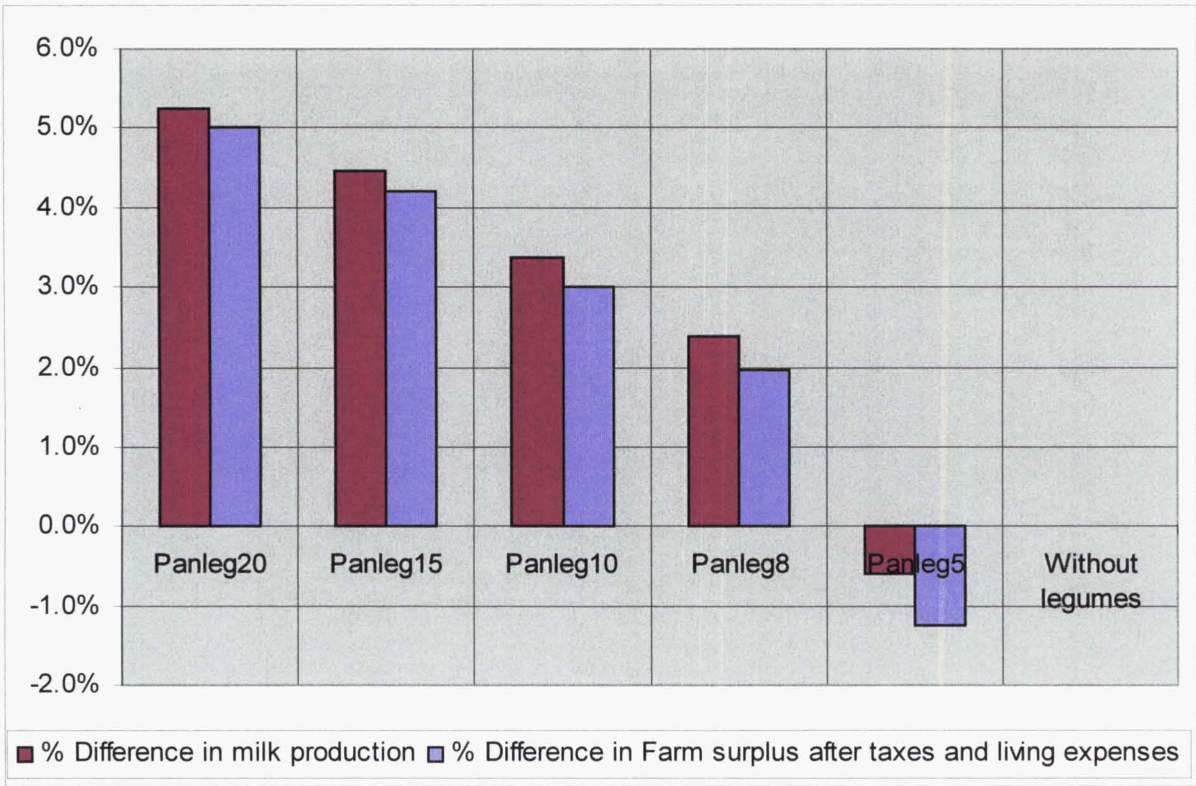

Figure 6.17 Difference in gross margin per ha and total milk production for different scenarios of Pangola-legume pasture compared to the optimal plan without legumes

6.6.2 Gatton panic-Leucaena hedgerow system

The fact that the only data available on the Gatton-leucaena hedgerow system in the Chaco has no data for one trimester of the year imposes limitations on the accuracy that can be expected when predicting the year around supply of this activity. Therefore, it was judged correct to combine three different yields of Gatton and three different yields of leucaena and explore their effect on the farm system. The yield assumptions are contained in the table below

Table 6.15 Yield assumptions explored.

Yield combinations explored		Leucaena yield as % of eatable yield of a high density stand. (100%= 8,832kg DM/year)*		
		Low 40%	Medium 59%	High 79%
Gatton yield as % of a pure Gatton panic pasture yield	80%	**G80LL** = Gatton 80% of normal yield, leucaena low yield	**G80LM** = Gatton 80% of normal yield, leucaena medium yield	**G80LH** = Gatton 80% of normal yield, leucaena high yield
	65%	**G65LL** = Gatton 65% of normal yield, leucaena low yield	**G65LM** = Gatton 65% of normal yield, leucaena medium yield	**G65LH** = Gatton 65% of normal yield, leucaena high yield
	50%	**G50%LL** = Gatton 50% of normal yield, leucaena low yield	**G55LM** = Gatton 50% of normal yield, leucaena medium yield	**G65LH** = Gatton 50% of normal yield, leucaena high yield

* Cabrera and Glatzle, 1996

Leucaena yield per period was approximated using data from a cutting trial of High density Leucaena stand (Cabrera and Glatzle, 1996) Gatton panic growth pattern was assumed to remain unchanged. This might actually change due to complementary and/or competitive relationships that might arise between the two components of the system in different periods of the year. Some other assumptions were also used, including:

- Leucaena-Gatton panic hedgerow system has a rotation length of 20 years.
- Hay making activity will be constrained to 1000 bale units. This ensures an upper limit of half the area under pasture can be utilized for hay production. This measure was taken to prevent the model from choosing the extra feed provided by leucaena for round bale hay production.
- Sorghum yield in both types of soils remains unchanged as in only grass systems.
- There is no 10% area shut for Gatton seed production per year in the gross margin calculation

The results of these experiments are shown in summarized form in Table 6.16

Table 6.16 Optimal plans for Different scenarios with Leucaena-Gatton panic hedgerow system compared to the optimal plan without legumes

	G80LH	G80LM	G80LL	G65LH	G65LM	G65LL	G50LH	G50LM	G50LL	Without legumes
Farm surplus after taxes and living expenses	$230,766.03	$211,581.07	$181,491.65	$225,848.33	$204,324.67	$172,928.38	$218,920.49	$194,457.37	$162,668.88	$126,751.80
% Difference	82%	67%	43%	78%	61%	36%	73%	53%	28%	0%
Total gross margin	$253,863.27	$235,255.05	$206,162.60	$248,820.63	$229,579.79	$197,380.17	$241,715.09	$219,459.83	$186,858.07	$148,100.44
Total gross margin per ha	$1,269.32	$1,176.28	$1,030.81	$1,244.10	$1,147.90	$986.90	$1,208.58	$1,097.30	$934.29	$740.50
Land use										
Sorghum Campo (ha)	23.5	25	23.2	25	25	22.2	25	25	21	3.9
Pangola with legumes5 (ha)	0	0	8.8	0	0	14.2	0	0	19.8	
Pangola (ha)	0	0	0	0	0	0	0	0	0	46.1
Ground nuts (ha)	25	25	18	25	25	13.6	25	25	9.2	
Sesame (ha)	1.5	0	0	0	0	0	0	0	0	0
Oats (ha)	25	25	23.2	25	25	22.2	25	25	21	3.9
Sorghum for silage Monte (ha)	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	34.64
Gatton with leucaena (ha)	130.4	130.4	130.4	130.4	130.4	130.4	130.4	130.4	130.4	0
Gatton 10 (ha)	0	0	0	0	0	0	0	0	0	115.4
Total hired labour (man day units)	1554	1539	1384	1546	1537	1327	1545	1507	1271	968
% Difference in labour demand	61%	59%	43%	60%	59%	37%	60%	56%	31%	0%
R1y replacements	61	60	55	61	60	53	61	59	52	41
R2y replacements	58	57	52	58	57	51	58	56	49	39
Buy replacements	19	19	17	19	19	17	19	19	16	13
Dairy 2C	282	378	256	379	289	248	379	274	241	256
Dairy 2D	96	0	87	0	86	84	0	93	82	0
Bull A	11	7	0	11	0	0	11	0	0	8
Bull B	0	4	10	0	11	10	0	11	10	0
Stocking rate AU/ha	4.0	4.0	3.4	4.0	4.0	3.2	4.0	3.9	3.0	2.3
% Difference in Stocking rate	75%	75%	50%	76%	74%	40%	76%	70%	32%	0%
Milk production per ha (L/ha)	7,612	7,588	6,901	7,627	7,570	6,702	7,627	7,401	6,504	5,156

The results of these trials shows that the introduction of Leucaena-Gatton panic hedgerow systems are expected to increase the productivity of the farm system quite dramatically with farm surplus expected to increase from 24% with the most conservative scenario explored (G50LL) and up to 82% for the most optimistic scenario (G80LH).

The land use pattern on Campo soils are expected to change with larger areas being used for sorghum for silage production and oats for grazing. Because of the fertility balance constraint, under low Leucaena-Gatton panic yield scenarios Pangola with legumes are included in the system with a five year rotation length. Whereas with increasing levels of Leucaena-Gatton panic yields an increasing area under ground nuts (replenishing crop) is expected to appear in the optimal plan (until its upper limit of 50% of total cropping area). This crop might have been replaced by other replenishing crops, such as annual legumes, if they would have been made available.

In Monte soils the result shows that there are opportunities for increasing farm profit by decreasing the rotation length under Leucaena-Gatton panic, in particular, if low yields are expected.

Milk production showed a large increase with higher yields of Leucaena yields which ranges from 26% to 48% for the conservative and optimistic scenarios, respectively. Another interesting outcome of introducing this activity is the reduction of supplements that must be bought in per L of milk produced. The model results show that between 28% and 42% decrease in the amount of concentrate fed per litre sold could be expected.

Labour demand increases between 31% and 61%, this is a combined effect of the increased stocking rate, more area under annual cropping and more silage fed per year.

In the area of study there is also a market for Leucaena seed. This opportunity plus the possibility of harvesting the Gatton panic seed component is an alternative that is currently utilized but was not included in the model.

6.7 Farm profit

As beef and dairy systems have different capital requirements it is necessary to include this fact into the optimal plans for both systems in order to obtain a fairer comparison. This will also provide a more complete picture of the farm profit that can be expected in the system studied.

The capital and fixed cost calculations are included in Appendix Q. In Table 6.17 the farm profit after discounting opportunity cost of capital (land, livestock, buildings and machinery) and fixed costs are presented for optimal plans generated by the model and compared to the constrained optimal plan obtained forcing the activity levels of the model at observed values in two case study farms.

Table 6.17 Farm profit per ha after taxes, opportunity cost of capital and fixed costs

	Interest rate	
Dairy	10%	4.5%
Optimal plan	$272.04	$466.25
Case study 2	-$328.83	-$134.62

	Interest rate	
Beef	10%	4.5%
Optimal plan	-$170	-38.77
Case study 1	-$185.42	-$54.17

The results in the tables above show that the optimal plan for dairy is profitable using the current interest rate of 10%. Note that inflation is frequently at least 5% giving a real rate of approximately 5%. However, the result from case study 2 shows a loss under both interest rates. The wide difference between the optimal plan farm profit and the observed typical farm profit is because the optimal plan is actually very different from what is currently being achieved in the area of study. This difference includes the use of seasonal calving, selling all calves at birth, the acquisition of 25% of all replacements from the market, and the use of a small frame high yielding cows to name the main differences.

On the other hand, the results from the optimal solution for beef systems and the observed value for a beef and crop farms show that neither are profitable under current market conditions regardless of the interest rate used. There is a close similarity between the result of the optimal plan for beef and the observed value from the case study farm and this is because both systems are quite similar in their activity levels. Thus, it can be concluded that beef systems are not profitable under the current market conditions.

The results suggest many dairy and beef farmers in the Central Chaco might be currently losing money and it is be a more profitable option to sell the farms and put all the capital into a saving account. The current study does not include the cost involved in shifting from the current situation to the optimal plans. Therefore, a sensible recommendation in this regard can not be given.

6.8 Summary

This chapter contains the results and discussion of all the experiments carried out with the linear programming model. Different experiments were utilized to study different aspects of the farming systems and to gain an insight on the system behaviour under different conditions.

The effects of changing the availability of different resources were explored by using different rotation lengths, simulating a drought scenario, changing the prices of milk and beef, selling all calves during the first week of life, introducing forage sugar cane and, finally, introducing legumes into the farming systems.

The results provided valuable information in relation to how different components of the farm system interact with each other. Moreover, constraints and opportunities for improvement were identified and the usefulness of the chosen research method was demonstrated.

The following chapter contains the conclusions, limitations and recommendation for further research.

Chapter 7

CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

7.1 Summary

The overall objective of this research was to identify farming systems that will improve farm productivity in the Central Chaco of Paraguay through changing management practices and adopting new technologies. This, in turn, will lead to poverty alleviation in the region through employment generation, identifying technologies for a sustainable increase in food production, and protecting the environment through better management of natural resources. Specifically, this study aimed to develop a whole farm system model for a typical farm in the Central Chaco, and then use this to experiment with different variables, thus, exploring optimal farming systems for the given set of resources and constraints.

In Chapter 2 the main features of Paraguay in relation to geographic location, economy, climate, farming systems were described. Furthermore, the subject of this study and the Central Chaco as a region were described including geographic location, climate, population, water resources, soils and farming systems. The issues of scarcity of water, risk of wind erosion, salinity build up and soil fertility depletion due to mismanagement were highlighted as well as the problem of the increasing socio-economic problems arising from the increasing population in the area (which increases the demand on water and employment opportunities).

In Chapter 3 the structure of the linear programming model developed for this research was described, and the relationships assumed for the model were discussed. Chapter 4 describes in detail the structure and relationships assumed for the nutritional sub-model. Chapter 5 contains a description of the procedures used for model validation. Predictive experiments were carried out with the three case study farms. It was concluded that the model was adequate for its purpose, following some adjustments.

In Chapter 5 the experiments that were carried out with the model were described and the results presented and discussed. Experimentation proceeded in six stages. The first stage explored the optimal pasture rotation length. Plans were obtained for seven different rotation length combinations. The purpose of this experiment was to identify the most profitable pasture rotation lengths both in Campo and Monte soils.

In the second stage, the model was used to generate optimal plans for a representative farm (100 ha effective) under different soil type ratios from 0% to 80% Campo soils (sandy loam). This reflects the variability in soil type ratio observed in the area of study.

In the third stage, the model was used to explore the farm system sensitivity to changes in milk and beef prices. The purpose of these experiments was to gain an understanding of the impact of beef and milk prices on the farming system and to identify the opportunity cost of 'on farm' rearing of all produced calves under different milk and beef price scenarios.

In the fourth stage the coefficients of crops and pastures yields, water supply and bought in supplements (hay) were modified in order to simulate an average drought scenario. Different pasture rotation lengths were forced into the model and optimal plans under these scenarios were obtained. These optimal plans under drought scenarios were then forced into the model with coefficients for average climatic conditions and the economic implications of maintaining a drought optimal plan under normal weather conditions was assessed.

The fifth set of experiments explored the introduction of forage sugar cane into the farming system. Sugar cane yield was changed parametrically and the model re run. The optimal plans were compared with an optimized plan with sugar cane set at observed typical levels. Finally, the period for sugar cane feeding was constrained to the dry season and the results were compared again with the optimal plan at the observed levels. The purpose of these experiments was to explore the impact of introducing this forage crop in the farm system and to test the optimality of the currently observed level.

Finally, the last set of experiments explored the impact of introducing legume-grass mixes in the farming system. This set of experiments was carried out in two phases. The first explored the impact of introducing grass legume mixes in Campo soils under four different pasture rotation lengths. These results were compared to the optimal solution without legumes. The second sub-set of experiments explored the impact of introducing Leucaena-Gatton panic hedgerow systems on Monte soils. As there was no information available, in relation to expected DM yield per ha, different scenarios were generated in order to cover a wider range of expected yields. The conclusions drawn from all these experiments are summarized below.

Conclusions

This study was the first attempt to study the farm systems of the central Chaco from a farm system perspective. It shows that linear programming is a useful tool for planning and provides insight into the behaviour of different components and their interrelationships in the farm system. Furthermore, the modelling approach has not yet been used in the Central

Chaco. It opens a new range of possibilities for the researchers in the area. For example, capital and money can be saved if field research is better designed once the modelling approach has identified which options have the highest potential of improvements.

The study of a farm from a system perspective brings together knowledge generated in different areas of expertise and, as such, provides a whole picture of the farm with a more reliable outcome compared to other methods such as budgeting or partial budgeting. The more familiar the model developer has with the system simulated the more accurate the model becomes.

The results of all experiments emphasised that a seasonal calving pattern is not only technically but also economically sound under the local conditions of the Central Chaco. This system guarantees a close match between pasture supply and pasture demand. 'On farm' prepared concentrate was the most important source of high quality feed and cereal grain was also utilized up to the imposed upper limit. The model consistently predicted that at current market prices, the optimal strategy is a dairy farm with dairy cows (450 kg lwt) yielding 4,500 L per lactation and calving in the month of July. Buying replacements up to the 25% upper limit is more profitable than rearing own replacements and that even at zero dollar price it pays to dispose all non replacements calves during the first week of life.

The result of the first set of experiments showed that on Campo soils a pasture rotation length of 20 years was the optimal strategy whereas on Monte soils a rotation length of 10 years appears as most profitable. It was concluded that more research should be undertaken in relation to the feasibility of shorter rotations lengths on Monte soils. However, it was also concluded that there might be other activities not included in the model that could change the optimal strategy on Campo soils, such as annual legumes other than ground nuts.

The second set of experiments highlighted the wide difference that can be expected between farms with different soil type ratios. Increasing the percentage of sandy soils increases, almost linearly, the gross margin per ha and the stocking rate of the farm. Labour demand peaks at 60% sandy soils and slightly declines again at higher percentages of sandy soils as less silage is fed and more area is utilized for direct grazing. It was concluded that special attention must be paid to the soil type ratio when planning new sub-divisions in order to ensure it has a minimum size that could ensure its economic viability.

The results of the third set of experiments explored the sensitivity of the optimal farming system for different beef prices. They had little effect. However, the farm system sensitivity increases when milk prices are lower than 90% of current prices. Under lower milk payouts the optimal solution decreases stocking rates and agriculture becomes increasingly important, with cash crops representing 0 ha under current prices but at 60% of current prices crops increase to 50 ha. Interestingly, the model indicates that even at the highest beef payout and lowest milk payout explored, the optimal strategy is to have a herd comprised mainly of high yielding (4,500 L) small frame cows (450 kg lwt). The optimal plan for beef at 140% of current prices and milk at 70% of current prices includes 10.9% of the dairy herd selected as low yielding (3,000 L) large frame cow (550 kg lwt). The second part of this experiment was to force into the model finishing all calves on the farm. The total gross margins per ha were then compared and result indicated that the opportunity cost of finishing all replacements on farm is more sensitive to milk prices than to beef prices. The opportunity cost ranged from $200 per ha at milk prices at 100% and beef prices at 140% to only $6/ ha for milk prices at 60% and beef prices at 100%.

The results of the fourth set of experiments indicated that a pasture rotation length of 15 years for Campo soils and 10 years for Monte soils would be the most profitable under a drought scenario. The optimal plan for a 10year rotation length for both Monte and Campo soils shows the least variation in gross margin when forced into the model for a normal year. Thus, this is the optimal strategy for those requiring narrow income variations due to climatic conditions. The optimal plan for a pasture rotation length of 20 years for Campo soils and 10 years for Monte soils was the strategy that generated the highest income when adding the results under drought and normal year scenarios. Furthermore, when attempting to run the optimal plans for average conditions in the model with coefficients set for average drought conditions always gave an infeasible solution. This highlighted the need of purchasing extra feed, or selling livestock under a drought scenario. It was concluded that a drought strategy with between 15 and 20 year pasture rotations on Campo soils and 10 years rotation on Monte soils would be both more profitable and less risky than other rotation combinations.

The fifth set of experiments carried out showed that forage sugar cane has a large potential for increasing farm productivity if it can be made available during the dry season and the first half of the rainy season, with increases of 14 to 16% of the total gross margin compared to the result of the optimal plan with sugar cane set at the, current, typical level. Also, the area under sugar cane was constrained by the upper limit of 50% of total medium quality feed demand imposed by the model. This, in turn, was limited by livestock numbers which, in turn, was constrained by water availability. However, if sugar cane is only made available from April to September, the potential to increase profitability compared to the optimal plan of sugar cane, at typical levels, is less than 1%. Thus it was concluded that more research is needed in relation of utilizing sugar cane outside the dry season. The possibility of ensiling sugar cane, for instance, should be explored. Moreover, the exact upper limit for sugar cane in different feed combinations should be explored to make more sensible recommendations.

The last set of experiments explored the implication of including legumes in the farm systems. The model results show that optimal pasture rotation length is not likely to be affected by the introduction of Pangola-legume pasture. Moreover, comparing the optimal solution with the optimal plan for a farm without legumes shows that the introduction of Pangola would increase milk production by 5.3% and the farm surplus after taxes and living expenses per ha is expected to increase by 2.3%. These differences are mainly due to less dependence on bought in concentrates and smaller area under crops as the sorghum yield on Campo soils would improve. The second sub-set of experiments explored the introduction of Leucaena-Gatton panic hedgerow systems assuming different DM yields. The model predicts that under all scenarios explored the farm surplus after taxes and living expenses is expected to increase between 28% and 82%. Milk production is also expected to increase between 26% and 48% for the pessimistic and the optimistic scenarios respectively. The model showed that it is possible to increase the profitability of the farm system by decreasing the rotation length of Leucaena which for this experiment was set at 20 years. However, Leucaena-hedgerow systems are grown as permanent crops rather than part of a rotation program. Therefore, shorter rotations were not included in this experiment.

Finally, by including fixed costs and opportunity cost of capital in the economic analysis it was shown that many farm units are expected to be unprofitable in the current situation.

Reviewing the experiments carried out, it is clear many areas for future research exist. The introduction of legume species in the farm system appears as an environmentally and economically sound strategy as it will not only improve productivity but also improve the sustainability of the resource system.

Limitations of the study

This study used a linear programming model that was developed with data collected in the area of study. This approach assumes that the results generated for the model can be applied to all farms in the region. Although the area in Central Chaco within the Mennonites colonies is quite homogeneous in terms of natural resources, there are still differences between farms related to the farmers' managerial skill and personal preferences. The applicability of this model to a larger region outside the Mennonites colonies might be prevented by lack of year round access to properties and lack of enough capital that could, for instance, prevent the adoption of a dairy activity and by the fact that some properties are outside the range of farms for which the linearity assumption of this mathematical model will hold.

This study showed that a seasonal strategy will increase production efficiency improving the match between energy demand and pasture availability, although this strategy is not available to everyone in the dairy industry as it relies heavily on the local demand of fresh products. Therefore, if a large proportion of dairy farmers move to seasonal production inefficiencies in the dairy plant utilization are likely to arise with marked milk peaks likely to appear during the summer months.

The lack of research data in many fields of the farm systems plus the absence of regular on-farm records constrains the accuracy of the model outcome. For instance, lack of data related to the availability of pasture supply for periods shorter than three monthly periods impacts on the accuracy of the nutritional sub-model because quite different feeding policies could end up with the same growth rate after such a long period of time. This, in turn, limits the alternative livestock management policies that could be explored.

Not all the production alternatives were included in the model. For instance, in the agricultural sector pumpkin seeds, watermelon, broom sorghum, aloe vera, millet, and summer legumes are all possibilities, whereas, in the livestock sector beekeeping, sheep for wool and meat and goat for meat and cheese could be explored. These products were not included in this study because they are not typical to the region, (they are recent introductions in an experimental phase, or their market opportunities are still uncertain) or there was no enough data available that could support their inclusion.

The use of a single utilization rate used for all categories of animals is a simplification of reality. It could be argued that the model would always give preference to a dairy activity because management strategies common in beef production such as utilizing rotational grazing with growing cattle as leaders and breeding stock as followers, can not be represented with the current approach. However, in the area of study rotational grazing is seldom utilized and the most common system is continuous grazing where feed is consumed as it becomes available. This reduces the margin of error. Even so, this unavoidable source of error should still be taken into account when evaluating the outcomes of the model.

This study assumes a steady state scenario and, as such, it does not include the cost of shifting from the current scenario to the optimal plan. This must be considered when interpreting the results. Variations often exist between individual farms. Therefore, each farmer would need to assess the resources available to his/her farm to successfully benefit from the different alternatives available before modifying their management system. Factors such as capital, land, water, machinery and labour availability, as well as the cost of extra infrastructure, all need to be considered.

There are other factors that impact on the farming systems that are difficult to approximate with linear relationships. These include cultural factors. For instance, even though rearing non-replacements is not economic under current market conditions, they might still be reared due, for example to an irregular property shape that prevents the use of the furthest paddock for grazing dairy cows (H. Bergen, personal communication, July 15, 2005).

Suggestions for further research

Although the model represents approximately 3,000 farm units, there are other farming systems present in the area of study. These are:

1. the "Estancia" farm system that has usually more than 1000 ha and is a fully commercial extensive beef production unit.,
2. the "Indigenous community" farm system that is a mixed system of subsistence cropping with some commercial cropping and extensive beef production on communally owned land,
3. the "Small producer" farm system that is usually a mixed farm system smaller than 100 ha partly commercial with some dairy, beef and cropping.

The modelling approach could be applied for these farming systems. Experiences from other parts of the world have shown the usefulness of this approach in gaining an insight into the farming systems and would help the research centres to identify their most limiting constraints and the best options for improvement.

Feed budgeting, as such, is not used yet and should be introduced. However, there is little data about the pasture on offer in different months of the year and pasture utilization rates. Long term grazing and cutting trials should be undertaken to develop a reference database that farmers could utilize when assessing their feed budgets. At a later stage pasture growth could be related to average temperature and rainfall in order to increase the prediction accuracy.

There is no local data related to labour efficiency ratios. This dramatically hampers planning on the farm. More studies are required to assess labour efficiency for different common tasks and strategies to match these standards might be sought. Furthermore, innovative labour arrangements are needed in order to motivate staff, improve labour efficiencies and reduce staff turn-over.

Considering the large inter-annual rainfall variation of the area, it might be worthy exploring probability distributions use in the calculation of each gross margin.

Further information on the fertility replenishing power of different types of crops and pastures mixes is required to develop a database. This could be used to estimate optimal crop rotations.

With a large proportion of Holstein Friesian present in the dairy herd (≥550 kg lwt) that have been selected on dairy systems highly reliant on concentrate feedings, it is likely that they will be less adapted to a grazing production system than, say, New Zealand genetics (450 kg lwt). This inadaptability to local conditions is usually expressed by low milk yields as well as reproductive and metabolic problems. A long term evaluation on the dairy genetics utilized in the area should be undertaken.

As it was consistently shown that rearing all calves 'on farm' is uneconomical, a shift to a seasonal calving pattern will provide many calves in a short period of time. This could create opportunities for farmers to specialize in rearing dairy calves for veal production, or for replacements on dairy farms (under contract or other type of arrangement). This will allow, on the one hand, dairy farmers to specialize and intensify their operation, and on the other, beef farms to specialize in bull beef systems in association with dairy farms. As discussed in Chapter 6 there is, currently, underutilized plant capacity in the killing work of the area of study. The possibility of processing four day old calves could improve plant capacity utilization, thus markets should be sought. Finally, alternative calf-rearing systems should be explored.

Improved techniques for silage and hay production should be developed in order to increase their nutritive value and decrease their cost of production.

As discussed in Chapter 6 section 6.5 there is need for further research in relation to the best cropping, harvesting and conservation system for forage sugar cane. Furthermore, optimal feed ratios for forage sugar cane in combination with other available feeds needs to be studied. Finally, the use of irrigation in this crop could also be explored.

The use of irrigation in the area is currently being studied in different field trials. There is also a need to study the possibility of utilizing deficit irrigation, or strategic irrigation. For example irrigation just prior sowing, with different crops and forages, to assess its feasibility and economic impact.

Lack of research on the behaviour of water stored in artificial ponds ("tajamares') in different periods of the year prevents accurately budgeting the water supply. An increasing need for sensible water use calls for the development of a simulation model.

The use of an improved rain water collection and storage systems is currently being studied. The implication of introducing this new technology in the whole farm system is required.

The model can be utilized in the research centres and extension services as a planning tool for obtaining general recommendations. The model should be updated regularly in response to market and technological changes. Its complexity could also be increased as more information is made available, and a user friendly interface could be developed

Furthermore, a multi-period linear programming model could be developed to explore the optimal plans for both development of unimproved land and conversions, such as, for example, from beef to dairy.

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Appendix A
- Physical data: calculation of the nutritional requirements of livestock

These requirements were based on data sourced from (AFRC, 1993; Kearl, 1982; National Research Council, 2001). A factorial approach was used. Thus, the requirements for the separate processes of maintenance, liveweight gain, milk production, activity level and pregnancy were estimated and then summed. The daily requirements were then aggregated into three monthly requirements. The process was made in a stepwise approach, changing the average metabolic energy content of the diet in order to recalculate the requirement. This was done to take into account the differences in energy efficiency utilization that are expected between feeds with different energy concentration.

ME Requirements of different livestock categories

Expected liveweight curve, calving date and milk production were approximated for a typical breeding beef cow of 450kg liveweight and this was used for calculating the energy requirements. A similar approach was made for all different livestock categories. A spreadsheet, programmed with appropriate formulae, was used for this purpose.

The first step comprised using low quality feed, whenever feed intake was limiting a higher category of feed was made available and the spread sheet recalculated the energy requirement using this higher quality of feed. This procedure was followed until energy requirements match was no longer limited by intake constraints. An example of the spreadsheet is presented below.

Table A. 1 Representation of the spreadsheet programmed to calculate ME requirements[15]

	Days after calving	Liveweight (Kg)	Expected bodyweight change in kg per day	Maintenance requirement in MJ ME/day	Growth requirement in MJ ME/day	Bodyweight loss (Kg)	Milk production requirement in MJ ME/day	Milk production in L/day	Pregnancy requirement	Total energy requirement in MJ/day	Maximum DM Intake in kg DM/day	Total intake in low quality feed 7.5MJ/kg DM	Total intake in medium quality feed 9.25MJ/kg DM	Total intake in high Quality feed >11MJ ME/Kg/DM
1/09/04	1	430.00	0.350	49.311	17.911	0.000	32.598	7.810	0.000	99.821	9.240	13.309	10.791	9.075
2/09/04	2	430.35	0.350	49.340	17.920	0.000	32.761	7.849	0.000	100.022	9.246	13.336	10.813	9.093
3/09/04	3	430.70	0.350	49.368	17.930	0.000	32.925	7.888	0.000	100.223	9.251	13.363	10.835	9.111
4/09/04	4	431.05	0.350	49.397	17.939	0.000	33.090	7.928	0.000	100.426	9.257	13.390	10.857	9.130

[15] The example is a breeding beef cow and the diet energy concentration is 9.25 MJ kg/DM

Table A.1 (contd)

	Days after calving	Liveweight (Kg)	Expected bodyweight change in kg per day	Maintenance requirement in MJ ME/day	Growth requirement in MJ ME/day	Bodyweight loss (Kg)	Milk production requirement in MJ ME/day	Milk production in L/day	Pregnancy requirement	Total energy requirement in MJ/day	Maximum DM Intake in kg DM/day	Total intake in low quality feed 7.5MJ/kg DM	Total intake in medium quality feed 9.25MJ/kg DM	Total intake in high Quality feed >11MJ ME/Kg/DM
5/09/04	5	431.40	0.350	49.426	17.949	0.000	33.255	7.967	0.000	100.630	9.262	13.417	10.879	9.148
6/09/04	6	431.75	0.350	49.454	17.959	0.000	33.421	8.007	0.000	100.834	9.268	13.445	10.901	9.167
7/09/04	7	432.10	0.350	49.483	17.968	0.000	33.589	8.047	0.000	101.039	9.274	13.472	10.923	9.185
8/09/04	8	432.45	0.350	49.511	17.978	0.000	33.756	8.087	0.000	101.245	9.279	13.499	10.945	9.204
9/09/04	9	432.80	0.350	49.540	17.987	0.000	33.925	8.128	0.000	101.452	9.285	13.527	10.968	9.223
10/09/04	10	433.15	0.350	49.568	17.997	0.000	34.095	8.168	0.000	101.660	9.290	13.555	10.990	9.242
11/09/04	11	433.50	0.350	49.597	18.006	0.000	34.265	8.209	0.000	101.868	9.296	13.582	11.013	9.261
12/09/04	12	433.85	0.350	49.625	18.016	0.000	34.437	8.250	0.000	102.077	9.301	13.610	11.035	9.280
13/09/04	13	434.20	0.350	49.653	18.025	0.000	34.609	8.292	0.000	102.288	9.307	13.638	11.058	9.299
14/09/04	14	434.55	0.350	49.682	18.035	0.000	34.782	8.333	0.000	102.499	9.312	13.666	11.081	9.318
15/09/04	15	434.90	0.350	49.710	18.044	0.000	34.956	8.375	0.000	102.711	9.318	13.695	11.104	9.337
16/09/04	16	435.25	0.350	49.739	18.054	0.000	35.131	8.417	0.000	102.923	9.323	13.723	11.127	9.357
17/09/04	17	435.60	0.350	49.767	18.063	0.000	35.306	8.459	0.000	103.137	9.329	13.752	11.150	9.376
18/09/04	18	435.95	0.350	49.796	18.073	0.000	35.483	8.501	0.000	103.351	9.334	13.780	11.173	9.396
19/09/04	19	436.30	0.350	49.824	18.082	0.000	35.660	8.543	0.000	103.567	9.340	13.809	11.196	9.415
20/09/04	20	436.65	0.350	49.853	18.092	0.000	35.838	8.586	0.000	103.783	9.346	13.838	11.220	9.435
21/09/04	21	437.00	0.350	49.881	18.101	0.000	36.018	8.629	0.000	104.000	9.351	13.867	11.243	9.455
22/09/04	22	437.35	0.350	49.909	18.111	0.000	36.198	8.672	0.000	104.218	9.357	13.896	11.267	9.474
23/09/04	23	437.70	0.350	49.938	18.120	0.000	36.379	8.716	0.000	104.437	9.362	13.925	11.290	9.494
24/09/04	24	438.05	0.350	49.966	18.130	0.000	36.561	8.759	0.000	104.657	9.368	13.954	11.314	9.514
25/09/04	25	438.40	0.350	49.995	18.139	0.000	36.743	8.803	0.000	104.877	9.373	13.984	11.338	9.534
26/09/04	26	438.75	0.350	50.023	18.149	0.000	36.927	8.847	0.000	105.099	9.379	14.013	11.362	9.554
27/09/04	27	439.10	0.350	50.051	18.158	0.000	37.112	8.891	0.000	105.322	9.384	14.043	11.386	9.575
28/09/04	28	439.45	0.350	50.080	18.168	0.000	37.297	8.936	0.000	105.545	9.390	14.073	11.410	9.595
29/09/04	29	439.80	0.350	50.108	18.177	0.000	37.484	8.980	0.000	105.769	9.395	14.103	11.435	9.615
30/09/04	30	440.15	0.350	50.137	18.187	0.000	37.671	9.025	0.000	105.995	9.401	14.133	11.459	9.636
1/10/04	31	440.50	0.350	50.165	18.196	0.000	37.860	9.070	0.000	106.221	9.406	14.163	11.483	9.656
2/10/04	32	440.85	0.350	50.193	18.206	0.000	38.049	9.116	0.000	106.448	9.412	14.193	11.508	9.677
3/10/04	33	441.20	0.350	50.222	18.215	0.000	38.239	9.161	0.000	106.676	9.417	14.223	11.533	9.698
4/10/04	34	441.55	0.350	50.250	18.225	0.000	38.430	9.207	0.000	106.905	9.423	14.254	11.557	9.719
5/10/04	35	441.90	0.350	50.278	18.234	0.000	38.623	9.253	0.000	107.135	9.428	14.285	11.582	9.740
6/10/04	36	442.25	0.350	50.307	18.244	0.000	38.816	9.299	0.000	107.366	9.434	14.315	11.607	9.761
7/10/04	37	442.60	0.350	50.335	18.253	0.000	39.204	9.392	0.000	107.792	9.439	14.372	11.653	9.799
8/10/04	38	442.95	0.350	50.363	18.263	0.000	39.596	9.486	0.000	108.222	9.445	14.430	11.700	9.838
9/10/04	39	443.30	0.350	50.392	18.272	0.000	39.992	9.581	0.000	108.655	9.450	14.487	11.747	9.878
10/10/04	40	443.65	0.350	50.420	18.282	0.000	40.392	9.677	0.000	109.093	9.456	14.546	11.794	9.918
11/10/04	41	444.00	0.350	50.448	18.291	0.000	40.796	9.774	0.000	109.535	9.461	14.605	11.842	9.958

Table A.1 (contd)

-	Days after calving	Liveweight (Kg)	Expected bodyweight change in kg per day	Maintenance requirement in MJ ME/day	Growth requirement in MJ ME/day	Bodyweight loss (Kg)	Milk production requirement in MJ ME/day	Milk production in L/day	Pregnancy requirement	Total energy requirement in MJ/day	Maximum DM Intake in kg DM/day	Total intake in low quality feed 7.5MJ/kg DM	Total intake in medium quality feed 9.25MJ/kg DM	Total intake in high Quality feed >11MJ ME/Kg/DM
12/10/04	42	444.35	0.350	50.476	18.300	0.000	41.204	9.872	0.000	109.980	9.467	14.664	11.890	9.998
13/10/04	43	444.70	0.350	50.505	18.310	0.000	41.616	9.970	0.000	110.430	9.472	14.724	11.938	10.039
14/10/04	44	445.05	0.350	50.533	18.319	0.000	42.032	10.070	0.000	110.884	9.478	14.785	11.987	10.080
15/10/04	45	445.40	0.350	50.561	18.329	0.000	42.452	10.171	0.000	111.342	9.483	14.846	12.037	10.122
16/10/04	46	445.75	0.350	50.590	18.338	0.000	42.877	10.272	0.000	111.804	9.489	14.907	12.087	10.164
17/10/04	47	446.10	0.350	50.618	18.348	0.000	43.305	10.375	0.000	112.271	9.494	14.969	12.137	10.206
18/10/04	48	446.45	0.350	50.646	18.357	0.000	43.738	10.479	0.000	112.742	9.500	15.032	12.188	10.249
19/10/04	49	446.80	0.350	50.674	18.367	0.000	44.176	10.584	0.000	113.217	9.505	15.096	12.240	10.292
20/10/04	50	447.15	0.350	50.703	18.376	0.000	44.618	10.689	0.000	113.696	9.511	15.159	12.291	10.336
21/10/04	51	447.50	0.350	50.731	18.385	0.000	45.064	10.796	0.000	114.180	9.516	15.224	12.344	10.380
22/10/04	52	447.85	0.350	50.759	18.395	0.000	45.514	10.904	0.000	114.668	9.522	15.289	12.397	10.424
23/10/04	53	448.20	0.350	50.787	18.404	0.000	45.970	11.013	0.000	115.161	9.527	15.355	12.450	10.469
24/10/04	54	448.55	0.350	50.816	18.414	0.000	46.429	11.123	0.000	115.658	9.533	15.421	12.504	10.514
25/10/04	55	448.90	0.350	50.844	18.423	0.000	46.894	11.235	0.000	116.160	9.538	15.488	12.558	10.560
26/10/04	56	449.25	0.350	50.872	18.433	0.000	47.362	11.347	0.000	116.667	9.544	15.556	12.613	10.606
27/10/04	57	449.60	0.350	50.900	18.442	0.000	47.836	11.461	0.000	117.178	9.549	15.624	12.668	10.653
28/10/04	58	449.95	0.350	50.928	18.451	0.000	48.314	11.575	0.000	117.694	9.555	15.693	12.724	10.699
29/10/04	59	450.30	0.350	50.957	18.461	0.000	48.798	11.691	0.000	118.215	9.560	15.762	12.780	10.747
30/10/04	60	450.65	0.350	50.985	18.470	0.000	52.914	12.677	0.000	122.369	9.566	16.316	13.229	11.124
31/10/04	61	451.00	0.350	51.013	18.480	0.000	52.705	12.627	0.000	122.198	9.571	16.293	13.211	11.109
1/11/04	62	451.35	0.350	51.041	18.489	0.000	52.497	12.577	0.000	122.027	9.577	16.270	13.192	11.093
2/11/04	63	451.70	0.350	51.069	18.498	0.000	52.288	12.527	0.000	121.856	9.582	16.247	13.174	11.078
3/11/04	64	452.05	0.350	51.097	18.508	0.000	52.079	12.477	0.000	121.685	9.588	16.225	13.155	11.062
4/11/04	65	452.40	0.350	51.126	18.517	0.000	51.871	12.427	0.000	121.513	9.593	16.202	13.137	11.047
5/11/04	66	452.75	0.350	51.154	18.527	0.000	51.662	12.377	0.000	121.342	9.599	16.179	13.118	11.031
6/11/04	67	453.10	0.350	51.182	18.536	0.000	51.453	12.327	0.000	121.171	9.604	16.156	13.100	11.016
7/11/04	68	453.45	0.350	51.210	18.545	0.000	51.245	12.277	0.000	121.000	9.610	16.133	13.081	11.000
8/11/04	69	453.80	0.350	51.238	18.555	0.000	51.036	12.227	0.000	120.829	9.615	16.111	13.063	10.984
9/11/04	70	454.15	0.350	51.266	18.564	0.000	50.827	12.177	0.000	120.658	9.621	16.088	13.044	10.969
10/11/04	71	454.50	0.350	51.294	18.574	0.000	50.618	12.127	0.000	120.486	9.626	16.065	13.026	10.953
11/11/04	72	454.85	0.350	51.322	18.583	0.000	50.410	12.077	0.000	120.315	9.632	16.042	13.007	10.938
12/11/04	73	455.20	0.350	51.351	18.592	0.000	50.201	12.027	0.000	120.144	9.637	16.019	12.989	10.922
13/11/04	74	455.55	0.350	51.379	18.602	0.000	49.992	11.977	0.000	119.973	9.643	15.996	12.970	10.907
14/11/04	75	455.90	0.350	51.407	18.611	0.000	49.784	11.927	0.000	119.802	9.648	15.974	12.952	10.891
15/11/04	76	456.25	0.350	51.435	18.620	0.000	49.575	11.877	0.000	119.630	9.653	15.951	12.933	10.875
16/11/04	77	456.60	0.350	51.463	18.630	0.000	49.366	11.827	0.000	119.459	9.659	15.928	12.914	10.860
17/11/04	78	456.95	0.350	51.491	18.639	0.000	49.158	11.777	0.000	119.288	9.664	15.905	12.896	10.844

