PRIFYSGOL CYMRU
UNIVERSITY OF WALES
BANGOR

CATIE Centro Agronómico Tropical de Investigación y Enseñanza

Effects of Silvopastoral Areas on Dual-purpose Cattle Production at the Semi-humid Old Agricultural Frontier in Central Nicaragua

Wataru Yamamoto

Effects of Silvopastoral Areas on Dual-purpose Cattle Production at the Semi-humid Old Agricultural Frontier in Central Nicaragua

A thesis submitted to the join program

for the degree of

Doctor of Philosophy

Wataru Yamamoto

Centro Agronómico Tropical de Investigación y Enseñanza

(CATIE), Turrialba, Costa Rica and

School of Agricultural and Forest Sciences,

University of Wales, Bangor, UK

December, 2004

Doctoral Advisory Committee

Dr. Muhammad Ibrahim (Major Advisor, CATIE)

Dr. Ioan Ap Dewi (Co-advisor, University of Wales, Bangor)

Dr. Eduardo Somarriba (Committee member, CATIE)

Dr. Fergus Sinclair (Committee member, University of Wales, Bangor)

This dissertation is dedicated to my wife Julita.

Declaration

This work has not been previously accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed ______________________________ (Candidate)

Data Dec 23 2004

This thesis is the results of my own investigation except where otherwise stated. Due acknowledgement is made on the following page for any assistance I have received; other sources are identified by explicit references. A bibliography is appended.

Signed ______________________________ (Candidate)

Data Dec 23. 2004

I hereby give consent for my thesis, if accepted, to be available for photocopying and interlibrary loan, and for the title and summary to be made available to outside organizations.

Signed ______________________________ (Candidate)

Data Dec. 23. 2004

Biography

Wataru Yamamoto was born in Osaka, Japan. In 1988, he obtained a bachelor of science in material physics from Osaka University. In 1993 he obtained master of environmental studies from Yale School of Forestry and Environmental Studies in USA.

He worked as a forestry and agroforestry specialist for international development projects in many tropical countries: Sri Lanka, Indonesia, Honduras, Brazil, Myanmar, Philippines, Mexico, and Costa Rica. His interests in tropical forestry with involvement of local communities finally led him to agroforestry, particularly the problems related to grazing lands, the largest land use in rural areas in Latin America. His current professional interests include planning and evaluation of agroforestry systems, livestock production and silvopastoral systems, social forestry and industrial forest plantations, rural development and carbon sequestration in agroforestry systems in the context of international development.

Acknowledgement

The study presented in this dissertation was undertaken under join doctoral program between Centro Agronómico Tropical de Investigación y Enseñanza, (CATIE), Costa Rica and the University of Wales, School of Agricultural and Forest Sciences, Bangor (UWB). The field survey of the study was benefited by the project, "Regional integrated silvopastoral approaches to ecosystem management project", undertaken by CATIE and NITLAPAN under the scheme of Global Environment Facility (GEF) of the World Bank. I wish to acknowledge, Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Costa Rica and University of Wales, School of Agricultural and Forest Sciences, and NITLAPAN in Nicaragua for providing the opportunity to undertake this study.

The study described in this dissertation was supervised by Dr. Muhammad Ibrahim, CATIE and Dr. Ioan Ap Dewi, UWB. I would like to express my gratitude to my supervisors for their assistance throughout my doctoral studies. Dr. Ibrahim introduced me to the world of silvopastoral systems and gave me an opportunity to work with the project in Nicaragua. Dr. Ap Dewi supported me from the planning, data analysis to writing process. His support and encouragement, and careful comments on each chapter were deeply appreciated. I thank my advisors and examiners for technical advice for the study and careful comments throughout the dissertation: Dr. Danilo Pezo and Dr. Eduardo Somarriba, CATIE, Dr. Fergus Sinclair and Dr. Hussain Omed, University of Wales, and Dr. Alfredo Alvarado, University of Costa Rica.

Secondly, I wish to express my gratitude to people in Nicaragua. NITLAPAN, the great institution to support rural farmers supported me during my field work: from introducing me to farmers and providing me data, to the extensive logistic support in the field. I would like to thank project staff of NITLAPAN, particularly Elian Ramirez, Omar Davila, Yuri Marín, Herty Betancourt, Aura Yorlene Cardenaz, Rene Gomez, Marlon Lopez, and Alfredo Ruiz Garcia for their support. I also thank farmers in Matiguas, who allowed me to conduct survey in their farms, and gave me invaluable information. They were very friendly and I had great time with them. I would like to thank Heberto Polanco, my field assistant, an extension worker and a farmer. I obtained practical knowledge of cattle production from him. I appreciate very much his energy to support the survey under harsh field conditions. I also thank Dalia Sanchez, Fundación Cocibolca, Carlos Ruiz, Universidad Nacional Agraria for identifying tree and pasture species.

Thirdly, I wish to thank people in CATIE for supporting my study: Cristobal Villanueva, Ottoniel Monterroso and Humberto Esquivel for technical discussion about cattle production, Tangaxuhan Llanderal for the comments on the presentation materials, Gustavo Lopez and Fernando Casanoves for statistical analysis, Jose Gobbi for economic analysis, Cristian Brenes and Stefan Kunth for GIS analysis, Paulo Dittel for pasture survey equipment, Sonia Ospina for identification of pasture species, and Lester Rocha for field information.

Finally, I wish to thank Dr. Tsuyoshi Hashimoto, the president of RECS International Inc. who allowed me to study in doctoral program with flexible job assignment. Without this arrangement, it would have been difficult to financially plan my doctoral study.

Abstract

Effects of silvopastoral areas on dual-purpose cattle production at the semi-humid old agricultural frontier in central Nicaragua

Wataru Yamamoto

CATIE/UWB

Cattle production in humid lowland tropics has been criticised for its extensive management. Dual-purpose cattle production system has been preferred by small and medium sized farms in such regions due to low capital and technical demands with low risk for farmers. In order to quantify the effects on production of silvopastoral areas in the dual-purpose cattle production system, relations between land use patterns and seasonal production and herd data were examined for 74 farms in semi-humid regions of central Nicaragua.

The results showed that grazing lands were largely covered by tree cover (23 % on average), and land use were largely composed of degraded pastures (32%) and pasture with low and moderate tree densities (45%). The results of regression analysis demonstrated the positive effects of degraded pastures (DGPS) ($p<0.001$), natural and cultivated pastures with moderate tree density (MTNP and MTCP) ($p<0.05$), and cultivated pastures with low tree density (LTCP) ($p<0.05$) on milk production. However, the negative effects of land use types under natural pasture with low tree density on milk production (LTNP) ($p<0.01$) was also observed, which may suggest overgrazing with higher stocking rates ($p<0.01$) on this land use type by smaller farms. The results of herd survey showed that although cattle were frequently moved from and to the farms, stocking rates did not differ by season ($p<0.05$), and that calving rates were significantly high in the dry season ($p<0.05$), resulting in significantly low milk production per cow ($p<0.05$) and tendency to have high adult mortality rates.