Table A.1 (contd)

	Days after calving	Liveweight (Kg)	Expected bodyweight change in kg per day	Maintenance requirement in MJ ME/day	Growth requirement in MJ ME/day	Bodyweight loss (Kg)	Milk production requirement in MJ ME/day	Milk production in L/day	Pregnancy requirement	Total energy requirement in MJ/day	Maximum DM Intake in kg DM/day	Total intake in low quality feed 7.5MJ/kg DM	Total intake in medium quality feed 9.25MJ/kg DM	Total intake in high Quality feed >11MJ ME/Kg/DM
18/11/04	79	457.30	0.350	51.519	18.649	0.000	48.949	11.727	0.000	119.117	9.670	15.882	12.877	10.829
19/11/04	80	457.65	0.350	51.547	18.658	0.000	48.740	11.677	0.000	118.945	9.675	15.859	12.859	10.813
20/11/04	81	458.00	0.350	51.575	18.667	0.000	48.531	11.627	0.000	118.774	9.681	15.837	12.840	10.798
21/11/04	82	458.35	0.350	51.603	18.677	0.000	48.323	11.577	0.000	118.603	9.686	15.814	12.822	10.782
22/11/04	83	458.70	0.350	51.631	18.686	0.000	48.114	11.527	0.000	118.431	9.692	15.791	12.803	10.766
23/11/04	84	459.05	0.350	51.659	18.695	0.000	47.864	11.467	0.000	118.218	9.697	15.762	12.780	10.747
24/11/04	85	459.40	0.350	51.687	18.705	0.000	47.613	11.407	0.000	118.005	9.703	15.734	12.757	10.728
25/11/04	86	459.75	0.350	51.715	18.714	0.000	47.363	11.347	0.000	117.792	9.708	15.706	12.734	10.708
26/11/04	87	460.10	0.350	51.744	18.723	0.000	47.112	11.287	0.000	117.579	9.714	15.677	12.711	10.689
27/11/04	88	460.45	0.350	51.772	18.733	0.000	46.862	11.227	0.000	117.366	9.719	15.649	12.688	10.670
28/11/04	89	460.80	0.350	51.800	18.742	0.000	46.611	11.167	0.000	117.153	9.724	15.620	12.665	10.650
29/11/04	90	461.15	0.350	51.828	18.751	0.000	46.361	11.107	0.000	116.940	9.730	15.592	12.642	10.631
30/11/04	91	461.50	0.350	51.856	18.761	0.000	46.111	11.047	0.000	116.727	9.735	15.564	12.619	10.612
1/12/04	92	461.85	-0.300	51.884	0.000	-6.786	45.860	10.987	0.000	90.958	9.741	12.128	9.833	8.269
2/12/04	93	461.55	-0.300	51.860	0.000	-6.786	45.610	10.927	0.000	90.684	9.736	12.091	9.804	8.244
3/12/04	94	461.25	-0.300	51.836	0.000	-6.786	45.359	10.867	0.143	90.552	9.731	12.074	9.789	8.232
4/12/04	95	460.95	-0.300	51.812	0.000	-6.786	45.109	10.807	0.146	90.280	9.727	12.037	9.760	8.207
5/12/04	96	460.65	-0.300	51.788	0.000	-6.786	44.858	10.747	0.149	90.009	9.722	12.001	9.731	8.183
6/12/04	97	460.35	-0.300	51.764	0.000	-6.786	44.608	10.687	0.152	89.737	9.717	11.965	9.701	8.158
7/12/04	98	460.05	-0.300	51.740	0.000	-6.786	44.357	10.627	0.155	89.466	9.713	11.929	9.672	8.133
8/12/04	99	459.75	-0.300	51.715	0.000	-6.786	44.107	10.567	0.158	89.195	9.708	11.893	9.643	8.109
9/12/04	100	459.45	-0.300	51.691	0.000	-6.786	43.857	10.507	0.161	88.923	9.703	11.856	9.613	8.084
10/12/04	101	459.15	-0.300	51.667	0.000	-6.786	43.606	10.447	0.164	88.652	9.699	11.820	9.584	8.059
11/12/04	102	458.85	-0.300	51.643	0.000	-6.786	43.356	10.387	0.168	88.381	9.694	11.784	9.555	8.035
12/12/04	103	458.55	-0.300	51.619	0.000	-6.786	43.105	10.327	0.171	88.110	9.689	11.748	9.525	8.010
13/12/04	104	458.25	-0.300	51.595	0.000	-6.786	42.855	10.267	0.175	87.839	9.685	11.712	9.496	7.985
14/12/04	105	457.95	-0.300	51.571	0.000	-6.786	42.604	10.207	0.178	87.568	9.680	11.676	9.467	7.961
15/12/04	106	457.65	-0.300	51.547	0.000	-6.786	42.354	10.147	0.182	87.297	9.675	11.640	9.438	7.936
16/12/04	107	457.35	-0.300	51.523	0.000	-6.786	42.104	10.087	0.185	87.026	9.671	11.604	9.408	7.911
17/12/04	108	457.05	-0.300	51.499	0.000	-6.786	41.853	10.027	0.189	86.756	9.666	11.567	9.379	7.887
18/12/04	109	456.75	-0.300	51.475	0.000	-6.786	41.603	9.967	0.193	86.485	9.661	11.531	9.350	7.862
19/12/04	110	456.45	-0.300	51.451	0.000	-6.786	41.352	9.907	0.197	86.214	9.657	11.495	9.320	7.838
20/12/04	111	456.15	-0.300	51.427	0.000	-6.786	41.102	9.847	0.201	85.944	9.652	11.459	9.291	7.813
21/12/04	112	455.85	-0.300	51.403	0.000	-6.786	40.851	9.787	0.205	85.673	9.647	11.423	9.262	7.788
22/12/04	113	455.55	-0.300	51.379	0.000	-6.786	40.601	9.727	0.209	85.403	9.643	11.387	9.233	7.764
23/12/04	114	455.25	-0.300	51.355	0.000	-6.786	40.350	9.667	0.213	85.133	9.638	11.351	9.204	7.739
24/12/04	115	454.95	-0.300	51.331	0.000	-6.786	40.100	9.607	0.217	84.862	9.633	11.315	9.174	7.715

Table A.1 (contd)

-	Days after calving	Liveweight (Kg)	Expected bodyweight change in kg per day	Maintenance requirement in MJ ME/day	Growth requirement in MJ ME/day	Bodyweight loss (Kg)	Milk production requirement in MJ ME/day	Milk production in L/day	Pregnancy requirement	Total energy requirement in MJ/day	Maximum DM Intake in kg DM/day	Total intake in low quality feed 7.5MJ/kg DM	Total intake in medium quality feed 9.25MJ/kg DM	Total intake in high Quality feed >11MJ ME/Kg/DM
25/12/04	116	454.65	-0.300	51.306	0.000	-6.786	39.850	9.547	0.222	84.592	9.628	11.279	9.145	7.690
26/12/04	117	454.35	-0.300	51.282	0.000	-6.786	39.599	9.487	0.226	84.322	9.624	11.243	9.116	7.666
27/12/04	118	454.05	-0.300	51.258	0.000	-6.786	39.349	9.427	0.231	84.052	9.619	11.207	9.087	7.641
28/12/04	119	453.75	-0.300	51.234	0.000	-6.786	39.098	9.367	0.236	83.782	9.614	11.171	9.058	7.617
29/12/04	120	453.45	-0.300	51.210	0.000	-6.786	38.848	9.307	0.240	83.512	9.610	11.135	9.028	7.592
30/12/04	121	453.15	-0.300	51.186	0.000	-6.786	38.597	9.247	0.245	83.243	9.605	11.099	8.999	7.568
31/12/04	122	452.85	-0.300	51.162	0.000	-6.786	38.347	9.187	0.250	82.973	9.600	11.063	8.970	7.543
1/01/05	123	452.55	-0.300	51.138	0.000	-6.786	38.096	9.127	0.255	82.704	9.596	11.027	8.941	7.519
2/01/05	124	452.25	-0.300	51.114	0.000	-6.786	37.846	9.067	0.260	82.434	9.591	10.991	8.912	7.494
3/01/05	125	451.95	-0.300	51.089	0.000	-6.786	37.596	9.007	0.266	82.165	9.586	10.955	8.883	7.470
4/01/05	126	451.65	-0.300	51.065	0.000	-6.786	37.345	8.947	0.271	81.896	9.582	10.919	8.854	7.445
5/01/05	127	451.35	-0.300	51.041	0.000	-6.786	37.095	8.887	0.276	81.626	9.577	10.884	8.824	7.421
6/01/05	128	451.05	-0.300	51.017	0.000	-6.786	36.844	8.827	0.282	81.357	9.572	10.848	8.795	7.396
7/01/05	129	450.75	-0.300	50.993	0.000	-6.786	36.594	8.767	0.288	81.089	9.567	10.812	8.766	7.372
8/01/05	130	450.45	-0.300	50.969	0.000	-6.786	36.343	8.707	0.293	80.820	9.563	10.776	8.737	7.347
9/01/05	131	450.15	-0.300	50.944	0.000	-6.786	36.093	8.647	0.299	80.551	9.558	10.740	8.708	7.323
10/01/05	132	449.85	-0.300	50.920	0.000	-6.786	35.843	8.587	0.305	80.282	9.553	10.704	8.679	7.298
11/01/05	133	449.55	-0.300	50.896	0.000	-6.786	35.592	8.527	0.312	80.014	9.549	10.669	8.650	7.274
12/01/05	134	449.25	-0.300	50.872	0.000	-6.786	35.342	8.467	0.318	79.746	9.544	10.633	8.621	7.250
13/01/05	135	448.95	-0.300	50.848	0.000	-6.786	35.091	8.407	0.324	79.477	9.539	10.597	8.592	7.225
14/01/05	136	448.65	-0.300	50.824	0.000	-6.786	34.841	8.347	0.331	79.209	9.534	10.561	8.563	7.201
15/01/05	137	448.35	-0.300	50.799	0.000	-6.786	34.590	8.287	0.337	78.941	9.530	10.526	8.534	7.176
16/01/05	138	448.05	-0.300	50.775	0.000	-6.786	34.340	8.227	0.344	78.674	9.525	10.490	8.505	7.152
17/01/05	139	447.75	-0.300	50.751	0.000	-6.786	34.089	8.167	0.351	78.406	9.520	10.454	8.476	7.128
18/01/05	140	447.45	-0.300	50.727	0.000	-6.786	33.839	8.107	0.358	78.138	9.516	10.418	8.447	7.103
19/01/05	141	447.15	-0.300	50.703	0.000	-6.786	33.589	8.047	0.365	77.871	9.511	10.383	8.418	7.079
20/01/05	142	446.85	-0.300	50.678	0.000	-6.786	33.338	7.987	0.373	77.604	9.506	10.347	8.390	7.055
21/01/05	143	446.55	-0.300	50.654	0.000	-6.786	33.088	7.927	0.380	77.337	9.502	10.312	8.361	7.031
22/01/05	144	446.25	-0.300	50.630	0.000	-6.786	32.837	7.867	0.388	77.070	9.497	10.276	8.332	7.006
23/01/05	145	445.95	-0.300	50.606	0.000	-6.786	32.587	7.807	0.396	76.803	9.492	10.240	8.303	6.982
24/01/05	146	445.65	-0.300	50.582	0.000	-6.786	32.336	7.747	0.404	76.536	9.487	10.205	8.274	6.958
25/01/05	147	445.35	-0.300	50.557	0.000	-6.786	32.086	7.687	0.412	76.269	9.483	10.169	8.245	6.934
26/01/05	148	445.05	-0.300	50.533	0.000	-6.786	31.836	7.627	0.420	76.003	9.478	10.134	8.217	6.909
27/01/05	149	444.75	-0.300	50.509	0.000	-6.786	31.585	7.567	0.429	75.737	9.473	10.098	8.188	6.885
28/01/05	150	444.45	-0.300	50.485	0.000	-6.786	31.335	7.507	0.437	75.471	9.468	10.063	8.159	6.861
29/01/05	151	444.15	-0.300	50.460	0.000	-6.786	31.084	7.447	0.446	75.205	9.464	10.027	8.130	6.837
30/01/05	152	443.85	-0.300	50.436	0.000	-6.786	30.834	7.387	0.455	74.939	9.459	9.992	8.102	6.813

Table A.1 (contd)

	Days after calving	Liveweight (Kg)	Expected bodyweight change in kg per day	Maintenance requirement in MJ ME/day	Growth requirement in MJ ME/day	Bodyweight loss (Kg)	Milk production requirement in MJ ME/day	Milk production in L/day	Pregnancy requirement	Total energy requirement in MJ/day	Maximum DM Intake in kg DM/day	Total intake in low quality feed 7.5MJ/kg DM	Total intake in medium quality feed 9.25MJ/kg DM	Total intake in high Quality feed >11MJ ME/Kg/DM
31/01/05	153	443.55	-0.300	50.412	0.000	-6.786	30.583	7.327	0.464	74.674	9.454	9.956	8.073	6.789
1/02/05	154	443.25	-0.300	50.388	0.000	-6.786	30.333	7.267	0.474	74.408	9.450	9.921	8.044	6.764
2/02/05	155	442.95	-0.300	50.363	0.000	-6.786	30.082	7.207	0.483	74.143	9.445	9.886	8.015	6.740
3/02/05	156	442.65	-0.300	50.339	0.000	-6.786	29.832	7.147	0.493	73.878	9.440	9.850	7.987	6.716
4/02/05	157	442.35	-0.300	50.315	0.000	-6.786	29.582	7.087	0.503	73.613	9.435	9.815	7.958	6.692
5/02/05	158	442.05	-0.300	50.290	0.000	-6.786	29.331	7.027	0.513	73.349	9.431	9.780	7.930	6.668
6/02/05	159	441.75	-0.300	50.266	0.000	-6.786	29.081	6.967	0.523	73.084	9.426	9.745	7.901	6.644
7/02/05	160	441.45	-0.300	50.242	0.000	-6.786	28.830	6.907	0.534	72.820	9.421	9.709	7.872	6.620
8/02/05	161	441.15	-0.300	50.218	0.000	-6.786	28.580	6.847	0.545	72.556	9.417	9.674	7.844	6.596
9/02/05	162	440.85	-0.300	50.193	0.000	-6.786	28.329	6.787	0.556	72.292	9.412	9.639	7.815	6.572
10/02/05	163	440.55	-0.300	50.169	0.000	-6.786	28.079	6.727	0.567	72.029	9.407	9.604	7.787	6.548
11/02/05	164	440.25	-0.300	50.145	0.000	-6.786	27.829	6.667	0.578	71.766	9.402	9.569	7.758	6.524
12/02/05	165	439.95	-0.300	50.120	0.000	-6.786	27.578	6.607	0.590	71.502	9.398	9.534	7.730	6.500
13/02/05	166	439.65	-0.300	50.096	0.000	-6.786	27.328	6.547	0.602	71.240	9.393	9.499	7.702	6.476
14/02/05	167	439.35	-0.300	50.072	0.000	-6.786	27.077	6.487	0.614	70.977	9.388	9.464	7.673	6.452
15/02/05	168	439.05	-0.300	50.047	0.000	-6.786	26.827	6.427	0.626	70.714	9.383	9.429	7.645	6.429
16/02/05	169	438.75	-0.300	50.023	0.000	-6.786	26.576	6.367	0.639	70.452	9.379	9.394	7.616	6.405
17/02/05	170	438.45	-0.300	49.999	0.000	-6.786	26.326	6.307	0.651	70.190	9.374	9.359	7.588	6.381
18/02/05	171	438.15	-0.300	49.974	0.000	-6.786	26.075	6.247	0.665	69.929	9.369	9.324	7.560	6.357
19/02/05	172	437.85	-0.300	49.950	0.000	-6.786	25.825	6.187	0.678	69.667	9.364	9.289	7.532	6.333
20/02/05	173	437.55	-0.300	49.926	0.000	-6.786	25.575	6.127	0.692	69.406	9.360	9.254	7.503	6.310
21/02/05	174	437.25	-0.300	49.901	0.000	-6.786	25.324	6.067	0.706	69.145	9.355	9.219	7.475	6.286
22/02/05	175	436.95	-0.300	49.877	0.000	-6.786	25.074	6.007	0.720	68.885	9.350	9.185	7.447	6.262
23/02/05	176	436.65	-0.300	49.853	0.000	-6.786	24.823	5.947	0.734	68.624	9.346	9.150	7.419	6.239
24/02/05	177	436.35	-0.300	49.828	0.000	-6.786	24.573	5.887	0.749	68.364	9.341	9.115	7.391	6.215
25/02/05	178	436.05	-0.300	49.804	0.000	-6.786	24.322	5.827	0.764	68.105	9.336	9.081	7.363	6.191
26/02/05	179	435.75	-0.300	49.779	0.000	-6.786	24.072	5.767	0.779	67.845	9.331	9.046	7.335	6.168
27/02/05	180	435.45	-0.300	49.755	0.000	-6.786	23.821	5.707	0.795	67.586	9.327	9.011	7.307	6.144
28/02/05	181	435.15	-0.300	49.731	0.000	-6.786	23.571	5.647	0.811	67.327	9.322	8.977	7.279	6.121
1/03/05	182	434.85	0.200	49.706	10.075	0.000	23.321	5.587	0.827	83.929	9.317	11.191	9.073	7.630
2/03/05	183	435.05	0.200	49.723	10.078	0.000	23.070	5.527	0.844	83.715	9.320	11.162	9.050	7.610
3/03/05	184	435.25	0.200	49.739	10.081	0.000	22.820	5.467	0.861	83.501	9.323	11.133	9.027	7.591
4/03/05	185	435.45	0.200	49.755	10.084	0.000	22.569	5.407	0.878	83.287	9.327	11.105	9.004	7.572
5/03/05	186	435.65	0.200	49.771	10.087	0.000	22.319	5.347	0.896	83.073	9.330	11.076	8.981	7.552
6/03/05	187	435.85	0.200	49.788	10.090	0.000	22.068	5.287	0.914	82.860	9.333	11.048	8.958	7.533
7/03/05	188	436.05	0.200	49.804	10.093	0.000	21.818	5.227	0.932	82.648	9.336	11.020	8.935	7.513
8/03/05	189	436.25	0.200	49.820	10.096	0.000	21.568	5.167	0.951	82.435	9.339	10.991	8.912	7.494

Table A.1 (contd)

	Days after calving	Liveweight (Kg)	Expected bodyweight change in kg per day	Maintenance requirement in MJ ME/day	Growth requirement in MJ ME/day	Bodyweight loss (Kg)	Milk production requirement in MJ ME/day	Milk production in L/day	Pregnancy requirement	Total energy requirement in MJ/day	Maximum DM Intake in kg DM/day	Total intake in low quality feed 7.5MJ/kg DM	Total intake in medium quality feed 9.25MJ/kg DM	Total intake in high Quality feed >11MJ ME/Kg/DM
9/03/05	190	436.45	0.200	49.836	10.100	0.000	21.317	5.107	0.970	82.223	9.342	10.963	8.889	7.475
10/03/05	191	436.65	0.200	49.853	10.103	0.000	21.067	5.047	0.990	82.011	9.346	10.935	8.866	7.456
11/03/05	192	436.85	0.200	49.869	10.106	0.000	20.816	4.987	1.009	81.800	9.349	10.907	8.843	7.436
12/03/05	193	437.05	0.200	49.885	10.109	0.000	20.566	4.927	1.030	81.589	9.352	10.879	8.820	7.417
13/03/05	194	437.25	0.200	49.901	10.112	0.000	20.315	4.867	1.050	81.379	9.355	10.850	8.798	7.398
14/03/05	195	437.45	0.200	49.918	10.115	0.000	20.065	4.807	1.072	81.169	9.358	10.822	8.775	7.379
15/03/05	196	437.65	0.200	49.934	10.118	0.000	19.814	4.747	1.093	80.959	9.361	10.795	8.752	7.360
16/03/05	197	437.85	0.200	49.950	10.121	0.000	19.564	4.687	1.115	80.750	9.364	10.767	8.730	7.341
17/03/05	198	438.05	0.200	49.966	10.124	0.000	19.564	4.687	1.137	80.791	9.368	10.772	8.734	7.345
18/03/05	199	438.25	0.200	49.982	10.127	0.000	19.564	4.687	1.160	80.834	9.371	10.778	8.739	7.349
19/03/05	200	438.45	0.200	49.999	10.130	0.000	19.564	4.687	1.184	80.876	9.374	10.783	8.743	7.352
20/03/05	201	438.65	0.200	50.015	10.133	0.000	19.564	4.687	1.207	80.919	9.377	10.789	8.748	7.356
21/03/05	202	438.85	0.200	50.031	10.136	0.000	19.564	4.687	1.232	80.963	9.380	10.795	8.753	7.360
22/03/05	203	439.05	0.200	50.047	10.139	0.000	19.564	4.687	1.256	81.007	9.383	10.801	8.757	7.364
23/03/05	204	439.25	0.200	50.064	10.142	0.000	19.564	4.687	1.282	81.051	9.387	10.807	8.762	7.368
24/03/05	205	439.45	0.200	50.080	10.145	0.000	19.564	4.687	1.307	81.096	9.390	10.813	8.767	7.372
25/03/05	206	439.65	0.200	50.096	10.148	0.000	19.564	4.687	1.333	81.142	9.393	10.819	8.772	7.377
26/03/05	207	439.85	0.200	50.112	10.151	0.000	19.564	4.687	1.360	81.188	9.396	10.825	8.777	7.381
27/03/05	208	440.05	0.200	50.128	10.154	0.000	19.564	4.687	1.388	81.234	9.399	10.831	8.782	7.385
28/03/05	209	440.25	0.200	50.145	10.157	0.000	19.564	4.687	1.415	81.281	9.402	10.837	8.787	7.389
29/03/05	210	440.45	0.200	50.161	10.160	0.000	19.564	4.687	1.444	81.329	9.405	10.844	8.792	7.394
30/03/05	211	440.65	0.200	50.177	10.163	0.000	0.000		1.473	61.813	9.409	8.242	6.682	5.619
31/03/05	212	440.85	0.200	50.193	10.166	0.000	0.000		1.502	61.862	9.412	8.248	6.688	5.624
1/04/05	213	441.05	0.200	50.209	10.169	0.000	0.000		1.533	61.911	9.415	8.255	6.693	5.628
2/04/05	214	441.25	0.200	50.226	10.172	0.000	0.000		1.563	61.961	9.418	8.261	6.698	5.633
3/04/05	215	441.45	0.200	50.242	10.175	0.000	0.000		1.595	62.012	9.421	8.268	6.704	5.637
4/04/05	216	441.65	0.200	50.258	10.178	0.000	0.000		1.627	62.063	9.424	8.275	6.710	5.642
5/04/05	217	441.85	0.200	50.274	10.181	0.000	0.000		1.659	62.115	9.428	8.282	6.715	5.647
6/04/05	218	442.05	0.200	50.290	10.184	0.000	0.000		1.693	62.167	9.431	8.289	6.721	5.652
7/04/05	219	442.25	0.200	50.307	10.187	0.000	0.000		1.727	62.220	9.434	8.296	6.727	5.656
8/04/05	220	442.45	0.200	50.323	10.190	0.000	0.000		1.761	62.274	9.437	8.303	6.732	5.661
9/04/05	221	442.65	0.200	50.339	10.193	0.000	0.000		1.796	62.329	9.440	8.311	6.738	5.666
10/04/05	222	442.85	0.200	50.355	10.196	0.000	0.000		1.833	62.384	9.443	8.318	6.744	5.671
11/04/05	223	443.05	0.200	50.371	10.199	0.000	0.000		1.869	62.440	9.446	8.325	6.750	5.676
12/04/05	224	443.25	0.200	50.388	10.202	0.000	0.000		1.907	62.497	9.450	8.333	6.756	5.682
13/04/05	225	443.45	0.200	50.404	10.205	0.000	0.000		1.945	62.554	9.453	8.341	6.763	5.687
14/04/05	226	443.65	0.200	50.420	10.208	0.000	0.000		1.984	62.612	9.456	8.348	6.769	5.692

Table A.1 (contd)

	Days after calving	Liveweight (Kg)	Expected bodyweight change in kg per day	Maintenance requirement in MJ ME/day	Growth requirement in MJ ME/day	Bodyweight loss (Kg)	Milk production requirement in MJ ME/day	Milk production in L/day	Pregnancy requirement	Total energy requirement in MJ/day	Maximum DM Intake in kg DM/day	Total intake in low quality feed 7.5MJ/kg DM	Total intake in medium quality feed 9.25MJ/kg DM	Total intake in high Quality feed >11MJ ME/Kg/DM
15/04/05	227	443.85	0.200	50.436	10.211	0.000	0.000		2.024	62.671	9.459	8.356	6.775	5.697
16/04/05	228	444.05	0.200	50.452	10.214	0.000	0.000		2.064	62.731	9.462	8.364	6.782	5.703
17/04/05	229	444.25	0.200	50.468	10.217	0.000	0.000		2.106	62.792	9.465	8.372	6.788	5.708
18/04/05	230	444.45	0.200	50.485	10.220	0.000	0.000		2.148	62.853	9.468	8.380	6.795	5.714
19/04/05	231	444.65	0.200	50.501	10.224	0.000	0.000		2.191	62.915	9.472	8.389	6.802	5.720
20/04/05	232	444.85	0.200	50.517	10.227	0.000	0.000		2.235	62.978	9.475	8.397	6.808	5.725
21/04/05	233	445.05	0.200	50.533	10.230	0.000	0.000		2.280	63.042	9.478	8.406	6.815	5.731
22/04/05	234	445.25	0.200	50.549	10.233	0.000	0.000		2.325	63.107	9.481	8.414	6.822	5.737
23/04/05	235	445.45	0.200	50.565	10.236	0.000	0.000		2.372	63.173	9.484	8.423	6.830	5.743
24/04/05	236	445.65	0.200	50.582	10.239	0.000	0.000		2.420	63.240	9.487	8.432	6.837	5.749
25/04/05	237	445.85	0.200	50.598	10.242	0.000	0.000		2.468	63.307	9.491	8.441	6.844	5.755
26/04/05	238	446.05	0.200	50.614	10.245	0.000	0.000		2.518	63.376	9.494	8.450	6.851	5.761
27/04/05	239	446.25	0.200	50.630	10.248	0.000	0.000		2.568	63.446	9.497	8.459	6.859	5.768
28/04/05	240	446.45	0.200	50.646	10.251	0.000	0.000		2.619	63.516	9.500	8.469	6.867	5.774
29/04/05	241	446.65	0.200	50.662	10.254	0.000	0.000		2.672	63.588	9.503	8.478	6.874	5.781
30/04/05	242	446.85	0.200	50.678	10.257	0.000	0.000		2.725	63.660	9.506	8.488	6.882	5.787
1/05/05	243	447.05	0.200	50.695	10.260	0.000	0.000		2.780	63.734	9.509	8.498	6.890	5.794
2/05/05	244	447.25	0.200	50.711	10.263	0.000	0.000		2.836	63.809	9.513	8.508	6.898	5.801
3/05/05	245	447.45	0.200	50.727	10.266	0.000	0.000		2.893	63.885	9.516	8.518	6.906	5.808
4/05/05	246	447.65	0.200	50.743	10.269	0.000	0.000		2.950	63.962	9.519	8.528	6.915	5.815
5/05/05	247	447.85	0.200	50.759	10.272	0.000	0.000		3.010	64.040	9.522	8.539	6.923	5.822
6/05/05	248	448.05	0.200	50.775	10.275	0.000	0.000		3.070	64.120	9.525	8.549	6.932	5.829
7/05/05	249	448.25	0.200	50.791	10.278	0.000	0.000		3.131	64.200	9.528	8.560	6.941	5.836
8/05/05	250	448.45	0.200	50.807	10.281	0.000	0.000		3.194	64.282	9.531	8.571	6.949	5.844
9/05/05	251	448.65	0.200	50.824	10.284	0.000	0.000		3.258	64.365	9.534	8.582	6.958	5.851
10/05/05	252	448.85	0.200	50.840	10.287	0.000	0.000		3.323	64.450	9.538	8.593	6.968	5.859
11/05/05	253	449.05	0.200	50.856	10.290	0.000	0.000		3.390	64.535	9.541	8.605	6.977	5.867
12/05/05	254	449.25	0.200	50.872	10.293	0.000	0.000		3.458	64.622	9.544	8.616	6.986	5.875
13/05/05	255	449.45	0.200	50.888	10.296	0.000	0.000		3.527	64.711	9.547	8.628	6.996	5.883
14/05/05	256	449.65	0.200	50.904	10.299	0.000	0.000		3.597	64.800	9.550	8.640	7.005	5.891
15/05/05	257	449.85	0.200	50.920	10.302	0.000	0.000		3.669	64.891	9.553	8.652	7.015	5.899
16/05/05	258	450.05	0.200	50.936	10.305	0.000	0.000		3.743	64.984	9.556	8.665	7.025	5.908
17/05/05	259	450.25	0.200	50.953	10.308	0.000	0.000		3.818	65.078	9.560	8.677	7.035	5.916
18/05/05	260	450.45	0.200	50.969	10.311	0.000	0.000		3.894	65.174	9.563	8.690	7.046	5.925
19/05/05	261	450.65	0.200	50.985	10.314	0.000	0.000		3.972	65.271	9.566	8.703	7.056	5.934
20/05/05	262	450.85	0.200	51.001	10.317	0.000	0.000		4.052	65.369	9.569	8.716	7.067	5.943
21/05/05	263	451.05	0.200	51.017	10.320	0.000	0.000		4.133	65.469	9.572	8.729	7.078	5.952

Table A.1 (contd)

	Days after calving	Liveweight (Kg)	Expected bodyweight change in kg per day	Maintenance requirement in MJ ME/day	Growth requirement in MJ ME/day	Bodyweight loss (Kg)	Milk production requirement in MJ ME/day	Milk production in L/day	Pregnancy requirement	Total energy requirement in MJ/day	Maximum DM Intake in kg DM/day	Total intake in low quality feed 7.5MJ/kg DM	Total intake in medium quality feed 9.25MJ/kg DM	Total intake in high Quality feed >11MJ ME/Kg/DM
22/05/05	264	451.25	0.200	51.033	10.323	0.000	0.000		4.215	65.571	9.575	8.743	7.089	5.961
23/05/05	265	451.45	0.200	51.049	10.326	0.000	0.000		4.300	65.675	9.578	8.757	7.100	5.970
24/05/05	266	451.65	0.200	51.065	10.329	0.000	0.000		4.386	65.780	9.582	8.771	7.111	5.980
25/05/05	267	451.85	0.200	51.081	10.332	0.000	0.000		4.473	65.887	9.585	8.785	7.123	5.990
26/05/05	268	452.05	0.200	51.097	10.335	0.000	0.000		4.563	65.995	9.588	8.799	7.135	6.000
27/05/05	269	452.25	0.200	51.114	10.338	0.000	0.000		4.654	66.105	9.591	8.814	7.147	6.010
28/05/05	270	452.45	0.200	51.130	10.341	0.000	0.000		4.747	66.218	9.594	8.829	7.159	6.020
29/05/05	271	452.65	0.200	51.146	10.344	0.000	0.000		4.842	66.332	9.597	8.844	7.171	6.030
30/05/05	272	452.85	0.200	51.162	10.347	0.000	0.000		4.939	66.448	9.600	8.860	7.184	6.041
31/05/05	273	453.05	0.200	51.178	10.350	0.000	0.000		5.038	66.565	9.603	8.875	7.196	6.051
1/06/05	274	453.25	0.300	51.194	15.769	0.000	0.000		5.139	72.101	9.607	9.614	7.795	6.555
2/06/05	275	453.55	0.300	51.218	15.776	0.000	0.000		5.241	72.235	9.611	9.631	7.809	6.567
3/06/05	276	453.85	0.300	51.242	15.783	0.000	0.000		5.346	72.371	9.616	9.649	7.824	6.579
4/06/05	277	454.15	0.300	51.266	15.789	0.000	0.000		5.453	72.509	9.621	9.668	7.839	6.592
5/06/05	278	454.45	0.300	51.290	15.796	0.000	0.000		5.562	72.649	9.625	9.686	7.854	6.604
6/06/05	279	454.75	0.300	51.314	15.803	0.000	0.000		5.673	72.791	9.630	9.705	7.869	6.617
7/06/05	280	455.05	0.300	51.339	15.810	0.000	0.000		5.787	72.935	9.635	9.725	7.885	6.630
8/06/05	281	455.35	0.300	51.363	15.817	0.000	0.000		5.902	73.082	9.639	9.744	7.901	6.644
9/06/05	282	455.65	0.300	51.387	15.824	0.000	0.000		6.020	73.231	9.644	9.764	7.917	6.657
10/06/05	283	455.95	0.300	51.411	15.830	0.000	0.000		6.141	73.382	9.649	9.784	7.933	6.671
11/06/05	284	456.25	0.300	51.435	15.837	0.000	0.000		6.263	73.535	9.653	9.805	7.950	6.685
12/06/05	285	456.55	0.300	51.459	15.844	0.000	0.000		6.388	73.692	9.658	9.826	7.967	6.699
13/06/05	286	456.85	0.300	51.483	15.851	0.000	0.000		6.516	73.850	9.663	9.847	7.984	6.714
14/06/05	287	457.15	0.300	51.507	15.858	0.000	0.000		6.646	74.011	9.668	9.868	8.001	6.728
15/06/05	288	457.45	0.300	51.531	15.865	0.000	0.000		6.779	74.175	9.672	9.890	8.019	6.743
16/06/05	289	457.75	0.300	51.555	15.871	0.000	0.000		6.915	74.341	9.677	9.912	8.037	6.758
17/06/05	290	458.05	0.300	51.579	15.878	0.000	0.000		7.053	74.510	9.682	9.935	8.055	6.774
18/06/05	291	458.35	0.300	51.603	15.885	0.000	0.000		7.194	74.682	9.686	9.958	8.074	6.789
19/06/05	292	458.65	0.300	51.627	15.892	0.000	0.000		7.337	74.857	9.691	9.981	8.093	6.805
20/06/05	293	458.95	0.300	51.651	15.899	0.000	0.000		7.484	75.034	9.696	10.005	8.112	6.821
21/06/05	294	459.25	0.300	51.675	15.906	0.000	0.000		7.633	75.214	9.700	10.029	8.131	6.838
22/06/05	295	459.55	0.300	51.699	15.912	0.000	0.000		7.786	75.398	9.705	10.053	8.151	6.854
23/06/05	296	459.85	0.300	51.724	15.919	0.000	0.000		7.941	75.584	9.710	10.078	8.171	6.871
24/06/05	297	460.15	0.300	51.748	15.926	0.000	0.000		8.100	75.773	9.714	10.103	8.192	6.888
25/06/05	298	460.45	0.300	51.772	15.933	0.000	0.000		8.262	75.966	9.719	10.129	8.213	6.906
26/06/05	299	460.75	0.300	51.796	15.940	0.000	0.000		8.427	76.162	9.724	10.155	8.234	6.924
27/06/05	300	461.05	0.300	51.820	15.946	0.000	0.000		8.595	76.361	9.728	10.181	8.255	6.942

Table A.1 (contd)

	Days after calving	Liveweight (Kg)	Expected bodyweight change in kg per day	Maintenance requirement in MJ ME/day	Growth requirement in MJ ME/day	Bodyweight loss (Kg)	Milk production requirement in MJ ME/day	Milk production in L/day	Pregnancy requirement	Total energy requirement in MJ/day	Maximum DM Intake in kg DM/day	Total intake in low quality feed 7.5MJ/kg DM	Total intake in medium quality feed 9.25MJ/kg DM	Total intake in high Quality feed >11MJ ME/Kg/DM
28/06/05	301	461.35	0.300	51.844	15.953	0.000	0.000		8.766	76.563	9.733	10.208	8.277	6.960
29/06/05	302	461.65	0.300	51.868	15.960	0.000	0.000		8.941	76.769	9.738	10.236	8.299	6.979
30/06/05	303	461.95	0.300	51.892	15.967	0.000	0.000		9.120	76.978	9.742	10.264	8.322	6.998
1/07/05	304	462.25	0.300	51.916	15.974	0.000	0.000		9.302	77.191	9.747	10.292	8.345	7.017
2/07/05	305	462.55	0.300	51.940	15.980	0.000	0.000		9.488	77.408	9.752	10.321	8.368	7.037
3/07/05	306	462.85	0.300	51.964	15.987	0.000	0.000		9.677	77.628	9.756	10.350	8.392	7.057
4/07/05	307	463.15	0.300	51.988	15.994	0.000	0.000		9.870	77.852	9.761	10.380	8.416	7.077
5/07/05	308	463.45	0.300	52.011	16.001	0.000	0.000		10.067	78.079	9.766	10.411	8.441	7.098
6/07/05	309	463.75	0.300	52.035	16.008	0.000	0.000		10.268	78.311	9.770	10.441	8.466	7.119
7/07/05	310	464.05	0.300	52.059	16.014	0.000	0.000		10.473	78.547	9.775	10.473	8.492	7.141
8/07/05	311	464.35	0.300	52.083	16.021	0.000	0.000		10.682	78.787	9.780	10.505	8.517	7.162
9/07/05	312	464.65	0.300	52.107	16.028	0.000	0.000		10.895	79.030	9.784	10.537	8.544	7.185
10/07/05	313	464.95	0.300	52.131	16.035	0.000	0.000		11.112	79.279	9.789	10.570	8.571	7.207
11/07/05	314	465.25	0.300	52.155	16.042	0.000	0.000		11.334	79.531	9.794	10.604	8.598	7.230
12/07/05	315	465.55	0.300	52.179	16.048	0.000	0.000		11.560	79.788	9.798	10.638	8.626	7.253
13/07/05	316	465.85	0.300	52.203	16.055	0.000	0.000		11.791	80.049	9.803	10.673	8.654	7.277
14/07/05	317	466.15	0.300	52.227	16.062	0.000	0.000		12.026	80.315	9.808	10.709	8.683	7.301
15/07/05	318	466.45	0.300	52.251	16.069	0.000	0.000		12.266	80.586	9.812	10.745	8.712	7.326
16/07/05	319	466.75	0.300	52.275	16.076	0.000	0.000		12.511	80.861	9.817	10.781	8.742	7.351
17/07/05	320	467.05	0.300	52.299	16.082	0.000	0.000		12.760	81.141	9.822	10.819	8.772	7.376
18/07/05	321	467.35	0.300	52.323	16.089	0.000	0.000		13.015	81.426	9.826	10.857	8.803	7.402
19/07/05	322	467.65	0.300	52.347	16.096	0.000	0.000		13.274	81.717	9.831	10.896	8.834	7.429
20/07/05	323	467.95	0.300	52.371	16.103	0.000	0.000		13.539	82.012	9.836	10.935	8.866	7.456
21/07/05	324	468.25	0.300	52.395	16.109	0.000	0.000		13.809	82.313	9.840	10.975	8.899	7.483
22/07/05	325	468.55	0.300	52.418	16.116	0.000	0.000		14.084	82.619	9.845	11.016	8.932	7.511
23/07/05	326	468.85	0.300	52.442	16.123	0.000	0.000		14.365	82.930	9.850	11.057	8.965	7.539
24/07/05	327	469.15	0.300	52.466	16.130	0.000	0.000		14.651	83.247	9.854	11.100	9.000	7.568
25/07/05	328	469.45	0.300	52.490	16.136	0.000	0.000		14.943	83.570	9.859	11.143	9.035	7.597
26/07/05	329	469.75	0.300	52.514	16.143	0.000	0.000		15.241	83.898	9.864	11.186	9.070	7.627
27/07/05	330	470.05	0.300	52.538	16.150	0.000	0.000		15.545	84.233	9.868	11.231	9.106	7.658
28/07/05	331	470.35	0.300	52.562	16.157	0.000	0.000		15.855	84.573	9.873	11.276	9.143	7.688
29/07/05	332	470.65	0.300	52.586	16.164	0.000	0.000		16.171	84.920	9.878	11.323	9.181	7.720
30/07/05	333	470.95	0.300	52.610	16.170	0.000	0.000		16.493	85.273	9.882	11.370	9.219	7.752
31/07/05	334	471.25	0.300	52.633	16.177	0.000	0.000		16.822	85.632	9.887	11.418	9.258	7.785
1/08/05	335	471.55	0.300	52.657	16.184	0.000	0.000		17.157	85.998	9.891	11.466	9.297	7.818
2/08/05	336	471.85	0.300	52.681	16.191	0.000	0.000		17.499	86.370	9.896	11.516	9.337	7.852
3/08/05	337	472.15	0.300	52.705	16.197	0.000	0.000		17.847	86.750	9.901	11.567	9.378	7.886