The study concluded that silvopastoral areas are largely utilized for cattle production with positive effects on milk production. Further studies are recommended on stocking rates and change of sward composition, feasibility study on pasture improvement with use of fertilization and/or silvopastoral techniques, and availability and nutritional values of broadleaved plants in dry season.

Table of Contents

Chapter 1 General Introduction

Chapter 2 Literature Reviews

Chapter 4 Evaluation of trees and grass covers of dual-purpose cattle farms at the semi-humid old agricultural frontier in central Nicaragua (Article2)

Chapter 7 General discussion and Conclusions

List of Figures

List of Tables

Appendices

Chapter 1 General Introduction

1.1 Introduction

Conversion of natural forests to pastures in the humid tropics of Central America has been criticized as a main cause of deforestation (Parsons, 1976; Myer, 1981; Kaimowitz, 1996). Extensive cattle grazing conducted in tropical pasture with low nutritive value (Minson, 1981) and low labour and capital inputs are exploitative for nutrients accumulated in original vegetation (Kaimowitz, 1996; Sunderlin and Rodriguez, 1996). At the old agricultural frontier in central Nicaragua, due to the political pressure during the civil war in the 1980s, large cattle farms that had been abandoned during the civil war in 1980s were divided into small and medium sized farms in the early 1990s (Levard et al., 2001). As a result, presently 90 % of cultivated lands in the lowlands are occupied by pastures, and small farms comprise most of the total farms (NITLAPAN, 1995; Szott,et al., 2000).

Extensive cattle production systems are an important activity in the rural economy due to their comparative advantages against other agricultural production: low requirement of skill and labour, low risk, and easy transfer of products to market (Hetch, 1992; Muchagata and Brown, 1999). In order to take advantage of family labour and overcome the constraints imposed by limited land and capital, such small and medium sized farms are largely engaged in dual-purpose (milk and meat) cattle production systems. The dual-purpose cattle production system has been described as the traditional cattle production system of family farms in the lowland tropics of Latin America (Sere and de Vaccaro, 1985). Dual-purpose cattle production systems have been preferred by small farms due to the advantages of 1) reducing risk from price changes of milk and meat, 2) little need for capital investment, 3) less technical support required than for specialized milk production, and 4) reduction of mastitis incidence because calves are nursed by their mothers (Holmann, 1989). In order to mitigate deforestation, intensification (increasing productivity per unit area) of existing dual-purpose cattle farms was recognized as an important target in Central America (Nicholson et al., 1995).

Nicaragua is considered to be one of the poorest countries in Latin America with a population of 5.3 million, a GNI per capita of US$720, and having 48% of the population under the national poverty line (World Bank, 2004). The agriculture sector comprises 32 % of the GDP. The cattle population has increased in the last few years reaching more than 3.3 million head (FAO, 2003). In particular milk exports have increased since 1996 reaching US$3.5 million in 2001, which is 30 times larger than in 1991 (FAO, 2003).

In small and medium sized farms in central Nicaragua, cattle are traditionally produced under extensive management. They include natural or naturalized grass species with naturally regenerated trees on pasture lands, thus forming heterogeneous grazing areas. Pastures have been sown to a certain extent, including ones for cut and carry systems. In addition, trees in grazing areas are considered to be beneficial for family farmers in order to obtain fuel wood, timber, fence posts, and fruits (Harvey and Harver, 1999). Consequently, farmers own a variety of pasture lands with natural and cultivated pastures with different tree densities. In addition, the main type of cattle, crossbreds between Zebu (*Bos indicus*) and European (*Bos taurus*) breeds, require tree shade for keeping cattle under lower temperatures in order to have high milk production in lowland tropical conditions (Souza de Abreu, 2002). Finally, in order to maintain production in the dry season, farmers may move cattle to more humid areas, but the use of trees may help to supply dry season fodder.

There is interest in increasing trees in pastures in the humid tropics in order to mitigate the vulnerability of the land and to increase carbon sequestration. Many projects by donor agencies attempt to increase the use of trees in livestock production, so called silvopastoral systems. Such projects aim to obtain benefits of trees through intensification of livestock production, diversification of products from trees and securing sustainability of existing production systems (Murgueitio, 1990). Intensification may not be accepted by rural farmers due to their socio-economic needs, their desire to increase land area as an inheritance for children and problems associated with increasing labour (Kaimowitz, 1996; Maldidier and Marchetti, 1996). Rather, management strategies based on ecological land use to increase tree cover on pastures may be more promising to improve the sustainability of cattle production while reducing negative impacts.

Trees in grazing areas may support cattle production in various ways: (1) improvement of chemical and physical soil conditions (Horne and Blair, 1991; Belsky, 1992; Belsky et al., 1993; Young, 1997), (2) stabilization of soil by protecting the soil surface from intensive rainfall (Pereira, 1989), (3) supporting higher grass production through improved nutritional levels and maintained moisture in the soil in the dry season (Young, 1997; Durr and Rangel, 2000), (4) improvement of pasture quality (Wilson, 1982; Smith and Whiteman, 1983), (5) increased animal production by improving the comforts for animals, and 6) provide leaves and fruits as fodder for animals (Pezo et al., 1990; Pezo and Ibrahim, 1999).

However, the evidence of positive contributions of trees to cattle production in grazing areas has mostly originated from limited-scale trials or experiments. The actual effects of pastureland with low and moderate tree density on production in existing farming systems have not been examined in detail at the farm level due to the variability caused by differences between individual farms and seasons as well as technical difficulties obtaining land use data for entire farms. The objective of this thesis is to examine the effects of silvopastoral areas on cattle production in dual-purpose cattle farms under existing farm conditions in order to contribute to potential modifications in land use, which will enhance the sustainability of cattle production systems.

1.2. The objectives of the study

1.2.1. General objective

The objective of the study is to examine the effects of silvopastoral areas on production in existing dual-purpose cattle production systems in the Matiguas region of central Nicaragua.

1.2.2. Specific objectives

1) Characterise the main features of the farming systems within the study area,

2) Evaluate grazing areas with regard to pasture, tree cover and slope in dual-purpose cattle production systems,

3) Describe the herd characteristics with regard to structure and production in dual-purpose cattle production systems,

4) Examine the effects of pasture with silvopastoral areas on cattle production and herd economics.

1.3. Hypotheses

Main hypothesis

Silvopastoral areas within dual-purpose cattle production systems in the Matiguas region of central Nicaragua have positive effects on cattle production and herd economics.

Sub-hypotheses

- Grass cover of cultivated pastures under tree cover is higher than that of natural pastures,
- Stocking rates are lower in the dry season than in the wet season ,

1.4 Strategies and approach of the study

The study is intended to analyse the effects of silvopastoral areas on cattle production. The study has five components: 1) general farm survey 2) pasture and tree survey, 3) land survey, 4) herd survey and 5) analysis of the relationships between cattle production and land use (Table 1.1). The general farm survey characterises the farming systems in the survey area, and the pasture and tree survey evaluates grazing areas with regard to grass cover, tree cover and slope level. The land survey defines land types based on stand density of trees, pasture types and conditions, and estimates the area and tree cover of each land type in the farms. The herd survey collected herd and production data and determines standardised values in relation to production units. Based on the survey results, the effects of land use types of silvopastoral areas were examined with reference to cattle management of the farms. In the analyses, regression models were developed to estimate milk yield based on land use parameters with herd and pasture parameters.