Table A.1 (contd)

	Days after calving	Liveweight (Kg)	Expected bodyweight change in kg per day	Maintenance requirement in MJ ME/day	Growth requirement in MJ ME/day	Bodyweight loss (Kg)	Milk production requirement in MJ ME/day	Milk production in L/day	Pregnancy requirement	Total energy requirement in MJ/day	Maximum DM Intake in kg DM/day	Total intake in low quality feed 7.5MJ/kg DM	Total intake in medium quality feed 9.25MJ/kg DM	Total intake in high Quality feed >11MJ ME/Kg/DM
4/08/05	338	472.45	0.300	52.729	16.204	0.000	0.000		18.203	87.136	9.905	11.618	9.420	7.921
5/08/05	339	472.75	0.300	52.753	16.211	0.000	0.000		18.565	87.529	9.910	11.671	9.463	7.957
6/08/05	340	473.05	0.300	52.777	16.218	0.000	0.000		18.935	87.929	9.915	11.724	9.506	7.994
7/08/05	341	473.35	0.300	52.800	16.224	0.000	0.000		19.312	88.337	9.919	11.778	9.550	8.031
8/08/05	342	473.65	0.300	52.824	16.231	0.000	0.000		19.697	88.752	9.924	11.834	9.595	8.068
9/08/05	343	473.95	0.300	52.848	16.238	0.000	0.000		20.089	89.175	9.929	11.890	9.641	8.107
10/08/05	344	474.25	0.300	52.872	16.245	0.000	0.000		20.489	89.606	9.933	11.947	9.687	8.146
11/08/05	345	474.55	0.300	52.896	16.251	0.000	0.000		20.897	90.045	9.938	12.006	9.735	8.186
12/08/05	346	474.85	0.300	52.920	16.258	0.000	0.000		21.314	90.491	9.943	12.065	9.783	8.226
13/08/05	347	475.15	0.300	52.943	16.265	0.000	0.000		21.738	90.946	9.947	12.126	9.832	8.268
14/08/05	348	475.45	0.300	52.967	16.272	0.000	0.000		22.171	91.410	9.952	12.188	9.882	8.310
15/08/05	349	475.75	0.300	52.991	16.278	0.000	0.000		22.612	91.881	9.956	12.251	9.933	8.353
16/08/05	350	476.05	0.300	53.015	16.285	0.000	0.000		23.062	92.362	9.961	12.315	9.985	8.397
17/08/05	351	476.35	0.300	53.039	16.292	0.000	0.000		23.522	92.852	9.966	12.380	10.038	8.441
18/08/05	352	476.65	0.300	53.062	16.299	0.000	0.000		23.990	93.351	9.970	12.447	10.092	8.486
19/08/05	353	476.95	0.300	53.086	16.305	0.000	0.000		24.467	93.859	9.975	12.514	10.147	8.533
20/08/05	354	477.25	0.300	53.110	16.312	0.000	0.000		24.954	94.376	9.980	12.583	10.203	8.580
21/08/05	355	477.55	0.300	53.134	16.319	0.000	0.000		25.451	94.903	9.984	12.654	10.260	8.628
22/08/05	356	477.85	0.300	53.157	16.325	0.000	0.000		25.957	95.440	9.989	12.725	10.318	8.676
23/08/05	357	478.15	0.300	53.181	16.332	0.000	0.000		26.474	95.987	9.994	12.798	10.377	8.726
24/08/05	358	478.45	0.300	53.205	16.339	0.000	0.000		27.001	96.545	9.998	12.873	10.437	8.777
25/08/05	359	478.75	0.300	53.229	16.346	0.000	0.000		27.538	97.112	10.003	12.948	10.499	8.828
26/08/05	360	479.05	0.300	53.253	16.352	0.000	0.000		28.086	97.691	10.007	13.025	10.561	8.881
27/08/05	361	479.35	0.300	53.276	16.359	0.000	0.000		28.645	98.280	10.012	13.104	10.625	8.935
28/08/05	362	479.65	0.300	53.300	16.366	0.000	0.000		29.215	98.881	10.017	13.184	10.690	8.989
29/08/05	363	479.95	0.300	53.324	16.372	0.000	0.000		29.796	99.492	10.021	13.266	10.756	9.045
30/08/05	364	480.25	0.300	53.348	16.379	0.000	0.000		30.389	100.115	10.026	13.349	10.823	9.101
31/08/05	365	480.55	0.300	53.371	16.386	0.000	0.000		30.993	100.750	10.031	13.433	10.892	9.159

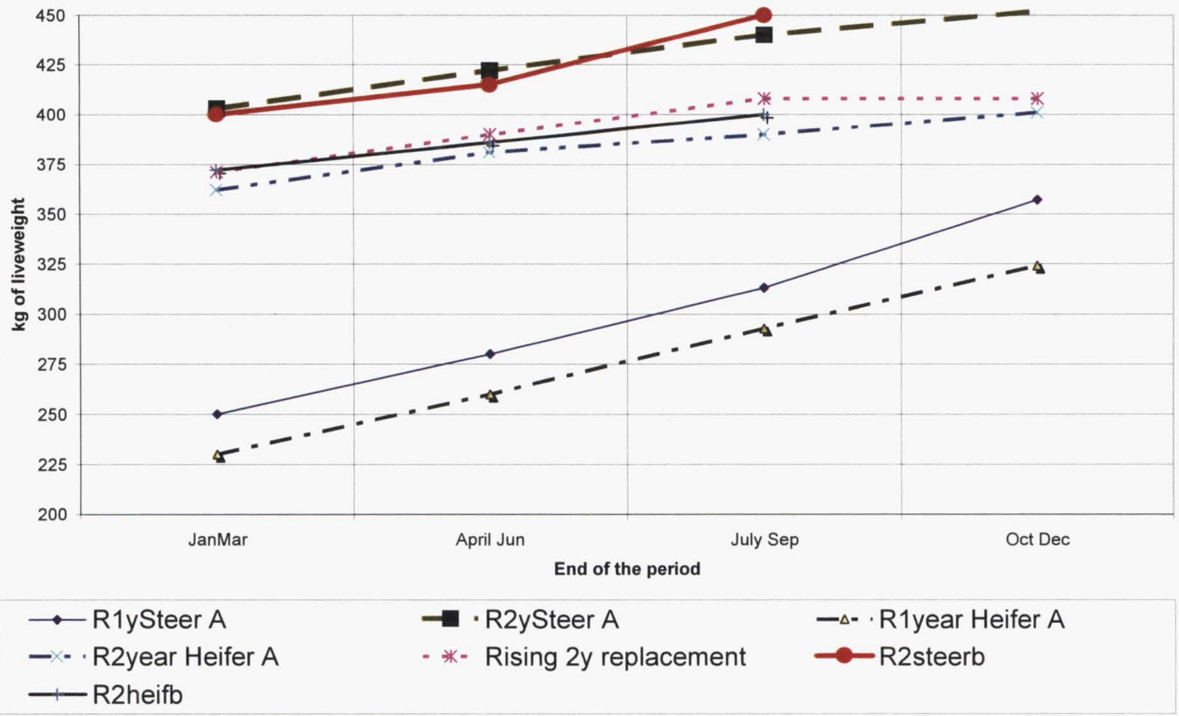

Figure A. 1 Liveweight pattern utilized for the beef finishing activities

Table A. 2 Liveweight pattern assumptions utilized for the dairy calves finishing activities

	July -September	October-December	January-March	April- June
R1y heifer dairy1C & dairy2C	76.55	131.75	182.95	222.95
R2y heifer dairy 1c & dairy 2C	260	315	369	405
R1y steer dairy 1c & dairy 2c	81.55	136.75	190.75	236.95
Ry2 steer dairy 1c & dairy 2c	273.85	335.25	407.25	452.75
Ry1c replacement dairy 1C & dairy 2C	76.55	131.75	182.95	228.95
Ry2 replacement dairy 1C & dairy 2C	276.5	327.1	376.6	413
R1y heifer dairy3C & dairy4C	81.55	136.75	186.55	223.45
R2y heifer dairy 3c & dairy 4C	260.35	314	363.5	404.45
R1y steer dairy 3c & dairy 4c	86.55	141.75	195.75	241.95
Ry2 steer dairy 3c & dairy 4c	278.85	340.25	412.25	453.2
Ry1c replacement dairy 3C & dairy 4C	84.4	145.6	214.8	267.2
Ry2 replacement dairy 3C & dairy 4C	305.65	373.2	454.2	495.15

Table A. 3 Daily liveweight assumptions per periods

	January - March	April - June	July - September	October - December
R1y heifer dairy1C & dairy2C	0.6	0.5	0.45	0.6
R2y heifer dairy 1c & dairy 2C	0.6	0.4	0.3	0.6
R1y steer dairy 1c & dairy 2c	0.6	0.55	0.55	0.6
Ry2 steer dairy 1c & dairy 2c	0.8	0.5	0.3	0.6
Ry1c replacement dairy 1C & dairy 2C	0.6	0.45	0.5	0.6
Ry2 replacement dairy 1C & dairy 2C	0.55	0.4	0.5	0.55
R1y heifer dairy3C & dairy4C	0.6	0.45	0.45	0.6
R2y heifer dairy 3c & dairy 4C	0.55	0.45	0.3	0.6
R1y steer dairy 3c & dairy 4c	0.6	0.6	0.45	0.6
Ry2 steer dairy 3c & dairy 4c	0.8	0.45	0.3	0.6
Ry1c replacement dairy 3C & dairy 4C	0.8	0.7	0.6	0.6
Ry2 replacement dairy 3C & dairy 4C	0.9	0.45	0.3	0.65

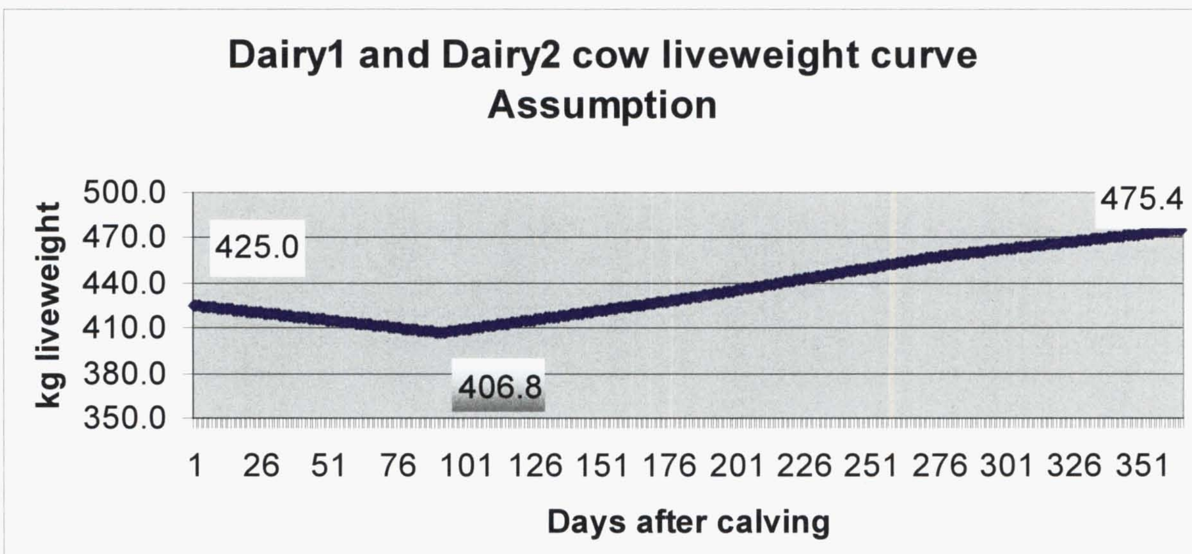

Figure A. 2 Dairy1 & dairy2 cow liveweight curve assumption

The model includes two different rearing activities for rearing calves from calving date until the age of 42 days. The gross margin calculation of these activities are shown next.

Appendix B
Economic data: Livestock activities gross margins

Table B. 1 Dairy activities gross margin calculations.

Total per category	Dairy 1& 2 C	Dairy 1& 2 D	Dairy 3 & 4 C	Dairy 3 & 4 D
Activity				
Vaccinations	$1.94	$1.94	$1.94	$1.94
Drenches	$1.26	$1.26	$1.26	$1.26
Mineral supplements	$7.20	$9.07	$7.20	$9.07
Pregnancy test	$0.47	$0.47	$0.47	$0.47
Breeding and veterinary expenses	$10.50	$12.88	$10.50	$12.88
Cull cow sales 18% (20% replacement rate, 2% death rate	-$49.37	-$49.07	-$59.88	-$59.51
Shed expenses	$21.28	$21.28	$21.28	$21.28
Total variable cost per year	-$6.72	-$2.16	-$17.23	-$12.61

Source: Case studies 2 & 3.

Table B. 2 Beef activities gross margin

	Animal health	Breeding	Culling sales	Total gross margin	Notes
R1y steer	-$2.00			-$2.00	
R2y steer A	-$14.64			-$14.64	
R2y steer B	-$9.86			-$9.86	
R1y heifer	-$2.00			-$2.00	
R2y heifer A	-$14.64			-$14.64	
R2y heifer B	-$9.98			-$9.98	
R2y replacement	-$14.09	-$1.00		-$15.09	1
Breeding cow	-$28.55	-$1.00	$49.37	$19.82	2
Bulls	-$17.00		$139.00	$122.00	3

Source: Adapted from Case studies 1 & 3

Notes

1 Replacement and non replacement heifers have the same cost during their first year of life.

2 Breeding cows' replacement rate is 20% per year and death rate is 2 %.

3 Bulls' replacement rate is 33% per year and death rate is 1%.

Table B. 3 Current rearing dairy calf activity costs calculation

Rearing and weaning b.				
Category	Unit	Price per unit	Amount	Total
Milk feeding				
2lt of milk twice a day for 42 days	Litres	0	168	
Total milk required (L)	0	0		168
Pellet feeding				
From birth to day 42 (0.1 to 1 kg of pellets per day)	0	$0.23	26.25	$6.14
Total pellet fed				26.25
Water (5 L per day)	lt	0	210	0
Labour required per calf	Man day unit	0	0.875	0
(Assuming 10 minutes per day)				

Source: Case study 2

Table B. 4 Improved rearing dairy calf activity costs calculation

Rearing and weaning c				
Category	Unit	Price per unit	Amount	Total
Milk feeding				
Milk (twice a day 2 L for one week)	L		28	
Milk (Once a day 3 L for five weeks)	L		105	
Total milk	L			133
Pellets fed				
First week (0.150 kg per day)	$	$0.23	1.05	$0.25
Second week (0.350 kg per day)	$	$0.23	2.45	$0.57
Third week (0.500 kg per day)	$	$0.23	3.5	$0.82
Four week (0.750 kg per day)	$	$0.23	5.25	$1.23
Fifth week (1 kg per day)	$	$0.23	7	$1.64
Sixth week (1.5 kg per day)	$	$0.23	10.5	$2.45
Total pellet feeding cost	0	0	29.75	$6.96
Water requirement (7.5 L per day*)	L	0	315	315
Labour required per calf	Man day unit	0	1	1
(Assuming 10 minutes per day)	0	0	0	0
Energy requirement (kg DM low quality feed)	kg of hay	0	2.5	2.5

Source: Adapted from Muir, P., 2003

* Increased amount of dry concentrates will increase water requirements

Appendix C
Economic data: machinery variable costs calculations

These costs were based on data sourced from one of the case study farmers the summary of machinery running cost is shown below

Table C. 1 Running cost for different activities requiring machinery.

Machinery running cost per hour without interest and depreciation.	(Gs)	(NZ$)
Tractor (MF275)	35,876	8.37
Tractor with light disks	41,465	9.67
Tractor with heavy disks	47,089	10.99
Tractor with sprayer	37,136	8.66
Tractor with cultivator	38,254	8.93
Tractor with Agricultural Blade	51,876	12.10
Tractor with Plough	45,233	10.55
Tractor with Ripper	40,818	9.52
Tractor with heavy roller blade	42,976	10.03
Tractor with Rotor mower	40,524	9.45
Mechanical weeding	37,423	8.73

Source: Bergen, 2004

Table C. 2 Tractor MF275

Input data	US$	Gs				
Buying cost	23,550	138,945,000				
Working hours/year		600				
Useful life in hours		10,000				
Category	Quantity	Unitary Price (Gs)	Total (Gs)	Hours	Hourly cost (Gs)	Hourly cost (NZ$)
Diesel	8	3,300	26,400	1	26,400	$6.16
Engine oil	10	15,000	150,000	200	750	$0.17
Oil	40	15,000	600,000	1000	600	$0.14
Oil filter	1	29,250	29,250	200	146	$0.03
Battery	1	346,800	346,800	2000	173	$0.04
Air filter	1	106,800	106,800	1000	107	$0.02
Air filter	1	35,100	35,100	1000	35	$0.01
Belt	1	36,100	36,100	3000	12	$0.00
Rear tyres	2	580,000	1,160,000	4000	290	$0.07
Back tyres	2	2,550,000	5,100,000	4000	1,275	$0.30
Repairs			30,000,000	5000	6,000	$1.40
Fuel filter	1	21,515	21,515	400	54	$0.01
Filter	1	13,440	13,440	400	34	$0.01
Total					35,876	$8.37
Direct cost per hour					35,876	$8.37

Table C. 3 Light Disk 32x20"

Input data	US$	Gs				
Buying cost	1950	11,505,000				
working hours/year		500				
Useful life in hours		10000				
Category	Quantity	Unitary price (Gs)	Total (Gs)	Hours	Hourly cost (Gs)	Hourly cost (NZ$)
Disks 20"	32	74,000	2,368,000	1,000	Gs 2,368	$0.55
Maintenance	8	273,000	2,184,000	1,000	Gs 2,184	$0.51
Graze	0.1	Gs 9,000	900	24	Gs 38	$0.01
Repair			500,000	500	Gs 1,000	$0.23
Direct cost per hour					Gs 5,590	$1.30

Table C. 4 Heavy disk 18x28"

Input data	US$		(Gs)			
Buying price	2,351		13,870,000			
Working hours per year			500			
Useful life in hours			10000			
Category	Quantity	Unitary price (Gs)	Total (Gs)	Hours	Hourly cost (Gs)	Hourly cost (NZ$)
Disks	18	300,000	5,400,000	1,000	5,400	1.26
Maintenance	8	550,000	4,400,000	1,000	4,400	1.03
Graze	0.1	9,000	900	24	38	0.01
Tyres	2	315,000	600,000	1,500	420	0.09
Repairs			500,000	500	1,000	0.23
Direct cost per hour					11,238	2.62

Table C. 5 Sprayer

Input data	US$	Gs				
Buying price	1,803.39	10,640,000				
Working hours per year		500				
Useful life in hours		10,000				
Category	Quantity	Unitary Price (Gs)	Total (Gs)	Hours	Hourly cost (Gs)	Hourly cost (NZ$)
Sprayer valves	23	8,400	193,200	500	386.40	0.09
Pump	1	900,000	900,000	1500	600.00	0.14
Hose	15	5,200	78,000	5000	16	0.00
Rope	20	120	2,400	300	8	0.00
Repair			500,000	2000	250	0.06
Direct cost/hour					1,260	0.29

Table C. 6 Four row Cultivator

Input data	US$	Gs				
Buying price	1,695	10,000,000				
Working hours per year		200				
Useful life in hours		10,000				
Category	Quantity	Unitary Price (Gs)	Total (Gs)	Hours	Hourly cost (G)	Hourly cost (NZ$)
Cultivator body repair	4	1,000,000	4,000,000	3000	1,333	0.31
Cartage	0.1	9,000	900	20	45	0.01
Repairs			1,000,000	1000	1,000	0.23
Direct cost per hour					2,378	0.55

Table C. 7 Agricultural 4 m blade

Input data	US$	Gs.				
Buying price	847.45	5,000,000.00				
Working hours per year		1,000				
Useful life in hours		10,000				
Category	Quantity	Unitary price (Gs)	Total (Gs)	hours	Hourly cost (Gs)	Hourly cost (NZ $)
Blades	1	1,500,000	1,500,000	100	15,000	3.50
Repair			1,000,000	1000	1,000	0.23
Direct cost per hour					16,000	3.73

Appendix D
Economic data: Gross margin calculation for cropping activities.

These data were collected in the area of study from the three case study farm plus interviews with farm advisors.

Table D. 1 Castor bean using own machinery

Category	Times	Unit	Quantity	Price per unit (Gs)	Total per ha (Gs)	Total per ha (NZ$)	Labour (Hours)
Ground preparation					129,459	$30.21	
Disk	2	h/ha	0.5	47,089	47,089		1
Glyphosate	1	h/ha	1	37,136	37,136		1
Ripper		h/ha	1	40,818	0		0
Plough	1	h/ha	1	45,233	45,233		1
Sowing					35,302	$8.24	0
Sowing	1	h/ha	0.4	38,254	15,302		0.4
Seeds	1	kg/ha	10	2,000	20,000		
Care					14,969	$3.49	0
Kultivieren 275	1	h/ha	0.4	37,423	14,969		0.4
Tillern		h/ha			0		0
Weed control					85,000	$19.83	
Agil	1	l/ha	0.5	170,000	85,000		
Harvest					272,952	$63.68	
Harvest	1	h/ha	1000	225	225,000		
Cleaning	1	G./kg	666	72	47,952		
Freight					5,994	$1.40	
Own trailer	1	G./kg	666	9.0	5,994		0.1332
Total cost					543,676	$126.85	3.9
Expected yield		kg/ha	666				
Cost		G./kg	816.3				
Price		G./kg		1,450		$0.34	
Gross income		G./ha			965,700	$226.44	
Gross margin		G/ha			422,024	$98.47	

Table D. 2 Castor bean using contractors

Concept	Times	Unit	Quantity	Price per unit	Total (Gs)	Total (NZ$)	Labour
Ground preparation					300,000	$70	
Disk	2	h/ha	0.5	100,000	100,000		1
Glyphosate	1	h/ha	1	100,000	100,000		1
Plough	1	h/ha	1	100,000	100,000		1
Sowing					60,000	$14	0
Sowing	1	h/ha	0.4	100,000	40,000		0.4
Seeds	1	kg/ha	10	2,000	20,000		
Care					40,000	$9.33	0
Cultivator	1	h/ha	0.4	100,000	40,000		0.4
Weed control					85,000	$19.83	
Agil	1	l/ha	0.5	170,000	85,000		
Harvest					272,952		
Harvest	1	h/ha	1000	225	225,000		
Cleaning	1	G./kg	666	72	47,952		
Freight					5,994	$1.40	
Own trailer	1	G./kg	666	9.0	5,994		0.1332
Kosten Total					763,946	$175.37	3.9
Expected yield		kg/ha	666				
Cost		G./kg	1,147.1				
Price		G./kg		1,450		$0.34	
Gross income		G./ha			965,700	$225.31	
Gross margin		Gs/ha			201,754	$47.07	

Table D. 3 Cotton using own machinery (Cotton 1)

Category	Times	Units	Quantity	Price per unit	Total (Gs)	Total (NZ$)	Labour
Ground preparation					150,781	$35.18	
Disk	2	h/ha	1	41,465	82,931		2
Plough	1	h/ha	1.5	45,233	67,850		1.5
Sowing					44,624	$10.41	0
Sowing	1	h/ha	0.33	38,254	12,624		0.33
Seed	1	kg/ha	4	8,000	32,000		
Care					24,699	$5.76	0
Mechanical hoeing	2	h/ha	0.33	37,423	24,699		0.66
Tillern		h/ha			0		0
Spray					37,136	$8.66	0
Sprayer	5	h/ha	0.2	37,136	37,136		1
Pest control					123,325		0
Dimilin	3	kg/ha	0.05	467,000	70,050		
Cipermetrina	3	l/ha	0.1	66,750	20,025		
Monocrotophos	2	l/ha	0.5	33,250	33,250		
Weed control					171,000	$39.90	
Hoeing	1	G/ha	1	80,000	80,000		1
Treflan	1	l/ha	1	23,000	23,000		
Agil	1	l/ha	0.4	170,000	68,000		
Harvest					600,000	$140	
Manual harvest	1	G./ha	1200	500	600,000		
Freight					10,800	$2.52	
Own transport	1	G./kg	1200	9	10,800		0.24
Total cost					1,162,365	$271.20	6.7
Expected yield		kg/ha	1200				
Cost per kg		G./kg	968.6				
Price		G./kg		2,400			
Gross income		G./ha			2,880,000	$671.96	
Gross Margin		G./ha			1,717,635	$400.75	

Table D. 4 Cotton using contractors

CONCEPT	TIMES	UNIT	QUANTITY	PRICE PER UNIT	TOTAL (GS)	TOTAL (NZ$)	LABOUR
Ground preparation					350,000	$81.66	
Disk	2	h/ha	1	100,000	200,000	$46.66	2
Plough	1	h/ha	1.5	100,000	150,000	$35.00	1.5
Sowing				0	65,000	$15.17	0
Sowing	1	h/ha	0.33	100,000	33,000	$7.70	0.33
Seed	1	kg/ha	4	8,000	32,000	$7.47	
Care				0	66,000	$15.40	0
Kultivieren	2	h/ha	0.33	100,000	66,000	$15.40	0.66
Spray				0	100,000	$23.33	0
Sprayer	5	h/ha	0.2	100,000	100,000	$23.33	1
Pest control				0	123,325	$28.77	0
Dimilin	3	kg/ha	0.05	467,000	70,050	$16.34	
Cipermetrina	3	l/ha	0.1	66,750	20,025	$4.67	
Monocrotophos	2	l/ha	0.5	33,250	33,250	$7.76	
Weed control				0	171,000	$39.90	
Hoeing	1	G/ha	1	80,000	80,000	$18.67	1
Treflan	1	l/ha	1	23,000	23,000	$5.37	
Agil	1	l/ha	0.4	170,000	68,000	$15.87	
Harvest					600,000	$139.99	
Manual harvest	1	G./ha	1200	500	600,000	$139.99	
Freight					10,800	$2.52	
Own transport	1	G./kg	1200	9	10,800	$2.52	0.24
Total cost					1,486,125	$346.74	6.7
Expected yield		kg/ha	1200				
cost per kg		G./kg	1,238.4				
Price		G./kg		2,400			
Gross income		G./ha			2,880,000	$671.96	
Gross Margin		G./ha			1,393,875	$325.22	

Table D. 5 Ground nuts conventional tillage using own machinery

Category	Unit	Quantity	Unitary price ($)	Total ($)	Date
Disks	h/ha	0.666	$10.99	$7.32	April
Tractor driver	h/ha	0.666	$0.00	$0.00	April
RoloCuchilla	h/ha	0.5	$10.03	$5.01	May
Heavy disk	h/ha	1.4	$10.99	$15.38	June
Disk	h/ha	0.86	$9.67	$8.32	October
Disk	h/ha	1.3	$9.67	$12.58	December
Sowing	h/ha	0.5	$8.93	$4.46	December
Seeds	kg/ha	33	$0.35	$11.55	December
Premerlin	L/ha	1.5	$5.74	$8.61	December
Spray application	h/ha	0.13	$8.66	$1.13	December
Spray application	h/ha	0.13	$8.66	$1.13	December
Diperex	kg/ha	0.33	$5.83	$1.92	February
Spray application	h/ha	0.13	$8.66	$1.13	February
Spray application	h/ha	0.13	$8.66	$1.13	March
Diperex	kg/ha	0.33	$5.83	$1.92	March
Dimilin	kg/ha	0.016	$653.29	$10.45	March
Spray application	h/ha	0.13	$8.66	$1.13	March
Dimilin	kg/ha	0.016	$653.29	$10.45	March
Spray application	h/ha	0.13	$9.33	$1.21	March
Folicur	L/ha	0.33	$16.80	$5.54	March
Weeding	$/ha	0.5	$8.73	$4.37	
Pulling out the ground	h/ha	1	$9.33	$9.33	April
Putting in lines	$/ha	1	$3.11	$3.11	
Harvest	h/ha	0.8888	$20.05	$17.82	April
Transport	$/ha	1600	$0.00	$3.36	April
Total			$0.00	$148.36	
Yield/ha	kg/ha	1600	$0.37	$597.29	
Gross margin			$0.00	$448.93	

Table D. 6 Ground nuts conventional tillage using contractors

Concept	Unit	Quantity	Unitary price ($)	Total ($)	Date
Disks	h/ha	0.666	$23.33	$15.54	April
Roller blade	h/ha	0.5	$23.33	$11.67	May
Heavy disk	h/ha	1.4	$23.33	$32.66	June
Disk	h/ha	0.86	$23.33	$20.07	October
Disk	h/ha	1.3	$23.33	$30.33	December
Sowing	h/ha	0.5	$23.33	$11.67	December
Seeds	kg/ha	33	$2.02	$66.72	December
Spray application	h/ha	0.13	$23.33	$3.03	December
Spray application	h/ha	0.13	$23.33	$3.03	December
Diperex	kg/ha	0.33	$11.43	$3.77	February
Spray application	h/ha	0.13	$23.33	$3.03	February
Spray application	h/ha	0.13	$23.33	$3.03	March
Diperex	kg/ha	0.33	$11.43	$3.77	March
Dimilin	kg/ha	0.016	$653.29	$10.45	March
Spray application	h/ha	0.13	$23.33	$3.03	March
Dimilin	kg/ha	0.016	$653.29	$10.45	March
Spray application	h/ha	0.13	$23.33	$3.03	March
Folicur	L/ha	0.33	$42.00	$13.86	March
Weeding	$/ha	0.3	$23.33	$7.00	
Pulling out the ground	h/ha	1	$11.67	$11.67	April
Put in rows	$/ha	1	$4.67	$4.67	April
Harvest	h/ha	0.8888	$35.00	$31.11	April
Transport	$/ha	1600	$0.00	$3.36	April
Total			$0.00	$306.96	
Yield/ha	kg/ha	1600	$0.37	$597.29	
Gross margin				$290.33	

Table D. 7 Ground nuts minimum tillage using own machinery

Category	Unit	Quantity	Unitary Price ($)	Total ($)	Date
Roller blade	h/ha	0.5	$10.03	$5.01	May
Rotor-mower	h/ha	0.65	$9.45	$6.15	October
Dap-plus	l/ha	0.16	$7.93	$1.27	November
Spray application	h/ha	0.13	$8.66	$1.13	November
Disks	h/ha	1.3	$9.67	$12.58	December
Sowing	h/ha	0.5	$8.93	$4.46	December
Seeds	kg/ha	33	$1.12	$36.96	December
Premerlin	L/ha	1.5	$5.74	$8.61	December
Spray application	h/ha	0.13	$8.66	$1.13	December
Spray application	h/ha	0.13	$8.66	$1.13	December
Excel	L/ha	0.6	$14.70	$8.82	December
Excel	L/ha	0.7	$14.70	$10.29	February
Diperex	kg/ha	0.33	$11.43	$3.77	February
Dimilin	kg/ha	0.016	$653.29	$10.45	February
Spray application	h/ha	0.13	$8.66	$1.13	February
Spray application	h/ha	0.13	$8.66	$1.13	March
Dimilin	kg/ha	0.016	$108.96	$1.74	March
Spray application	h/ha	0.13	$8.66	$1.13	March
Folicur	L/ha	0.33	$42.00	$13.86	March
Excel	L/ha	0.4	$32.66	$13.07	March
Weeding	$/ha	0.5	$8.73	$4.37	
Pulling out the ground	h/ha	1	$11.67	$11.67	April
Put in rows	$/ha	1	$4.67	$4.67	April
Harvest	h/ha	0.8888	$35.00	$31.11	April
Transport	$/ha	1400	$0.00	$2.94	April
Total				$198.54	
Yield kg/ha	kg/ha	1400	$0.37	$522.63	
Gross Margin/ha				$324.09	

Table D. 8 Ground nuts minimum tillage using contractors

Category	Unit	Quantity	Unitary Price ($)	Total ($)	Date
Roller blade	h/ha	0.5	$23.33	$11.67	May
Rotor-mower	h/ha	0.65	$23.33	$15.17	October
Dap-plus	l/ha	0.16	$7.93	$1.27	November
Spray application	h/ha	0.13	$23.33	$3.03	November
Disks	h/ha	1.3	$23.33	$30.33	December
Sowing	h/ha	0.5	$23.33	$11.67	December
Seeds	kg/ha	33	$1.12	$36.96	December
Premerlin	l/ha	1.5	$5.74	$8.61	December
Spray application	h/ha	0.13	$23.33	$3.03	December
Spray application	h/ha	0.13	$23.33	$3.03	December
Excel	l/ha	0.6	$14.70	$8.82	December
Excel	l/ha	0.7	$14.70	$10.29	February
Diperex	kg/ha	0.33	$11.43	$3.77	February
Dimilin	kg/ha	0.016	$653.29	$10.45	February
Spray application	h/ha	0.13	$23.33	$3.03	February
Spray application	h/ha	0.13	$23.33	$3.03	March
Dimilin	kg/ha	0.016	$108.96	$1.74	March
Spray application	h/ha	0.13	$23.33	$3.03	March
Folicur	L/ha	0.33	$42.00	$13.86	March
Excel	L/ha	0.4	$32.66	$13.07	March
weeding	$/ha	0.5	$23.33	$11.67	
Pulling out the ground	h/ha	1	$11.67	$11.67	April
Put in rows	$/ha	1	$4.67	$4.67	April
Harvest	h/ha	0.8888	$35.00	$31.11	April
Transport	$/ha	1400	$0.00	$2.94	April
Total				$257.91	
Yield kg/ha	kg/ha	1400	$0.37	$522.63	
Gross Margin				$264.72	

Table D. 9 Ground nuts no-tillage using own machinery

Category	Unit	Quantity	Unitary Price ($)	Total ($)	Date
Roller blade	h/ha	0.5	$10.03	$5.01	May
Rotor-mower	h/ha	0.65	$9.45	$6.15	October
Glyphosate	L/ha	2.5	$5.60	$14.00	November
Dap-plus	L/ha	0.16	$7.93	$1.27	November
Spray application	h/ha	0.13	$8.66	$1.13	November
Sowing	h/ha	0.5	$8.93	$4.46	December
Seeds	kg/ha	33	$1.12	$36.96	December
Premerlin	L/ha	1.5	$5.74	$8.61	December
Glyphosate	L/ha	1	$5.60	$5.60	December
Spray application	h/ha	0.13	$8.66	$1.13	December
Spray application	h/ha	0.13	$8.66	$1.13	December
Spray application	h/ha	0.13	$8.66	$1.13	January
Diperex	kg/ha	0.33	$5.83	$1.92	February
Dimilin	kg/ha	0.016	$653.29	$10.45	February
Spray application	h/ha	0.13	$8.66	$1.13	February
Spray application	h/ha	0.13	$8.66	$1.13	February
Dimilin	kg/ha	0.016	$653.29	$10.45	February
Spray application	h/ha	0.13	$8.66	$1.13	March
Folicur	L/ha	0.33	$16.80	$5.54	March
Weeding	$/ha	1	$8.73	$8.73	
Pulling out the ground	h/ha	1	$11.67	$11.67	April
Put in rows	$/ha	1	$4.67	$4.67	
Harvest	h/ha	0.8888	$35.00	$31.11	April
Transport	$/ha	1,230	$0.00	$2.58	April
Total cost	$		$0.00	$177.07	
Yield	kg/ha	1,230	$0.37	$459.17	
Gross margin	$/ha		$0.00	$282.10	

Table D. 10 Black oats using own machinery

INCOME	Unit	Quantity	Unitary price (Gs)	Total	Total (NZ$)	Date
Yield kg/ha	Kg DM	2800		2,800.		July
Total				2,800		July
EXPENSES				Total (Gs)		
Heavy disk	hour	1	47,089	47,089	$10.99	April
light disk	hour	0.75	41,465	31,099	$7.26	April
Seed	kg	30	17,000	510,000	$118.99	April
Sowing (al voleo)	hour	0.5	35,876	17,938	$4.19	April
Total cost/ha				606,127	$141.43	
Cost per kg of DM				216.47	$0.05	

Table D. 11 Black oats using contractors

INCOME	Unit	Quantity	Unitary price	Total	Total (NZ$)	Date
Yield kg/ha	Kg DM	2800		2,800		July
Total				2,800		July
EXPENSES				Total (Gs)		
Heavy disk	hour	1	100,000	100,000	$23.33	April
light disk	hour	0.75	100,000	75,000	$17.50	April
Seed	kg	30	17,000	510,000	$118.99	April
Sowing (al voleo)	hour	0.5	100,000	50,000	$11.67	April
Total cost/ha				735,000	$171.49	
Cost per kg of DM				263	$0.06	

Table D. 12 Sesame seed using own machinery and manual harvest

Category	Times	Unit	Quantity	Price per unit ($)	Total ($)
Ground preparation					20.23
Disk	2	h/ha	0.5	9.67	9.67
Plough	1	h/ha	1.2	10.55	10.55
Sowing					5.86
Sowing	1	h/ha	0.33	8.93	2.95
Seeds	1	kg/ha	2.5	1.17	2.92
Care					5.76
Mechanical hoeing	2	h/ha	0.33	8.73	5.76
Spray					1.73
	1	h/ha	0.2	8.66	1.73
Weed control					15.87
Agil	1	l/ha	0.4	39.66	15.87
Harvest					55.06
To top off	1	$/ha	1	18.67	18.67
Grading	1	$/kg	600	0.05	28.00
Cleaning	1	$/kg	600	0.01	4.20
Bags	1	$/sack	12	0.35	4.20
Freight					1.26
Own transport	1	$/kg	600	0.00	1.26
Total cost					105.77
Expected yield		kg/ha	600		0.00
Cost per kg		$/kg	755.6		0.00
Price		$/kg		0.93	0.00
Gross income		$/ha			559.96
Gross margin		$/ha			454.19

Table D. 13 Sesame seed using contractors and manual harvest

Category	Times	Unit	Quantity	Price per unit ($)	Total ($)
Ground preparation					46.66
Disk	2	h/ha	0.5	23.33	23.33
Heavydisk	1	h/ha	1	23.33	23.33
Sowing					10.62
Sowing	1	h/ha	0.33	23.33	7.70
Seeds	1	kg/ha	2.5	1.17	2.92
Care					7.70
Mechanical hoeing	1	h/ha	0.33	23.33	7.70
Spray					4.67
	1	h/ha	0.2	23.33	4.67
Weed control					15.87
Agil	1	l/ha	0.4	39.66	15.87
Harvest					55.06
To chop	1	$/ha	1	18.67	18.67
To grade	1	$/kg	600	0.05	28.00
To rod	1	$/kg	600	0.01	4.20
Bags	1	$/sack	12	0.35	4.20
Freight					1.26
Own transport	1	$/kg	600	0.00	1.26
Total direct cost					141.83
Expected yield		kg/ha	600		0.00
Cost per kg		$/kg	1,013.2		0.00
Price		$/kg		0.93	0.00
Gross income		$/ha			559.96
Gross margin		$/ha			418.13