Table 1.1 Study framework

Survey and analysis	Objectives	Methods	Chapter
General farm survey	Characterise the main features of the farming systems in the study area	Existing farm interview data of 43 farms	3
Pasture and tree survey	Evaluate grazing areas with regard to pasture, tree cover and slope in dual-purpose cattle production systems	Stratified samplings of grass cover by grass type, tree cover and slope classes (153 plots of 31 farms)	4
Land survey	Define and specify the areas of main land use types with regard to pasture types and tree density in dual-purpose cattle production systems	GIS analysis of land use data of farm lands based on satellite images, farmer interviews, and field surveys (74 farms)	5
Herd survey	Describe the herd characteristics with regard to structure and production in dual-purpose cattle production systems	Seasonal interviews (4 times every three months) on herd and production data for 74 farms	5
Analysis 1	Examine the relations between land use pattern and herd characteristics	Correlation analysis between herd management, land use parameters and milk production (74 farms from the land and herd surveys)	5
Analysis 2	Examine the effects of silvopastoral areas on milk production	Multiple regression analysis of herd management and land use parameters on milk production (74 farms from the land and herd surveys)	6
Analysis 3	Examine the effects of silvopastoral areas on milk production	Multiple regression analysis of herd management and land use parameters on milk production by using principal components (74 farms from the land and herd surveys)	6

Chapter 2 Literature Review

2.1 Introduction

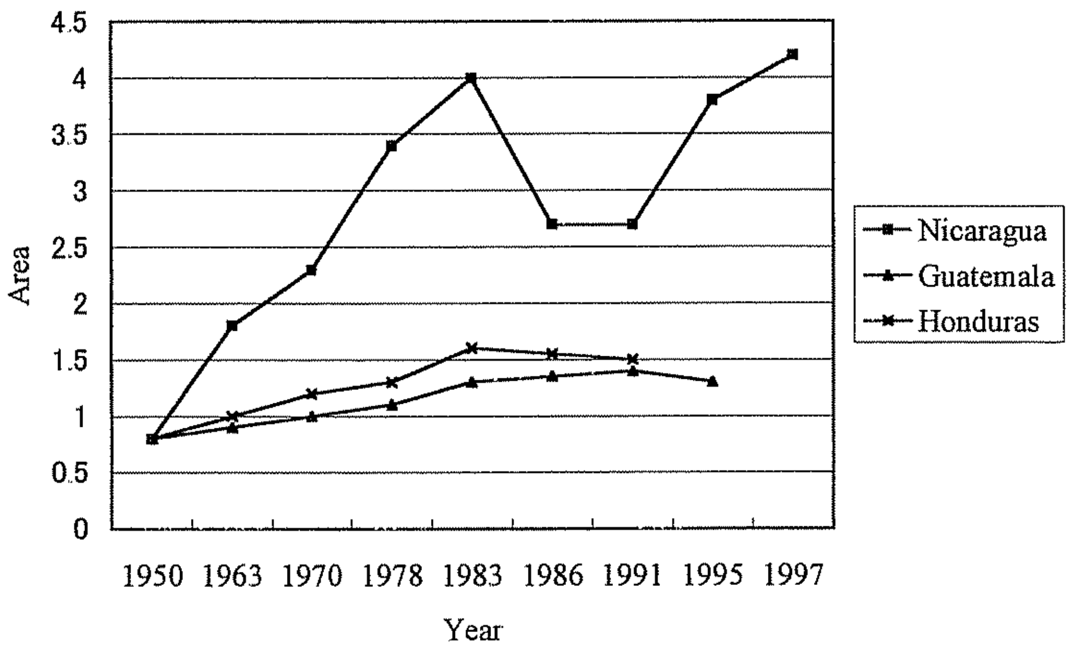
This chapter covers general issues about deforestation, characteristics of tropical pasture species and dual-purpose cattle production systems, grazing management, and effects and use of trees in cattle production. Since each chapter is written as an independent article in this thesis, the general issues are also covered in the introduction of each chapter.

2.2 Deforestation and pasture development in Central America

According to the United Nations' tropical forest survey report, southern Mexico and Central America had a deforestation rate of 1.5 percent per year in the 1980s (FAO, 1993). It was estimated that 82 percent of Central America's original natural forest had disappeared by 1989 (Myer, 1994). During the period of 1990-1995, natural forest cover continued to decrease in Central America with an annual rate of 2.1 percent, which is the highest in Latin America (UNEP, 2000). It was estimated that total deforestation in Central America was around 400,000 hectares per year in the late 1970s and 300,000 hectares in 1990 (Kaimowitz, 1996). It is generally recognized that deforestation in Central America is a result of conversion to pasture (Parsons, 1976; Myer, 1981; Kaimowitz, 1996). Geographically, pasture expansion has moved from dry areas of the Pacific and central regions towards the more humid area of the Atlantic plains (Kaimowitz, 1996).

In Nicaragua, the deforestation rate was once reduced between 1983 and 1989 due to the military conflict, but it increased again after the end of the conflict (Maldidier, 1993). As shown in Figure 2.1, pasture area was reduced in the mid 1980s and increased rapidly again in the 1990s.

Figure 2.1: Pasture development in Central America
(unit: million ha)



Source: Szott et al. (2000).

2.3 Dual-purpose cattle production systems

2.3.1 General characteristics of dual-purpose cattle production systems in Latin America

In Latin America, cattle production is an important activity in the rural economy due to its advantages compared to other forms of agricultural production: low requirement of skill and labour, low risk, daily income from milk sales, cattle as a savings, and easy transfer of products to market (Hecht, 1992; Muchagata and Brown, 1999).

Dual-purpose cattle production (milk and meat) systems have been described as the traditional cattle production systems of small and medium sized family farms in the lowland tropics of Latin America (Sere and de Vaccaro, 1985). Dual-purpose cattle production systems have been preferred by small and medium sized farms due to the advantages of 1) reducing risk from price changes of milk and meat, 2) higher economic productivity per area than meat production, 3) adaptation to the climate conditions of the lowland tropics, 4) less capital investment and technical support required than for specialized milk production, 4) reduction of mastitis incidences because calves are suckled by their mothers (Sere et al., 1985; Holmann, 1989).

Dual-purpose cattle production systems in the lowland tropics are of intermediate intensity, very efficient in the use of medium and poor quality forage resources, and fluctuating in terms of quantity and quality in order to produce beef and milk at reasonable prices (Sere and de Vaccaro, 1985). These systems are based on production from local cattle of mixed Zebu, Criollo and European inheritance (Aragon, 1981). In dual-purpose cattle production systems, milking cows are milked once in the morning and calves are kept with their mothers for a certain time during the day until weaning (Aragon, 1981). After weaning, generally male calves are sold and female calves are kept as replacement heifers.

In dual-purpose cattle production systems, cattle constitute the main capital investment in the system: very small allowance for depreciation is needed. Mating is natural or uncontrolled, and calves are enclosed for the night frequently without access to feed or water. Very few farms implement adequate health programmes for cattle. There is a low calving rate, in the range of 50-60% (Sere and Vaccaro 1985).

2.3.2 Milk production of dual-purpose cattle production systems

Milk production of dual-purpose cattle in lowland tropics with calves and with limited use of concentrates have been reported by several authors: Sere and de Vaccaro (1985) in Colombia and Panama (750 and 950 litres/cow/lactation), Vaccaro et al. (1992) in Venezuela (700-1,000 litres/cow/lactation), and by Wilkins et al. (1979) in Bolivia (600-1,200 litres/cow/year). Based on production data of FAO 1974 to 1989, Simpson and Conrad (1993) estimated the average milk production in Central America, is 946-995 litres/cow/lactation. In Bolivia, Wilkins et al. (1979) observed that when grazed on improved pastures and supplemented with concentrates, cows produced 2300 litres of milk per year including approximately 700 litres consumed by the calf before weaning. He also estimated that maximum milk production per cow with improved pastures without concentrates was approximately 2,000 litres/year without the presence of calves.

In dual-purpose cattle production systems, generally calves suckle their mothers. The advantage of this system is to produce calves, while avoiding mastitis, but saleable milk production is reduced due to the milk consumption by calves. In addition, the presence of calves restricts mating at the early stage of the lactation period, resulting in longer calving intervals.

2.3.3 Intensification of dual-purpose cattle production systems

The intensification of dual-purpose production systems to increase productivity per area were discussed by several researchers. Nicholson et al. (1994) found in dual-purpose cattle production systems in Venezuela that using locally available feeds such as molasses and urea is profitable and nutritionally feasible, but the results depend upon labour costs and availability because feeding with supplementary fodder requires more labour. Other studies reported for Central America showed that profitability of intensification of the system is constrained by credit availability in Nicaragua and by high infrastructure costs in Costa Rica (Holmann, 1999). Murgueitio (1990) proposed that intensification of cattle production should be based on some advantages of the tropical environments: the high potential for biomass production and genetic diversity of the plants, the use of sugar cane as an energy source and diversified nitrogen fixing trees as protein sources.

2.4 Grazing management

Grazing management systems on farms can be largely divided into two main systems: 1) continuous grazing and 2) rotational grazing. Continuous grazing favours production per head during the growing season due to the selective grazing by animals but may result in overgrazing of palatable species. Rotational grazing can eliminate overgrazing, but requires a greater level of managerial skill (Crowder, 1985). In rotational grazing, animals are kept in fenced pastures (paddocks) where water is provided in each paddock. In general, animal performance does not differ significantly between the systems when the grazing area is small, but rotational grazing shows better animal performance when the grazing area becomes large (Heitschmidt and Tayor, 1991). In rotational systems, paddocks may be occupied by animals for long periods with low stocking rates or for short periods with higher stocking rates. Short duration rotational grazing is more common in the humid tropics in order to take advantage of the rapid forage growth (Payne and Wilson, 1999). However, the costs of fence construction for paddocks and labour needs for herding restrict farmers from using short duration systems.

2.4.1 Stocking rate and productivity

Jones and Sandland (1974) examined the results of 114 experiments with stocking rate for beef cattle in temperate and tropical regions and concluded that a simple linear relationship could be used to predict production per animal as a function of stocking rates ($y_a = a - bx$ where y_a is animal gain/head and x is stocking rates expressed as animals/hectare). It suggests that production per area (y_h) is $y_h = ax - bx^2$. The Jones and Sandland model illustrates that in order to reach maximum animal production per area, stocking rate is optimal at only half of the stocking rates (a/2b) in order to maintain animal weight (Point c). This result implies that animal production per animal is higher with lower stocking rates because animals can select forages with higher nutritional value, while at higher stocking rates, animals need to consume the poorer parts of available forage (Bayer and Waters-Bayer, 1998).

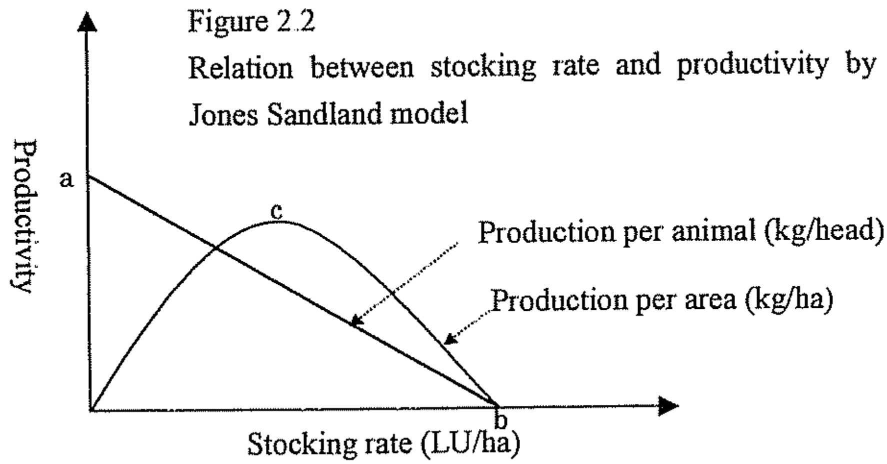


Figure 2.2
Relation between stocking rate and productivity by the Jones Sandland model

2.4.2 Stocking rates in rotational grazing

Stocking rate is defined as the number of animals of a specified class or animal units per area of land over a specified period of time (Heitschmidt and Tayor, 1991). One method of calculating stocking rates utilises livestock units (Upton, 1993). Bodyweights of animals of different types are converted into livestock units by using conversion factors based on the relative feed energy requirements per head. In rotational systems, the stocking rates for each paddock may vary seasonally depending upon pasture growth. The effective stocking rate for each paddock can be calculated as follows:

$$\text{Stocking rate (livestock unit /ha/day)} = \frac{\text{Herd size (livestock units)} \times \text{Grazing period (day)}}{\text{Area of Paddock (ha)} \times (\text{Grazing period} + \text{Resting period})\ \text{(day)}}$$

2.4.3 Herd stratification for rotational grazing

Stratification of herds within the farms can be a tool to improve grazing management. Animals can be grazed in different groups based on nutritional requirements. Lactating cows, young heifers and fattening steers have the greatest requirements. Cows with larger unweaned calves, heifers approaching the age for first mating, and non-working bulls can be grazed on the nutritionally poorer pastures (Chesworth, 1992; Payne and Wilson, 1999).

2.5 Pasture management in the humid tropics

2.5.1 Pastures in the tropics

Tropical grasses in general have lower voluntary intake and dry matter digestibility than temperate grasses due to the higher fibre contents associated with tropical climates (Minson, 1981). The reasons for low digestibility are a) thick epidermis and high concentration of silica in the surface of forage, b) early lignification of vasculars tissues, and c) high percentage of lignin (Gutierrez, 1996). High temperatures in the tropics facilitate biochemical reactions towards lignification of tissues, resulting in reduced digestibility of the forage. As light intensity increases, concentration of soluble carbohydrate increases, but crude protein, structural carbohydrates, and crude fibre concentrations are reduced (Gutierrez, 1996).