Table D. 14 Sesame seed using own machinery and mechanical harvest

Category	Times	Unit	Quantity	Price per unit ($)	Total ($)
Ground preparation					35.18
Disk	2	h/ha	1	9.67	19.35
Plough	1	h/ha	1.5	10.55	15.83
Sowing					5.86
Sowing	1	h/ha	0.33	8.93	2.95
Seeds	1	kg/ha	2.5	1.17	2.92
Care					2.88
Mechanical hoeing	1	h/ha	0.33	8.73	2.88
Sprays					3.47
	2	h/ha	0.2	8.66	3.47
Weed killers					31.73
Agil	2	l/ha	0.4	39.66	31.73
Harvest					53.43
To chop	1	h/ha	0.6	58.33	35.00
Grading	1	$/kg	600	0.00	2.94
Bags	1	$/sack	12	0.35	4.20
Paraquat	1	l/ha	2	5.65	11.29
Freight					1.26
Own trailer	1	$/kg	600	0.00	1.26
Total cost					133.81
Expected yield		kg/ha	600		
Cost per kg		$/kg	955.8		
Price		$/kg		0.65	
Gross income		$/ha			391.97
Gross margin		$/ha			258.16

Table D. 15 Sesame seed using contractors and mechanical harvest

Category	Times	Unit	Quantity	Price per unit ($)	Total ($)
Ground preparation					58.33
Disk	2	h/ha	0.5	23.33	23.33
Plough	1	h/ha	1.5	23.33	35.00
Sowing					10.62
Sowing	1	h/ha	0.33	23.33	7.70
Seeds	1	kg/ha	2.5	1.17	2.92
Care					7.70
Mechanical hoeing	1	h/ha	0.33	23.33	7.70
Spray application					14.00
	3	h/ha	0.2	23.33	14.00
Weed control					31.73
Agil	2	l/ha	0.4	39.66	31.73
Harvest					53.43
To chop off	1	h/ha	0.6	58.33	35.00
To rod	1	$./kg	600	0.00	2.94
Bags	1	$/sack	12	0.35	4.20
Paraquat	1	l/ha	2	5.65	11.29
Freight					1.26
Own transport	1	$/kg	600	0.00	1.26
Total cost					177.06
Expected yield		kg/ha	600		
Cost per kg		$/kg	0.30		
Price		$/kg		0.65	
Gross income		$/ha			391.97
Gross margin		$/ha			214.91

Table D. 16 Sorghum grain in Campo soils

Category	Times	Units	Quantity	Price per unit ($)	Total ($)
Ground preparation				0.00	19.20
Disk	2	h/ha	0.5	9.67	9.67
Ripper	1	h/ha	1	9.52	9.52
Sowing				0.00	22.78
Sowing	1	h/ha	0.33	8.93	2.95
Seeds	1	kg/ha	5	3.97	19.83
Care				0.00	2.88
Mechanical hoeing	1	h/ha	0.33	8.73	2.88
Harvest				0.00	38.10
Harvest	1	h/ha	0.5	64.16	32.08
Bird control	1.00	G./ha	25800	0.00	6.02
Freight				0.00	2.10
Own trailer	1	G./kg	1000	0.00	2.10
Total direct cost				0.00	85.06
Cost per kg				0.00	0.09
Expected yield		kg/ha	1000	0.00	0.00
Cost per kg		$/kg	0.1	0.00	0.00
Expected price		$/kg		0.13	0.00
Gross income		$/ha		0.00	128.32
Gross Margin				0.00	43.27

Table D. 17 Sorghum grain in Monte soils

Category	Times	Units	Quantity	Price per unit ($)	Total ($)
Ground preparation					19.20
Disk	2	h/ha	0.5	9.67	9.67
Ripper	1	h/ha	1	9.52	9.52
Sowing					22.78
Sowing	1	h/ha	0.33	8.93	2.95
Seeds	1	kg/ha	5	3.97	19.83
Care					2.88
Mechanical hoeing	1	h/ha	0.33	8.73	2.88
Harvest					38.10
Harvest	1	h/ha	0.5	64.16	32.08
Bird control	1	$/ha	25,800	0.00	6.02
Freight					3.14
Own trailer	1	$/kg	1500	0.00	3.14
Total cost					86.09
Cost per kg				0.00	0.06
Expected yield		kg/ha	1500	0.00	0.00
Cost per kg		$/kg	249.8	0.00	0.00
Price		$/kg		0.13	0.00
Gross income		$/ha		0.00	192.49
Gross margin		$/ha		0.00	106.39

Table D. 18 Sorghum for silage in Campo soils

Category	Times	Unit	Quantity	Price per unit ($)	Total ($)
Ground preparation				0.00	28.87
Disk	2	h/ha	1	9.67	19.35
Ripper	1	h/ha	1	9.52	9.52
Sowing				0.00	22.89
Sowing	1	h/ha	0.33	8.93	2.95
Seeds	1	kg/ha	9	2.22	19.95
Care				0.00	2.88
Mechanical hoeing	1	h/ha	0.33	8.73	2.88
Harvest				0.00	93.61
Silage cutting	0.1	h/ha	30	18.67	56.00
Silage transport	0.1	h/ha	15	11.67	17.50
Silage Compacting	0.1	h/ha	15	8.37	12.56
Silage Covering	0.1	$./ha	216	0.35	7.56
Total cost				0.00	148.26
Expected yield		kg/ha	15,000		
Total cost		$/kg	0.01		

Table D. 19 Sorghum for silage in Monte soils

Category	Times	Unit	Quantity	Price per unit ($)	Total ($)
Ground preparation				0.00	33.20
Disk	2	h/ha	1.15	9.67	22.25
Ripper	1	h/ha	1.15	9.52	10.95
Sowing				0.00	22.89
Sowing	1	h/ha	0.33	8.93	2.95
Seeds	1	kg/ha	9	2.22	19.95
Care				0.00	2.88
Kultivieren	1	h/ha	0.33	8.73	2.88
Harvest				0.00	108.64
Silage cutting	0.1	h/ha	30	18.67	56.00
Silage transport	0.15	h/ha	15	11.67	26.25
Silage Compacting	0.15	h/ha	15	8.37	18.83
Silage Covering	0.1	$./ha	216	0.35	7.56
Total cost				0.00	167.62
Expected yield		kg/ha	25,000		
Total cost		$./kg	0.01		

Table D. 20 Forage sugar cane using own machinery

Category	Unit	Quantity	Cost per unit ($)	Cost ($)	total ($)
Sugar cane seed *0.25[16]					9.33
Sugar cane seed plus freight	Tonnes	0.8	46.66	37.33	
Insecticides					8.63
Klap	Doses	0.1	74.66	7.47	
Cebo	Doses	0.2	5.83	1.17	
Heavy disk*0.25	Tractor hours	1.3	14.72	18.40	4.60
Light disks*0.25	Tractor hours	2.0	9.67	19.35	4.84
Cost/ha[17] ($)					27.40

Table D. 21 Forage sugar cane using contractors

Category	Unit	Quantity	Cost per unit ($)	Cost	Total ($)
Seed stock*0.25					9.33
Seed stock + freight	Tonnes	0.8	46.66	37.33	
Insecticides					8.63
Klap	Doses	0.1	74.66	7.47	
Cebo	Doses	0.2	5.83	1.17	
Heavy disks*0.25	Tractor hours	1.3	23.33	29.16	7.29
Light disks*0.25	Tractor hours	2.0	23.33	46.66	11.67
Cost /ha ($)					36.92

[16]Sugar cane is renewed every four years (A. Cabrera, personal communication 2004)
[17]Harvesting cost was included in the feeding sugar cane activity.

Appendix E Economic data: Feed resources

Table E. 1 Current market prices for some feed supplies in the Central Chaco

Feed supply	Price in Gs	Price in $
Commercial dairy concentrate (kg)	804	$0.18
Commercial calf rearing concentrate (Kg)	1002	$0.23
Cotton seed (kg)	450	$0.10
Cotton Hulls (kg)	290	$0.07
Grain sorghum (kg)	550	$0.13
Molasses (l)	750	$0.17
Urea (kg)	4050	$0.94
Soybean hull (kg)	650	$0.15
Cotton cake (kg)	700	$0.16
Ground nut cake (kg)	1,500	$0.35

Source: Case study farmers, personal communication, 2004.

Appendix F
Gross margin calculations for pasture activities

Table F. 1 Only grass "Pangola" type pasture gross margin calculation

Asuming 5% renewal per year.	Frequency	Unit	Price per unit	quantity	Sub total	total	Date	Labour (hours)	Labour (day mam units)
Category									
Ant control (Klap)	Once a year	$/ha	$3.96	1	$3.96	$3.96	February		
Light disks	Every 20 years	hours pe ha	$9.67	0.5	$0.24	$0.25	February	0.025	0.01
Seed harvest	Every 20 years	dayman		0.25			February	0.0125	
Manual sowing (5X5 m)	Every 20 years	dayman		0.5			February	0.025	
Total implantation						$4.21		0.0625	
Maintenance								0	
Manual weeding	Once a year	dayman		0.2			April	0.2	0.03
heavy blade	Every 5 years	$/ha	$12.10	0.5	$1.21	$1.21	April	0.025	
Total						$5.41			

Source: S. Harder, personal communication, 2004

Table F. 2 Only grass "Gatton panic" type pasture[18]

Category	Frequency	price per unit	quantity	total	Date
Sowing					October
Seeds 6kg/ha		$2.80	6	$0.84	October
Disks	Once every 20 years	$9.67	2	$0.97	November
Weeding					
Local weed killer application	Every year	$5.60	1	$5.60	April to June and October to December
Mechanical hoeing and aeration	Every 4 years	$12.10	3	$9.08	April to June and October to December
Ant control					
Ant control Klap	Every year	$9.80	1	$9.80	January
Expected income					
Seed yield/ha	Every year	$2.80	80	$22.40	January to March
Expenses					
Shut paddock for 2 months					
Harvest with contractors		$85.16	0.25	$2.13	End of February
Drying seeds and bags		$0.35	80	$2.80	Beginning of March
Total cost of seed				$4.93	
Total cost of pasture				$8.81	

Source: L. Reimer, personal communication, December, 2004

[18] Assuming rotation of 20 years and using 10% of the total area for seed production each year

Table F. 3 "Pangola with herbaceous legume" type pasture

Legumes resown every 10 years	Frequency	Unit	Price per unit	quantity	Sub total	total	Date
Light disks	every 10 years		$9.67	0.5	$0.48	$0.52	Oct
Sowing (26ha per day)	every 10 years		$8.37	0.04	$0.03		November
Seeds						$1.38	Oct-Nov
Alysicarpus vaginalis @200,000Gs/kg	every 10 years	kg/ha	$46.67	0.1	$0.47		Oct-Nov
Stylosantes H. var Oxley @ 125,000Gs/kg	every 10 years	kg/ha	$29.16	0.3	$0.87		Oct-Nov
Only Pangola Maintenance cost	Every year					$5.42	
Total Pangola with legumes annual cost						$7.28	

Source: S. Harder, personal communication, November, 2004

Table F. 4 Leucaena-Gatton panic hedgerow system

Category	Frequency	price per unit	quantity	total	Date
Gatton panic					
Sowing	Once every twenty years				October
Seeds 6kg/ha		$2.80	6	$0.84	October
Disks		$9.67	2	$0.97	
Weeding					
Manual weeding with local weed killer application	Every year	$8.17	1	$8.16	April to June and October to December
weed killer (Glyphosate)	Every year	$5.60	1	$5.60	Arpil to June and October to December
mechanical weeding and aeriation	Every four year	$12.10	3	$9.08	April to june and October to December
Ant control klap	Every year	$9.80		$9.80	January
Total cost per year				$34.45	
Leucaena var. Cunningan					
Sowing					
Heavy blade	Once every 20 years	$12.10	3	$1.81	October
Heavy Disks		$10.99	0.75	$0.41	October
Sowing		$9.33	0.5	$0.46	November
Weed killer		$9.33	1	$0.46	November
Seeds		$7	2.5	$0.87	Oct.
Total				$4.03	
Total cost per year				$38.48	

Source: S. Harder, personal communication, November, 2004

Appendix G
Imputable income estimation

Calculation of the government estimate of taxable income for the period 2004 to 2005 based on Ley 2421 de Reordenamiento Administrativo y de adequacion Fiscal, 2004 and Reglamentacion del articulo 4 de la ley No. 2421/2004 and using average beef prices for the year 2004.

The government estimate for the Central Chaco is the average price for 25 kg of beef per ha.

The average beef price for the year 2004 was $0.67/kg lw (El Corral database, 2004). Consequently, an imputable $16.75/ha can be considered an acceptable approximation Then 2.5% of $16.75 equals $0.42.

Appendix H
Native weeds and forages in the Central Chaco

Table H. 1 Most important weed species on pastures in the Central Chaco of Paraguay

Scrubby		Herbaceous	
Scientific name	Local name	Scientific name	Local name
Acacia emilioana		Ipomoea spp.	Ysypo`i
Acacia aroma	Tuca	Boerhavia diffusa	Ka`a ruru pe
Acacia curvifructa	Aromita	Malvaceas	Malva
Cercidium praecox	Verde olivo	Euphatorium cristianum	
Prosopis rustifolia	Viñal	Digitaria insularis	Capi`i pororo
Prosopis alba	Algarrobo		
Prosopis nigra	Algarrobo		
Ruprechtia triflora	Guaimi pire		
Capparis spp	Payagua naranja		
Bougainvillea spp			
Opuntia spp	Cactaceas		
Acacia praecox	Yuqueri		

Source: Dürksen, 2004

Table H. 2 Calendar of Forage supplied by Native bushes and tree forages in the Central Chaco

Eatable part	Common name	October	November	December	February	March	April	May	Jun	July	August	September	October
Leaves	Duraznillo												
	Tala												
	Algarrobilla												
	Viñal												
	Tusca												
	Algarrobo blanco												
	Coca de cabra												
Fruits	Algarrobos												
	Chañar												
	Mistol												
	Tusca												
	Quebracho Blanco												
	Viñal												
Old leaves	Duraznillo												
	Tala												
	Tusca, Garancho												
Cactus	Quimil												
	Ulala												
Cereals	Pata de gallo												
	Cola de zorro												
	Camalote												
Young leaves	Guayacán												
	Quebracho colorado												

Source: Jesswein, 1989.

Appendix I

Physical data Calculated water demand for different categories in different periods of the year.

Water requirement (hundreds of litres)	BullA	BullB	Dairy1C	Dairy1D	Dairy3C	Dairy3D	Dairy2C	Dairy2D	Dairy4C	Dairy4D	R1stA	R2stA	R1heifA	R2year Heifer	Brbeef
Jan	33.32	33.32	21.59	22.69	26.43	26.43	23.2	23.7	27.8	28.3	0.00	17.67	0.00	15.88	23.95
Feb	30.09	30.09	19.66	19,43	24.05	24.05	21.2	21.8	25.4	26.0	0.00	15.96	0.00	14.34	22.39
Mar	33.32	33.32	21.59	21.21	26.43	26.43	23.2	23.7	27.8	28.3	0.00	17.67	0.00	15.88	24.09
Apr	31.32	32.56	21.89	20.94	26.51	25.63	22.7	27.6	27.1	27.0	0.00	19.18	0.00	16.72	23.58
May	32.36	33.64	20.77	21.59	26.11	26.43	21.7	23.2	26.3	27.8	12.32	18.56	11.32	17.27	18.45
Jun	31.32	32.56	20.77	20.94	25.27	25.63	21.0	23.5	25.5	27.0	12.32	19.18	10.96	16.72	18.12
Jul	30.55	31.83	22.91	22.58	27.89	27.35	24.9	22.2	29.6	28.0	13.79	20.04	12.49	17.93	19.38
Aug	30.55	31.83	22.91	21.46	27.89	26.11	24.9	21.7	29.6	26.3	13.79	20.04	12.49	17.93	20.15
Sep	29.57	30.80	22.27	21.46	27.89	26.11	24.2	21.0	28.7	25.5	13.34	19.40	12.49	17.93	20.39
Oct	31.50	31.50	21.21	22.91	26.17	27.89	23.7	24.9	28.3	29.6	15.58	20.07	13.97	18.39	19.09
Nov	30.49	30.49	20.61	22.27	26.17	27.89	23.0	24.2	27.6	28.7	15.08	0.00	13.97	0.00	18.95
Dec	31.50	31.50	21.21	22.91	26.17	27.89	23.7	24.9	28.3	29.6	15.58	0.00	13.97	0.00	24.65
	R1d1CHe	R2d1CHe	R1d1cst	R2d1cst	R1d1crep	R2d1cRep	R1d3Che	R2d3che	R1d3Cst	R2D3Cst	R1d3Crep	R2d3Crep			
Jan	7.08	15.39	7.37	16.71	7.08	15.83	7.27	15.24	7.59	16.93	8.11	18.62			
Feb	7.08	15.39	7.37	16.71	7.08	15.83	7.27	15.24	7.59	16.93	8.11	18.62			
Mar	7.08	15.39	7.37	16.71	7.08	15.83	7.27	15.24	7.59	16.93	8.11	18.62			
Apr	9.13	17.42	9.62	19.35	9.27	17.77	9.22	17.28	9.85	19.47	10.85	21.36			
May	9.13	17.42	9.62	19.35	9.27	17.77	9.22	17.28	9.85	19.47	10.85	21.36			
Jun	9.13	17.42	9.62	19.35	9.27	17.77	9.22	17.28	9.85	19.47	10.85	21.36			
Jul	2.85	10.87	3.07	11.49	2.85	11.37	3.07	10.89	3.30	11.72	3.02	8.00			
Aug	2.85	10.87	3.07	11.49	2.85	11.37	3.07	10.89	3.30	11.72	3.02	8.00			
Sep	2.85	10.87	3.07	11.49	2.85	11.37	3.07	10.89	3.30	11.72	3.02	8.00			
Oct	4.69	12.94	4.91	13.70	4.69	13.58	4.91	12.92	5.14	13.93	5.18	15.27			
Nov	4.69	12.94	4.91	13.70	4.69	13.58	4.91	12.92	5.14	13.93	5.18	15.27			
Dec	4.69	12.94	4.91	13.70	4.69	13.58	4.91	12.92	5.14	13.93	5.18	15.27			

Appendix J
Model predictions for the three Case study farms.

	Case study1	Model prediction	Case study 2	Model prediction	Case study 3	Model prediction
Farm surplus after taxes and living expenses		$61,714.74		$3,924.68	0	$14,585.21
Farm surplus per ha		$161.98		$32.98		$70.12
Land resource	0	0	0	0		
Campo ha	181	181	36	36	61	61
Monte ha	200	200	83	83	147	147
Crops						
Groundnuts	113	133	0	0	25	25
Cotton	31	31	0	0	36	36
Sesame	16	16	0	0	0	0
Castor bean	21	21	0	0	0	0
Labour resource	0	0	0	0	1.5	1.5
Fix labour	1	1	2	2	0	0
Children	1	1	2	2		
Hiring labour January-March	>150	175	0	0	308	372.6
Hiring labour April-September	>300	312	>50	89	300	189
Hiring labour October-December	>150	325	0	0	150	124
Selling fix labour	0	0	0	0	200	0
Sorghum for silage	7.5	9	0	0	0	0
Type Campo "pure"	0	0	0	0	0	0
Type Campo "mix"	0	0	10	10	0	0
Type Monte "pure"	180	171	0	0	0	0
Type Monte "mix"	20	20	82	82	147	147
Beef animals	0	0	0	0	0	0
Breeding cows 80% calving rate	100	97	0	0	0	0
Bulls			0	0	11	11
Calves			2	2	2	2
R1y Steer			0	0	0	0

	Case study1	Model prediction	Case study 2	Model prediction	Case study 3	Model prediction
R1y Heifer			0	0	5	5
R2y Steer			0	0	5	5
R2yHeifer			0	0	4	4
Dairy cattle 90%			0	0	4	4
Milking cows			0	0	0	0
Calves			60	67	50	55
R1ySteer			0	0	0	0
R1yHeifer			27	27	25	26.6
R2ySteer			27	27	25	26.6
R2yHeifer			20	25	23	24.6

Appendix K
Optimal plans under different pasture rotation length combinations

	A	B	C	D	E	F	G
Farm surplus after taxes and living expenses (FS)	$116,478.54	$120,694.54	$121,805.50	$126,014.80	$127,023.37	$110,975.15	$106,127.27
FS per ha	$582.39	$603.47	$609.03	$630.07	$635.12	$554.88	$530.64
Gross margin	$113,988.96	$142,551.24	$141,923.12	$146,168.59	$147,366.94	$131,027.24	$126,085.46
Gross margin per ha	$569.94	$712.76	$709.62	$730.84	$736.83	$655.14	$630.43
Pangola (ha)	25.3	33	45.9	46.4	46.1	50	41.8
Sorghum silage campo (ha)	14.3	9.7	4.1	3.6	3.9	0	8.2
Gatton panic (ha)	130.4	125.0	115.4	115.4	115.4	115.4	125.0
Sorghum silage monte (ha)	19.6	25.0	34.6	34.6	34.6	34.6	25.0
Ground nuts (ha)	10.5	7.4	0	0	0	0	0
Oats (ha)	14.3	9.7	4.1	3.6	3.9	0	8.2
Total area	200	200	200	200	200	200	200
Hired labour Jan-Mar (man day units)	233	238	250	249	251	221	217
Hired labour Apr-Sept (man day units)	448	460	472	481	484	440	426
Hired labour Oct-Dec (man day units)	228	225	216	219	233	193	189
Total hired labour required (man day units)	909	923	938	949	968	854	832
Dairy cows	230	236	247	254	256	226	217
Milk production Jan-Mar (thousands of L)	203	211	220	224778	226465	203	196
Milk AprJun (thousands of L)	44	47	49	49293	49302	46	44
MilkJulSep (thousands of L)	344	353	370	378373	382678	338	325
OctDec (thousands of L)	335	347	362	369424	372757	332	321
Total milk (thousands of L)	925.992	958.295	1000.041	1021868	1031202	918.493	886.955
Buy hay (350 kg bale units)	11	23	0	0	0	0	0

Appendix L
Optimal plans for different soil type ratio

	% of total effective area with Campo soil.								
Category	0%	10%	20%	30%	40%	50%	60%	70%	80%
Livestock numbers in heads									
Dairy cows calving in July	71	84	95	104	108	111	113	113	114
Dairy cows calving in October	26	24	23	21	21	20	20	20	20
R1 year Replacements	10	12	19	20	21	21	21	21	21
R2 year replacements	10	11	18	19	20	20	20	20	20
Buying replacements	5	5	6	6	6	7	7	7	7
R1ysteer	6	5	0	0	0	0	0	0	0
Bulls	3	3	4	4	4	4	4	4	4
Hired Labour requirement in man day units									
January to March	68	77	83	90	93	95	96	97	97
April to September	159	167	173	176	170	165	157	148	140
October to December	51	63	66	77	82	88	91	94	98
Total labour requirement	278	307	322	343	345	348	344	339	335

Optimal plans for different soil type ratio (contd)

	% of total effective area with Campo soil.								
Category	0%	10%	20%	30%	40%	50%	60%	70%	80%
Milk Production in thousands of litres									
January to March	88	98	106	113	115	118	119	120	120
April to June	29	30	32	33	33	33	33	33	34
July to September	110	129	144	158	163	168	171	172	173
October to December	129	146	161	173	178	182	184	185	138
Total milk production in thousands of litres	355.371	403.156	441.321	476.788	489.213	501.637	508.001	509.983	511.965
Milk production per ha (l/ha)	3,553.71	4,031.56	4,413.21	4,767.88	4,892.13	5,016.37	5,080.01	5,099.83	5,119.65
Difference in milk production %	-25%	-15%	-7%	0%	3%	5%	7%	7%	7%
Feed supply									
Concentrate mix formula in tonnes of DM	154.502	172.906	181.524	202.416	210.962	219.508	223.203	224.061	224.898
Grain fed in tonnes	43.343	48.512	50.928	56.796	59.192	61.591	62.626	62.869	63.098
Silage fed in tonnes of DM	80.909	90.83	98.286	98.675	94.996	91.322	88.478	86.244	84.018
hay fed in bale units (350kg)	10	10	0	0	0	0	0	0	0

Optimal plans for different soil type ratio (contd)

MVP Campo February	$0.00	$0.00	$1,057.50	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
MVP Campo March	$0.00	$411.71	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
MVP Campo Apr2	$0.00	$0.00	$206.20	$561.08	$561.08	$561.08	$527.49	$527.49	$527.49
MVP Campo May	$200.35	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
MVP Campo July	$0.00	$200.50	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
MVP Campo October	$1,203.78	$0.00	$0.00	$386.50	$0.00	$386.50	$379.25	$3,785.69	$0.00
MVP Campo December	$0.00	$757.27	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
MVP Monte February	$0.00	$666.75	$680.36	$0.00	$0.00	$0.00	$789.79	$789.79	$789.79
MVP Monte March	$666.38	$0.00	$0.00	$750.88	$750.84	$750.84	$0.00	$0.00	$0.00
Labour January to March	$10.03	$10.03	$10.03	$10.03	$10.03	$10.03	$10.03	$10.03	$10.03
Labour April to September	$7.21	$7.21	$7.21	$7.21	$7.21	$7.21	$7.21	$7.21	$7.21
Labour October to December	$9.16	$9.16	$9.16	$9.16	$9.16	$9.16	$9.16	$9.16	$9.16

Appendix M
Farm system Sensitivity to milk and beef prices

Table M. 1 Optimal plans under different milk and beef price combination scenarios.

BEEF PRICE INDEX	1	1	1	1	1	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.2
MILK PRICE INDEX	1	0.9	0.8	0.7	0.6	1	0.9	0.8	0.7	0.6	1	0.9	0.8	0.7	0.6
Farm surplus ($)[19]	110,865.3	86,594.4	62,988.7	42,345.1	28,131.8	111,932.0	87,661.1	63,989.9	43,123.1	28,566.0	113,595.8	89,324.9	65,590.3	44,355.4	29,857.9
Farm surplus per ha ($/ha)	554.33	432.97	314.94	211.73	140.66	559.66	438.31	319.95	215.62	142.83	567.98	446.62	327.95	221.78	149.29
Ground nut	0	0	0	14.2	25	0	0.0	0.0	14.2	25.0	0.0	0.0	0.0	11.3	25.0
Sesame seed	0	0	6.5	17	0	0	0	6.5	17.0	0.0	0.0	0.0	6.5	14.9	0.0
Cotton	0	0	0	0	25	0	0	0.0	0.0	25.0	0.0	0.0	0.0	0.0	25.0
Pangola	46.1	46.1	43.5	18.8	0	46.1	46.1	43.5	18.8	0.0	46.1	46.1	43.5	23.9	0.0
Oats	3.9	3.9	6.5	17	0	3.9	3.9	6.5	17.0	0.0	3.9	3.9	6.5	14.9	0.0
Gatton	115.40	115.40	115.40	115.40	115.40	115.40	115.40	115.40	115.40	115.40	115.40	115.40	115.40	115.40	115.40
Sorghum Campo	3.90	3.90	0.00	0.00	0.00	3.90	3.90	0.00	0.00	0.00	3.90	3.90	0.00	0.00	0.00
Sorghum Monte	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6
Dairy 2C[20]	256	256	202	187	104	256	256	202	187	104	256	256	244	200	67
Dairy 2D[21]	0	0	41	0	0	0	0	41	0	0	0	0	5	0	0
Dairy3D[22]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23
Total dairy	256	256	243	187	104	256	256	243	187	104	256	256	249	200	90

[19] Farm surplus is after taxes and living expenses
[20] Dairy cow with 450 kg liveweight calving in July producing 4,500 L of milk per lactation
[21] Dairy cow with 450 kg liveweight calving in October producing 4,500 L of milk per lactation
[22] Dairy cow with 550 kg liveweight calving in October producing 3,000 L of milk per lactation

Table M. 1 Additional columns

Beef price index MILK PRICE INDEX	1.3 1	1.3 0.9	1.3 0.8	1.3 0.7	1.3 0.6	1.4 1	1.4 0.9	1.4 0.8	1.4 0.7	1.4 0.6
Eat ($)	114,064.1	89,793.2	66,044.0	44,720.4	29,644.7	115,132.3	90,861.5	67,080.1	45,684.7	33,013.9
Farm surplus per ha after tax and living expenses ($/ha)	570.32	448.97	330.22	223.60	148.22	575.66	454.31	335.40	228.42	165.07
Ground nut	0.0	0.0	0.0	11.3	25.0	0.0	0.0	0.0	5.5	25.0
Sesame seed	0.0	0.0	6.5	14.9	0.0	0.0	0.0	6.5	10.6	0.0
Cotton	0.0	0.0	0.0	0.0	25.0	0.0	0.0	0.0	0.0	25.0
Pangola	46.1	46.1	43.5	23.9	0.0	46.1	46.1	43.5	34.0	0.0
Oats	3.9	3.9	6.5	14.9	0.0	3.9	3.9	6.5	10.6	0.0
Gatton	115.40	115.40	115.40	115.40	115.40	115.40	115.40	115.40	115.40	115.40
Sorghum Campo	3.90	3.90	0.00	0.00	0.00	3.90	3.90	0.00	0.00	0.00
Sorghum Monte	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6
Dairy 2C	256	256	244	200	86	256	256	244	188	67
Dairy 2D	0	0	5	0	0	0	0	5	0	0
Dairy 3D	0	0	0	0	0	0	0	0	23	34
Total dairy	256	256	249	200	86	256	256	249	211	101

Table M. 2 Output level in optimal plans under different beef and milk prices scenarios

BEEF PRICE INDEX MILK PRICE INDEX	1 1	1 0.9	1 0.8	1 0.7	1 0.6	1.1 1	1.1 0.9	1.1 0.8	1.1 0.7	1.1 0.6	1.2 1	1.2 0.9	1.2 0.8	1.2 0.7	1.2 0.6
Milk sales January to March (l)	226,465	226,465	237,865	165,193	92,168	226,465	226,465	237,865	165,193	92,168	226,465	226,465	222,635	176,536	81,425
Milk sales April to June (l)	49,302	49,302	74,817	35,963	20,065	49,302	49,302	74,817	35,963	20,065	49,302	49,302	51,161	38,432	26,345
Milk sales July to September (l)	382,678	382,678	309,003	279,142	155,744	382,678	382,678	309,003	279,142	155,744	382,678	382,678	365,344	298,308	102,609
Milk sales October to December (l)	372,757	372,757	355,836	271,905	151,706	372,757	372,757	355,836	271,905	151,706	372,757	372,757	362,283	290,574	119,284
Milk production (thousands of litres)	1031.20	1031.20	977.52	752.20	419.68	1031.20	1031.20	977.52	752.20	419.68	1031.20	1031.20	1001.42	803.85	329.66
Milk production per ha (Thousand of litres/ha)	5.156	5.156	4.888	3.761	2.098	5.156	5.156	4.888	3.761	2.098	5.156	5.156	5.007	4.019	1.648
S450Jul															
S400Jul															
S450Oct															18
Selling yearling heifer															9
Culling Bull calves	115	115	109	84	47	115	115	109	84	47	115	115	112	90	30
Culling heifer calves	72	72	68	53	29	72	72	68	53	29	72	72	70	56	15
Hay making	0	0	0	10	244	0	0	0	10	244	0	0	0	0	290
Sell hay					244					244					290

Table M.2 Additional columns

Beef price index MILK PRICE INDEX	1.3 1	1.3 0.9	1.3 0.8	1.3 0.7	1.3 0.6	1.4 1	1.4 0.9	1.4 0.8	1.4 0.7	1.4 0.6
Milk sales January to March (l)	226,465	226,465	222,636	176,536	75,955	226,495	226,465	222,636	188,585	91,461
Milk sales April to June (l)	49,302	49,302	51,161	38,432	16,535	49,302	49,302	51,161	49,623	32,586
Milk sales July to September (l)	382,678	382,678	365,344	298,308	123,209	382,678	382,678	365,344	283,891	99,361
Milk sales October to December (l)	372,757	372,757	362,283	290,574	125,020	372,757	372,757	362,283	295,753	128,865
Milk production (thousands of litres)	1031.20	1031.20	1001.42	803.85	340.72	1031.23	1031.20	1001.42	817.85	352.27
Milk production per ha (Thousand of litres/ha)	5.156	5.156	5.007	4.019	1.704	5.156	5.156	5.007	4.089	1.761
S450Jul					34					27
S400Jul										
S450Oct									18	27
Selling yearling heifer									9	12
Culling Bull calves	115	115	112	90		115	115	112	85	
Culling heifer calves	72	72	70	56	24	72	72	70	49	15
Hay making	0	0	0	0	316	0	0	0	0	245
Sell hay					316					245

Appendix N Farming behaviour under drought conditions

Table N. 1 Optimal plans under drought conditions

Gatton: Pangola	Rotation 20:20	Rotation 15:15	Rotation 10:10	Rotation 10:15	Rotation 10:20
Scenario	A	B	C	D	E
Farm surplus after tax and living expenses (FS)	$70,687.16	$77,103.85	$83,188.74	$83,905.11	$82,180.07
FS/ha	$353.44	$385.52	$415.94	$419.53	$410.90
Taxable income per ha.	$462.47	$495.48	$519.53	$530.07	$521.25
Pangola (ha)	16.1	41.7	41.2	41.7	47.6
sorghum silage Campo (ha)	17.4	8.3	8.8	8.3	2.4
Gatton panic (ha)	130.4	125	115.4	115.4	115.4
Sorghum silage Monte (ha)	19.6	25	34.6	34.6	34.6
Ground nuts (ha)	16.5	0	0	0	0
Oats (ha)	17.4	8.3	8.8	8.3	2.4
Hired labour demand					
Labour Jan-Mar (man day units)	172	166	199	196	179
Apr-Sept (man day units)	319	304	330	333	311
Oct-Dec (man day units)	178	131	184	187	168
Total labour required (man day units)	669	601	713	716	658
Dairy cows	159	163	183	185.6	173
Milk production					
Milk Jan-Mar (Thousands of L)	140.743	143.943	162.224	164.104	153.307
Milk Apr-Jun (Thousands of L)	30.64	31.337	35.316	35.725	33.375
Milk Jul-Sep (Thousands of L)	237.828	243.234	274	277.302	259.057
Oct-Dec (Thousands of L)	231.662	236.928	267.017	270.113	252.34
Total milk (Thousands of L)	640.873	655.442	738.557	747.244	698.079
Hay making (350kg bale units)	23	77	0	0	0
Sell hay (350 kg bale units)	7	60	0	0	0
Buy hay (350 kg bale units)	0	0	0	18	17
Bull A	0	0	6	0	0
Bull B	5	5	0	6	5
R1yheif	26	26	29	30	28
R2yheif	24	25	28	28	26

Table N. 2 Optimal plans compared with optimal drought plan forced into a model for average weather condition

	A		B		C		D		E	
	Optimal	Optimal Drought	Optimal	Optimal Drought	Optimal	Optimal Drought	Optimal	Optimal Drought	Optimal	Optimal Drought
Gross margin	$137,315.86	$109,260.41	$142,920.15	$111,084.77	$142,399.06	$109,225.94	$146,424.78	$122,361.67	$147,366.95	$117,007.39
Surplus after tax and living expenses	$579.93	$444.64	$602.66	$451.95	$609.20	$444.90	$629.17	$511.33	$633.85	$483.21
Surplus after tax and living expenses per ha	$2.90	$2.22	$3.01	$2.26	$3.05	$2.22	$3.15	$2.56	$3.17	$2.42
Difference		-23.3%		-25.0%		-27.0%		-18.7%		-23.8%
Land use pattern										
Pangola grass	25.3	16.1	37.1	41.7	45.8	41.2	46.3	41.7	46.1	47.6
Silage campo	14.26	17.4	10.2	8.3	4.2	8.8	3.7	8.3	3.9	2.4
Ground nuts	10.5	16.5	3.7	0	0	0	0	0	0	0
Gatton panic grass	130.4	130.4	125	125	115.4	115.4	115.4	115.4	115.4	115.4
Silage monte	15.58	19.6	25	25	34.6	34.6	34.6	34.6	34.6	34.6
Oats	10.5	16.5	10.8	8.3	4.2	8.8	3.7	8.3	3.9	2.4
Stocking rate AU/ha	2.1	1.6	2.2	1.5	2.2	1.5	2.3	1.7	2.3	1.5
% difference in stocking rate		-0.27		-0.33		-0.32		-0.25		-0.33
Bulls	7	5	7	5	7	5	7	5	7	5
R1y replacements	37	25	39	37	40	26	41	30	41	28
R2y replacements	35	24	37	25	38	25	39	28	39	26
Dairy cows	230	159	244	163	249	163	254	186	256	173
% Difference cow numbers	0	0.308695652	0	0.331967213	0	0.34538153	0	0.267716535	0	0.32421875
Milk production per farm (Thousands of litres)	926,004.00	640,524.00	981,949.00	656,639.00	1,003,607.00	656,639.00	1,024,081.00	749,293.00	1,031,201.00	696,923.00
Milk sold per ha (litres)	4,630.02	3,202.62	4,909.75	3,283.20	5,018.04	3,283.20	5,120.41	3,746.47	5,156.01	3,484.62
Bales of hay made	0	477	0	733	0	815	0	379	0	379
Bales of hay bought	0	0	23	0	0	0	0	0	0	0

Table N.2 (contd)

	A		B		C		D		E	
	Optimal	Optimal Drought	Optimal	Optimal Drought	Optimal	Optimal Drought	Optimal	Optimal Drought	Optimal	Optimal Drought
Bales of hay sold	0	477	0	733	0	815	0	379	0	602
Labour requirement	781	679	937	620	950	644	961	721	968	661
Silage fed Jul Sep (DM tonnes)	90.95	75.42	104.85	99.805	126.93	98.62	131.009	116.65	131.356	121.04
Silage fed Oct Dec (DM tonnes)	67.34	93.45	72.212	68.83	82.09	125.698	76.19	105.988	76.739	81.68
Total silage fed (DM tonnes)	158.29	168.87	177.062	168.635	209.02	224.318	207.199	222.638	208.095	202.72
Formula 1 Jan Mar (DM tonnes)	96.66	47.79	102.505	46.769	104.765	46.769	106.902	55.49	107.646	49.64
Formula 1 Apr Jun (DM tonnes)	20.46	14.15	29.991	14.511	37.143	14.511	34.53	16.56	35.04	15.401
Formula 1 Jul Sep (DM tonnes)	123.7	67	130.8	68.685	134.47	68.7	137.22	78.38	148.015	72.74
Formula 1 Oct Dec (DM tonnes)	132.92	66.86	140.946	68.538	144.055	68.54	146.99	78.21	148.015	72.74
Total formula 1 (tonnes)	373.74	195.8	404.242	198.503	420.433	198.52	425.642	228.64	438.716	210.521
Grain Jan Mar (tonnes)	27.12	13.41	28.76	13.12	29.395	13.12	29.99	15.59	30.2	13.93
Grain Apr Jun (tonnes)	5.74	3.97	8.41	4.07	10.42	4.07	9.7	4.64	9.83	4.32
Grain Jul Sep (tonnes)	34.71	18.8	36.7	19.27	37.73	19.27	38.5	21.99	38.769	20.4544
Grain Oct Dec (tonnes)	37.29	18.76	39.55	19.23	40.42	19.23	41.24	21.94	41.53	20.41
Total Grain (tonnes)	104.86	54.94	113.42	55.69	117.965	55.69	119.43	64.16	120.329	59.1144

Appendix O
Optimal plans for sugar cane forage

Table O. 1 Optimal plans with sugar cane available from March to December

	Yield Assumptions								
	12500	15000	17500	20000	22500	25000	27500	30000	Observed level
Total gross margin	$179,987.04	$184,750.62	$187,684.10	$190,367.38	$192,331.06	$193,796.65	$194,875.92	$195,679.61	$171,740.88
Surpluss after taxes and living expenses	$156,815.19	$163,558.24	$167,232.27	$169,879.24	$171,816.16	$173,256.06	$174,329.54	$175,137.48	$151,111.61
Gross margin per ha	$899.94	$923.75	$938.42	$951.84	$961.66	$968.98	$974.38	$978.40	$858.70
Difference with observed value	4%	8%	11%	12%	14%	15%	15%	16%	0%
Land use pattern									
Sorghum for silage campo	4.6	6.2	6.5	5.1	3.7	2.6	2.1	1.5	4.4
Ground nuts	12.6	12.1	11.9	8.2	4.6	1.6	2.3	2.8	0
Sesame seed	0	0	0	0	0	0	0.4	1.8	0
Pangola 15 year rotation	0.6	4.6	5.7	13.5	21.2	27.7	0	0	0
Pangola 20 year rotation	0	0	0	0	0	0	28.7	28.7	39.6
Sugar cane	32.2	27.1	25.9	23.2	20.5	18.2	16.4	15.1	6
	4.37	3.52	3.32	2.87	2.42	2.03	1.73	1.52	-
Oats	4.6	6.2	6.5	5.1	3.8	2.6	2.5	3.4	4.4
Sorghum for silage monte	34.7	34.7	34.6	34.6	34.6	34.6	34.6	34.6	34.6
Gatton	115.4	115.4	115.4	115.4	115.4	115.4	115.4	115.4	115.4
Hired labour requirement per periods	50	50	50	50	50	50.1	49.9	50.1	50
Labour January to March	453	456	455	440	431	423	422	430	339
Labour April to September	797	810	837	854	849	844	843	843	637
Labour October to December	540	546	545	519	501	486	484	483	367
Total Hired labour	**1790**	**1812**	**1837**	**1813**	**1781**	**1753**	**1749**	**1756**	**1343**
Livestock numbers									
R1repl	59	60	61	61	61	61	61	61	52
R2repl	56	57	58	58	58	58	58	58	49
Dairy cow 450kg lw producing 4500 ltDairy2C	365	377	379	379	379	379	379	379	326