Pasture can be classified in many ways (Table 2.1). Natural pastures are indigenous to the region or naturalized after a long history of introduction. Natural plants grow without cultivation or sowing. Cultivated pastures are sown or managed specifically for livestock production in order to have higher nutrient values and/or growth rates and because of ease of establishment and persistence. Natural pasture can contain palatable or non-palatable species, while introduced/cultivated pasture are generally palatable species. Some introduced pasture species is either cultivated or naturalized (e.g. *H.rufa*). Major cultivars for the tropics are presented in Table 2.2.

Table 2.1

Classification of pasture species

Type of classification	Precedence	Natural or cultivated	Palatable or non-palatable	Examples of Pasture species
Classification	Native	Natural (Native)	Palatable	*Paspalum notatum*
			Non-palatable	*Paspalum virgatum*
	Introduced	Naturalized	Palatable	*H.rufa* *Ischaemun ciliare*
		Cultivated	Palatable	*Panicum maximum* *B.brizantha H.rufa*

Table 2.2

Characteristics of major cultivated pasture species

Name	Productivity	Crude Protein	Digestibility	Main Characteristics
/Unit	DMt/ha/year	%	%	
Andropogon gayanus	10-25	7-10	50-55	Resistant to spittlebug, low soil fertility requirements, drought tolerance, medium quality
Brachiaria brizantha	8-20	7-14	50-55	Medium soil fertility requirements, medium to high quality, resistance to dry conditions, high resistance to spittlebug, not tolerant to wet soil
Brachiaria humidicola	low	6-8	50-56	Low quality, long dormant period for germination, tolerant to flooding
Cynodon nlemfuensis	20-30	10-15	60-70	High quality, medium to high soil fertility required, short resting period required, rapid lignification of stolon
Hyparrhenia rufa	15	4-8	50-60	Tolerant to dry/wet and trampling conditions, medium to low soil fertility requirements, high fertility of seeds, lose green in dry season
Panicum maximum	10-30	10-14	60-70	High yield and high soil fertility required, less tolerant to dry climate than *Brachiaria spp.*, seed production all year
Pennisetum purpurenum	40-50 80-120 (King grass)	7-10	50-60	Medium yield and high soil fertility required, appropriate management and fertilization are required to maintain production, Normally cut every 50-70 days

Source; Peters et al. (2003); Serrão and Toledo (1992).

2.5.2 Pasture quality and grazing management

Stocking rates, grazing systems, and grazing intervals in rotational systems also affect pasture quality. Longer periods of occupation and shorter periods of rest improve pasture quality (Vickery, 1981). Vickery (1981) also noted that higher stocking rates can increased forage utilization and animal production per unit area through increased nitrogen cycling and by changing the botanical composition of the pasture. Whiteman (1980) suggested that longer rest periods in a rotational system reduce pasture quality, decreasing the digestibility of dry matter and crude protein content. It has also been observed that pasture crude protein content was increased with higher grazing pressure because higher tillering levels lead to better quality (Martinez et al., 1993).

2.5.3 Sustainability of pasture management

The main aspects of pasture management are 1) regulating grazing to maintain cover and production of palatable perennial grasses that are the forage base for livestock, and 2) limiting invasion or encroachment of unpalatable woody vegetation (Archer, 1996). Sustainable pasture management requires maintaining soil resources in order to ensure production of favourable palatable vegetation. In the humid tropics the equilibrium of grass and herbivores seems to be appropriate because rainfall is relatively constant and predictable and the community is largely comprised of perennial plants (Tainton et al., 1996). It is generally agreed that it is inevitable that pasture productivity in the humid tropics will be reduced in the absence of fertilization or symbiotic nitrogen fixation by legumes (Humphrey, 1994; Fisher et. al., 1996).

2.5.4 Fertilisation for pasture production

Tropical grasses are capable of producing 50t DM/ha/year, but in practice, the yield is less than one third of the potential (Minson et al., 1993). Fertilizer application may improve and/or maintain pasture yield and milk production. The response of grass to nitrogen application varies, but generally high yielding grasses such as *Panicum maximum* and *Pennisetum purpureum* respond better with higher stocking rates. Nitrogen application can increase pasture yield by up to 100kgDM/ha per kg of N applied (Gutierrez, 1996). The experiment of *Panicum maximum* with 200kg/ha/year of N application showed that total digestible nutrient did not decrease during nitrogen application but decreased after ceasing the application (Humphreys, 1987). Jones et al. (1995) observed in a 20 year experiment of N and superphosphates with various stocking rates on mixtures of *Panicum maximum* and *Chloris gayana* that the proportion of *P. maximum* declined without N with higher stocking rate, but *P. maximum* became dominant with N application and higher stocking rates. Gartner (1966), cited by Humphreys (1987), illustrated the change of botanical composition between *Pennisetum clandestinum*, *Paspalum dilatatum* and *Axonopus affinis* along with nitrogen application. Pasture species such as *Brachiaria brizantha* and *Andropogon gayanus* have relatively low critical phosphorous levels (Gutierrez, 1996). In order to maintain the productivity of *Pennisetum purpureum*, fertilization of N 50-75kg/ha/year, P 20kg/ha/year and K 50kg/ha/year should be applied (Peters et al., 2003). Hernandez-Garay et al. (2004) observed a weight gain response to three levels of N application (112-336 kg/ha/year) on various stocking rates (2.5-7.5 bull/ha) in *Cynodon nlemfuensis*, and suggested that in order to be profitable with higher N applications, stocking rates need to be sufficiently high. Moreover, it should be noted that nitrogen fertilizers may cause acidification through nitrification of NH_3 to NO_3^- (Lal et al., 1989).

Grasses respond well to nitrogen, but in general tropical legumes respond better to phosphates than grasses (Gutierrez, 1996; Bayer and Waters-Bayer, 1998). In soils deficient in elements, phosphorous application can increase the legume contents up to ten times (Bayer and Waters-Bayer. 1998).

2.5.5 Legume-grass mixture

Legume-grass mixtures are favourable for cattle production for several reasons: 1) legumes stabilize soil nitrogen and organic carbon contents in the root zone and provides nitrogen for the grass by their nitrogen fixing capacity, 2) legumes provide higher animal production through increased crude protein content of herbage and voluntary intake by cattle, 3) legumes mitigate seasonal reductions in forage production due to their abilities to maintain growth during drier periods (Crowder, 1985; Humphreys, 1987; Crowder and Chheda, 1982).

However, management skills are needed to maintain legume-grass mixtures. In general, legumes cannot compete against grasses under fertile soil conditions (Bayer and Waters-Bayer, 1998). In addition, legumes are more susceptible to diseases and pests than grasses. In legume-grass mixtures, frequent grazing reduces total dry matter yield but may help to sustain the legume component due to the increased light availability for prostrate species (Vickery, 1981). In legume-grass mixtures, well-timed grazing during the period of strong grass growth in the early wet season may reduce competition from grass, favouring the legume component. Since management of competition between grassrd and legumed is not easy, compatibility of the selected species needs to be considered. In general twining tropical pasture legumes are unstable under commercial stocking rates (Minson et al., 1993). Ibrahim and 't Mannetje (1998) concluded that *Brachiaria brizantha* and *Arachis pintoi* showed high compatibility in systems with high stocking rated under humid tropical conditions.

2.6 Fodder management in the dry season

In extensively managed cattle production systems in the semi-humid tropics with limited supplemental feeding, production is directly affected by seasonality of forage production. Fodder availability and quality in the dry season is critical to livestock production. Crude protein content of mature grasses often drops below 1.5% (Crowder, 1985), which is far lower than the level at which microbial activity in the rumen is depressed by lack of nitrogen (less than 7% CP). Weight loss of animals during the dry season can be 50-60% of the weight gained during the wet season (Bayer and Waters-Bayer, 1998). Stocking rates during the dry season can be maintained by introducing improved pastures, applying N fertilizers, and using grass/legume mixtures so that pastures have higher crude protein level (Golding, 1985).

Small farms in the tropics, under extensive management and with limited use of concentrates and/or fertilizer may not pursue either high production per animal or per area, but are interested in acceptable production from locally available resources. They may feed animals for growth when good forage is available, but use other low quality feeds to meet maintenance requirements when forage is in short supply. Management strategies to overcome problems associated with forage availability are to 1) reduce the number of animals, 2) conserve forage for the critical period, 3) use supplemental fodder from other available sources, 4) use fallow as a source of fodder, and 5) use trees in grazing areas (i.e. introduce silvopastoral systems).

2.6.1 Forage conservation

Forage conservation is essential where fodder shortage is severe during the dry season. Forage may be conserved as pasture reserves (range enclosure), conserved forage from pasture as hay or silage, stored crop residues, and conserved other forage crops as hay, silage or fodder banks (Bayer and Waters-Bayer. 1998). Pasture reserves are more effective when used to feed those that would benefit most from supplementary feeding (e.g. weaners) (Payne and Wilson, 1999).

However, haymaking from tropical pastures is highly unsuccessful due to poor herbage quality (Crowder, 1985). In addition, silage is not generally favoured because of the coarse stems, high crude fibre and low soluble carbohydrates of tropical pastures (Crowder, 1985). In order to have successful silage, most tropical forages need extra supply of sugar which allows micro-organisms to produce lactic acids and create a low pH environment for fermentation except for those that contain some starch and sugars from grain development

(Choesworth, 1992). Dry standing hay has been a valuable forage source for ruminants. Crude protein level of standing hay can be as low as 7% at the beginning of dry season (Golding, 1985).

2.6.2 Supplementation using alternative feeds

Alternative feeds include non-protein nitrogen, plant sources and by-products. Small farms in rural areas generally have access to plant sources and occasionally to non-protein sources for supplementary fodder.

2.6.2.1 Non-protein nitrogen

Ruminants have the ability to use both protein and non-protein sources of nitrogen. Non-protein nitrogen (NPN) provides ammonia, which can be converted to microbial protein by micro-organism in the rumen. Common non-protein nitrogen sources in Central America are urea and poultry waste. Urea contains about 46% N which is equivalent to 287% CP and poultry waste contains 50-60% CP (Chesworth, 1992).

2.6.2.2 Plant sources

Crop residues, tree leaves and fruits, surplus vegetables and fruits and cover crops can be used as fodder in the dry season. Cereal grains are usually expensive due to the low levels of production in the humid tropics and the demand for them as human foods. Crop residues available in Central America include a variety of forages such as maize stover, leaves, pods and stems of grain legumes, sugar cane residues and cassava leaves. Crop residues are generally low in nutrients, but when supplemented with small amounts of energy, untreated crop residues plus urea, or ammonia treated residuals have maintained cattle weight (Golding, 1985). Sugarcane (*Saccharum officinarum*) maintains a relatively constant nutritive value as it matures due to its increasing sugar content and decreasing digestibility of the fibrous components (Golding, 1985). In Costa Rica, bananas rejected for export are successfully utilized for cattle feed (Golding, 1985) and did not show differences in live weight gain from the supplement of Erythrina protein bank (Ibrahim, 2000). As fodder from trees, legume trees have leaves rich in crude protein, vitamin and minerals. Due to the deeper root systems, the nutritional quality of tree leaves tends to change less during the dry season (Pezo et al., 1990).

2.6.3 Fallow grazing

The land unused for organic matter accumulation when weeds surpass after years of cultivation is generally called fallows (Arnon, 1987). Fallows can be an important fodder source for animals in the dry season. In woodland areas managed under grazing, herbaceous undergrowth of trees is grazed, but leaves, fruits, pods, and seeds of trees are also an important forage source. Several authors have reported fallow grazing in Central America. Alfaro and Rojas (1992) explained that leaves and fruits of legume trees such as *Mimosa tenuiflora, Gliricidia sepium, Pithecellobium dulce,* and *Enterolobium ciclocarpum* in fallow areas are consumed by cattle during the dry season in the Pacific side of Costa Rica.

For the Pacific side of Honduras, Kass et al. (1993) described cattle grazing under short-term fallows with *Mimosa tenuiflora* after maize-sorghum cultivation. This system helps maintain soil fertility with low levels of external inputs (e.g. labour, fertilizers and pesticides). In Guatemala, Flores-Ruano (1994) observed that cattle and goats consumed *Guazuma ulmifolia*, *Gliricidia sepium*, *Erythrina berteroana* and *Spondias spp.* In West Africa it was observed that some fallow fields have a relatively high proportion of palatable legumes, thus providing better quality diets to animals than the natural range (Bayer and Waters-Bayer, 1998).

2.7. Pasture Degradation

2.7.1 Definition

Pasture degradation can be considered as a negative change of pasture conditions (quality, productivity and botanical composition) through ecological and environmental changes or simply as a decrease in pasture quality that reduces animal production (Szott et al., 2000). It has been stated that pasture degradation is the most serious problem in cattle production in Central America (de Groot et al., 1996; Szott et al., 2000).

Pasture productivity may decline after years of grazing due to lack of appropriate fertilization or combination with legume as well as the encroachment of weeds and low quality naturalized grass on the sown pasture. In grass-based pastures, it was observed that pasture productivity decreased due to the gradual immobilization of N in the system (Humphreys. 1987).

2.7.2 Pasture degradation caused by soil degradation

Pasture degradation can be caused by soil degradation as a result of overgrazing, particularly when combined with frequent burning. These practices often lead to soil compaction and loss of nutrient and organic matter in the soil (Szott et al., 2000). Soil degradation is defined as diminution of soil quality (current and potential) and/or a reduction in its ability to be a multi-purpose resource due to both natural and man-induced causes (Lal et al., 1989).