Table O.1 (contd)

	Yield Assumptions								
	12500	15000	17500	20000	22500	25000	27500	30000	Observed level
BullA	0	8	11	11	11	11	11	11	10
BullB	11	3	0	0	0	0	0	0	0
Silage April-June	0	0	0	0	0	0	0	0	17.279
Silage Jul-Sept	184.276	190.896	192.602	195.912	199.149	201.904	202.03	200.018	168.74
Silage Oct-Dec	26.201	24.915	24.299	16.244	8.38	1.68	0	0	23.81
Total silage	210.477	215.811	216.901	212.156	207.529	203.584	202.03	200.018	209.829
Sugar Apr-June	139.34	140.344	139.91	139.91	139.91	139.91	139.91	139.91	53.8
Sugar Jul-Sep	85.43	82.92	129.3	138.6	135.62	129.08	127.42	127.42	0
Sugar Oct-Dec	178.151	183.81	184.76	184.76	184.76	184.76	184.76	184.76	111.19
Total sugar	402.9	407.1	454.0	463.3	460.3	453.8	452.1	452.1	165.0
Feeding concentrate mix in tonnes of DM									
Concentrate January to March	153.547	158.425	159.25	151.42	143.777	137.27	135.65	135.65	137.2
Concentrate April to June	77.55	78.913	47.846	36.707	33.711	33.711	33.711	33.711	68.015
Concentrate July to September	195.932	203.051	204.403	204.403	204.403	204.403	204.403	204.403	176.102
Concentrate October to December	211.13	217.8	218.965	218.965	218.965	218.965	218.965	218.965	188.65
Total concentrate feeding in Tonnes of DM	**638.159**	**658.189**	**630.464**	**611.495**	**600.856**	**594.349**	**592.729**	**592.729**	**569.967**
Feeding grain in tonnes of fresh matter.									
Grain January to March	43.082	44.45	44.68	42.485	40.34	38.52	38.06	38.06	38.49
Grain April to June	21.761	22.14	13.425	10.299	9.459	9.459	9.469	9.459	19.084
Grain July to September	54.975	56.973	57.352	57.352	57.352	57.352	57.352	57.352	49.411
Grain October to December	59.24	61.12	61.44	61.44	61.44	61.44	61.44	61.44	52.93
Total grain fed	**179.058**	**184.683**	**176.897**	**171.576**	**168.591**	**166.771**	**166.321**	**166.311**	**159.915**
Hay buying	35	9	0	0	0	0	0	0	0
Fed hay	35	9	0	0	0	0	0	0	0
Buy replacement	19	19	19	19	19	19	19	19	17
Use of high quality feed as medium quality feed (kg)									
January to March (kg DM)	60.221	62.135	62.456	52.795	43.361	35.327	33.323	33.323	53.809

Table O.1 (contd)

	Yield Assumptions								
	12500	15000	17500	20000	22500	25000	27500	30000	Observed level
April to June (kg DM)	55.618	56.019	17.451	3.699	0	0	0	0	48.114
July to September	51.94	54.694	55.35	55.35	55.35	55.35	55.35	55.35	47.686
October to December	71.111	73.37	73.75	73.75	73.75	73.75	73.75	73.75	63.538
Total high quality feed used as medium quality feed in tonnes of DM	**238.89**	**246.218**	**209.007**	**185.594**	**172.461**	**164.427**	**162.423**	**162.423**	**213.147**
Milk Jan-Mar	323.031	333.295	335.019	335.019	335.019	335.019	335.019	335.019	288.821
Milk Arp-Jun	70.324	72.559	72.934	72.934	72.934	72.934	72.934	72.934	62.877
Milk Jul-Sep	545.856	563.198	566.111	566.111	566.111	566.111	566.111	566.111	488.048
Milk Oct-Dec	531.704	548.597	551.434	551.434	551.434	551.434	551.434	551.434	475.395
Total milk production in thousands of litres	**1,470.92**	**1,517.65**	**1,525.50**	**1,525.50**	**1,525.50**	**1,525.50**	**1,525.50**	**1,525.50**	**1,315.14**
MVP Campo Apr2	$681.46	$541.90	$463.49	$361.64	$321.78	$315.10	$240.01	$240.01	$402.57
MVP MonteMar	$821.53	$678.32	$598.12	$503.73	$457.22	$449.43	$375.10	$374.36	$684.14
MVP highJanMar	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17
MVP medium Jul-Sept	$0.38	$0.31	$0.28	$0.23	$0.22	$0.21	$0.18	$0.18	$0.25
MVP mediumOct-Dec	$0.38	$0.31	$0.28	$0.23	$0.22	$0.21	$0.14	$0.15	$0.25
MVPLow Oct Dec	$0.07	$0.07	$0.06	$0.02	$0.04	$0.04	$0.03	$0.03	$0.00
MVP Ton sugar	$100.84	$69.90	$53.11	$38.73	$31.73	$28.15	$21.44	$19.66	$162.81
MVP silage	$356.12	$296.93	$263.68	$220.48	$203.58	$200.75	$168.90	$168.90	$237.84
Water Sept	$0.00	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00
MVP new cow	$663.35	$676.34	$683.36	$681.16	$692.06	$694.48	$700.53	$701.66	$640.39

Table O. 2 Optimal plans with sugar cane available from March to September

Sugar cane yield (kg DM/ha)	12500	15000	17500	20000	22500	25000	27500	30000	Observed level
Eat ($)	131,172.88	133,045.24	134,504.66	135,687.85	136,901.53	137,791.94	138,732.89	139,532.30	138,261.38
Gross margin ($)	151,708.26	153,592.29	157,250.24	158,458.97	159,446.13	160,488.25	161,449.25	162,265.68	161,069.62
Difference with observed value	-5.81%	-4.64%	-2.37%	-1.62%	-1.01%	-0.36%	0.24%	0.74%	0.00%
Sorghum for silage Campo (ha)	18.7	19.6	20	20.5	20.6	19.7	20.14	20.5	21.25
Ground nuts (ha)	21.2	21.8	22	22.3	22.3	21.8	22.1	22.3	22.8
Sesame seed (ha)	0	0	0	0	0	0	0	0	0
Pangola 15 (ha)	0	0	0	0	0	0	0	0	0
Sugar cane (ha)	10	8.6	8	7.2	7.1	8.5	7.8	7.2	6
Oats (ha)	18.7	19.6	20	20.5	20.6	19.7	20.1	20.5	21.3
Sorghum silage Monte (ha)	34.64	34.64	34.64	34.64	34.64	34.64	34.64	34.64	34.64
Gatton (ha)	115.36	115.36	115.36	115.36	115.36	115.36	115.36	115.36	115.36
Labour (man day units)									
January March	326	327	331	332	333	331	332	332	334
April September	615	625	639	645	654	675	680	684	662
October December	365.5	369	376	379	379	375	377	379	382
Total labour	1306.5	1321	1346	1356	1366	1381	1389	1395	1378
Rising 1 year replacements	46	46	47	47	47	47	47	47	48
Rising 2 year replacements	43	44	45	45	45	45	45	45	46
Dairy2C	285	288	293	296	296	292	294	296	299
BullA	9	9							
BullB			9	9	9	9	9	9	9
Stoking rate AU/ha	3.6	3.6	3.7	3.7	3.7	3.7	3.7	3.7	3.8
Silage JulSept (tonnes DM)	112.13	112.21	109.78	109.82	109.82	109.8	109.8	109.8	109.8
Silage OctDec (tonnes DM)	146	148.8	152.48	154.26	154.5	151.6	153.04	154.3	156.7
Total silage (tonnes DM)	258.13	261.01	262.26	264.08	264.32	261.4	262.84	264.1	266.5
Sugar AprJune (tonnes DM)	90.31	92.68	95.79	97.3	113.02	111.54	112.28	112.91	114.2
SugarJulSep (tonnes DM)	34.73	36.85	44.98	46.37	46.52	100.06	101.55	102.82	50.8
SugarOctDec (tonnes DM)	0	0	0	0	0	0	0	0	0
Total sugar (Tonnes DM)	125.04	129.53	140.77	143.67	159.54	211.6	213.83	215.73	165
F1 JanMar (Tonnes DM)	119.69	121.3	123.4	124.4	114.5	112.3	113.37	114.32	116.26

Table O.2 (Contd)

Sugar cane yield (kg DM/ha)	12500	15000	17500	20000	22500	25000	27500	30000	Observed level
F1AprJun (tonnes DM)	59.34	60.13	62.33	62.85	62.9	26.02	26.2	26.3	61.9
F1JulSep (tonnes DM)	153.63	155.7	157.5	158.8	158.9	156.8	157.9	158.77	160.57
F1OctDec (tonnes DM)	164.6	166.78	169.69	171.1	171.25	169	170.13	171.08	173.03
Total F1 (tonnes DM)	497.26	503.91	512.92	517.15	507.55	464.12	467.6	470.47	511.76
Feeding grain January to March (tonnes)	33.58	34.03	34.62	34.91	32.12	31.49	31.81	32.077	32.62
Feeding grain April to June (tonnes)	16.64	16.87	17.49	17.63	17.65	7.3	7.35	7.39	17.37
Feeding grain July to September (tonnes)	43.11	43.69	44.18	44.55	44.6	44	44.3	44.55	45.05
Feeding grain October to December (tonnes)	46.17	46.8	47.61	48	48	47.42	47.74	48	48.6
Total grain (tonnes)	139.5	141.39	143.9	145.09	142.37	130.21	131.2	132.017	143.64
Hay buying (350kg Bale unit)	0	0	0	29	29	29	29	29	29
Fed hay				29	29	29	29	29	29
Buy replacement (%of total required)	25%	25%	25%	25%	25%	25%	25%	25%	25%
Use high asmedium JanMar	46.942	47.573	48.401	48.803	36.43	35.05	35.742	36.329	37.526
Using high as Medium AJ	41.975	42.539	44.702	45.073	45.113	0	0	0	43.577
Using high as mediumJS	41.601	42.16	41.745	42.092	42.129	41.577	41.854	42.089	42.568
Using high as medium OD	55.43	56.175	57.153	57.627	57.679	56.922	57.301	57.623	58.28
Total high feed used as medium quality feed (Tonne DM)	185.948	188.447	192.001	193.595	181.351	133.549	134.897	136.041	181.951
MilkJanMar	251.8	255.085	259.628	261.78	262.015	258.577	260.3	261.764	264.745
MilkArpJun	54.817	55.554	56.521	56.99	57.041	56.292	56.667	56.986	57.635
MilkJulSep	425.49	431.209	438.72	442.357	442.75	436.942	439.854	442.327	447.364
MilkOctDec	414.459	420.03	427.344	430.889	431.272	425.61	428.45	430.859	435.766
Totalmilk (Thousands of litres)	1146.566	1161.878	1182.213	1192.016	1193.078	1177.421	1185.271	1191.936	1205.51

Appendix P
Optimal plans including legumes in pasture

Table P. 1 Optimal plans including Pangola-legume pastures

	Panleg20	Panleg15	Panleg10	Panleg8	Panleg5	Without legumes
Farm surplus after taxes and living expenses (FS)	$133,096.49	$132,087.70	$130,563.70	$129,242.87	$125,169.37	$126,751.80
FS/ha	$665.48	$660.44	$652.82	$646.21	$625.85	$633.76
% Difference in Farm surplus after taxes and living expenses	5.0%	4.2%	3.0%	2.0%	-1.2%	0.0%
Total gross margin	$154,507.05	$153,486.79	$151,945.46	$150,609.50	$146,489.02	$148,100.44
Gross margin per ha	$772.54	$767.43	$759.73	$753.05	$732.45	$740.50
% Difference in gross margin per ha	**4.33%**	**3.64%**	**2.60%**	**1.69%**	**-1.09%**	**0.00%**
Sorghum Campo (ha)	6.4	6.1	5.7	5.3	4.2	3.9
Pangola with legumes (ha)	43.6	43.85	44.28	44.66	45.78	0
Pangola (ha)	0	0	0	0	0	46.1
Oats (ha)	6.4	6.1	5.7	5.3	4.2	3.9
Sorghum for silage Monte (ha)	34.6	34.6	34.6	34.6	34.6	34.6
Gatton 10	115.4	115.4	115.4	115.4	115.4	115.4
Labour (man day units)						
January to march	267	265	262	259	251	251
April to SeptemberJune	506	503	498	494	481	483
October to December	250	248	245	242	233	233
Total Labour	1023	1016	1005	995	965	967
Difference	5.79%	5.07%	3.93%	2.90%	-0.21%	0.00%
R1yrepl	43	43	42	42	41	41
R2yrepl	41	41	40	40	39	39
Buy repl	14	14	13	13	13	13
Dairy 2C	269	267	265	262	254	256
Bull A	8	8	8	8	8	8
Bull B	0	0	0	0	0	0
Stocking rate AU/ha	2.43	2.42	2.39	2.36	2.28	2.29
% Difference	6.09%	5.36%	4.06%	2.97%	-0.45%	0.00%

Table P.1 (contd)

	Panleg20	Panleg15	Panleg10	Panleg8	Panleg5	Without legumes
Milk production (Thousands of l)						
JanMar	238.359	236.657	234.087	231.872	225.093	226.464
AprJun	51.891	51.52	50.961	50.479	49.003	49.302
JulSep	402.776	399.9	395.558	391.815	380.36	382.678
OctDec	392.334	389.011	385.302	381.657	370.499	372.757
Total milk production	1085.36	1077.088	1065.908	1055.823	1024.955	1031.201
Milk production (L/ha)	5,426.80	5,385.44	5,329.54	5,279.12	5,124.78	5,156.01
% Difference in milk production	**5.3%**	**4.4%**	**3.4%**	**2.4%**	**-0.6%**	**0.0%**
Silage JulSep	132.84	132.44	131.852	131.67	129.79	131.356
Silage OctDec	86.5868	85.93	84.88	83.92	81.22	76.74
Total silage	219.4268	218.37	216.732	215.59	211.01	208.096
Diference in silage fed per cow	**0.35%**	**0.61%**	**0.61%**	**1.23%**	**2.20%**	**0.00%**
F1JanMar	121.74	120.87	119.56	118.43	114.96	107.646
F1ArpJun	45.79	45.09	43.97	43	40.11	35.043
F1JulSep	152.911	151.819	150.17	148.75	144.4	138.172
F1OctDec	165.75	164.575	162.79	161.25	156.53	148.016
Total F!	486.191	482.354	476.49	471.43	456	428.877
Difference	**13.36%**	**12.47%**	**11.10%**	**9.92%**	**6.32%**	**0.00%**
Grain feeding						
JanMar	21.69	21.53	21.3	21.1	20.47	30.204
AprJun	6.73	6.68	6.61	6.55	6.35	9.833
JulSep	31.85	31.63	31.28	30.98	30.08	38.77
OctDec	31.79	31.56	31.22	30.92	30.02	41.53
Total grain	92.06	91.4	90.41	89.55	86.92	120.337
Difference	-23.50%	-24.05%	-24.87%	-25.58%	-27.77%	0.00%
High quality feed bought per litre of milk sold (kg/litre/year)	0.448	0.448	0.447	0.447	0.445	0.416
Difference	7.70%	7.67%	7.48%	7.35%	6.96%	0.00%
Campo March	$688.41	$686.91	$671.90	$658.89	$618.77	$402.57
Campo May	$0.00	$0.00	$0.00	$0.00	$0.00	$366.15
Monte Feb	$644.32	$642.95	$640.87	$639.08	$633.54	$0.00
MonteMar	$0.00	$0.00	$0.00	$0.00	$0.00	$642.65
HighQFJanMar	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17
MedQFJM	$0.38	$0.39	$0.40	$0.40	$0.43	$0.24
LowQFOD	$0.02	$0.07	$0.07	$0.02	$0.01	$0.02
Silage	$225.90	$223.30	$219.37	$215.97	$205.48	$222.37

Table P. 2 Optimal plans including leucaena-gatton hedgerow systems

	G80LH	G80LM	G80LL	G65LH	G65LM	G65LL	G50LH	G50LM	G50LL	Without legumes
Farm surplus after taxes and living expenses	$230,766.03	$211,581.07	$181,491.65	$225,848.33	$204,324.67	$172,928.38	$218,920.49	$194,457.37	$162,668.88	$126,751.80
Total gross margin	$253,863.27	$235,255.05	$206,162.60	$248,820.63	$229,579.79	$197,380.17	$241,715.09	$219,459.83	$186,858.07	$148,100.44
Total gross margin per ha	$1,269.32	$1,176.28	$1,030.81	$1,244.10	$1,147.90	$986.90	$1,208.58	$1,097.30	$934.29	$740.50
Difference	82%	67%	43%	78%	61%	36%	73%	53%	28%	0%
Sorghum Campo	23.5	25	23.2	25	25	22.2	25	25	21	3.9
Pangola with legumes5	0	0	8.8	0	0	14.2	0	0	19.8	
Pangola	0	0	0	0	0	0	0	0	0	46.1
Ground nuts	25	25	18	25	25	13.6	25	25	9.2	
Sesame	1.5	0	0	0	0	0	0	0	0	0
Oats	25	25	23.2	25	25	22.2	25	25	21	3.9
Sorghum for silage monte	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	34.64
Gatton with leucaena	130.4	130.4	130.4	130.4	130.4	130.4	130.4	130.4	130.4	0
Gatton 10	0	0	0	0	0	0	0	0	0	115.4
Labour (man day units)										
January to march	383	370	331	372	369	318	372	361	306	251
April to SeptemberJune	732	721	664	728	720	644	725	706	623	484
October to December	439	448	389	446	448	365	448	440	342	233
Total hired labour	1554	1539	1384	1546	1537	1327	1545	1507	1271	968
Difference	61%	59%	43%	60%	59%	37%	60%	56%	31%	0%
R1yrepl	61	60	55	61	60	53	61	59	52	41
R2yrepl	58	57	52	58	57	51	58	56	49	39
Buy repl	19	19	17	19	19	17	19	19	16	13

Optimal plans including leucaena-gatton Hedgerow systems (contd)

	G80LH	G80LM	G80LL	G65LH	G65LM	G65LL	G50LH	G50LM	G50LL	Without legumes
Dairy 2C	282	378	256	379	289	248	379	274	241	256
Dairy 2D	96	0	87	0	86	84	0	93	82	0
Bull A	11	7	0	11	0	0	11	0	0	8
Bull B	0	4	10	0	11	10	0	11	10	0
Stocking rate AU/ha	4.0	4.0	3.4	4.0	4.0	3.2	4.0	3.9	3.0	2.3
	75%	75%	50%	76%	74%	40%	76%	70%	32%	0%
Total dairy	378	378	343	379	375	332	379	367	323	226.5
JanMar	389.157	333.264	352.792	335.019	381.888	342.647	335.019	378.39	332.487	226.5
AprJun	139.171	72.552	126.166	72.934	132.201	122.537	72.934	135.32	118.904	49.302
JulSep	437.894	563.146	396.975	566.111	447.352	385.559	566.111	425.779	374.127	382.678
OctDec	556.189	548.546	504.215	551.434	552.572	489.714	551.434	540.799	475.195	372.757
Total milk production	1,522.41	1,517.51	1,380.15	1,525.50	1,514.01	1,340.46	1,525.50	1,480.29	1,300.71	1,031.24
% Difference in milk production	48%	47%	34%	48%	47%	30%	48%	44%	26%	0%
Milk production per ha	7,612	7,588	6,901	7,627	7,570	6,702	7,627	7,401	6,504	5,156
Hay making	1000	611	0	1000	347	0	1000	241	0	0
Sell hay	1000	598	0	1000	310	0	1000	206	0	0
Buy hay	0	0	33	0	0	32	0	0	3	0
Hay fed	0	13	33	0	37	32	0	35	3	
Silage April June	0	0	0	0	0	0	0	0	0	
Silage JulSep	99.68	62.99	79.72	78.66	65.61	76.83	67.54	61.65	73.99	131.356
Silage OctDec	89.65	131.53	108.88	115.87	128.92	108.08	126.99	132.87	107.188	76.74
Total silage	189.33	194.52	188.6	194.53	194.53	184.91	194.53	194.52	181.178	208.10
Diference silage fed per cow	-38%	-37%	-32%	-37%	-36%	-31%	-37%	-35%	-31%	0%
F1JanMar	123.041	108.08	111.54	108.66	120.99	108.34	108.66	119.64	105.124	35.043
F1ArpJun	0	73.75	91.92	9.01	108.94	98.194	50.96	132.02	114.599	138.172
F1JulSep	182.08	213.24	163.72	214.92	182.63	159.016	214.92	175.6	154.301	148.016
F1OctDec	230.58	231.76	209.03	232.98	229.49	203.022	232.98	224.2	197	321.231
Total F!	535.701	626.83	576.21	565.57	642.05	568.572	607.52	651.46	571.024	642.462

Optimal plans including leucaena-gatton Hedgerow systems (contd)

	G80LH	G80LM	G80LL	G65LH	G65LM	G65LL	G50LH	G50LM	G50LL	Without legumes
Difference F1 fed per lt of milk sold	-44%	-34%	-33%	-40%	-32%	-32%	-36%	-29%	-30%	0%
Grain										
JanMar	34.52	30.33	31.3	30.5	33.95	30.4	30.49	33.57	29.5	30.204
AprJun	0	9.4	13.08	9.45	13.88	12.7	9.45	14.03	12.33	9.833
JulSep	35.05	44.54	31.77	44.77	35.75	30.86	44.68	43.88	38.56	38.769
OctDec	45.13	44.54	40.91	44.68	44.83	39.74	44.67	34.08	38.56	41.531
Total grain	114.7	128.81	117.06	129.4	128.41	113.7	129.29	125.56	118.95	120.337
Difference	-35%	-27%	-27%	-27%	-27%	-27%	-27%	-27%	-22%	0%
milk sold in lt per kg DM of high quality feed bought	- 0.42	- 0.33	- 0.32	- 0.39	- 0.31	- 0.31	- 0.35	- 0.29	- 0.28	-
Buy water sept (10,000 L)	5			5			5			
Campo February	$0.00	$0.00	$337.07	$256.77	$306.30	$0.00	$12.18	$0.00	$0.00	$0.00
Campo March	$237.15	$300.37	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$9.19
Campo April2	$239.91	$533.03	$703.19	$330.86	$560.49	$703.19	$330.86	$760.12	$703.19	$274.27
Campo June	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Monte Jan	$575.69	$945.32	$977.31	$0.00	$922.91	$0.00	$0.00	$0.00	$0.00	$0.00
Monte Feb	$0.00	$0.00	$0.00	$685.55	$0.00	$920.22	$639.36	$1,040.75	$851.82	$642.73
MonteMar	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Monte June	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.17
HighQFJanMar	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17	$0.00	$0.00	$0.00	$0.16
High QFAJ	$0.13	$0.16	$0.16	$0.16	$0.16	$0.16	$0.00	$0.00	$0.00	$0.16
HighQFJS	$0.16	$0.16	$0.16	$0.16	$0.16	$0.16	$0.00	$0.00	$0.00	$0.16
High QF OD	$0.16	$0.16	$0.16	$0.16	$0.16	$0.16	$0.00	$0.00	$0.00	$0.39
MedQFJM	$0.00	$0.06	$0.10	$0.00	$0.06	$0.10	$0.00	$0.06	$0.10	$0.14
MedQFAJ	$0.11	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14	$0.24
MedQFJS	$0.18	$0.31	$0.39	$0.22	$0.32	$0.39	$0.22	$0.41	$0.39	$0.24
MedQFOD	$0.18	$0.31	$0.39	$0.22	$0.32	$0.39	$0.22	$0.41	$0.39	$0.00
LowQFJM	$0.00	$0.07	$0.00	$0.00	$0.05	$0.07	$0.00	$0.02	$0.00	$0.00

Optimal plans including leucaena-gatton Hedgerow systems (contd)

	G80LH	G80LM	G80LL	G65LH	G65LM	G65LL	G50LH	G50LM	G50LL	Without legumes
LowQFAJ	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.03	$0.00	$0.00
LowQFJS	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.02
LowQFOD	$0.00	$0.06	$0.07	$0.04	$0.06	$0.07	$0.00	$0.06	$0.07	$0.00
Water September/litre	$0.01	$0.00	$0.00	$0.01	$0.00	$0.00	$0.01	$0.00	$0.00	$222.37
Silage	$168.82	$293.14	$365.31	$207.40	$304.78	$365.31	$207.40	$389.45	$365.31	$0.00

Appendix Q
Fixes costs estimates for typical farms

Table Q. 1 Fixed costs estimates for typical dairy farm in the Central Chaco.

Capital cost					
Category	Liveweight	Number	Price per Kg lw or per head (G)	Total (G)	Total ($)
Livestock					
Dairy cow		256	6,000,000.00	1,536,000,000	358,376.11
Calves		230.4			0.00
R1y heifer		30	750,000.00	22,500,000	5,249.65
R2y heifer		28	2,000,000.00	56,000,000	13,065.80
Bulls		9	3,300,000.00	29,700,000	6,929.54
Total capital in livestock				**1,644,200,000**	**383,621.09**
Land Gs2,500,000/ha	**200**			**500,000,000**	**116,658.89**
House				200,000,000	46,663.56
Dairy shed				40,000,000	9,332.71
Milking machine herring bone 12 units				72,000,000	16,798.88
Milk tank 8000 L				195,000,000	45,496.97
Tractor shed				30,000,000	6,999.53
Tractor and machineries				100,000,000	23,331.78
Water supply Tajamar+Turkish tank 110,000m3	US$0.37/m3			244,200,000	56,976.20
Collection area preparation US$166.7/ha*1.5				1,500,300	350.05
Other investments (buildings and machinery)				**882,700,300**	205,949.67
Total capital invested				**3,026,900,300**	706,229.65
Total capital opportunity cost (10% interest rate)				302,690,030	70,622.97
Fixed costs	Formula			Total (G)	Total ($)
Coop membership fee				1,730,000	403.64
Council Rates	492,031Gs total area*1%			1,672,905	390.32
Water system maintenance =US$33.3*1.5				299,700	69.93
Insurance	0.03% of the insured building			81,000	18.90
	1% of the insured machinery			3,670,000	856.28
Total fixed cost to discount				7,453,605	1,739.06
Total cost to discount				**1,954,343,635**	**72,362.02**

Source: A. Funk, personal communication, July, 2005 and Case study 2.

Table Q. 2 Fixed costs estimates for a typical beef and crop farm in the Central Chaco

Category	Liveweight	Number	Price per Kg lw (G)	Total (G)	Total ($)
Livestock					
Breeding cows	450	39	3000	52,650,000	12,284.18
Calves	100	34	3000	10,200,000	2,379.84
R1y steer	350	17	3300	19,635,000	4,581.19
R1y heifers	350	8	3300	9,240,000	2,155.86
Bulls	700	1	3300	2,310,000	538.96
Total capital in livestock				94,035,000	21,940.04
Other investments (buildings and machinery)				1,205,965,000	281,373.08
Water supply Tajamar+Turkish tank 110,000m3	US$0.37/m3*			244,200,000	56,976.20
Collection area preparation US$166.7/ha*1.5				1,500,300	350.05
Land (2,500,000*200)				500,000,000	116,658.89
Total capital invested				2,045,700,300	477,298.25
Total capital cost (10% interest rate)				204,570,030	47,729.83
	Formula				
Fixed costs					
Coop membership fee				1,730,000	403.64
Rates	492,031*Total area*1%			1,672,905.40	390.32
Water system maintenance =US$33.3*1.5				299,700.00	69.93
Insurance	0.03% of the insured building			271,342.13	63.31
	1% of the insured machinery			3,014,912.50	703.43
Total fixed cost				6,988,860	1,630.63
Total cost to discount				211,558,890	49,360.45

Source: T. Dürksen, personal communication, August, 2005, Case study 1

* Giesbrecht, W., Harder, W., Thiesen, H. and Klassen, N. (2004)

Appendix R
The Linear Programming model

Key to the codes used in the equations

Key to the codes used in the equations.

- **EAT** = Earning after tax which is materialized at the end of the fiscal year on the 31st of December.
- **SORGGC**= Cropping activity representing one hectare of grain sorghum on "Campo soils"
- **SORGS1EC**= Cropping activity representing one hectare of forage sorghum for silage planted early (October) in the rainy season on "Campo soils"
- **SORGS1LC**= Cropping activity representing one hectare of forage sorghum for silage planted late (January) in the rainy season on "Campo soils"
- **MANICON1**= Cropping activity representing one hectare of groundnuts growing under conventional tillage system and utilizing farmer's own tractor.
- **MANICON2**= Cropping activity representing one hectare of groundnuts growing under conventional tillage system and utilizing contractors.
- **MANIMIN1**=Cropping activity representing one hectare of groundnuts growing under minimum tillage system using farmer's own machinery.
- **MANIMIN2**= Cropping activity representing one hectare of groundnuts under minimum tillage system using contractors.
- **COTTON1**= Cropping activity representing one hectare of cotton under conventional tillage system using farmer's own machinery .
- **COTTON2**= Cropping activity representing one hectare of cotton under conventional tillage system using contractors.
- **SESAM1**= Cropping activity representing one hectare of sesame seed under conventional tillage system with manual harvest and using own machinery for sowing.
- **SESAM2**= Cropping activity representing one hectare of sesame seed under conventional tillage system with manual harvest and using contractors.
- **SESAMEC1**= Cropping activity representing one hectare of sesame seed under conventional tillage system with mechanic harvest and using own machinery.
- **SESAMEC2**= Cropping activity representing one hectare of sesame seed under conventional tillage system with mechanic harvest and using contractors.
- **CASTOR1E**= Cropping activity representing one hectare of castor bean sown early in the rainy season utilizing own machinery.
- **CASTOR2E**= Cropping activity representing one hectare of castor bean sown early in the rainy season utilizing contractors.
- **CASTOR1L** = Cropping activity representing one hectare of castor bean sown in the second half of the rainy season using own machinery.
- **CASTOR2L**= Cropping activity representing one hectare of castor bean sown in the second half of the rainy season using own machinery.
- **PANGOLA** = Pasture activity representing one hectare of Digitaria spp or *Cynodom spp* pasture with a renewal rate of 5% per year.
- **PAN15** = Pasture activity representing Pangola pasture with 15 year rotation length.
- **PAN10**= Pasture activity representing one hectare of Digitaria spp or Cynodon spp on light soils with a renewal rate of 10% per year.
- **PANLEG20** = Pasture activity representing one hectare of mixed pasture (Pangola, Crotalaria spp and Alysicarpus spp) with a renewal rate of 10% per year for leguminous and 5% per year for the grass component of the pasture
- **PANLEG15** Similar activity as previous but with 15 year rotation length
- **PANLEG10** = Similar activity as previous but with 10 year rotation length
- **PANLEG8** = Similar activity as previous but with 8 year rotation length
- **PANLEG5** = Similar activity as previous but with 5 year rotation length
- **CANA1**= Cropping activity representing one hectare of Sugar cane replanted every 4 years using own machinery.
- **CANA2**= Cropping activity representing one hectare of Sugar cane replanted every 4 years using contractors.
- **OATS1**= Cropping activity representing one hectare of black OATs using own machinery.
- **OATS2** = Cropping activity representing one hectare of black OATs using contractors.
- **SORGGM** = Cropping activity representing one hectare of sorghum for grain in Monte soils using own machinery.
- **SORGS1EM**= Cropping activity representing one hectare of sorghum for silage planted in the first half of the rainy season on Monte soils using own machinery.

- **SORGS1LM** = Cropping activity representing one hectare of sorghum for silage planted in the second half of the rainy season on Monte soils using own machinery.
- **R20G1S**= Rotation activity representing 20 years under Gatton/Cenchrus/Urocloa pasture and one year under sorghum for silage.
- **R20G2S**= Rotation activity representing 20 years under Gatton/Cenchrus/Urocloa pasture and two year under sorghum for silage.
- **R20G3S**= Rotation activity representing 20 years under Gatton/Cenchrus/Urocloa pasture type and three year under sorghum for silage.
- **GATTON**= Pasture activity representing Gatton/Cenchrus/Urocloa type pasture with a renewal rate of 5% per annum.
- **GATTON15** = Pasture activity similar as previous with 15 year rotation length
- **GATTON10** = Pasture activity similar as previous with 10 year rotation length
- **GATLEUC** =Pasture activity representing Gatton/Cenchrus/Urocloa with Leucaena pasture consociation with a renewal rate of 5% per annum.
- **FL** = Labour resource representing the free labour provided by the farmer and wife.
- **SFXL** =Opportunity to work off farm.
- **CHILD** =Labour resource representing the free labour provided by the farmer's children
- **HLJANMAR** = Labour resource representing hiring a labour unit for one day (Eight hours) during the period January to March
- **R1D1CHE** = Livestock activity representing rearing one rising one year heifer for activity Dairy 1C.
- **R1D1DHE** = Livestock activity representing rearing one rising one year heifer for activity Dairy 1D.
- **R2D1CHE** = Livestock activity representing rearing one rising two year heifer for activity Dairy 1C
- **R2D1DHE** = Livestock activity representing rearing one rising two year heifer for activity Dairy 1D
- **R1D1CST** = Livestock activity representing rearing one rising one year Steer for activity Dairy 1C
- **R1D1DST** = Livestock activity representing rearing one rising one year Steer for activity Dairy 1D
- **R2D1CST** = Livestock activity representing rearing one rising two year Steer for activity Dairy 1C
- **R2D1DST** = Livestock activity representing rearing one rising two year Steer for activity Dairy 1D
- **R1D1CREP** = Livestock activity representing rearing one rising one year heifer replacement for activity Dairy 1C
- **R1D1DREP** = Livestock activity representing rearing one rising one year heifer replacement for activity Dairy 1D
- **R2D1CREP** = Livestock activity representing rearing one rising two year heifer replacement for activity Dairy 1C
- **R2D1DREP** = Livestock activity representing rearing one rising two year heifer replacement for activity Dairy 1D
- **R1D3CHE** = Livestock activity representing rearing one raising one year heifer for activity Dairy 3C.
- **R1D3DHE** = Livestock activity representing rearing one raising one year heifer for activity Dairy 3D.
- **R2D3CHE** = Livestock activity representing rearing one rising two year heifer for activity Dairy 3C
- **R2D3DHE** = Livestock activity representing rearing one rising two year heifer for activity Dairy 3D
- **R1D3CST** = Livestock activity representing rearing one rising one year steer for activity Dairy 3C
- **R1D3DST** = Livestock activity representing rearing one rising one year steer for activity Dairy 3D
- **R2D3CST** = Livestock activity representing rearing one rising two year steer for activity Dairy 3C
- **R2D3DST** = Livestock activity representing rearing one rising two year steer for activity Dairy 3D
- **R1D3CREP** = Livestock activity representing rearing one rising one year heifer replacement for activity Dairy 3C
- **R1D3DREP** = Livestock activity representing rearing one rising one year heifer replacement for activity Dairy 3D
- **R2D3CREP** = Livestock activity representing rearing one rising two year heifer replacement for activity Dairy 3C
- **R2D3DREP** = Livestock activity representing rearing one rising two year heifer replacement for activity Dairy 1D
- **R1D2CHE** = Livestock activity representing rearing one raising one year heifer for activity Dairy 2C.
- **R1D2DHE** = Livestock activity representing rearing one raising one year heifer for activity Dairy 2D.
- **R2D2CHE** = Livestock activity representing rearing one rising two year heifer for activity Dairy 2C
- **R2D2DHE** = Livestock activity representing rearing one rising two year heifer for activity Dairy 2D
- **R1D2CST** = Livestock activity representing rearing one rising one year steer for activity Dairy 2C
- **R1D2DST** = Livestock activity representing rearing one rising one year steer for activity Dairy 2D
- **R2D2CST** = Livestock activity representing rearing one rising two year steer for activity Dairy 2C
- **R2D2DST** = Livestock activity representing rearing one rising two year steer for activity Dairy 2D
- **R1D2CREP** = Livestock activity representing rearing one rising one year heifer replacement for activity Dairy 2C
- **R1D2DREP** = Livestock activity representing rearing one rising one year heifer replacement for activity Dairy 2D
- **R2D2CREP** = Livestock activity representing rearing one rising two year heifer replacement for activity Dairy 2C
- **R2D2DREP** = Livestock activity representing rearing one rising two year heifer replacement for activity Dairy 2D
- **R1D4CHE** = Livestock activity representing rearing one raising one year heifer for activity Dairy 4C.
- **R1D4DHE** = Livestock activity representing rearing one raising one year heifer for activity Dairy 4D.
- **R2D4CHE** = Livestock activity representing rearing one rising two year heifer for activity Dairy 4C.
- **R2D4DHE** = Livestock activity representing rearing one rising two year heifer for activity Dairy 4D.
- **R1D4CST** = Livestock activity representing rearing one rising one year steer for activity Dairy 4C.

- **R1D4DST** = Livestock activity representing rearing one rising one year steer for activity Dairy 4D.
- **R2D4CST** = Livestock activity representing rearing one rising two year Steer for activity Dairy 4C.
- **R2D4DST** = Livestock activity representing rearing one rising two year Steer for activity Dairy 4D
- **R1D4CREP** = Livestock activity representing rearing one rising one year heifer replacement for activity Dairy 4C
- **R1D4DREP** = Livestock activity representing rearing one rising one year heifer replacement for activity Dairy 4D
- **R2D4CREP** = Livestock activity representing rearing one rising two year heifer replacement for activity Dairy 4C
- **R2D4DREP** = Livestock activity representing rearing one rising two year heifer replacement for activity Dairy 4D
- **DAIRY1C** = Dairy activity representing cows of 450 kg mature liveweight calving in July and producing 3,000 l of milk per lactation.
- **DAIRY1D** = Dairy activity representing cows of 450 kg mature liveweight calving in October and producing 3,000 l of milk per lactation.
- **DAIRY2C**= Dairy activity representing cows of 450 kg mature liveweight calving in July and producing 4,500 l of milk per lactation.
- **DAIRY2D** = Dairy activity representing cows of 450 kg mature liveweight calving in October and producing 4,500 l of milk per lactation.
- **DAIRY3C**= Dairy activity representing cows of 550 kg mature liveweight calving in July and producing 3,000 l of milk per lactation.
- **DAIRY3D** = Dairy activity representing cows of 550 kg mature liveweight calving in October and producing 3,000 l of milk per lactation.
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- **DAIRY4C**= Dairy activity representing cows of 550 kg mature liveweight calving in July and producing 4,500 l of milk per lactation.
- **DAIRY4D** = Dairy activity representing cows of 550 kg mature liveweight calving in October and producing 4,500 l of milk per lactation.
- **R2HEIFA** = livestock activity representing rearing one rising two year heifer to be finished at 400 kg liveweight in October.
- **R2STA** =Livestock activity representing rearing one rising two year steer to be finished at 450 kg liveweight in October.
- **BRBEEFA** = Livestock activity representing breeding beef cows of 450 kg mature liveweight calving at the end on September.
- **BULLA** = Livestock activity representing breeding bulls which are replaced every three years.
- **BULLB** = Livestock activity representing breeding bulls which are replaced every three years.
- **R2STB** = Livestock activity representing rearing one rising two year steers to be finished at 450 kg liveweight in August.
- **R2HEIFB** = Livestock activity representing rearing one rising two year heifer to be finished at 400 kg liveweight in August.
- **FSUGJM** = Feeding activity representing feeding one tonne DM of Sugar cane between January to March.
- **HLAPRSEP** = Labour resource representing hiring a labour unit for one day (Eight hours) during the period April to September.
- **WEAN1CB** = Livestock activity representing rearing calves from activity Dairy 1C with a traditional method.
- **WEAN1CC** =Livestock activity representing rearing calves from activity Dairy 1C with an improved method.
- **WEAN2CB** = Livestock activity representing rearing calves from activity Dairy 2C with a traditional method.
- **WEAN2CC** =Livestock activity representing rearing calves from activity Dairy 2C with an improved method.
- **WEAN3CB** = Livestock activity representing rearing calves from activity Dairy 3C with a traditional method.
- **WEAN3CC** =Livestock activity representing rearing calves from activity Dairy 3C with an improved method.
- **WEAN4CB** = Livestock activity representing rearing calves from activity Dairy 4C with a traditional method.
- **WEAN4CC** =Livestock activity representing rearing calves from activity Dairy 4C with an improved method.
- **R1STA** =Livestock activity representing rearing one rising one year steer for beef production.
- **R1HEIFA** = Livestock activity representing rearing one rising one year heifer for beef production.
- **SGRAIN** = Selling activity representing the sale of 1ton of sorghum grain produced on farm
- **SFEEDAJ** = Feeding activity representing feeding one tonne DM of silage during the period April to June
  SFEEDJS = Feeding activity representing feeding one tonne DM of silage during the period April to June
- **FSUGAJ** = Feeding activity representing feeding one tonne DM of sugar cane during the period April to June.
- **FSUGJS** = Feeding activity representing feeding one tonne DM of sugar cane during July to September
- **HLOCTDEC** = Labour resource representing hiring a labour unit for one day (Eight hours) during the period October to December.
- **WEAN1DB** = Livestock activity representing rearing calves from activity Dairy 1D with a traditional method.
- **WEAN1DC** = Livestock activity representing rearing calves from activity Dairy 1D with an improved method.
- **WEAN2DB** = Livestock activity representing rearing calves from activity Dairy 2D with a traditional method.
- **WEAN2DC** = Livestock activity representing rearing calves from activity Dairy 2D with an improved method.

- **WEAN3DB** = Livestock activity representing rearing calves from activity Dairy 3D with a traditional method.
- **WEAN3DC** = Livestock activity representing rearing calves from activity Dairy 3D with an improved method.
- **WEAN4DB** = Livestock activity representing rearing calves from activity Dairy 4D with a traditional method.
- **WEAN4DC** = Livestock activity representing rearing calves from activity Dairy 4D with an improved method.
- **SFEEDOD** = Feeding activity representing feeding one tonne DM of silage during the period October to December.
- **FSUGOD** = Feeding activity representing feeding one tonne DM of sugar cane during the period October to December.
- **LIVINGEX** = Minimum cash requirement for the farmer's personal expenses
- **SMILKJM** = Selling activity representing selling 100 litres of milk for the period January to March.
- **BORRJAN** = Activity representing the opportunity of borrowing 10,000 Gs for one month in January.
- **BORRDEC** = Activity representing the opportunity of borrowing 10,000 Gs for one month in December.
- **LENDDEC** = Money transfer activity representing the opportunity of lending out 10,000 Gs for one month in December.
- **LENDJAN** = Money transfer activity representing the opportunity of lending out 10,000 Gs for one month in January.
- **PELLETJM** = Feeding activity representing feeding one tonne of commercial concentrate in the period January to March.
- **F1JM** = Feeding activity representing feeding one tonne of a home made formula in the period January to March.
- **BORRFEB** = Activity representing the opportunity of borrowing 10,000 Gs for one month in February.
- **LENDFEB** = Activity representing the opportunity of lending out 10,000 Gs for one month in February
- **BORRMAR** = Activity representing the opportunity of borrowing 10,000 Gs for one month in March.
- **LENDMAR** = Activity representing the opportunity of lending out 10,000 Gs for one month in March.
- **BDAIRY1C** = Buying activity representing buying a pregnant heifer for replacement of Dairry1C activity.
- **BDAIRY3C** = Buying activity representing buying a pregnant heifer for replacement of Dairry3C activity.
- **BDAIRY2C** = Buying activity representing buying a pregnant heifer for replacement of Dairry2C activity.
- **BDAIRY4C** = Buying activity representing buying a pregnant heifer for replacement of Dairry4C activity.
- **SREP1C** = Selling activity representing selling a pregnant heifer from Dairy 1C activity
- **SREP2C** = Selling activity representing selling a pregnant heifer from Dairy 2C activity
- **SREP3C** = Selling activity representing selling a pregnant heifer from Dairy 3C activity
- **SREP4C** = Selling activity representing selling a pregnant heifer from Dairy 4C activity
- **SMILKAJ** = Selling activity representing selling 100 litres of milk for the period April to June.
- **BUYREPL** = Buying activity representing buying a pregnant heifer for replacing a cow of activity BrbeefA
- **SBEEFRP1**= Selling activity representing selling a pregnant heifer from activity BrbeefA
- **BWST1**= Buying activity representing buying weaned steers at low price
- **BWST2**= Buying activity representing buying weaned steers at medium price BWHEIFER
- **BORRAPR** = Activity representing the opportunity of borrowing 10,000 Gs for one month in April.
- **LENDAPR** = Activity representing the opportunity of lending out 10,000 Gs for one month in April.
- **PELLETAJ** = Feeding activity representing feeding one tonne DM of a commercial concentrate during the period April to June.
- **F1AJ** = Feeding activity representing feeding one tonne DM of a home made mix during the period April to June.
- **BUYWMAY** = Buying activity representing buying ten thousands of litres in May.
- **S250APR** = Selling weaned steers with 250kg liveweight in April
- **S230APR** = Selling weaning heifers with 230 kg liveweight in April
- **BUYSORGO** = Buying grain sorghum for supplementation.
- **BORRMAY**= Activity representing the opportunity of borrowing 10,000 Gs for one month in May.
- **LENDMAY** = Activity representing the opportunity of lending out 10,000 Gs for one month in May.
- **BUYHAY** = Buying activity representing buying 10 bales of high quality hay in April.
- **BUYWJUN** = Buying activity representing buying ten thousands of litres of water in June
- **BORRJUN** = Activity representing the opportunity of borrowing 10,000 Gs for one month in June.
- **LENDJUN** = Activity representing the opportunity of lending out 10,000 Gs for one month in June.
- **S450JUL** = Selling activity representing selling steers with 450kg liveweight in July.
- **S400JUL** = Selling activity representing selling heifers with 400 kg liveweight in July.
- **BDAIRY1D** = Buying activity representing buying a pregnant heifer for replacement in activity Dairy1D
- **BDAIRY2D** = Buying activity representing buying a pregnant heifer for replacement in activity Dairy2D
- **BDAIRY3D** = Buying activity representing buying a pregnant heifer for replacement in activity Dairy3D
- **BDAIRY4D** = Buying activity representing buying a pregnant heifer for replacement in activity Dairy4D
- **SREP1D** = Selling activity representing selling one pregnant heifer from Dairy1D
- **SREP2D** = Selling activity representing selling one pregnant heifer from Dairy2D
- **SREP3D** = Selling activity representing selling one pregnant heifer from Dairy3D
- **SREP4D** = Selling activity representing selling one pregnant heifer from Dairy4D
- **BUYWJUL** = Buying activity representing buying water in July

- **SMILKJS** = Selling activity representing selling 100 l units of milk during the period July to December
- **BORRJUL** =Activity representing the opportunity of borrowing 10,000 Gs for one month in July
- **LENDJUL** = Activity representing the opportunity of lending out 10,000 Gs for one month in July
- **PELLETJS** = Feeding activity representing feeding one tonne DM of a commercial concentrate during the period July to September.
- **F1JS** = Feeding activity representing feeding one tonne DM of a home made mix during the period April to June.
- **BUYWAUG** = Buying activity representing buying ten thousands litres of water in August.
- **S450AUG** = Selling activity representing selling one steer with 450 kg liveweight in August.
- **S400AUG** = Selling activity representing selling one heifer with 400 kg liveweight in August
- **BUYBULL** = Buying activity representing buying a bull for replacement.
- **BORRAUG** = Activity representing the opportunity of borrowing 10,000 Gs for one month in August
- **LENDAUG** = Activity representing the opportunity of lending out 10,000 Gs for one month in August
- **BUYWSEP** = Buying activity representing buying ten thousands litres of water in September
- **BORRSEP**= Activity representing the opportunity of borrowing 10,000 Gs for one month in September
- **LENDSEP** = Activity representing the opportunity of lending out 10,000 Gs for one month in September
- **S450OCT** = Selling activity representing selling one steer with 450 kg liveweight in October.
- **S400OCT** = Selling activity representing selling one heifer with 400 kg liveweight in October.
- **BUYWOCT** = Buying activity representing buying ten thousand litres of water in October
- **SMILKOD** = Selling activity representing selling 100 l units of milk during the period October to December
- **BORROCT** = Activity representing the opportunity of borrowing 10,000 Gs for one month in October
- **LENDOCT**= Activity representing the opportunity of lending out 10,000 Gs for one month in October
- **PELLETOD** =Feeding activity representing feeding one tonne of DM of a commercial concentrate during the period October to December
- **F1OD** = Feeding activity representing feeding one tonne of DM of a home made mix during the period October to December.
- **BUYWNOV** = Buying activity representing buying ten thousand litres of water in November.
- **S450NOV** = Selling activity representing selling one steer with 450 kg liveweight in November
- **S400NOV** = Selling activity representing selling one heifer with 400 kg liveweight in November
- **BORRNOV** = Activity representing the opportunity of borrowing 10,000 Gs for one month in October
- **LENDNOV** = Activity representing the opportunity of lending out 10,000 Gs for one month in October
- **TAX** = Activity representing the expected taxation implication of the selected farm system assuming a 30% of taxation rate
- **HFMJM** = Transfer activity representing the transfer of one unit of high quality feed to medium quality feed during the period of January to March
- **HODTHJM** = Transfer activity representing an inter-temporal transfer of high quality feed from October-December to January-March.
- **HJMTHAJ** = Transfer activity representing an inter-temporal transfer of high quality feed from January-March to April-June.
- **FSORGOJM** = Feeding activity representing feeding one tone DM of grain sorghum during the period January to March.
- **HFMAJ**= Transfer activity representing the transfer of one unit of high quality feed to medium quality feed during the period April to June.
- **HAJTHJS** = Transfer activity representing an inter-temporal transfer of high quality feed from April-June to July-September.
- **FSORGOAJ** = Feeding activity representing feeding one tone DM of grain sorghum during the period April to June.
- **HFMJS** = Transfer activity representing the transfer of one unit of high quality feed to medium quality feed during the period of July to September.
- **FSORGOJS** = Feeding activity representing feeding one tone DM of grain sorghum during the period July to September
- **HFMOD** = Transfer activity representing the transfer of one unit of high quality feed to medium quality feed during the period of October to December.
- **FSORGOOD** = Feeding activity representing feeding one tone DM of grain sorghum during the period October to December
- **HAYMFEB** = Feed transfer activity that utilizes medium quality feed in the in the period January to March and provides hay to the hayshed
- **HayB** = Feed transfer activity that utilizes medium quality feed in the period April to June and provides hay for the hayshed.
- **MFLJM** = Transfer activity representing the transfer of one unit of medium quality feed to low quality feed during the period of January to March.

- **MJMTMAJ** = Transfer activity representing an inter-temporal transfer of medium quality feed from January-March to April-June.
- **MODTMJM** = Transfer activity representing an inter-temporal transfer of medium quality feed from October-December to January-March
- **MFLAJ** = Transfer activity representing the transfer of one unit of medium quality feed to low quality feed during the period of April to June.
- **MAJTMJS** = Transfer activity representing an inter-temporal transfer of medium quality feed from April-June to July-September.
- **HFEEDAJ** = Feeding activity representing feeding 10 bales of hay from the hayshed during the period of April to June MFLJS = Transfer activity representing the transfer of one unit of medium quality feed to low quality feed during the period of July to September.
- **HFEEDJS** = Feeding activity representing feeding 10 bales of hay from the hayshed during the period of June to September.
- **HAYMNOV** = Feed transfer activity which utilizes medium quality feed in the in the period October to December and provides hay to the hayshed
- **MFLOD** = Transfer activity representing the transfer of one unit of medium quality feed to low quality feed during the period of October to December
- **HFEEDOD** = Feeding activity representing feeding 10 bales of hay from the hayshed during the period of October to December.
- **LJMTAJ** = Transfer activity representing an inter-temporal transfer of low quality feed from January-March to April-June
- **LODTJM** = Transfer activity representing an inter-temporal transfer of low quality feed from October-December to January-March
- LAJTJS Transfer activity representing an inter-temporal transfer of low quality feed from April-June to July-September.
- **RAIN** = Represent the level of rainfall expected in the year simulated using a value of 1 as the mean average rainfall.
- **WDEC_JAN** = Transfer activity representing transfer of water from December to January
- **WJAN_FEB** = Transfer activity representing transfer of water from January to February
- **WFEB_MAR** = Transfer activity representing transfer of water from February to march
- **WMAR_APR** = Transfer activity representing transfer of water from March to April
- **WAPR_MAY** = Transfer activity representing transfer of water from April to May
- **WMAY_JUN** = Transfer activity representing transfer of water from May to June
- **WJUN_JUL** = Transfer activity representing transfer of water from June to July
- **WJUL_AUG** = Transfer activity representing transfer of water from July to August.
- **WAUG_SEP** = Transfer activity representing transfer of water from August to September
- **WSEP_OCT** = Transfer activity representing transfer of water from September to October
- **WOCT_NOV** = Transfer activity representing transfer of water from October to November
- **WNOV_DEC** = Transfer activity representing transfer of water from November to December
- **REPLA** = Livestock activity representing a replacement for activity brbeefA.
- **G80LH** = Gatton-leucaena hedgerow system with Gatton yields at 80% of normal yield and Leucaena at high yield
- **G80LM** = Gatton-leucaena hedgerow system with Gatton yields at 80% of normal yield and Leucaena at medium yield
- **G80LL** = Gatton-leucaena hedgerow system with Gatton yields at 80% of normal yields and leucaena at low yield
- **G65LH** = Gatton-leucaena hedgerow system with Gatton yield at 65% of normal yields and leucaena at high yield
- **G65LM**= Gatton-leucaena hedgerow system with Gatton yield at 65% of normal yields and leucaena at medium yield
- **G65LL** = Gatton-leucaena hedgerow system with Gatton yield at 65% of normal yields and leucaena at low yield
- **G50LH** = Gatton-leucaena hedgerow system with Gatton yield at 50% of normal yields and leucaena at high yield
- **G50LM** = Gatton-leucaena hedgerow system with Gatton yield at 50% of normal yields and leucaena at medium yield
- **G50LL** = Gatton-leucaena hedgerow system with Gatton yield at 50% of normal yields and leucaena at low yield
- **BOBYST** = The activities with this root are selling activities selling bull calves at $0 price in their first week of life
- **CULL**= The activities with this root are selling activities selling heifer calves at $0 price in their first week of life

The linear Programming model in algebraic form

Title: Optimum Farming System for the Central Chaco

Max eat !max profit after tax.

st

!Here goes our "Campo" land constraints

CampoJa) +SorggC +sorgs1ec +sorgs1lc +manicon1 +manicon2 +manimin1 +manimin2 +Cotton1 +Cotton2 +sesam1 +sesam2 +sesamec1 +sesamec2 +Castor1E+Castor2E +Castor1L +Castor2L +Pangola +pan15+Cana1 +Cana2 +Pan10 +Panleg5 +Panleg8 +Panleg10 +Panleg15+Panleg20 =<50

CampoFe) +SorggC +sorgs1ec +sorgs1lc +manicon1 +manicon2 +manimin1 +manimin2 +Cotton1 +Cotton2 +sesam1 +sesam2 +sesamec1 +sesamec2 +Castor1E +Castor2E +Castor1L +Castor2L +Pangola +pan15+Cana1 +Cana2+Pan10 +Panleg5 +Panleg8 +Panleg10 +Panleg15+Panleg20 =<50

CampoMa) +SorggC +sorgs1ec +sorgs1lc +manicon1 +manicon2 +manimin1 +manimin2 +Cotton1 +Cotton2+sesam1 +sesam2 +sesamec1 +sesamec2 +Castor1E +Castor2E +Castor1L +Castor2L +Pangola +pan15 +Cana1 +Cana2+Pan10 +Panleg5+Panleg8 +Panleg10 +Panleg15+Panleg20 =<50

CampoAp1) +SorggC +manicon1 +sorgs1lc +manicon2 +manimin1 +manimin2 +Cotton1 +Cotton2 +Castor1E +Castor2E +Castor1L +Castor2L +Pangola +pan15 +Cana1 +Cana2+Pan10 +Panleg5 +Panleg8 +Panleg10 +Panleg15 +Panleg20 =<50

CampoAp2) +SorggC +manicon1 +sorgs1lc +manicon2 +manimin1 +manimin2 +Cotton1 +Cotton2 +Castor1L +Castor2L +Pangola +pan15 +Cana1 +Cana2 +Oats1 +Oats2 +Pan10 +Panleg5 +Panleg8 +Panleg10 +Panleg15 +Panleg20 =<50

CampoMA) +sorgs1lc +Cotton1 +Cotton2 +Castor1l +Castor2L +Pangola +1pan15 +Cana1 +cana2 +Oats1 +Oats2 +Pan10 +Panleg5 +Panleg8 +Panleg10 +Panleg15 +Panleg20 =<50

CampoJu) +sorgs1lc +Pangola +pan15 +Cana1 +cana2 +Oats1 +Oats2 +Pan10 +Panleg5+Panleg8 +Panleg10 +Panleg15+Panleg20 =<50

CampoJl) +Pangola +Cana1 +cana2 +pan15 +Oats1 +Oats2 +Pan10 +Panleg5+Panleg8 +Panleg10 +Panleg15 +Panleg20 =<50

CampoAu) +Pangola +pan15 +Cana1 +cana2 +Pan10 +Panleg5 +Panleg8+Panleg10 +Panleg15 +Panleg20 =<50

CampoSe) +Pangola +pan15 +Cana1 +cana2+Pan10 +Panleg5+Panleg8 +Panleg10 +Panleg15 +Panleg20 =<50

CampoOc) +sorgs1ec +manicon1 +1manicon2 +manimin1 +manimin2 +Castor1E +Castor2E +Pangola +pan15 +Cana1 +cana2 +Pan10 +Panleg5+Panleg8 +Panleg10 +Panleg15 +Panleg20 =<50

CampoNo) +sorgs1ec +manicon1 +1manicon2 +manimin1 +manimin2 +Cotton1 +Cotton2 +Sesam1 +sesam2 +sesamec1 +sesamec2 +Castor1E +Castor1L +Castor2E +Castor2L +Pangola +pan15 +Cana1 +cana2+Pan10 +Panleg5+Panleg8+Panleg10+Panleg15+Panleg20 =<50

CampoDe) +sorgs1ec +manicon1 +1manicon2 +manimin1 +manimin2 +Cotton1 +Cotton2 +Sesam1 +sesam2 +sesamec1 +sesamec2 +Castor1E +Castor1L +Castor2E +Castor2L +Pangola +pan15 +Cana1 +Cana2 +Pan10 +Panleg5+Panleg8+Panleg10+Panleg15+Panleg20 =<50

!Here goes our "Monte" Land constraints

MontJan) +SorggM +sorgs1eM +sorgs1lM + R20g1s +R20g2s +R20g3s +G80LH +G80LM +G80LL +G65LH +G65LM+G65LL+G50LH+G50LM+G50LL +Gatton +Gatton15 +Gatton10 <=150

MontFeb) +SorggM +sorgs1eM +sorgs1lM + R20g1s +R20g2s +R20g3s +G80LH +G80LM +G80LL +G65LH+G65LM+G65LL+G50LH+G50LM+G50LL +Gatton +Gatton15 +Gatton10 <=150
MontMar) +SorggM +sorgs1eM +sorgs1lM + R20g1s +R20g2s +R20g3s +G80LH+G80LM +G80LL +G65LH +G65LM+G65LL+G50LH+G50LM+G50LL +Gatton +Gatton15 +Gatton10 <=150
MontApr) +SorggM +sorgs1lM +R20g1s +R20g2s +R20g3s +G80LH+G80LM +G80LL +G65LH +G65LM+G65LL+G50LH+G50LM+G50LL +Gatton +Gatton15 +Gatton10 <=150
MontMay) +sorgs1lM + R20g1s +R20g2s +R20g3s +G80LH+G80LM +G80LL+G65LH +G65LM +G65LL +G50LH+G50LM+G50LL +Gatton +Gatton15 +Gatton10 <=150
MontJun) +sorgs1lM + R20g1s +R20g2s +R20g3s +G80LH +G80LM +G80LL +G65LH +G65LM +G65LL+G50LH+G50LM+G50LL +Gatton +Gatton15 +Gatton10 <=150
MontJul) + R20g1s +R20g2s +R20g3s +G80LH +G80LM+G80LL +G65LH+G65LM +G65LL +G50LH +G50LM +G50LL +Gatton +Gatton15 +Gatton10 <=150
MontAug) + R20g1s +R20g2s +R20g3s +G80LH +G80LM +G80LL +G65LH +G65LM +G65LL +G50LH +G50LM+G50LL +Gatton +Gatton15 +Gatton10 <=150
MontSep) + R20g1s +R20g2s +R20g3s +G80LH +G80LM +G80LL +G65LH +G65LM +G65LL +G50LH +G50LM+G50LL +Gatton +Gatton15 +Gatton10 <=150
MontOct) +sorgs1eM + R20g1s +R20g2s +R20g3s +G80LH +G80LM +G80LL +G65LH +G65LM +G65LL+G50LH+G50LM+G50LL +Gatton +Gatton15 +Gatton10 <=150
MontNov) +sorgs1eM + R20g1s +R20g2s +R20g3s +G80LH +G80LM +G80LL +G65LH +G65LM +G65LL+G50LH+G50LM+G50LL +Gatton +Gatton15 +Gatton10 <=150
MontDec) +sorgs1eM + R20g1s +R20g2s +R20g3s +G80LH +G80LM +G80LL+G65LH +G65LM +G65LL +G50LH+G50LM+G50LL +Gatton +Gatton15 +Gatton10 <=150
!here is our labour constraints in Day-man units
LabourJM) -63fl +12sfxl -48Child -hlJanMar +0.4R1d1CHe +0.4R1d1dhe +0.4R2d1CHe +0.4R2d1dhe +0.4R1d1cst +0.4R1d1dst +0.4R2d1cst +0.4R2d1dst +0.4R1d1crep +0.4R1d1drep +0.4R2d1cRep +0.4R2d1drep +0.4R1d3Che +0.4R1d3dhe +0.4R2d3che +0.4R2d3dhe +0.4R1d3Cst +0.4R1d3dst +0.4R2D3Cst +0.4R2d3dst +0.4R1d3Crep +0.4R1d3drep +0.4R2d3Crep +0.4R2d3drep +0.4R1d2CHe +0.4R1d2dhe +0.4R2d2CHe +0.4R2d2dhe +0.4R1d2cst +0.4R1d2dst +0.4R2d2cst +0.4R2d2dst +0.4R1d2crep +0.4R1d2drep +0.4R2d2cRep +0.4R2d2drep +0.4R1d4Che +0.4R1d4dhe +0.4R2d4che +0.4R2d4dhe +0.4R1d4Cst +0.4R1d4dst +0.4R2d4Cst +0.4R2d4dst +0.4R1d4Crep +0.4R1d4drep +0.4R2d4Crep +0.4R2d4drep+ 0.9Dairy1C +0.9Dairy1D +0.9Dairy2C +0.9Dairy2D +0.9Dairy3C +0.9Dairy3D +0.9Dairy4C +0.9Dairy4D +0.3Repla+0.3R2HeifA +0.3R2stA +0.3brbeefA +0.3bullA +0.3bullB +0.3R2stB +R2heifB +0.01Pangola +0.01pan15 +0.14Pan10 +0.03Panleg5 +0.02Panleg8 +0.02Panleg10 +0.01Panleg15 +0.01Panleg20 +0.4sorggC +0.4sorggM +0.8sorgs1eC +0.46sorgs1lC +0.9sorgs1eM +0.5sorgs1lM +0.1manicon1 +0.4manimin1 +0.3R20g1s +0.3R20g2s +0.3R20g3s +0.03G80LH +0.03G80LM +0.03G80LL +0.03G65LH +0.03G65LM +0.03G65LL +0.03G50LH +0.03G50LM +0.03G50LL +0.25Gatton +0.25Gatton15 +0.25Gatton10 +0.33cotton1 +0.33Cotton2 +8sesam1 +8sesam2 +0.2sesamec1 +0.2sesamec2 +2.5cana2 +2.5cana1 =<0
LabourAS) -114fl +24sfxl -33Child -hlAprSep +0.6R1d1CHe +0.7R1d1dhe +0.7R2d1CHe +0.7R2d1dhe +0.6R1d1cst +0.7R1d1dst +0.7R2d1cst +0.7R2d1dst +0.6R1d1crep +0.7R1d1drep +0.7R2d1cRep +0.7R2d1drep +0.6R1d3Che +0.7R1d3dhe +0.7R2d3che +0.7R2d3dhe +0.6R1d3Cst +0.7R1d3dst +0.7R2D3Cst +0.7R2d3dst +0.6R1d3Crep +0.7R1d3drep +0.7R2d3Crep +0.7R2d3drep +0.6R1d2CHe +0.7R1d2dhe +0.7R2d2CHe +0.7R2d2dhe +0.6R1d2cst +0.7R1d2dst +0.7R2d2cst +0.7R2d2dst +0.6R1d2crep +0.7R1d2drep +0.7R2d2cRep +0.7R2d2drep +0.6R1d4Che +0.7R1d4dhe +0.7R2d4che +0.7R2d4dhe +0.6R1d4Cst +0.7R1d4dst +0.7R2d4Cst +0.7R2d4dst +0.6R1d4Crep +0.7R1d4drep +0.7R2d4Crep +0.7R2d4drep +0.875wean1CB +1wean1CC +0.875wean2CB

+1wean2CC +0.875wean3CB +1wean3CC +0.875wean4CB +1wean4CC +0.875rear1CB +1rear1CC+0.875rear2CB +1rear2CC +0.875rear3CB +1rear3CC +0.875rear4CB +1rear4CC +1.2Dairy1C + 1.2Dairy1D +1.2Dairy2C +1.2Dairy2D +1.2Dairy3C +1.2Dairy3D +1.2Dairy4C +1.2Dairy4D +0.6Repla +0.6R1stA +0.6 R1heifA +0.6R2heifA +0.6R2stA +0.6R2StB +0.6R2heifB +0.6brbeefA +0.6bullA +0.6bullB +0.03Pangola +0.04pan15 +0.04Pan10 +0.03Panleg5 +0.03Panleg8+0.03Panleg10 +0.03Panleg15 +0.03Panleg20 +0.1sorggC +0.1sorggM +0.8sorgs11C +0.9sorgs11M +0.03sgrain +0.2manicon1 +0.9manimin1+0.04manimin2 +0.1manicon2 +0.1manimin2 +1.04R20g1s +1R20g2s +1R20g3s +1.34G80LH +1.34G80LM +1.34G80LL +1.34G65LH +1.34G65LM +1.34G65LL +1.34G50LH+1.34G50LM +1.34G50LL +1.1Gatton +1.1Gatton15 +1.1Gatton10 +0.03cotton1 +0.03cotton2 +0.01sesam1 +0.01sesam2 +0.01sesamec1 +0.01sesamec2 +0.1Castor1E +0.1Castor1L +0.1Castor2E +0.1Castor2L +0.28125Oats1 +0.23sfeedAJ +0.23sfeedJS +0.55fsugAJ +0.55fsugJS+0.05HfeedAJ+0.06HfeedJS =<0

LabourOD) -63fl +12sfxl -61.5Child -hlOctDec +0.4R1d1CHe +0.3R1d1dhe +0.4R2d1CHe +0.4R2d1dhe +0.4R1d1cst +0.3R1d1dst +0.4R2d1cst +0.4R2d1dst +0.4R1d1crep +0.3R1d1drep +0.4R2d1cRep +0.4R2d1drep +0.4R1d3Che +0.3R1d3dhe +0.4R2d3che +0.4R2d3dhe +0.4R1d3Cst +0.3R1d3dst +0.4R2D3Cst +0.4R2d3dst +0.4R1d3Crep +0.3R1d3drep +0.4R2d3Crep +0.4R2d3drep +0.4R1d2CHe +0.3R1d2dhe +0.4R2d2CHe +0.4R2d2dhe +0.4R1d2cst +0.3R1d2dst +0.4R2d2cst +0.4R2d2dst +0.4R1d2crep +0.3R1d2drep +0.4R2d2cRep +0.4R2d2drep +0.4R1d4Che +0.3R1d4dhe +0.4R2d4che +0.4R2d4dhe +0.4R1d4Cst +0.3R1d4dst +0.4R2d4Cst +0.4R2d4dst +0.4R1d4Crep +0.3R1d4drep +0.4R2d4Crep +0.4R2d4drep +0.875wean1DB +1wean1DC +0.875wean2DB +1wean2DC +0.875wean3DB +1wean3DC +0.875wean4DB +1wean4DC+0.875rear1DB +1rear1DC +0.875rear2DB +1rear2DC +0.875rear3DB +1rear3DC +0.875rear4DB +1rear4DC +0.9Dairy1C +0.9Dairy1D +0.9Dairy2C +0.9Dairy2D +0.9Dairy3C +0.9Dairy3D +0.9Dairy4C +0.9Dairy4D +0.3Repla +0.3R1stA +0.3R1heifA +0.3R2heifA +0.3R2stA +0.3brbeefA +0.3bullA +0.3bullB +0.01Panleg5 +0.01Panleg8+0.01Panleg10 +0.46sorgs1eC +0.5sorgs1eM +0.4manicon1 +2.8manimin1 +0.03R20g1s +0.05R20g2s +0.07R20g3s +0.07G80LH +0.07G80LM +0.07G80LL+0.07G65LH +0.07G65LM+0.07G65LL +0.07G50LH +0.07G50LM +0.07G50LL +0.01Gatton +0.05Gatton15 +0.1Gatton10 +0.5cotton1 +0.4sesam1 +0.5sesamec1 +0.5Castor1E +0.5Castor1L +2cana2 +2.1cana1 +0.23sfeedOD +0.55fsugOD+0.06hfeedOD =<0

MaxFl)fl=<1

Mchild) child=0

Maxsfl)sfxl=0

!here is our cashflows in 10 thousands of guaranis units

CashJan)+0.083 livingex -49.28sfxl +1.33hlJanMar +0.738R1d1che +0.738R1d3che +0.738R1d1Crep +0.738R1d3crep +0.738R1d1cst +0.738R1d3cst +0.559R1d1Dhe +0.559R1d3dhe +0.559R1d1Drep +0.559R1d3drep +0.559R1d1Dst +0.559R1d3dst +0.483R2d1che +0.483R2d3che +0.483R2d1Crep +0.483R2d3crep +0.483R2d1cst +0.483R2d3cst +0.483R2d1Dhe +0.483R2d3dhe +0.483R2d1Drep +0.483R2d3drep +0.483R2d1dst +0.483R2d3dst +0.738R1d2che +0.738R1d4che +0.738R1d2Crep +0.738R1d4crep +0.738R1d2cst +0.738R1d4cst +0.559R1d2Dhe +0.559R1d4dhe +0.559R1d2Drep +0.559R1d4drep +0.559R1d2Dst +0.559R1d4dst +0.483R2d2che +0.483R2d4che +0.483R2d2Crep +0.483R2d4crep +0.483R2d2cst +0.483R2d4cst +0.483R2d2Dhe +0.483R2d4dhe +0.483R2d2Drep +0.483R2d4drep +0.483R2d2dst +0.483R2d4dst +1.36Dairy1C +1.36Dairy1D +1.36Dairy2C +1.36Dairy2D +1.36Dairy3C +1.36Dairy3D +1.36Dairy4C +1.36Dairy4D -3.2066smilkJM +0.4834R2stA +0.4834R2HeifA +0.4834repla+0.4834R2stB +0.4834R2HeifB +0.9284brbeefA +0.4834bullA +0.4834bullB +10.1410sorggC +10.1410sorggM +12.3749sorgs11C + 14.2311sorgs11M +4R20g1s +3.8181R20g2s +3.6521R20g3s +4.2G80LH+4.2G80LM+4.2G80LL+4.2G65LH+4.2G65LM+4.2G65LL+4.2G50LH+4.2G50

LM+4.2G50LL +4.2Gatton +4.2Gatton15 +4.2Gatton10 +2.4699cotton1 +6.6000cotton2 +7.5427sesam1 +8.8000sesam2 +16.3203sesamec1 +22.9000sesamec2 +8.5Castor1e +8.5Castor2e -10borrJan +10.175borrDec -10.1lendDec +10lendJan +94.5000pelletJM +67F1JM +55bysorgJM=0

CashFeb)+0.083 livingex -49.28sfxl +1.33hlJanMar +0.31R1d1che+ 0.31R1d3che +0.31R1d1Crep +0.31R1d3crep +0.31R1d1cst +0.31R1d3cst +0.265R1d1Dhe +0.265R1d3dhe +0.265R1d1Drep +0.265R1d3drep +0.285R1d1Dst +0.285R1d3dst +0.236R2d1che +0.236R2d3che +0.236R2d1Crep +0.236R2d3crep +0.236R2d1cst +0.236R2d3cst +0.236R2d1Dhe +0.236R2d3dhe +0.236R2d1Drep +0.236R2d3drep +0.236R2d1dst +0.236R2d3dst +0.31R1d2che+ 0.31R1d4che +0.31R1d2Crep +0.31R1d4crep +0.31R1d2cst +0.31R1d4cst +0.265R1d2Dhe +0.265R1d4dhe +0.265R1d2Drep +0.265R1d4drep +0.285R1d2Dst +0.285R1d4dst +0.236R2d2che +0.236R2d4che +0.236R2d2Crep +0.236R2d4crep +0.236R2d2cst +0.236R2d4cst +0.236R2d2Dhe +0.236R2d4dhe +0.236R2d2Drep +0.236R2d4drep +0.236R2d2dst +0.236R2d4dst +1.03Dairy1C +1.03Dairy1D + 1.03Dairy2C +1.03Dairy2D +1.03Dairy3C +1.03Dairy3D +1.03Dairy4C +1.03Dairy4D -3.2066smilkJM +0.2364R2stA +0.2364R2HeifA +0.2364repla+0.2364R2stB +0.2364R2HeifB +0.4344brbeefA +0.2364bullA +0.2364bullB +1.8037pangola +1.8451pan15 +1.9073Pan10 +0.75Panleg5+0.47Panleg8+0.38Panleg10+0.25Panleg15+0.19Panleg20 +9.7624sorggC +9.7624sorggM +40.1514sorgs1eC +9.8124sorgs11C +9.8124sorgs11M +46.5621sorgs1eM + 30.0863R20g1s +5.0624R20g2s +6.8668R20g3s +0.91G80LH +0.91G80LM +0.91G80LL +0.91G65LH +0.91G65LM+0.91G65LL+0.91G50LH+0.91G50LM+0.91G50LL +0.9Gatton +0.91Gatton15 +0.9Gatton10 +1.308manicon1 +2.917manicon2 +10.9898manimin1 +11.807manimin2 +10.7154cotton1 +13.1442cotton2 +8.5Castor1l +8.5Castor2l-10borrFeb +10.175borrJan -10.1lendJan +10lendFeb =0

CashMar)+0.083 livingex -49.28sfxl +1.33hlJanMar +0.227R1d1che +0.227R1d3che +0.227R1d1Crep +0.227R1d3crep +0.227R1d1cst +0.227R1d3cst +0.16R1d1Dhe +0.16R1d3dhe +0.16R1d1Drep +0.16R1d3drep +0.16R1d1Dst +0.16R1d3dst +0.16R2d1che +0.16R2d3che +0.16R2d1Crep +0.16R2d3crep +0.16R2d1cst +0.16R2d3cst +0.16R2d1Dhe +0.16R2d3dhe +0.16R2d1Drep +0.16R2d3drep +0.16R2d1dst +0.16R2d3dst +0.227R1d2che +0.227R1d4che +0.227R1d2Crep +0.227R1d4crep +0.227R1d2cst +0.227R1d4cst +0.16R1d2Dhe +0.16R1d4dhe +0.16R1d2Drep +0.16R1d4drep +0.16R1d2Dst +0.16R1d4dst +0.16R2d2che +0.16R2d4che +0.16R2d2Crep +0.16R2d4crep +0.16R2d2cst +0.16R2d4cst +0.16R2d2Dhe +0.16R2d4dhe +0.16R2d2Drep +0.16R2d4drep +0.16R2d2dst +0.16R2d4dst +1.12Dairy1C +1.32Dairy1D +1.12Dairy2C +1.32Dairy2D +1.12Dairy3C +1.32Dairy3D +1.12Dairy4C +1.32Dairy4D -3.2066smilkJM +0.1598R2stA +0.1598R2HeifA+0.1598repla +0.1598R2stB +0.1598R2HeifB+0.3195brbeefA -58.9666bullA -58.9666bullB +1.2349sorggC +1.2349sorggM +1.2349sorgs11C +1.2349sorgs11M -8R20g1s-7.6363R20g2s -7.3043R20g3s-8.4Gatton -8.4Gatton15 -8.4Gatton10 +15.518manicon1 +23.417manicon2 +15.1239manimin1 +18.872manimin2 +10.7153cotton1 +13.1441cotton2 +23.6000sesam1 +23.6000sesam2 +22.9000sesamec1 +22.9000sesamec2 +13.6476Castor1E +3.5haymMar - 10borrMar +10.175borrFeb -10.1lendFeb +10lendMar =0

CashApr)+0.083 livingex +3.5hayb-49.28sfxl +0.5hlAprSep +0.7R1d1che +0.7 R1d3che +0.2R1d1Crep +0.2R1d3crep +0.2R1d1cst +0.2R1d3cst +0.51R1d1Dhe +0.51R1d3dhe +0.67R1d1Drep +0.67R1d3drep +0.51R1d1Dst +0.51R1d3dst +0.84R2d1che +0.84R2d3che +0.33R2d1Crep +0.33R2d3crep +0.33R2d1cst +0.33R2d3cst +0.84 R2d1Dhe +0.84R2d3dhe +0.84R2d1Drep +0.84R2d3drep +0.33R2d1dst +0.33R2d3dst +0.7R1d2che +0.7 R1d4che +0.2R1d2Crep +0.2R1d4crep +0.2R1d2cst +0.2R1d4cst +0.51R1d2Dhe +0.51R1d4dhe +0.67R1d2Drep +0.67R1d4drep +0.51R1d2Dst +0.51R1d4dst +0.84R2d2che +0.84R2d4che +0.33R2d2Crep +0.33R2d4crep +0.33R2d2cst +0.33R2d4cst +0.84 R2d2Dhe +0.84R2d4dhe +0.84R2d2Drep +0.84R2d4drep +0.33R2d2dst +0.33R2d4dst +210 bdairy1C +210bdairy3C +210bdairy2C +210bdairy4C -190SREP1C -190SREP2C -190SREP3C -

190SREP4C -19.8787Dairy1C +1.2819Dairy1D -19.8788Dairy2C +1.2819Dairy2D -24.3811Dairy3C +1.28195Dairy3D -24.3811Dairy4C +1.282Dairy4D -3.8733smilkAJ +0.7280R2stA +0.7280R2HeifA+0.7280repla +0.7280R2stB +0.7280R2HeifB +1.41125brbeefA +0.7280bullA +0.7280bullB +130.0000buyrepl -125sbeefrp1 +71bwst1 +72bwst2 +54bwheifer +0.5188pangola +0.5188pan15 + 0.5Pan10 +0.52Panleg5 +0.52Panleg8 +0.52Panleg10 +0.52Panleg15+0.52Panleg20 +16.3300sorggC +16.3300sorggM +1.2351R20g1s +1.1789R20g2s +1.1277R20g3s +1.3G80LH +1.3G80LM +1.3G80LL +1.3G65LH+1.3G65LM+1.3G65LL+1.3G50LH+1.3G50LM+1.3G50LL +1.2968Gatton +1.2968Gatton15 +1.2968Gatton10 -238.452manicon1 -227.568manicon2 -202.408manimin1 -202.408manimin2 +70.7153cotton1 +73.1441cotton2 -239.4600sesam1 -239.4600sesam2 -167.4600sesamec1 -167.4600sesamec2 +13.6476Castor1L -82.1032Castor1E -82.1032Castor2E -60sellhay +64.97oats1 +73.5oats2 -10borrApr +10.175borrMar -10.1lendMar +10lendApr +10.46FsugAJ +94.5000pelletAJ +67F1AJ+55bysorgAJ =0