It has been argued that lower pasture productivity is inevitable in extensive livestock production systems in the humid tropics in the absence of fertilization or symbiotic nitrogen fixation by legumes (Humphrey, 1994; Fisher et al., 1996). Since tropical grasses in general have poor nutritional values due to the lower voluntary intake and dry matter digestibility (Minson, 1981), farmers may need to eliminate woody weeds in pastures by weeding or burning. Pasture productivity may increase for a short time by burning due to improved soil fertility and the elimination of woody weeds, but productivity may fall afterwards due to the loss of organic matter (Da Veiga, 1995). Invasion by undesirable weed plants may be worsened when this practice continue. Boddey et al. (2000) reviewed the process of pasture degradation and suggested that it is important to apply 25kg P and 15kg K/ha/year in order to maintain pasture productivity.

Reduction of nutrient contents in the soil occurs after overgrazing. Soil N is the first constraint for pasture production, and mineralization of organic matter is the main source of nitrogen (Humphreys, 1994). Serrao et al. (1978) found that in Oxisols and Ultisols, pasture productivity fell as a consequence of overgrazing due to the loss of P in the soil and particularly when the clay content of the soil was high. Da Veiga. (1995) also suggested that under low soil fertility, the availability of P is the critical element for pasture stability since N, K, Ca and Mg do not suffer great losses. However, the extraction of phosphorus by animals is limited since most of the phosphorus extracted is for bones and teeth. Therefore, it is suggested that phosphorus changed forms in the soil and became unavailable due to the lowered pH which was caused by the reduction of organic matter from overgrazing. Organic matter maintains soil pH by producing organic acids which are responsible for the removal of large quantities of base-forming cations (Na^+, Ca^{2+}, Mg^{2+}, K^+, etc.) by dissolution and leaching, thus contributing to a reduction in acidity (Brady, 1990). Asner et al. (2004) found in the Amazon Basin that aboveground and soil C and P stocks decreased with pasture age and that the decline of plant biomass is correlated with the reduction of C, available P and Ca in the soil. RongGui et al. (2003) also found in China that reclaiming grasslands from farmlands resulted in a sharp decline of organic phosphorus in the soil.

2.7.3 Pasture degradation and changes in botanical composition

Pasture degradation may simply be loss of vegetation cover of desirable pasture species on the ground. Muller et al. (2004) observed different levels of degradation of *Panicum maximum* followed by *Andropogon gayanus* in Brazil and found that soil bulk density at the topsoil increased but organic carbon and total nitrogen did not differ between pastures under different levels of degradation. Lilienfein and Wilcke (2003) compared different ecosystems in the Brazilian savanna and concluded that there were no significant differences in total C, N, P and S storage between productive pasture and degraded pasture. Soares et al. (2001) concluded after a seven year experiment that application of P_2O_5 every two years increased dry matter yields but did not prevent pasture degradation.

The loss of pasture cover may be caused by poor weed control (Szott et al., 2000). Pastures encroached on by unpalatable weeds may easily allow more invasion due to overgrazing of palatable species, heading to an initial stage of succession toward original vegetation (Wiseman, 1978).

Botanical composition may be changed by different grazing pressure due to the different resistance of pasture species. Deterioration of botanical composition by overgrazing may occur due to an increase in unpalatable or toxic plants (Humphreys, 1994; Bayer and Waters-Bayer, 1998). Stobbs (1969) observed a higher rate of weed invasion under higher stocking rates between *Hyparrhenia rufa* and *Sporobolus pyramidalis* (Humphreys, 1987). In the short-grass prairies of the United States, bunchgrass, (*Agropyron desertorum)* which grows well under heavy grazing, can effectively replace the native species *A. spicatum* which is favoured by lower grazing intensities (Aber and Melillo, 1991). Humphreys (1987) reported that grassland on loose textured soil in India lost *Dichanthium* due to its high palatability as grazing pressure increased. Over time, the pastures were dominated by *Cynodon dactylon* and *Eleusine compressa*, then *Aristida* spp. and then by annual *Cenchrus biflosrus*. They were finally dominated only by unpalatable annual weeds and bare soil.

2.8 Effects of trees on livestock production in the humid tropics

The use of trees has multiple effects on livestock production. There are direct effects on animals and also indirect effects through pasture, fodder and soil. By using trees, livestock production may become intensified, diversified and more sustainable, thus aiding soil conservation.

2.8.1 Effects of trees on soil conditions

Trees increase organic matter levels in soils resulting in an increase in the quantity of mineralizable nitrogen, lower bulk densities, and an increase in available phosphorous through higher litter accumulation (Belsky et al., 1993; Young, 1997). Trees, particularly leguminous species improve soil fertility. Belsky (1992) found in Kenya that grass growth and nitrogen, phosphorous, potassium, and calcium contents in soil were higher under *Acacia tortilis* and *A. digitata*. Montagnini and Sancho (1994) found on abandoned pastures in Costa Rica that net nitrification potential rates under plantations of *Stryphnodendron microstachyum* and *Dalbergia tucurensis* were higher than under non-leguminous trees and were comparable to those in secondary forests.

Trees contribute to soil stability by protecting the soil surface from the effects of intensive rainfall in the humid tropics. Organic litter provided by trees on the soil surface with high pore spacing contribute to the development of roots and soil fauna, maintaining a lower water table and higher infiltration capacity in the uppermost layers (Hamilton and Pearce, 1987; Pereira, 1989). As a result, trees on slopes slow torrent flow and they smooth the peaks of stream flow preventing soil erosion for a given watershed during intensive rainfall (Hamilton and Pearce, 1987; Pereira, 1989).

Soil under trees may be influenced by the presence of more animals who look for the cooler environments during hot temperatures. Soil under shade trees may have more nitrogen because of animal excrements, but soil may be more compacted due to higher pressure of animal trampling (Agüero and Alvarado, 1983), which potentially causes lower grass yields .

2.8.2 Effects of shading on pasture

The magnitude of shading produced by trees depends upon the species, density, height, physiology and spatial arrangement of trees. Since most tropical grasses are C_4 plants which have maximum photosynthesis levels at high radiation, radiation reduction by shading can reduce pasture production (Minson, 1981; Shelton, 1987; Somarriba, 1988).

However, soil under tree cover may support a higher level of grass production in the dry season due to the higher water holding capacity of the soil and the lower moisture loss through evaporation as a consequence of lower temperatures in the daytime (Horne and Blair, 1991; Young, 1997). Durr and Rangel (2000) found under simulated sub-canopy environments that soil from under trees enhanced nitrogen levels and even under 70% shade conditions, produced higher dry weight of *P. maximum* than soil under full sun. Wong (1990) reviewed shade tolerance of tropical pastures and highlighted the importance of shading when nitrogen is not sufficiently applied.

Shading has positive impacts on pasture quality. Shading increases crude protein but reduces non-structural carbohydrates in forage grasses (Wilson, 1982). Shaded plants have thinner leaves and higher nitrogen concentrations than unshaded plants (Smith and Whiteman, 1983). Under shading, plants have higher leaf to root ratios. In general radiation has a larger impact on grasses than legumes in the tropics (Wilson and Ludlow, 1991) because legumes are favoured by lower temperatures.