CashMay)+0.083 livingex -49.28sfxl +0.5hlAprSep +0.77 R1d1che +0.77R1d3che +0.77R1d1Crep +0.77 R1d3crep +0.77R1d1cst +0.77 R1d3cst +0.88R1d1Dhe +0.88R1d3dhe +0.88R1d1Drep +0.88R1d3drep +0.88R1d1Dst +0.88R1d3dst +0.77R2d1che +0.77 R2d3che +0.77R2d1Crep +0.77 R2d3crep +0.77 R2d1cst +0.77 R2d3cst +0.77 R2d1Dhe +0.77 R2d3dhe +0.77 R2d1Drep +0.77 R2d3drep +0.77 R2d1dst +0.77 R2d3dst +0.77 R1d2che +0.77R1d4che +0.77R1d2Crep +0.77 R1d4crep +0.77R1d2cst +0.77 R1d4cst +0.88R1d2Dhe +0.88R1d4dhe +0.88R1d2Drep +0.88R1d4drep +0.88R1d2Dst +0.88R1d4dst +0.77R2d2che +0.77 R2d4che +0.77R2d2Crep +0.77 R2d4crep +0.77 R2d2cst +0.77 R2d4cst +0.77 R2d2Dhe +0.77 R2d4dhe +0.77 R2d2Drep +0.77 R2d4drep +0.77 R2d2dst +0.77 R2d4dst+0.67Dairy1C +1.44Dairy1D +0.67Dairy2C +1.44Dairy2D +0.67Dairy3C +1.44Dairy3D +0.67Dairy4C +1.44Dairy4D +20buywMay-3.8733smilkAJ +0.8780R2stA +0.8780R2HeifA +0.8780repla +0.8780R2stB +0.8780R2HeifB +0.8780R1stA +0.8780R1heifA -17.26brbeefA +0.8780bullA +0.8780bullB -60.9250 s250Apr -53.7510 s230Apr -54.1sgrain +40.1514sorgs1lC +46.5621sorgs1lM+2.149manicon1 +5manicon2 +2.1488manimin1 +5manimin2 +1.2351R20g1s +1.1789R20g2s +1.1277R20g3s +1.3G80LH +1.3G80LM +1.3G80LL+1.3G65LH+1.3G65LM+1.3G65LL+1.3G50LH+1.3G50LM+1.3G50LL +1.2968Gatton +1.2968Gatton15 +1.2968Gatton10 -286.9200cotton1 -286.9200cotton2 -82.1032Castor1L-82.1032Castor2L -10borrMay +10.175borrApr -10.1lendApr +10lendMay +10.46FsugAJ+70buyhay =0

CashJun)+0.083 livingex -49.28sfxl +0.5hlAprSep +0.77R1d1che +0.77R1d3che +0.77R1d1Crep +0.77 R1d3crep +0.77R1d1cst +0.77 R1d3cst +0.85R1d1Dhe +0.85R1d3dhe +0.85R1d1Drep +0.85R1d3drep +0.85R1d1Dst +0.85 R1d3dst +0.88R2d1che +0.88R2d3che +0.88 R2d1Crep +0.88 R2d3crep +0.88 R2d1cst +0.88 R2d3cst +0.72R2d1Dhe +0.72R2d3dhe +0.72R2d1Drep +0.72R2d3drep +0.88 R2d1dst +0.88 R2d3dst +0.77R1d2che +0.77R1d4che +0.77R1d2Crep +0.77 R1d4crep +0.77R1d2cst +0.77 R1d4cst +0.85R1d2Dhe +0.85R1d4dhe +0.85R1d2Drep +0.85R1d4drep +0.85R1d2Dst +0.85 R1d4dst +0.88R2d2che +0.88R2d4che +0.88 R2d2Crep +0.88 R2d4crep +0.88 R2d2cst +0.88 R2d4cst +0.72R2d2Dhe +0.72R2d4dhe +0.72R2d2Drep +0.72R2d4drep +0.88 R2d2dst +0.88 R2d4dst +0.67Dairy1C +1.41Dairy1D +0.67Dairy2C +1.41Dairy2D +0.67Dairy3C +1.41Dairy3D 0.67Dairy4C +1.41Dairy4D +20BuywJun -3.8733smilkAJ +0.8795R2stA +0.8795R2HeifA +0.9795repla +0.8795R2stB +0.8795R2HeifB +0.8795R1stA +0.8795R1heifA +0.8795brbeefA +0.8795bullA +0.8795bullB +6.593manicon1 +14manicon2 +1.2351R20g1s +1.1789R20g2s +1.1277R20g3s +1.3G80LH +1.3G80LM +1.3G80LL+1.3G65LH +1.3G65LM+1.3G65LL +1.3G50LH+1.3G50LM +1.3G50LL +1.2968Gatton +1.2968Gatton15 +1.2969Gatton10 -10borrJun +10.175borrMay -10.1lendMay +10lendJun +10.46FsugAJ =0

CashJul)+0.083 livingex -49.28sfxl +0.5hlAprSep +0.1R1d1che +0.1R1d3che +0.1R1d1Crep +0.1 R1d3crep +0.1R1d1cst +0.1R1d3cst +0.85R1d1Dhe +0.85R1d3dhe +0.85R1d1Drep +0.85R1d3drep +0.80R1d1Dst +0.80R1d3dst +1.16 R2d1che +1.16 R2d3che +1.16 R2d1Crep +1.16 R2d3crep +1.16 R2d1cst +1.16 R2d3cst +R2d1Dhe +R2d3dhe +R2d1Drep +R2d3drep +1.16R2d1dst +1.16 R2d3dst +0.1R1d2che +0.1R1d4che +0.1R1d2Crep +0.1 R1d4crep +0.1R1d2cst +0.1R1d4cst +0.85R1d2Dhe +0.85R1d4dhe +0.85R1d2Drep +0.85R1d4drep +0.80R1d2Dst +0.80R1d4dst +1.16 R2d2che +1.16 R2d4che +1.16 R2d2Crep +1.16 R2d4crep +1.16 R2d2cst +1.16 R2d4cst +R2d2Dhe +R2d4dhe +R2d2Drep +R2d4drep +1.16R2d2dst +1.16 R2d4dst -131.8850 S450Jul - 107.1154 S400Jul +1.2275wean1CB +1.2275wean1CC +1.2275wean2CB +1.2275wean2CC +1.2275wean3CB +1.2275wean3CC +1.2275wean4CB +1.2275wean4CC +1.2275rear1CB +1.2275rear1CC +1.2275rear2CB +1.2275rear2CC +1.2275rear3CB +1.2275rear3CC +1.2275rear4CB +1.2275rear4CC+210bdairy1D +210bdairy2D +210 bdairy3D +210 bdairy4D -190SREP1D -190SREP2D -190SREP3D -190SREP4D +1.57095Dairy1C-19.4604Dairy1D +1.5710Dairy2C -19.4604Dairy2D +1.5710Dairy3C -23.9352Dairy3D +1.5710Dairy4C -23.9352Dairy4D +20BuywJul-3.8733smilkJS +0.9130R2stA +0.9130R2HeifA +0.9130repla+0.9130R2stB +0.9130R2HeifB +1.1400R1stA +1.1400R1heifA +1.18brbeefA +1.0930bullA +1.0930bullB -10borrJul +10.175borrJun - 10.1lendJun +10lendJul +10.46FsugJS +94.5000pelletJS +67F1JS +55bysorgJS -50Heifcx1-53.4Steercx1-50.5Heifcx3-54.5Steercx3=0

CashAug)+0.083 livingex -49.28sfxl +0.5hlAprSep +0.13R1d1che +0.13R1d3che +0.13R1d1Crep +0.13R1d3crep +0.13R1d1cst +0.13R1d3cst +0.59R1d1Dhe +0.59R1d3dhe +0.59R1d1Drep +0.59R1d3drep +0.59R1d1Dst +0.59R1d3dst +0.95R2d1che +0.95R2d3che +0.95R2d1Crep +0.95 R2d3crep +0.95 R2d1cst +0.95 R2d3cst +0.79R2d1Dhe +0.79R2d3dhe +0.79R2d1Drep +0.79R2d3drep +0.95 R2d1dst +0.95 R2d3dst +0.13R1d2che +0.13R1d4che +0.13R1d2Crep +0.13R1d4crep +0.13R1d2cst +0.13R1d4cst +0.59R1d2Dhe +0.59R1d4dhe +0.59R1d2Drep +0.59R1d4drep +0.59R1d2Dst +0.59R1d4dst +0.95R2d2che +0.95R2d4che +0.95R2d2Crep +0.95 R2d4crep +0.95 R2d2cst +0.95 R2d4cst +0.79R2d2Dhe +0.79R2d4dhe +0.79R2d2Drep +0.79R2d4drep +0.95 R2d2dst +0.95 R2d4dst+1.4028Wean1CB +1.7535wean1CC+1.4028Wean2CB +1.7535wean2CC +1.4028Wean3CB +1.7535wean3CC +1.4028Wean4CB +1.7535wean4CC+1.4028rear1CB +1.7535rear1CC+1.4028rear2CB +1.7535rear2CC +1.4028rear3CB +1.7535rear3CC +1.4028rear4CB +1.7535rear4CC +1.22Dairy1C +1.22Dairy1D +1.22Dairy2C +1.22Dairy2D +1.22Dairy3C +1.22Dairy3D +1.22Dairy4C +1.22Dairy4D +20BuywAug -3.8733smilkJS +0.9472R2stA +0.9472R2HeifA +0.9472repla +0.8764R1stA +0.8764R1heifA +0.9672brbeefA -131.8850s450Aug -107.1154s400Aug +1.1272bullA +1.1272bullB +500.0000buybull -10borrAug +10.175borrJul -10.1lendJul +10lendAug +10.46FsugJS =0

CashSep)+0.083 livingex -49.28sfxl +0.5hlAprSep +0.29R1d1che +0.29R1d3che +0.29R1d1Crep +0.29R1d3crep +0.29R1d1cst +0.29R1d3cst +0.75R1d1Dhe +0.75R1d3dhe +0.75R1d1Drep +0.75R1d3drep +0.75R1d1Dst +0.75R1d3dst +0.95R2d1che +0.95R2d3che +4.95 R2d1Crep +4.95R2d3crep +0.95R2d1cst +0.95R2d3cst +0.95R2d1Dhe +0.95R2d3dhe +0.95R2d1Drep +0.95R2d3drep +0.95R2d1dst +0.95R2d3dst +0.29R1d2che +0.29R1d4che +0.29R1d2Crep +0.29R1d4crep +0.29R1d2cst +0.29R1d4cst +0.75R1d2Dhe +0.75R1d4dhe +0.75R1d2Drep +0.75R1d4drep +0.75R1d2Dst +0.75R1d4dst +0.95R2d2che +0.95R2d4che +4.95 R2d2Crep +4.95R2d4crep +0.95R2d2cst +0.95R2d4cst +0.95R2d2Dhe +0.95R2d4dhe +0.95R2d2Drep +0.95R2d4drep +0.95R2d2dst +0.95R2d4dst+5.72Dairy1C +1.39Dairy1D +5.72Dairy2C +1.39Dairy2D +5.72Dairy3C +1.39Dairy3D +5.72Dairy4C +1.39Dairy4D +20BuywSep -3.8733smilkJS +0.8130R2stA +0.8130R2HeifA +0.8130repla+0.8764R1stA +0.8764R1heifA +0.9672brbeefA +0.6210bullA +0.6210bullB -10borrSep +10.175borrAug - 10.1lendAug +10lendSep +10.46FsugJS =0

CashOct)+0.083 livingex -49.28sfxl +1.33hlOctDec +0.3R1d1che +0.3R1d3che +0.3R1d1Crep +0.3R1d3crep +0.3R1d1cst +0.3R1d3cst +0.2R1d1Dhe +0.2R1d3dhe

+0.2R1d1Drep +0.2R1d3drep +0.2R1d1Dst +0.2R1d3dst +0.2R2d1che +0.24 R2d3che +0.24R2d1Crep +0.24R2d3crep +0.24R2d1cst +0.24R2d3cst +0.24R2d1Dhe +0.24R2d3dhe +0.24R2d1Drep +0.24R2d3drep +0.24R2d1dst +0.24R2d3dst +0.3R1d2che +0.3R1d4che +0.3R1d2Crep +0.3R1d4crep +0.3R1d2cst +0.3R1d4cst +0.2R1d2Dhe +0.2R1d4dhe +0.2R1d2Drep +0.2R1d4drep +0.2R1d2Dst +0.2R1d4dst +0.2R2d2che +0.24 R2d4che +0.24R2d2Crep +0.24R2d4crep +0.24R2d2cst +0.24R2d4cst +0.24R2d2Dhe +0.24R2d4dhe +0.24R2d2Drep +0.24R2d4drep +0.24R2d2dst +0.24R2d4dst -144.3897 S450Oct -119.7902 S400Oct +1.2275wean1DB +1.2275wean1DC+1.2275wean3DB +1.2275wean3DC +1.2275wean2DB +1.2275wean2DC+1.2275wean4DB +1.2275wean4DC +1.2275rear1DB +1.2275rear1DC+1.2275rear3DB +1.2275rear3DC+1.2275rear2DB +1.2275rear2DC +1.2275rear4DB +1.2275rear4DC +1.12Dairy1C +1.28Dairy1D +1.12Dairy2C +1.28Dairy2D +1.12Dairy3C +1.28Dairy3D +1.12Dairy4C +1.28Dairy4D +20BuywOct - 3.2066smilkOD +0.2364R2stA +0.2364R2HeifA+0.2364repla +0.7426R1stA +0.7426R1heifA +0.5006brbeefA +0.2364bullA +0.2364bullB +12.3749sorgs1eC +14.2311sorgs1eM +3.566manicon1 +8.6manicon2 +2.634manimin1 +6.5manimin2 +2.1773R20g1s +2.7252R20g2s +3.2255R20g3s +2.9G80LH +2.9G80LM +2.9G80LL +2.9G65LH +2.9G65LM+2.9G65LL+2.9G50LH+2.9G50LM+2.9G50LL +1.5746Gatton +1.9329Gatton15 +2.3493Gatton10 +16.4761Castor1E +36.0000Castor2E -10borrOct +10.175borrSep -10.1lendSep +10lendOct +1046FsugOD +94.5000pelletOD +67F1OD +55bysorgOD -65heifdx1-69.4steerdx1-65.6Heifdx3-70.9Steerdx3= 0

CashNov)+0.083 livingex -49.28sfxl +1.33hlOctDec +0.265R1d1che +0.265R1d3che +0.265R1d1Crep +0.265R1d3crep +0.265R1d1cst +0.265R1d3cst +0.245R1d1Dhe +0.245R1d3dhe +0.245R1d1Drep +0.245R1d3drep +0.245R1d1Dst +0.245R1d3dst +0.2364R2d1che +0.2364 R2d3che +0.4364R2d1Crep +0.4364R2d3crep +0.2364R2d1cst +0.2364R2d3cst +0.23645R2d1Dhe +0.2364R2d3dhe +0.2364R2d1Drep +0.2364R2d3drep +0.2364R2d1dst +0.2364R2d3dst +0.265R1d2che +0.265R1d4che +0.265R1d2Crep +0.265R1d4crep +0.265R1d2cst +0.265R1d4cst +0.245R1d2Dhe +0.245R1d4dhe +0.245R1d2Drep +0.245R1d4drep +0.245R1d2Dst +0.245R1d4dst +0.2364R2d2che +0.2364 R2d4che +0.4364R2d2Crep +0.4364R2d4crep +0.2364R2d2cst +0.2364R2d4cst +0.23645R2d2Dhe +0.2364R2d4dhe +0.2364R2d2Drep +0.2364R2d4drep +0.2364R2d2dst +0.2364R2d4dst +1.4028Wean1DB +1.7535wean1DC +1.4028Wean3DB +1.7535wean3DC +1.4028Wean2DB +1.7535wean2DC +1.4028Wean4DB +1.7535wean4DC +1.4028rear1DB +1.7535rear1DC +1.4028rear3DB +1.7535rear3DC +1.4028rear2DB +1.7535rear2DC +1.4028rear4DB +1.7535rear4DC +1.09Dairy1C +1.09Dairy1D +1.09Dairy2C +1.09Dairy2D +1.09Dairy3C +1.09Dairy3D +1.09Dairy4C + 1.09Dairy4D +20BuywNov - 3.2066smilkOD +0.2364R1stA +0.2364R1heifA +0.5006brbeefA +0.2364bullA +0.2364bullB -147.5100s450Nov -123.2800s400Nov +1.59Panleg5 +1Panleg8 +0.8Panleg10 +0.8Panleg15 +0.8Panleg20 +9.8124sorgs1eC +9.8124sorgs1eM +1.0268manimin1 +1.844manimin2+ 1.2291R20g1s +1.6193R20g2s +1.9755R20g3s +1.2G80LH +1.2G80LM+1.2G80LL +1.2G65LH+1.2G65LM +1.2G65LL +1.2G50LH +1.2G50LM +1.2G50LL +0.8Gatton +0.8Gatton15 +0.8Gatton10 +8.6698sesam1 +20.0000sesam2 +15.0781sesamec1 +25.0000sesamec2 +1.4969Castor1E +16.4761Castor1L +4.0000Castor2E +36.0000Castor2L+3.5haymNov -10borrNov +10.175borrOct -10.1lendOct +10lendNov +1046FsugOD =0

CashDec)+0.083 livingex -49.28sfxl +1.33hlOctDec +0.1981R1d1che +0.1981R1d3che +0.3551R1d1Crep +0.3551R1d3crep +0.1981R1d1cst +0.1981R1d3cst +0.2451R1d1Dhe +0.2451R1d3dhe +0.2451R1d1Drep +0.2451R1d3drep +0.2451R1d1Dst +0.2451R1d3dst +0.35R2d1che +0.35 R2d3che +0.35R2d1Crep +0.35R2d3crep +0.35R2d1cst +0.35R2d3cst +1.79 R2d1Dhe +1.79 R2d3dhe +1.79 R2d1Drep +1.79R2d3drep +0.35R2d1dst +0.35R2d3dst +0.1981R1d2che +0.1981R1d4che +0.3551R1d2Crep +0.3551R1d4crep +0.1981R1d2cst +0.1981R1d4cst +0.2451R1d2Dhe +0.2451R1d4dhe +0.2451R1d2Drep +0.2451R1d4drep +0.2451R1d2Dst +0.2451R1d4dst +0.35R2d2che +0.35 R2d4che

+0.35R2d2Crep +0.35R2d4crep +0.35R2d2cst +0.35R2d4cst +1.79 R2d2Dhe +1.79 R2d4dhe +1.79 R2d2Drep +1.79R2d4drep +0.35R2d2dst +0.35R2d4dst+1.43Dairy1C +5.73Dairy1D +1.43Dairy2C +5.73Dairy2D +1.43Dairy3C +5.73Dairy3D +1.43Dairy4C +5.73Dairy4D - 3.2066smilkOD +0.3499R1stA +0.3499R1heifA +0.6806brbeefA +0.3499bullA +0.3499bullB +1.2349sorgs1eC +1.2349sorgs1eM +0.8207R20g1s +0.8395R20g2s +0.8567R20g3s +0.8G80LH+0.8G80LM+0.8G80LL+0.8G65LH+0.8G65LM +0.8G65LL +0.8G50LH +0.8G50LM +0.8G50LL +0.8Gatton +0.8Gatton15 +0.8Gatton10 +16.909manicon1 +49.1978manicon2 +31.5788manimin1 +43.91manimin2 +2.5124sesam1 +4.5500sesam2 +2.5124sesamec1 +4.5500sesamec2 +1.4969Castor1L +4.0000Castor21 +15.825cana2 +11.7453cana1 -10borrDec +10.175borrNov -10.1lendNov +10lendDec +10.46FsugOD +0.025tax +1eat=0
!here is our Income tax calculation
Inctax)+3.5hayb-591.36sfxl +4hlJanMar +3hlAprSep +4hlOctDec +4.8016R1d1che +4.8016R1d3che +4.4523R1d1Crep +4.4523R1d3crep +4.2953R1d1cst +4.2953R1d3cst +6.1128 R1d1Dhe +6.1128R1d3dhe +6.26979R1d1Drep +6.26979R1d3drep +6.0828R1d1Dst +6.0828R1d3dst +7.2419R2d1che +7.2419R2d3che +10.9357R2d1Crep +10.9357R2d3crep +6.7357R2d1cst +6.7357R2d3cst +8.2004R2d1Dhe +8.2004R2d3dhe +10.9357R2d1Drep +10.9357R2d3drep +6.7357R2d1dst +6.7357R2d3dst +4.8016R1d2che +4.8016R1d4che +4.4523R1d2Crep +4.4523R1d4crep +4.2953R1d2cst +4.2953R1d4cst +6.1128 R1d2Dhe +6.1128R1d4dhe +6.26979R1d2Drep +6.26979R1d4drep +6.0828R1d2Dst +6.0828R1d4dst +7.2419R2d2che +7.2419R2d4che +10.9357R2d2Crep +10.9357R2d4crep +6.7357R2d2cst +6.7357R2d4cst +8.2004R2d2Dhe +8.2004R2d4dhe +10.9357R2d2Drep +10.9357R2d4drep +6.7357R2d2dst +6.7357R2d4dst-131.8850 S450Jul -107.1154 S400Jul -144.3897 S450Oct -119.7902 S400Oct +2.6303wean1CB +2.6303wean1DB +2.6303wean2CB +2.6303wean2DB +2.9810wean1CC +2.9810wean1DC +2.9810wean2CC +2.9810wean2DC +2.6303wean3CB +2.6303wean3DB +2.6303wean4CB +2.6303wean4DB+2.9810wean3CC +2.9810wean3DC+2.9810wean4CC +2.9810wean4DC +2.6303rear1CB +2.6303rear1DB +2.6303rear2CB +2.6303rear2DB +2.9810rear1CC +2.9810rear1DC +2.9810rear2CC +2.9810rear2DC +2.6303rear3CB +2.6303rear3DB +2.6303rear4CB +2.6303rear4DB+2.9810rear3CC +2.9810rear3DC +2.9810rear4CC +2.9810rear4DC -2.8815Dairy1C -0.9222Dairy1D -2.8815Dairy2C-0.9222Dairy2D - 7.3838Dairy3C -5.397Dairy3D -7.3838Dairy4C -5.397Dairy4D +210 bdairy1C +210bdairy3C +210bdairy2C +210bdairy4C +210bdairy1D +210bdairy2D +210 bdairy3D +210bdairy4D -190SREP1C -190SREP2C -190SREP3C -190SREP4C-190SREP1D - 190SREP2D -190SREP3D -190SREP4D +20BuywMay +20BuywJun +20BuywJul +20BuywAug +20BuywSep +20BuywOct +20BuywNov -9.62SmilkJM -11.620SmilkAJ - 11.620SmilkJS -9.62SmilkOD +6.2745R2stA +6.2745R2HeifA +6.2745repla +4.2780R2stB +4.2780R2HeifB +5.979R1stA +5.9790R1heifA -8.5brbeefA -52.0977bullA -52.09702bullB +500.0000buybull +130.0000buyrepl -125sbeefrp1 +71bwst1 +72bwst2 +54bwheifer - 60.9250s250Apr -53.7510s230Apr-147.5100s450Nov -123.2800s400Nov -131.8850s450Aug -107.1154s400Aug +2.3224pangola +2.3639pan15 +2.4261Pan10 +2.86Panleg5 +1.99Panleg8 +1.7Panleg10 +1.57Panleg15+1.510Panleg20 +37.4684 sorggC +37.4684 sorggM -54.1sgrain +55bysorgJM +55bysorgAJ+55bysorgJS+55bysorgOD +63.5436sorgs1eC +63.5436sorgs1lC +71.8405sorgs1eM +71.8405sorgs1lM - 192.411manicon1 -124.4362manicon2 -138.906manimin1 -114.7598manimin2 - 171.7635cotton1-139.3875cotton2-194.6651sesam1 -179.2100sesam2 -110.6491sesamec1 - 92.1100sesamec2 -41.9827Castor1e -41.9827Castor1L -19.9556Castor2e +3.5haymMar +3.5haymNov -60sellhay -19.9556Castor2L +64.97oats1 +73.5oats2 + 7.0189R20g1s +9.9654R20g2s +12.6556R20g3s +13.91G80LH +13.91G80LM +13.91G80LL +13.91G65LH +13.91G65LM+13.91G65LL+13.91G50LH+13.91G50LM+13.91G50LL +3.7779Gatton +4.0361Gatton15 +4.5525Gatton10 +15.825cana2 +11.745cana1 +0.175borrJan +0.175borrFeb +0.175borrMar +0.175borrApr +0.175borrMay +0.175borrJun

+0.175borrJul +0.175borrAug +0.175borrSep +0.175borrOct +0.175borrNov +0.175borrDec -0.1lendJan -0.1lendFeb -0.1lendMar -0.1lendApr -0.1lendMay -0.1lendJun -0.1lendJul -0.1lendAug -0.1lendSep -0.1lendOct -0.1lendNov -0.1lendDec +31.39fsugAJ +31.39fsugJS +31.39fsugOD+70buyhay +94.5000pelletJM +94.5000pelletAJ +94.5000pelletJS +94.5000pelletOD +67F1JM +67F1AJ +67F1JS +67F1OD-50Heifcx1-53.4Steercx1-50.5Heifcx3-54.5Steercx3-65heifdx1-69.4steerdx1-65.6Heifdx3-70.9Steerdx3 +1tax=0

!here goes the living expenses

Livcons)livingex= 8400

!Here is our ME balance

!Here goes our high quality feed balance in kg of DM (11MJ ME/kg DM)

HQFJM) +203R1d1che +244R1d1dhe +155R1d1Dst +583R2d1cst +183R2d1dst +203r1d1crep +244r1d1drep +195r2d1crep + 251r1d3dhe +207r2d3che +138r1d3dst +588r2d3cst +185r2d3dst +377r1d3crep +271r1d3drep +729R2d3Crep +573R2d3drep +203R1d2che +244R1d2dhe +155R1d2Dst +583R2d2cst +183R2d2dst +203r1d2crep +244r1d2drep +195r2d2crep + 251r1d4dhe +207r2d4che +138r1d4dst +588r2d4cst +185r2d4dst +377r1d4crep +271r1d4drep +729R2d4Crep +573R2d4drep +146Dairy1C+240Dairy1D+292Dairy2C+480Dairy2D+146Dairy3C+240Dairy3D+292Dairy4C+480Dairy4D +1hfmJM +1hJMtMAJ -1000pelletJM -1000f1JM -836fsorgoJM-1000legHJM <=0

HQFAJ) +203R1d1dhe +583r2d1dst +203r1d1drep +308r2d1crep +195r2d1drep +207r2d3dhe +588r2d3dst +291r1d3crep+377r1d3drep +359R2d3crep +729r2d3drep +203R1d2dhe +583r2d2dst +203r1d2drep +308r2d2crep +195r2d2drep +207r2d4dhe +588r2d4dst +291r1d4crep+377r1d4drep +359R2d4crep +729r2d4drep +32Dairy1C +146Dairy1D +63Dairy2C +292Dairy2D +32Dairy3C +146Dairy3D +63Dairy4C +292Dairy4D +1hfmAJ +1hAJtmJS -1000pelletAJ -1000F1AJ -836fsorgoAJ -1000legHAJ <=0

HQFJS) +95r1d1che + 71r1d1cst +95r1d1crep +308r2d1drep +99R1d3che + 66R1d3cst+ 106r1d3crep +291R1d3drep +166R2d3crep +359R2d3drep +95r1d2che + 71r1d2cst +95r1d2crep +308r2d2drep +99R1d4che + 66R1d4cst+ 106r1d4crep +291R1d4drep +166R2d4crep +359R2d4drep +278Dairy1C+32Dairy1D+505Dairy2C+63Dairy2D+276Dairy3C+32Dairy3D+506Dairy4C+63Dairy4D +1hfmJS -1000pelletJS -1000F1JS -836fsorgoJS <=0

HQFOD) +244r1d1che +95r1d1dhe +155r1d1cst +71r1d1dst +183r2d1cst +244r1d1crep +95r1d1drep +251r1d3che +99r1d3dhe +138r1d3cst +66r1d3dst +185r2d3cst +271R1d3crep +106r1d3drep +573r2d3crep +166r2d3drep +244r1d2che +95r1d2dhe +155r1d2cst +71r1d2dst +183r2d2cst +244r1d2crep +95r1d2drep +251r1d4che +99r1d4dhe +138r1d4cst +66r1d4dst +185r2d4cst +271R1d4crep +106r1d4drep +573r2d4crep +166r2d4drep +240Dairy1C +278Dairy1D +480Dairy2C +505Dairy2D +240Dairy3C +276Dairy3D +480Dairy4C +506Dairy4D +1hfmOD +1hODtmJM -1000PelletOD -1000F1OD -836fsorgoOD -1000legHOD <=0

!Feed transfer constraints

maxODtJM) -692G80LH-519G80LM-374G80LL-692G65LH-519G65LM-374G65LL-692G50LH -519G50LM-374G50LL +2hODtmJM <=0

maxJMtAJ) -190Panleg5-207Panleg8-213Panleg10-220Panleg15-225Panleg20 -2328G80LH-1746G80LM-1164G80LL-2328G65LH-1746G65LM-1164G65LL-2328G50LH -1746G50LM -1164G50LL +2hJMtmAJ <=0

maxAJtJS) -1862G80LH -1397G80LM-931G80LL-1862G65LH-1397G65LM-931G65LL-1862G50LH -1397G50LM-931G50LL+2hAJtmJS <=0

!use of high quality feed as medium quality feed contraint 25% upper limit.

mxhtmJM) +611Repla +130R1d1che +646r2d1che +605r2d1dhe +392R1d1cst +109r1d1dst +390r2d1dst +130R1d1Crep +445r2d1crep +618r2d1drep +127R1d3che +647r2d3che +612r2d3dhe +400r1d3cst +140r1d3dst +394r2d3dst +130R1d2che +646r2d2che

+605r2d2dhe +392R1d2cst +109r1d2dst +390r2d2dst +130R1d2Crep +445r2d2crep +618r2d2drep +127R1d4che +647r2d4che +612r2d4dhe +400r1d4cst +140r1d4dst +394r2d4dst +690Dairy1C +838Dairy1D +668Dairy2C +798Dairy2D +782Dairy3C +943Dairy3D +760Dairy4C+902Dairy4D +54brbeefA +643R2stA +604R2HeifA +719R2stB +753R2heifB +949bullA +949bullB -4.76hfmJM =>0

mxhtmAJ) +622Repla +427R1d1che +130r1d1dhe +661r2d1che +646r2d1dhe +445r1d1cst +392R1d1dst +709r2d1cst +427r1d1crep +130R1d1drep+ 395r2d1cRep +445r2d1drep + 417r1d4che +127r1d4dhe +661r2d4che +647R2d4dhe +452r1d4cst +400R1d4dst +688R2d4Cst +149R1d4crep +454r2d4crep +708Dairy1C+690Dairy1D+702Dairy2C+668Dairy2D+809Dairy3C+782Dairy3D+803Dairy 4C+760Dairy4D+36brbeefA +329R1stA +553R2stA +666R2stB +571R2heifB +324R1heifA +527R2heifA +769BullB -4.76hfmAJ =>0

mxhtmJS) +498Repla +427r1d1dhe +467r2d1che +661r2d1dhe +30r1d1cst +445r1d1dst +466r2d1cst +709r2d1dst +427r1d1drep +467r2d1crep +395r2d1drep +417r1d3dhe +467R2d3che +661r2d3dhe +42r1d3cst +452r1d3dst +472r2d3cst +688r2d3dst +149r1d3drep +313r2d3crep +454r2d3drep +427r1d2dhe +467r2d2che +661r2d2dhe +30r1d2cst +445r1d2dst +466r2d2cst +709r2d2dst +427r1d2drep +467r2d2crep +395r2d2drep +417r1d4dhe +467R2d4che +661r2d4dhe +42r1d4cst +452r1d4dst +472r2d4cst +688r2d4dst +149r1d4drep +313r2d4crep +454r2d4drep +646Dairy1C +708Dairy1D +606Dairy2C +702Dairy2D +736Dairy3C +809Dairy3D +686Dairy4C +803Dairy4D +436R1stA +577R2stA +317R2stB +445R1heifA +499R2heifA +514R2stB +370R2HeifB + 326brbeefA +621bullA -4.76hfmJS =>0

mxhtmOD) +605r2d1che +467r2d1dhe +109r1d1cst +30R1d1dst + 390r2d1cst +466r2d1dst +618r2d1crep +467r2d1drep +612r2d3che +467r2d3dhe +140r1d3Cst +42r1d3dst +394r2d3Cst +472r2d3dst +313r2d3drep +605r2d2che +467r2d2dhe +109r1d2cst +30R1d2dst + 390r2d2cst +466r2d2dst +618r2d2crep +467r2d2drep +612r2d4che +467r2d4dhe +140r1d4Cst +42r1d4dst +394r2d4Cst +472r2d4dst +313r2d4drep +838Dairy1C +646Dairy1D+798Dairy2C +606Dairy2D+943Dairy3C +736Dairy3D +902Dairy4C +686Dairy4D +648brbeefA +656R1stA +231R2stA +566R1heifA +221R2heifA +1164BullA +1164BullB -4.76hfmOD =>0

!Here goes our medium quality feed balance in kg of DM (9.25MJ ME/kg DM)

MQFJM) +611Repla +130R1d1che +646r2d1che +605r2d1dhe +392R1d1cst +109r1d1dst +390r2d1dst +130R1d1Crep +445r2d1crep +618r2d1drep +127R1d3che +647r2d3che +612r2d3dhe +400r1d3cst +140r1d3dst +394r2d3dst +130R1d2che +646r2d2che +605r2d2dhe +392R1d2cst +109r1d2dst +390r2d2dst +130R1d2Crep +445r2d2crep +618r2d2drep +127R1d4che +647r2d4che +612r2d4dhe +400r1d4cst +140r1d4dst +394r2d4dst +690Dairy1C +838Dairy1D+668Dairy2C +798Dairy2D +782Dairy3C +943Dairy3D +760Dairy4C+902Dairy4D +54brbeefA +645R2stA +604R2HeifA +738R2stB +753R2heifB + 949bullA +949bullB +101haymMar -1496Pangola -1465pan15 -1417Pan10 -1260Panleg5 -1378Panleg8 -1418Panleg10 -1465Panleg15 -1496Panleg20 -603R20g1s -550R20g2s -503R20g3s -665G80LH-665G80LM-665G80LL-541G65LH-541G65LM-541G65LL -416G50LH-416G50LM-416G50LL -748Gatton -732Gatton15 -709Gatton10 -950fsugAJ -1.19hfmJM -0.75hODtmJM +1MflJM +1mJMtlAJ-1189legMJM =<0

MQFAJ) +622Repla +427R1d1che +130r1d1dhe +661r2d1che +646r2d1dhe +445r1d1cst +392R1d1dst +709r2d1cst +427r1d1crep +130R1d1drep+ 395r2d1cRep +445r2d1drep + 417r1d4che +127r1d4dhe +661r2d4che +647R2d4dhe +452r1d4cst +400R1d4dst +688R2d4Cst +149R1d4crep +454r2d4crep +708Dairy1C +690Dairy1D +702Dairy2C +668Dairy2D +809Dairy3C+782Dairy3D+803Dairy4C+760Dairy4D+36brbeefA +328R1stA +555R2stA +597R2stB +571R2heifB +324R1heifA +527R2heifA +769BullB -950sfeedAJ -973pangola -952pan15 -787Pan10 -895Panleg5 -979Panleg8 -1007Panleg10 -1040Panleg15 -1063Panleg20 -969R20g1s -883R20g2s -808R20g3s -855G80LH-855G80LM-855G80LL-694G65LH-694G65LM-694G65LL-440G50LH-440G50LM-440G50LL -1069Gatton -

1046Gatton15 -1013Gatton10 -950fsugJS -1.19hfmAJ-0.75hJMtmAJ +1mflAJ +1mAJtlJS+179hayb-1189legMAJ =<0

MQFJS) +494Repla +427r1d1dhe +467r2d1che +661r2d1dhe +30r1d1cst +445r1d1dst +466r2d1cst +709r2d1dst +427r1d1drep +467r2d1crep +395r2d1drep +417r1d3dhe +467R2d3che +661r2d3dhe +42r1d3cst +452r1d3dst +472r2d3cst +688r2d3dst +149r1d3drep +313r2d3crep +454r2d3drep +427r1d2dhe +467r2d2che +661r2d2dhe +30r1d2cst +445r1d2dst +466r2d2cst +709r2d2dst +427r1d2drep +467r2d2crep +395r2d2drep +417r1d4dhe +467R2d4che +661r2d4dhe +42r1d4cst +452r1d4dst +472r2d4cst +688r2d4dst +149r1d4drep +313r2d4crep +454r2d4drep +646Dairy1C +708Dairy1D +606Dairy2C +702Dairy2D +736Dairy3C +809Dairy3D +686Dairy4C +803Dairy4D -106G80LH-80G80LM-53G80LL-106G65LH-80G65LM-53G65LL-106G50LH-80G50LM-53G50LL +435R1stA +578R2stA +398R2stB +445R1heifA +499R2heifA +370R2HeifB + 326brbeefA +621bullA -950sfeedJS -1.19hfmJS -0.75hAJtmJS +1mflJS -2240oats1 -2240oats2 =<0

MQFOD) +605r2d1che +467r2d1dhe +109r1d1cst +30R1d1dst + 390r2d1cst +466r2d1dst +618r2d1crep +467r2d1drep +612r2d3che +467r2d3dhe +140r1d3Cst +42r1d3dst +394r2d3Cst +472r2d3dst +313r2d3drep +605r2d2che +467r2d2dhe +109r1d2cst +30R1d2dst + 390r2d2cst +466r2d2dst +618r2d2crep +467r2d2drep +612r2d4che +467r2d4dhe +140r1d4Cst +42r1d4dst +394r2d4Cst +472r2d4dst +313r2d4drep +838Dairy1C+646Dairy1D+798Dairy2C+606Dairy2D+943Dairy3C+736Dairy3D+902Dairy 4C+686Dairy4D +648brbeefA +630R1stA +231R2stA +566R1heifA +221R2heifA +1164BullA +1164BullB -950sfeedOD +120haymNov -996Pangola -975pan15 -787Pan10 -886Panleg5 -970Panleg8 -997Panleg10 -1030Panleg15 -1053Panleg20 -302R20g1s -275R20g2s -251R20g3s -433G80LH-433G80LM-433G80LL-352G65LH-352G65LM-352G65LL-271G50LH-271G50LM-271G50LL -542Gatton -530Gatton15 -513Gatton10 -950fsugOD -1.19hfmOD +1mFlOD +1mODtlJM -1189legMOD =<0

!Feed transfer constraint

maxODtJM) -996Pangola -975pan15 -787Pan10 -886Panleg5 -970Panleg8 -997Panleg10 -1030Panleg15 -1053Panleg20 -302R20g1s -275R20g2s -251R20g3s -433G80LH-433G80LM -433G80LL-352G65LH-352G65LM-352G65LL-271G50LH -271G50LM -271G50LL -542Gatton -530Gatton15 -513Gatton10 +2mODtlJM =<0

maxJMtAJ) -1496Pangola -1465pan15 - 1418Pan10 -1260Panleg5 -1378Panleg8 -1418Panleg10 -1465Panleg15 -1496Panleg20 -603R20g1s -550R20g2s -503R20g3s -665G80LH-665G80LM-665G80LL-541G65LH-541G65LM-541G65LL-416G50LH-416G50LM-416G50LL -748Gatton -732Gatton15 -708Gatton10 +2mJMtlAJ =<0

maxAJtJS) -973pangola -952pan15 -921Pan10 -895Panleg5 -979Panleg8 -1007Panleg10 -1040Panleg15 -1063Panleg20 -969R20g1s -883R20g2s -808R20g3s -855G80LH-855G80LM-855G80LL-694G65LH-694G65LM-694G65LL-440G50LH-440G50LM-440G50LL-1069Gatton -1046Gatton15 -1013Gatton10 +2mAJtlJS =<0

!Here goes our low quality feed balance 7.6 to 6.5MJ ME/kgDM.

LQFJM)+965 brbeefA -151R20g1s -137R20g2s -126R20g3s -83Gatton -81Gatton15 -79Gatton10 -1.233mflJM +1lJMtAJ -0.906lODtJM -0.84mODtlJM =<0

LQFAJ) +887brbeefA -1.233mflJM -0.906lJMtAJ +1lAJtJS -0.84mJMtlAJ-250hfeedAJ =<0

LQFJS) +924brbeefA +2.5wean1Cc +2.5wean2cc+2.5wean3Cc +2.5wean4cc +2.5rear1Cc +2.5rear2cc+2.5rear3Cc +2.5rear4cc+810bullA -310R20g1s -283R20g2s -259R20g3s -288G80LH-288G80LM-288G80LL-234G65LH-234G65LM-234G65LL-180G50LH-180G50LM-180G50LL -342Gatton -335Gatton15 -324Gatton10 -354Pangola -347pan15 -335Pan10 -386Panleg5 -423Panleg8 -435Panleg10 -449Panleg15 -459Panleg20 -1.233mflJS -0.84mAJtlJS -0.906lAJtJS -250hfeedJS =<0

LQFOD) +524brbeefA +2.5wean1dc +2.5wean2dC +2.5wean3dc +2.5wean4dC +2.5rear1dc +2.5rear2dC +2.5rear3dc +2.5rear4dC +809bullB -1.233mflOD +1 lODtJM-250hfeedOD =<0

!Here goes our high quality legumes balance sheet in kg of DM

LeucJM)-2328G80LH-1746G80LM-1164G80LL-2328G65LH-1746G65LM-1164G65LL-2328G50LH -1746G50LM-1164G50LL-190Panleg5-207Panleg8-213Panleg10-220Panleg15-225Panleg20+1000legHJM+1000legMJM=<0
LeucAJ)-1862G80LH-1397G80LM-931G80LL-1862G65LH-1397G65LM-931G65LL-1862G50LH -1397G50LM-931G50LL+1000legHAJ+1000legMAJ=<0
LeucOD)-692G80LH-519G80LM-374G80LL-692G65LH-519G65LM-374G65LL-692G50LH -519G50LM-374G50LL+1000legHOD+1000legMOD=<0
!Here goes our sugar cane balance sheet in tonnes of DM. 5% loses at feeding
Sugarc) -25cana2 -25canal +FSugAJ +FSugJS +FSugOD=<0
!Assume an upper limit of 50% total energy supply
MsugAJ) +622Repla +427R1d1che +130r1d1dhe +661r2d1che +646r2d1dhe +445r1d1cst +392R1d1dst +709r2d1cst +427r1d1crep +130R1d1drep+ 395r2d1cRep +445r2d1drep + 417r1d4che +127r1d4dhe +661r2d4che +647R2d4dhe +452r1d4cst +400R1d4dst +688R2d4Cst +149R1d4crep +454r2d4crep +708Dairy1C +690Dairy1D +702Dairy2C +668Dairy2D +809Dairy3C +782Dairy3D +803Dairy4C +760Dairy4D +36brbeefA +329R1stA +553R2stA +666R2stB +571R2heifB +324R1heifA +527R2heifA +769BullB - 1900fsugAJ =>0
MsugJS) +494Repla +427r1d1dhe +467r2d1che +661r2d1dhe +30r1d1cst +445r1d1dst +466r2d1cst +709r2d1dst +427r1d1drep +467r2d1crep +395r2d1drep +417r1d3dhe +467R2d3che +661r2d3dhe +42r1d3cst +452r1d3dst +472r2d3cst +688r2d3dst +149r1d3drep +313r2d3crep +454r2d3drep +427r1d2dhe +467r2d2che +661r2d2dhe +30r1d2cst +445r1d2dst +466r2d2cst +709r2d2dst +427r1d2drep +467r2d2crep +395r2d2drep +417r1d4dhe +467R2d4che +661r2d4dhe +42r1d4cst +452r1d4dst +472r2d4cst +688r2d4dst +149r1d4drep +313r2d4crep +454r2d4drep +646Dairy1C +708Dairy1D +606Dairy2C +702Dairy2D +736Dairy3C +809Dairy3D +686Dairy4C +803Dairy4D +436R1stA +577R2stA +317R2stB +445R1heifA +499R2heifA +514R2stB +370R2HeifB + 326brbeefA +621bullA -1900fsugJS =>0
MsugOD) +605r2d1che +467r2d1dhe +109r1d1cst +30R1d1dst + 390r2d1cst +466r2d1dst +618r2d1crep +467r2d1drep +612r2d3che +467r2d3dhe +140r1d3Cst +42r1d3dst +394r2d3Cst +472r2d3dst +313r2d3drep +605r2d2che +467r2d2dhe +109r1d2cst +30R1d2dst + 390r2d2cst +466r2d2dst +618r2d2crep +467r2d2drep +612r2d4che +467r2d4dhe +140r1d4Cst +42r1d4dst +394r2d4Cst +472r2d4dst +313r2d4drep +838Dairy1C +646Dairy1D +798Dairy2C +606Dairy2D +943Dairy3C +736Dairy3D +902Dairy4C +686Dairy4D +648brbeefA +630R1stA +231R2stA +566R1heifA +221R2heifA +1164BullA +1164BullB -1900fsugOD=>0
!Here goes our sorghum grain reconciliation row in tonnes of grain units.
sorghum)-2sorggC -3sorggM +fgrainJM +fgrainAJ +fgrainJS +fgrainOD +1sgrain=0
!feeding sorghum assumes 5% losses during feeding
GfedJM) -fgrainJM -bysorgJM +1fsorgoJM=<0
GfedAJ) -fgrainAJ -bysorgAJ +1FsorgoAJ=<0
GfedJS) -fgrainJS -bysorgJS +1FsorgoJS =<0
GfedOD) -fgrainOD -bysorgOD +1FsorgoOD =<0
!Assuming upper limit of 20%
mxsorJM)+203R1d1che +244R1d1dhe +155R1d1Dst +583R2d1cst +183R2d1dst +203r1d1crep +244r1d1drep +195r2d1crep + 251r1d3dhe +207r2d3che +138r1d3dst +588r2d3cst +185r2d3dst +377r1d3crep +271r1d3drep +729R2d3Crep +573R2d3drep +203R1d2che +244R1d2dhe +155R1d2Dst +583R2d2cst +183R2d2dst +203r1d2crep +244r1d2drep +195r2d2crep + 251r1d4dhe +207r2d4che +138r1d4dst +588r2d4cst +185r2d4dst +377r1d4crep +271r1d4drep +729R2d4Crep +573R2d4drep +146Dairy1C +240Dairy1D +292Dairy2C +480Dairy2D +146Dairy3C +240Dairy3D +292Dairy4C +480Dairy4D +1hfmJM -4400fsorgoJM >=0

mxsorAJ) +203R1d1dhe +583r2d1dst +203r1d1drep +308r2d1crep +195r2d1drep +207r2d3dhe +588r2d3dst +291r1d3crep+377r1d3drep +359R2d3crep +729r2d3drep +203R1d2dhe +583r2d2dst +203r1d2drep +308r2d2crep +195r2d2drep +207r2d4dhe +588r2d4dst +291r1d4crep+377r1d4drep +359R2d4crep +729r2d4drep +32Dairy1C +146Dairy1D +63Dairy2C+292Dairy2D+32Dairy3C+146Dairy3D+63Dairy4C +292Dairy4D +1hfmAJ -4400fsorgoAJ >=0

mxsorJS) +95r1d1che + 71r1d1cst +95r1d1crep +308r2d1drep +99R1d3che + 66R1d3cst+ 106r1d3crep +291R1d3drep +166R2d3crep +359R2d3drep +95r1d2che + 71r1d2cst +95r1d2crep +308r2d2drep +99R1d4che + 66R1d4cst+ 106r1d4crep +291R1d4drep +166R2d4crep +359R2d4drep +278Dairy1C +32Dairy1D +505Dairy2C +63Dairy2D +276Dairy3C +32Dairy3D+506Dairy4C+63Dairy4D +1hfmJS -4400fsorgoJS >=0

mxsorOD) +244r1d1che +95r1d1dhe +155r1d1cst +71r1d1dst +183r2d1cst +244r1d1crep +95r1d1drep +251r1d3che +99r1d3dhe +138r1d3cst +66r1d3dst +185r2d3cst +271R1d3crep +106r1d3drep +573r2d3crep +166r2d3drep +244r1d2che +95r1d2dhe +155r1d2cst +71r1d2dst +183r2d2cst +244r1d2crep +95r1d2drep +251r1d4che +99r1d4dhe +138r1d4cst +66r1d4dst +185r2d4cst +271R1d4crep +106r1d4drep +573r2d4crep +166r2d4drep +240Dairy1C +278Dairy1D +480Dairy2C +505Dairy2D +240Dairy3C +276Dairy3D +480Dairy4C +506Dairy4D +1hfmOD -4400fsorgoOD >=0

!Here goes our hay shed balance in bales units

Hayshed) -10buyhay -1haymNov-1haymMar-hayb+1hfeedAJ+1hfeedJS +hfeedOD+10sellhay=<0

buyhay=<10

!here goes our silage balance in tonnes of DM

Silage)-3.375sorgs1eC -3.375sorgs1lC-5.625sorgs1eM -5.625sorgs1lM +1sfeedAJ +1sfeedJS +1sfeedOD -0.321R20g1s -0.614R20g2s -0.880R20g3s =<0

!here is our water supply constraints in hundreds of lt

WbalJan)-20819Rain -0.9375wDec_Jan +1wJan_Feb +7.1R1d1CHe +4.7R1d1dhe +15.4R2d1CHe +12.9R2d1dhe+7.4R1d1cst+4.9R1d1dst+16.7R2d1cst+13.7R2d1dst +7.1R1d1crep +4.7R1d1drep +15.8R2d1cRep +13.6R2d1drep +7.3R1d3Che +4.9R1d3dhe +15.2R2d3che +12.9R2d3dhe +7.6R1d3Cst +5.1R1d3dst +16.9R2D3Cst +13.9R2d3dst +8.1 R1d3Crep +5.2R1d3drep +18.6R2d3Crep +15.3R2d3drep +7.1R1d2CHe +4.7R1d2dhe +15.4R2d2CHe +12.9R2d2dhe +7.4R1d2cst +4.9R1d2dst+16.7R2d2cst+13.7R2d2dst +7.1R1d2crep +4.7R1d2drep +15.8R2d2cRep +13.6R2d2drep +7.3R1d4Che +4.9R1d4dhe +15.2R2d4che +12.9R2d4dhe +7.6R1d4Cst +5.1R1d4dst+16.9R2d4Cst+13.9R2d4dst +8.1 R1d4Crep +5.2R1d4drep +18.6R2d4Crep +15.3R2d4drep +33.32BullA +33.32BullB +20.07Dairy1C +20.19Dairy1D +24.72 Dairy3C +23.35Dairy3D + 23.18Dairy2C +23.67Dairy2D +27.84Dairy4C +28.33Dairy4D +17.67R2stA +15.88R2heifA +17.67R2stB +15.88R2heifB +24.92brbeefA +15.3Repla +54clean <=0

WbalFeb)-20468Rain -0.9375wJan_Feb +1wFeb_Mar +7.1R1d1CHe +4.7R1d1dhe +15.4R2d1CHe +12.9R2d1dhe+7.4R1d1cst+4.9R1d1dst+16.7R2d1cst+13.7R2d1dst +7.1R1d1crep +4.7R1d1drep +15.8R2d1cRep+13.6R2d1drep+7.3R1d3Che+4.9R1d3dhe+15.2R2d3che+12.9R2d3dhe+7.6 R1d3Cst+5.1R1d3dst+16.9R2D3Cst+13.9R2d3dst +8.1 R1d3Crep+5.2R1d3drep +18.6R2d3Crep +15.3R2d3drep +7.1R1d2CHe +4.7R1d2dhe +15.4R2d2CHe +12.9R2d2dhe+7.4R1d2cst+4.9R1d2dst+16.7R2d2cst+13.7R2d2dst +7.1R1d2crep +4.7R1d2drep +15.8R2d2cRep +13.6R2d2drep+7.3R1d4Che +4.9R1d4dhe+15.2R2d4che +12.9R2d4dhe +7.6R1d4Cst+5.1R1d4dst+16.9R2d4Cst+13.9R2d4dst +8.1 R1d4Crep +5.2R1d4drep +18.6R2d4Crep +15.3R2d4drep +30.09bullA +30.09BullB +18.14Dairy1C +16.92Dairy1D +22.34 Dairy3C +21.12Dairy3D +21.19Dairy2C +21.79Dairy2D +25.39Dairy4C +26Dairy4D +15.96R2stA +14.34R2HeifA +15.96R2stB +14.34R2HeifB +24.16brbeefA+15.3Repla +54clean=<0

WbalMar)-17494Rain -0.9375wFeb_Mar +1wMar_Apr +7.1R1d1CHe +4.7R1d1dhe +15.4R2d1CHe +12.9R2d1dhe+7.4R1d1cst+4.9R1d1dst+16.7R2d1cst+13.7R2d1dst +7.1R1d1crep +4.7R1d1drep +15.8R2d1cRep +13.6R2d1drep +7.3R1d3Che +4.9R1d3dhe +15.2R2d3che +12.9R2d3dhe+7.6R1d3Cst +5.1R1d3dst+16.9R2D3Cst+13.9R2d3dst +8.1 R1d3Crep+5.2R1d3drep +18.6R2d3Crep +15.3R2d3drep +7.1R1d2CHe +4.7R1d2dhe +15.4R2d2CHe +12.9R2d2dhe+7.4R1d2cst+4.9R1d2dst+16.7R2d2cst+13.7R2d2dst +7.1R1d2crep +4.7R1d2drep +15.8R2d2cRep +13.6R2d2drep +7.3R1d4Che +4.9R1d4dhe +15.2R2d4che +12.9R2d4dhe +7.6R1d4Cst +5.1R1d4dst+16.9R2d4Cst+13.9R2d4dst +8.1 R1d4Crep +5.2R1d4drep +18.6R2d4Crep +15.3R2d4drep +33.32bullA +33.32bullB +20.7Dairy1C +18.7 Dairy1D +24.72 Dairy3C +23.35 Dairy3D + 23.18Dairy2C +23.67Dairy2D +27.84Dairy4C +28.33Dairy4D +17.67R2stA +15.88R2heifA +17.67R2stB +15.88R2heifB +27.03brbeefA +15.3Repla +54clean=<0

WbalApr)-14579Rain -0.995wMar_Apr +1wApr_May +9.1R1d1CHe +7.1R1d1dhe +17.4R2d1CHe +15.4R2d1dhe+9.6R1d1cst+7.4R1d1dst+19.4R2d1cst+16.7R2d1dst +9.3R1d1crep +7.1R1d1drep +17.8R2d1cRep+15.8R2d1drep +9.2R1d3Che +7.3R1d3dhe +17.3R2d3che+15.2R2d3dhe +9.8R1d3Cst +7.6R1d3dst +19.5R2D3Cst +16.9R2d3dst +10.8R1d3Crep +8.1R1d3drep+21.4R2d3Crep +18.6R2d3drep +9.1R1d2CHe +7.1R1d2dhe +17.4R2d2CHe +15.4R2d2dhe+9.6R1d2cst+7.4R1d2dst+19.4R2d2cst+16.7R2d2dst +9.3R1d2crep +7.1R1d2drep +17.8R2d2cRep+15.8R2d2drep+9.2R1d4Che+7.3R1d4dhe+17.3R2d4che+15.2R2d4dhe+9.8 R1d4Cst+7.6R1d4dst+19.5R2d4Cst+16.9R2d4dst +10.8R1d4Crep +8.1R1d4drep +21.4R2d4Crep +18.6R2d4drep+31.32BullA +32.56BullB +20.81Dairy1C +19.42 Dairy1D +25.31 Dairy3C +23.92 Dairy3D +22.66Dairy2C +27.65Dairy2D +27.15Dairy4C +27.02Dairy4D +19.18R2stA +16.72R2heifA +19.18R2stB +16.72R2heifB +25.49brbeefA+16.9Repla +54clean=<0

WbalMay)-8145Rain -0.96wApr_May +1wMay_Jun -100buywMay +9.1R1d1CHe +7.1R1d1dhe +17.4R2d1CHe +15.4R2d1dhe +9.6R1d1cst +7.4R1d1dst +19.4R2d1cst +16.7R2d1dst +9.3R1d1crep +7.1R1d1drep +17.8R2d1cRep +15.8R2d1drep +9.2R1d3Che +7.3R1d3dhe +17.3R2d3che +15.2R2d3dhe +9.8R1d3Cst +7.6R1d3dst+19.5R2D3Cst+16.9R2d3dst +10.8R1d3Crep +8.1R1d3drep +21.4R2d3Crep +18.6R2d3drep +9.1R1d2CHe +7.1R1d2dhe +17.4R2d2CHe +15.4R2d2dhe+9.6R1d2cst+7.4R1d2dst+19.4R2d2cst+16.7R2d2dst +9.3R1d2crep +7.1R1d2drep +17.8R2d2cRep +15.8R2d2drep +9.2R1d4Che +7.3R1d4dhe +17.3R2d4che +15.2R2d4dhe +9.8R1d4Cst +7.6R1d4dst +19.5R2d4Cst+16.9R2d4dst +10.8R1d4Crep +8.1R1d4drep +21.4R2d4Crep+18.6R2d4drep +32.36BullA +33.64bullB +21.5 Dairy1C +20.7Dairy1D +26.15Dairy3C +26.15Dairy3D +21.68Dairy2C +23.18Dairy2D +26.32Dairy4C +27.84Dairy4D +12.32R1stA +11.32R1heifA +18.56R2stA +17.27R2heifA +18.56R2stB +17.27R2heifB +19.42brbeefA+16.9Repla +54clean =<0

WbalJun)-2988Rain -0.96wMay_Jun +1wJun_Jul -100buywJun +9.1R1d1CHe +7.1R1d1dhe +17.4R2d1CHe +15.4R2d1dhe +9.6R1d1cst+7.4R1d1dst +19.4R2d1cst +16.7R2d1dst +9.3R1d1crep +7.1R1d1drep +17.8R2d1cRep +15.8R2d1drep +9.2R1d3Che +7.3R1d3dhe +17.3R2d3che +15.2R2d3dhe +9.8R1d3Cst +7.6R1d3dst +19.5R2D3Cst+16.9R2d3dst +10.8R1d3Crep +8.1R1d3drep +21.4R2d3Crep +18.6R2d3drep +9.1R1d2CHe +7.1R1d2dhe +17.4R2d2CHe +15.4R2d2dhe +9.6R1d2cst +7.4R1d2dst+19.4R2d2cst+16.7R2d2dst +9.3R1d2crep +7.1R1d2drep +17.8R2d2cRep +15.8R2d2drep +9.2R1d4Che +7.3R1d4dhe +17.3R2d4che +15.2R2d4dhe +9.8R1d4Cst +7.6R1d4dst+19.5R2d4Cst+16.9R2d4dst +10.8R1d4Crep +8.1R1d4drep +21.4R2d4Crep +18.6R2d4drep+31.32bullA +32.56BullB +20.81 Dairy1C +19.42Dairy1D +25.31Dairy3C +13.92Dairy3D +20.98Dairy2C +23.55Dairy2D +25.47Dairy4C +27.02Dairy4D +12.32R1stA +10.96R1heifA +19.18R2stA +16.72R2heifA +19.18R2stB +16.72R2heifB+18.12brbeefA+16.9Repla +54clean =<0

WbalJul)-1968Rain -0.96wJun_Jul +1wJul_Aug -100buywJul +9.1R1d1dhe +10.9R2d1CHe +17.4R2d1dhe +9.6R1d1dst+11.5R2d1cst+19.4R2d1dst +9.3R1d1drep +11.4R2d1cRep +17.8R2d1drep +9.2R1d3dhe+10.9R2d3che+17.3R2d3dhe +9.8R1d3dst +11.7R2D3Cst +19.5R2d3dst +10.8R1d3drep +8 R2d3Crep +21.4R2d3drep +9.1R1d2dhe +10.9R2d2CHe +17.4R2d2dhe +9.6R1d2dst+11.5R2d2cst+19.4R2d2dst +9.3R1d2drep +11.4R2d2cRep +17.8R2d2drep +9.2R1d4dhe +10.9R2d4che+17.3R2d4dhe +9.8R1d4dst+11.7R2d4Cst +19.5R2d4dst +10.8R1d4drep+8 R2d4Crep +21.4R2d4drep +1.5wean1CB +1.5wean1CC +1.5wean2CB +1.5wean2CC+1.5wean3CB +1.5wean3CC +1.5wean4CB +1.5wean4CC+1.5rear1CB +1.5rear1CC +1.5rear2CB +1.5rear2CC+1.5rear3CB +1.5rear3CC +1.5rear4CB +1.5rear4CC +30.55bullA +31.83BullB +20.30 Dairy1C +21.5Dairy1D +24.95Dairy3C +26.15Dairy3D +24.91Dairy2C +22.19Dairy2D 29.56Dairy4C +28Dairy4D +13.79 R1stA +12.49R1heifA +20.04 R2stA +17.93R2heifA +20.04 R2stB +17.93R2heifB +19.38brbeefA +17.9Repla+54clean =0

WbalAug)-1550Rain -0.96wJul_Aug +1wAug_Sep -100buywAug +2.8R1d1CHe +9.1R1d1dhe +10.9R2d1CHe +17.4R2d1dhe+3.1R1d1cst+9.6R1d1dst+11.5R2d1cst+19.4R2d1dst +2.8R1d1crep +9.3R1d1drep +11.4R2d1cRep+17.8R2d1drep+3.1R1d3che+9.2R1d3dhe+10.9R2d3che+17.3R2d3dhe+3.3 R1d3Cst+9.8R1d3dst+11.7R2D3Cst+19.5R2d3dst +3 R1d3Crep+10.8R1d3drep +8 R2d3Crep +21.4R2d3drep +2.8R1d2CHe +9.1R1d2dhe +10.9R2d2CHe +17.4R2d2dhe+3.1R1d2cst+9.6R1d2dst+11.5R2d2cst+19.4R2d2dst +2.8R1d2crep +9.3R1d2drep +11.4R2d2cRep+17.8R2d2drep+3.1R1d4che+9.2R1d4dhe+10.9R2d4che+17.3R2d4dhe+3.3 R1d4Cst+9.8R1d4dst+11.7R2d4Cst+19.5R2d4dst +3 R1d4Crep+10.8R1d4drep +8 R2d4Crep+21.4R2d4drep +0.6wean1CB +1.65wean1CC +0.6wean2CB +1.65wean2CC+0.6wean3CB +1.65wean3CC+0.6wean4CB +1.65wean4CC +0.6rear1CB +1.65rear1CC +0.6rear2CB +1.65rear2CC+0.6rear3CB +1.65rear3CC+0.6rear4CB +1.65rear4CC +30.55bullA +31.83BullB +20.3Dairy1C +21.5Dairy1D +24.95Dairy3C +26.15Dairy3D +24.9104475Dairy2C +21.68Dairy2D +29.56Dairy4C +26.329Dairy4D +13.79R1stA +20.01R2stA +12.49R1heifA +17.93R2heifA +10R2stB +8R2HeifB +20.15brbeefA +17.9Repla +54clean =0

WbalSep)-3026Rain -0.9375wAug_Sep +1wSep_Oct -100buywSep +2.8R1d1CHe +9.1R1d1dhe +10.9R2d1CHe +17.4R2d1dhe+3.1R1d1cst+9.6R1d1dst+11.5R2d1cst+19.4R2d1dst +2.8R1d1crep +9.3R1d1drep +11.4R2d1cRep+17.8R2d1drep+3.1R1d3che+9.2R1d3dhe+10.9R2d3che+17.3R2d3dhe +3.3R1d3Cst +9.8R1d3dst +11.7R2D3Cst +19.5R2d3dst +3R1d3Crep +10.8R1d3drep +8R2d3Crep +21.4R2d3drep +2.8R1d2CHe +9.1R1d2dhe +10.9R2d2CHe +17.4R2d2dhe+3.1R1d2cst+9.6R1d2dst+11.5R2d2cst+19.4R2d2dst +2.8R1d2crep +9.3R1d2drep +11.4R2d2cRep +17.8R2d2drep +3.1R1d4che +9.2R1d4dhe +10.9R2d4che +17.3R2d4dhe +3.3R1d4Cst+9.8R1d4dst+11.7R2d4Cst+19.5R2d4dst +3R1d4Crep +10.8R1d4drep +8R2d4Crep +21.4R2d4drep +29.57BullA +30.8BullB +19.66Dairy1C +21.5Dairy1D +24.95Dairy3C +25.31Dairy3D +24.25Dairy2C +20.98Dairy2D +28.75Dairy4C +25.47Dairy4D +13.34R1stA +19.4R2stA +12.49R1heifA +17.93R2heifA +20.39brbeefA +54clean =0

WbalOct)-12308Rain -0.9375wSep_Oct +1wOct_Nov -100buywOct +4.7R1d1CHe +12.9R2d1CHe +10.9R2d1dhe+4.9R1d1cst +13.7R2d1cst+11.5R2d1dst +4.7R1d1crep +13.6R2d1cRep+11.4R2d1drep+4.9R1d3Che +12.9R2d3che+10.9R2d3dhe+5.1R1d3Cst +13.9R2D3Cst+11.7R2d3dst +5.2R1d3Crep+15.3R2d3Crep +8 R2d3drep +4.7R1d2CHe +12.9R2d2CHe +10.9R2d2dhe+4.9R1d2cst +13.7R2d2cst+11.5R2d2dst +4.7R1d2crep +13.6R2d2cRep+11.4R2d2drep+4.9R1d4Che +12.9R2d4che+10.9R2d4dhe+5.1R1d4Cst +13.9R2d4Cst+11.7R2d4dst +5.2R1d4Crep +15.3R2d4Crep +8R2d4drep +1.5wean1DB

+1.5wean1DC +1.5wean2DB +1.5wean2DC+1.5wean3DB +1.5wean3DC+1.5wean4DB +1.5wean4DC +1.5rear1DB +1.5rear1DC +1.5rear2DB +1.5rear2DC+1.5rear3DB +1.5rear3DC+1.5rear4DB +1.5rear4DC +31.50bullA +31.5BullB +18.70Dairy1C +20.30Dairy1D 23.35Dairy3C +24.95Dairy3D +23.67Dairy2C +24.91Dairy2D +28.33Dairy4C +29.56Dairy4D +15.58R1stA +20.07R2stA +13.97R1heifA +18.39R2heifA +19.09brbeefA +54clean=0

WbalNov)-16342Rain -0.9375wOct_Nov +1wNov_Dec -100buywNov+4.7R1d1CHe +2.8R1d1dhe +12.9R2d1CHe +10.9R2d1dhe+4.9R1d1cst+3.1R1d1dst+13.7R2d1cst+11.5R2d1dst +4.7R1d1crep +2.8R1d1drep +13.6R2d1cRep +11.4R2d1drep +4.9R1d3Che+3.1R1d3dhe +12.9R2d3che +10.9R2d3dhe +5.1R1d3Cst+3.3R1d3dst+13.9R2D3Cst+11.7R2d3dst +5.2R1d3Crep +3R1d3drep +15.3R2d3Crep +8 R2d3drep +4.7R1d2CHe +2.8R1d2dhe +12.9R2d2CHe +10.9R2d2dhe+4.9R1d2cst+3.1R1d2dst+13.7R2d2cst+11.5R2d2dst +4.7R1d2crep +2.8R1d2drep +13.6R2d2cRep+ 11.4R2d2drep+4.9R1d4Che+ 3.1R1d4dhe+12.9R2d4che +10.9R2d4dhe+5.1R1d4Cst+3.3R1d4dst+13.9R2d4Cst+11.7R2d4dst +5.2R1d4Crep +3R1d4drep +15.3R2d4Crep +8R2d4drep +0.6wean1DB +1.65wean1DC +0.6wean2DB +1.65wean2DC+0.6wean3DB +1.65wean3DC +0.6wean4DB +1.65wean4DC+0.6rear1DB +1.65rear1DC +0.6rear2DB +1.65rear2DC+0.6rear3DB +1.65rear3DC +0.6rear4DB +1.65rear4DC +30.49BullA +30.49BullB +18.11Dairy1C +19.66Dairy1D +23.35Dairy3C +24.95Dairy3D +23.04Dairy2C +24.25Dairy2D +27.56Dairy4C +28.75Dairy4D +15.08R1stA +13.97 R1heifA +18.95brbeefA +54clean=<0

WbalDec)-19219RAin -0.9375wNov_Dec +1wDec_Jan +4.7R1d1CHe +2.8R1d1dhe +12.9R2d1CHe +10.9R2d1dhe+4.9R1d1cst+3.1R1d1dst+13.7R2d1cst+11.5R2d1dst +4.7R1d1crep +2.8R1d1drep +13.6R2d1cRep +11.4R2d1drep +4.9R1d3Che +3.1R1d3dhe +12.9R2d3che +10.9R2d3dhe+5.1R1d3Cst+3.3R1d3dst+13.9R2D3Cst+11.7R2d3dst +5.2R1d3Crep +3 R1d3drep +15.3R2d3Crep +8 R2d3drep +4.7R1d2CHe +2.8R1d2dhe +12.9R2d2CHe +10.9R2d2dhe+4.9R1d2cst+3.1R1d2dst+13.7R2d2cst+11.5R2d2dst +4.7R1d2crep +2.8R1d2drep +13.6R2d2cRep +11.4R2d2drep+4.9R1d4Che +3.1R1d4dhe +12.9R2d4che +10.9R2d4dhe +5.1R1d4Cst+3.3R1d4dst+13.9R2d4Cst +11.7R2d4dst +5.2R1d4Crep +3 R1d4drep +15.3R2d4Crep +8 R2d4drep +31.5BullA +31.5BullB +18.7Dairy1C +20.30Dairy1D +23.35Dairy3C +24.16Dairy3D +23.67Dairy2C +24.91Dairy2D +28.33Dairy4C +29.56Dairy4D +15.58R1stA +13.97R1heifA +24.65brbeefA +54clean=<0

mxbwater)buywMay+buywJun+buywJul+buywAug+buywSep+buywOct+buywNov=<5

wDec_Jan=<110000

wJan_Feb=<110000

wFeb_Mar=<110000

wMar_Apr=<110000

wApr_May=<110000

wOct_Nov=<110000

wNov_Dec=<110000

Rainfall) Rain=1

Clean) -0.02Dairy1c -0.02dairy1c -0.02dairy2c -0.02dairy2d-0.02dairy3c -0.02dairy3d - 0.02dairy4c -0.02dairy4d +Clean =0

!Here goes our beef cattle reconciliation.

Weanheif)-0.45brbeefA -1bwheifer +R1heifA +s230Apr=0

Weanst)-0.45brbeefA -bwst1 -bwst2 +R1stA +s250Apr=0

HeifR2)-0.98R1heifA +R2heifA +R2heifB +ReplA=0

SteerR2)-0.98R1StA +R2stA +R2stB =0

st450Nov)-0.99R2stA +1s450Nov=0

h400Nov)-0.99R2heifA +1s400Nov=0

st450Aug)-0.99R2stB+1s450Aug =0

H400Aug)-0.99R2heifB +1s400Aug =0
Newcow)+0.20brbeefA -0.99ReplA -1buyrepl +1sbeefrp1=0
bulls)-1Buybull +0.33bullA +0.33bullB=0
Sbeefrp1=0
!Bull:cow ratio
bullcow) 0.03brbeefA+ 0.03dairy1C +0.03dairy1d +0.03dairy3C +0.03dairy3D +0.03dairy2c+0.03dairy2D+0.03dairy4c+0.03dairy4D -bullA -BullB =<0
Mxbwst1) bwst1=<100
Mxbwst2) bwst2=<200
!Here goes our dairy 1C reconciliation rows 3000lt of milk 450kg dairy cow calving in July.
calfF1C)-0.45Dairy1C+1wean1CB+1wean1CC +cull1C=0
calfM1C)-0.45Dairy1C +rear1cb+rear1cc +bobyst1C=0
DHef1C) -0.88wean1Cb-0.95Wean1CC+R1d1CHe +R1d1Crep=0
Dst1C) -0.88rear1Cb-0.95rear1CC+R1d1Cst=0
R2d1Che)-0.95R1d1Che +1R2d1CHe +heifcX1=0
R2d1Cst)-0.95R1d1Cst +1R2d1Cst +steercX1 = 0
R2d1Crep)-0.95R1D1Crep +1R2d1Crep = 0
New1Ccow)-0.98R2d1Crep +0.20dairy1C -1bdairy1C +srep1C=0
!Here goes our dairy 1D reconciliation rows 3000lt of milk 450kg dairy cow calving in October.
calfF1D)-0.45Dairy1D +1wean1DB +1wean1DC +cull1D =0
calfM1D)-0.45Dairy1D +rear1Db +rear1Dc +bobyst1D =0
DHef1D)-0.88wean1Db-0.95Wean1DC+R1d1DHe +R1d1Drep=0
Dst1D) -0.88rear1Db-0.95rear1DC+R1d1Dst=0
R2d1Dhe)-0.95R1d1Dhe +1R2d1DHe +heifdx1=0
R2d1Dst)-0.95R1d1Dst +1R2d1Dst +steerdx1= 0
R2d1Drep)-0.95R1D1Drep +1R2d1Drep = 0
New1Dcow)-0.98R2d1Drep+0.20dairy1D- 1bdairy1D +srep1D =0
!Here goes our dairy2C reconciliation rows 4500L of milk 450kg dairy cow calving in July
CalfF2C) -0.45dairy2C +wean2CB +wean2CC +cull2C =0
CalfM2C) -0.45dairy2C +rear2Cb +rear2Cc +bobyst2C=0
Dhef2C)-0.88wean2CB -0.95wean2CC +R1d2Che +R1d2Crep =0
Dst2C)-0.88rear2CB -0.95rear2CC +R1d2Cst =0
R2d2che)-0.95R1d2Che +R2d2Che =0
R2d2st)-0.95r1d2Cst +R2d2Cst =0
R2d2crep)-0.95R1d2crep+1R2d2crep =0
New2Ccow) -0.98R2d2Crep +0.20Dairy2C -bdairy2C +srep2C=0
!Here goes our dairy2D reconciliation rows 4500L of milk 450kg dairy cow calving in October
CalfF2D) -0.45dairy2D +wean2DB +wean2DC +cull2D =0
CalfM2D) -0.45dairy2D +rear2Db +rear2Dc +bobyst2D=0
Dhef2D)-0.88wean2DB -0.95wean2DC +R1d2Dhe +R1d2Drep =0
Dst2D) -0.88wean2DB -0.95wean2DC +R1d2Dst =0
R2d2Dhe) -0.95R1d2Dhe +R2d2Dhe =0
R2d2Dst) -0.95r1d2Dst +R2d2Dst =0
Red2drep)-0.95r1d2drep +r2d2drep=0
New2Dcow)-0.98R2d2Drep +0.20Dairy2D -bdairy2D +srep2D=0
!Here goes our dairy 3C reconciliation rows 3000L of milk 550kg dairy cow calving in July.
calfF3C)-0.45Dairy3C +1wean3CB +1wean3CC +cull3C=0
calfM3C)-0.45Dairy3C +1rear3Cb +1rear3Cc +bobyst3C=0
Dst3C) -0.44wean3Cb -0.475Wean3Cc +1R1d3Cst =0
DHef3C) -0.44wean3Cb -0.475Wean3Cc +1R1d3CHe +R1d3Crep =0

R2d3Che) -0.95R1d3che +1R2d3cHe +heifcx3=0
R2d3Cst) -0.95R1d3cst +1R2d3cst +steercx3 = 0
R2d3Crep)-0.95R1d3crep +1R2d3crep = 0
New3Ccow)-0.98R2d3crep+0.20dairy3c- 1bdairy3c +srep3C =0
!Here goes our dairy 3D reconciliation rows 3000L of milk 550kg dairy cow calving in October.
calfF3D)-0.45Dairy3d+1wean3dB+1wean3dC+ cull3D=0
calfM3D)-0.45Dairy3D +rear3Db+ rear3Dc+ bobyst3D=0
DHef3D) -0.88wean3Db -0.95Wean3DC +1R1d3DHe +R1d3Drep=0
Dst3D) -0.88wean3db-0.95Wean3dC+R1d3dst=0
R2d3Dhe)-0.95R1d3Dhe +1R2d3DHe +heifdx3 =0
R2d3Dst)-0.95R1d3Dst +1R2d3Dst +steerdx3 = 0
R2d3Drep)-0.95R1d3Drep +1R2d3Drep = 0
New3Dcow)-0.98R2d3Drep+0.20dairy3D- 1bdairy3D +srep3D=0
!Here goes our dairy4C reconciliation rows 4500L of milk 550kg dairy cow calving in July
CalfF4C) -0.45dairy4C +wean4CB + wean4CC +cull4C =0
CalfM4C) -0.45dairy4C +rear4cB + rear4Cc +bobyst4C=0
Dhef4C) -0.88wean4CB -0.95wean4CC +R1d4Che +R1d4Crep =0
Dst4C) -0.88rear4CB -0.95rear4CC +R1d4Cst =0
R2d2st) -0.95r1d4Cst +R2d4Cst =0
R2d4Che) -0.95R1d4Che +R2d4Che =0
R2d4crep)-0.95R1d4crep +r2d4Crep =0
New4Ccow)-0.98R2d4Crep +0.25Dairy4C -bdairy4C +srep4C=0
!Here goes our dairy4D reconciliation rows 4500L of milk 550kg dairy cow calving in October
CalfF4D)-0.45dairy4D +wean4DB + wean4DC +cull4D =0
calfM4D)-0.45dairy4D +rear4Db + rear4Dc +bobyst4D=0
Dhef4D) -0.88wean4DB -0.95wean4DC +R1d4Dhe +R1d4Drep =0
Dst4D) -0.88rear4DB -0.95rear4DC +R1d4Dst =0
R2D2st) -0.95r1d4Dst +R2D4Dst =0
R2D4Dhe)-0.95R1d4Dhe +R2d4Dhe =0
R2d4drep)-0.95R1d4drep +R2d4drep=0
New4Dcow)-0.98R2d4Drep +0.20Dairy4D'-bdairy4D +srep4D =0
!here goes our dairy finishing activities balance
s450Jul)-0.98R2d1cst -0.98R2d2Cst -0.98R2d3cst -0.98R2d4Cst +S450Jul =0
s400Jul)-0.98R2d1che -0.98R2d2che -0.98R2d3che -0.98R2d4che +S400Jul =0
s450Oct)-0.98R2d1dst -0.98R2d2dst -0.98R2d3dst -0.98R2d3dst +S450Oct =0
S400Oct)-0.98R2d1dhe -0.98R2d2dhe -0.98R2d3dhe -0.98R2d4dhe +S400Oct =0
!Here goes our maximum replacement sales per year
sellrep) srep1c+srep2c+srep3c+srep4c+srep1d+srep2d+srep3d+srep4d=<0
buyrepl) 3bdairy1C +3bdairy2C +3bdairy3C +3bdairy4C +3bdairy1d +3bdairy2d +3bdairy3d +3bdairy4d-R2d1Crep-R2d1drep-R2d2crep -R2d2drep-R2d3crep-R2d3drep - R2d4crep-R2d4drep =0
!Here goes our milk tank reconciliation rows in 10L units.
MilkJM) -58.95Dairy1C -97.11Dairy1D -58.95Dairy3C -97.11Dairy3D -88.47Dairy2C - 145.62Dairy2D -88.47Dairy4C -145.62Dairy4D +10SmilkJM =0
MilkAJ) -12.87Dairy1C -58.95Dairy1D -12.87Dairy3C -58.95Dairy3D -19.26Dairy2C - 88.47Dairy2D -19.26Dairy4C -88.47Dairy4D +10SmilkAJ =0
MilkJS) -101.16Dairy1C -12.87Dairy1D -101.16Dairy3C -12.87Dairy3D -151.74Dairy2C - 19.26Dairy2D -151.74Dairy4C -19.26Dairy4D +10SmilkJS +16.8wean1cb +16.8wean3cb +13.3wean1cc +13.3wean3cc +16.8wean2cb +16.8wean4cb +13.3wean2cc +13.3wean4cc

+16.8rear1cb +16.8rear3cb +13.3rear1cc +13.3rear3cc +16.8rear2cb +16.8rear4cb +13.3rear2cc +13.3rear4cc =0

MilkOD)-97.11Dairy1C -101.16Dairy1D -97.11Dairy3C -101.16Dairy3D -145.62Dairy2C -151.74Dairy2D -145.62Dairy4C -151.74Dairy4D +10SmilkOD +16.8wean1db +16.8wean3db +13.3wean1dc +13.3wean3dc +16.8wean2db +16.8wean4db +13.3wean2dc +13.3wean4dc +16.8rear1db +16.8rear3db +13.3rear1dc +13.3rear3dc +16.8rear2db +16.8rear4db +13.3rear2dc +13.3rear4dc=0

! Fertility reconciliation rows

AgroC3)-0.2pan15 -0.3pan10 -0.15Pangola -0.6Panleg5 -0.375Panleg8 -0.3Panleg10 -0.2Panleg15 -0.15Panleg20 -Manicon1-manicon2-manimin1-manimin2+sesam1 +sesam2 +sesamec1+sesamec2+cotton1+cotton2+1sorggc+1sorgs1ec+1sorgs1lc+cana1 +cana2 +castor1e+castor1l+castor2e+castor2l =<0

AgroM)+0.333SorggM +0.333sorgs1eM +0.333sorgs1lM -0.05Gatton -0.07Gatton15 -0.1Gatton10 -0.15G80LH-0.15G80LM-0.15G80LL-0.15G65LH-0.15G65LM-0.15G65LL-0.15G50LH-0.15G50LM-0.15G50LL=<0

!Market contraints

+cana1+cana2+manicon1+manicon2+panleg5+panleg8+panleg10+panleg15+panleg20 +G80LH+G80LM+G80LL+G65LH+G65LM+G65LL+G50LH+G50LM+G50LL=0

!Financial constraints

MaxbJan) borrJan=<500

MaxbFeb) borrFeb=<500

MaxlDec) lendDec=<500

END