2.8.3 Effects of leguminous trees on pasture production

It has been found that leguminous trees improve biomass production and nutrient values of pasture through nitrogen fixation. Pezo et al. (1990) compared intercropping with the leguminous tree, Poró (*Erythrina poeppigiana*) and the non-leguminous tree, Laurel (*Cordia alliodora)* and observed higher dry matter yields and significant increases in crude protein contents in African star grass (*Cynodon nlemfuensis*) when associated with leguminous trees. Benavides et al. (1994) conducted a two year experiment with Poró (*Erythrina poeppigiana*) and King grass (*Pennisetum purpureum*) in Costa Rica and observed that the total biomass production was higher in pastures with trees than without trees. Bolivar (1999) observed higher pasture production of *Brachiaria humidicola* sown with *Acacia mangium* (3m x 8m, 11m height on average) than in monoculture.

2.8.4 Effects of trees on animal production

Trees can have direct effects on animal production through shading, shelter, and feeding. The environment under trees is considered to have 2-3^{0}C lower temperatures (Wilson and Ludlow, 1991). Shading by trees in grazing areas may improve animal production: increased forage consumption by increased grazing and ruminating time, reduced water requirements, improved feed conversion efficiency, increased weight gain and reproduction (Pezo and Ibrahim, 1999). In particular, pure breeds and crossbreds of European origin (e.g. Holstein, Jersey, and Brown Swiss) require lower ambient temperatures for high milk production (Cowan et al., 1993).

2.8.5 Use of trees for animal fodders

Leaves and fruits of trees have the potential to provide fodder for animals. By feeding animals with tree fodder as supplements, farmers can prevent weight losses when the basal diet is nutritionally poor. Especially the leguminous tree leaves are rich in crude protein, vitamins and minerals. The nutritional quality of tree leaves tends to be maintained from season to season whereas the quality of grasses decline in the dry season (Pezo et al., 1990; Pezo and Ibrahim, 1999). However, the conditions and performance of animal may be worsened due to the presence of toxic secondary metabolic compounds [e.g. lower digestibility of protein by tannins (e.g. *Caliandra calothyrsus*), poor growth and reproduction and eye problems by mimosin (e.g. *Leucaena leucocephala*) and low consumption and weight loss by cumarin (e.g *Gliricidia sepium*)] (Norton, 1994; Pezo and Ibrahim, 1999). Soca et al. (1999) compared the nutritive values of *Albizia lebbeck* in the dry and wet seasons and concluded that this species is valuable as dry season fodder. Palma et al. (1999) found no seasonal differences in crude protein, crude fibre, or organic matter digestibility of *Leucaena leucocephala* and *Calliandtra calothyrsus*. Crude protein and *in vitro* forage digestibility of major trees found in pastures in Guanacaste, Costa Rica are shown in Table 2.3.

2.9 Silvopastoral systems

Silvopastoral systems (SPS) are livestock production systems that include trees with pastures and animals in order to improve sustainability under integrated management in the long-term (Pezo and Ibrahim, 1999). The potential role of silvopastoral systems is to produce material outputs (e.g. fuel, fruits, timber, fodder, fences) and/or services to create intangible benefits (e.g. shelter, soil fertility, soil erosion control, wind breaks) (Torres, 1983). Silvopastoral systems can be classified into several types based on functions and structures of trees in pastures, namely: 1) live fences, 2) protein banks, 3) alley farming, 4) dispersed trees in pastures, 5) grazing under forest or fruit plantations, and 6) wind breaks (Pezo and Ibrahim, 1999).

Table 2.3

Crude protein and *in vitro* dry matter digestibility (IVDMD) of leaves and fruits found in pastures in Guanacaste, Costa Rica

Species	Local names	CP (%)	IVDMD
Leaves			
Gliricidia sepium	Madero negro	17.5	51.8
Pithecellobium saman	Cenizaro	19.9	41.2
Spondias purpurea	Jocote	13.7	55.4
Tabebuia ochracea	Cortez amarillo	16.7	40.6
Piscidia carthagenensis	Pellejode toro	15.5	41.7
Enterolobium cyclocarpum	Guanacaste	17.4	36.0
Lysiloma divaricata	Quebracho	10.2	47.5
Guazuma ulmifolia	Guacimo	12.4	48.1
Fruits			
Enterolobium cyclocarpum	Guanacaste	16.2	79.0
Pithecellobium saman	Cenizaro	16.2	73.7
Spondia purpurea	Jocote	3.2	95.6
Mangifera indica	Mango	1.8	95.4
Piscidia carthagenensis	Pellejode toro	19.6	52.1
Guazuma ulmifolia	Guacimo	5.7	61.7
Lonchocarpus minimiflorus	Chaperno	16.0	48.2
Bauhinia ungulata	Casco de venado	10.1	59.0
Cresentia alata	Jicaro	5.8	60.6

Source: Pezo and Ibrahim, 1999.

2.9.1 Characteristics of major silvopastoral systems

Live fences to divide grazing areas into paddocks by using trees are traditional used in Latin America. Holmann et al. (1992) estimated that live fences cost 46% less than conventional fences. Farmers can obtain posts and fuelwood from live fences thus reducing the pressure on natural forests. Common species utilized for live fences in Latin America are 1) trees for cattle forage such as Madero negro (*Gliricidia sepium)*, Poró (*Erythrina berteroana)*, Leucaena (*Leucaena leucocephala)*, etc. 2) fruit trees such as jocote (*Spondias purpurea)*, Marañon (*Anacardium occidentale*), etc. and 3) timber species such as jinocuabo (*Bombacopsis quinatum*), Cipres (*Cupressus lusitanica*), Cedro (*Cedrella odorata*), Teca (*Tectona grandis*), *Eucaliptus spp.*, etc. (Pezo and Ibrahim, 1999).

Forage banks are one technique to conserve forage in high density blocks. Forage banks are generally established near the place where animals are supplemented. Forage banks can be used for protein or as an energy bank depending upon the purpose of the establishment. By using forage banks, production per unit area and/or stocking rates can be increased, but more labour work are needed for cut and carry or maintaining the trees at a height that animals can reach for browsing (Pezo and Ibrahim, 1999).

Alley cropping is one type of agroforestry technique used to establish cultivation of annual crops in between the lines of fast growing trees. Trees are periodically thinned and the pruned branches and leaves are left as mulch (Pezo and Ibrahim, 1999). Alley cropping systems can be established as cut and carry systems with high yielding grasses (*Pennisetum purpureum* or *Panicum maximum*) and leguminous trees (Librero et al., 1994). Alley cropping systems can also be used for erosion control on steep slopes.

Cattle can be grazed in forest or fruit plantations. Cattle grazing in coconut, palm oil and rubber plantations is common in Asian countries (Chen, 1990; Shelton, 1990; Chong et al., 1990). In Latin America, grazing in fruit plantations including mango, orange, Pejibaje (*Bactris gasipaes*) and marañon (*Anacardium occidentalis*) are common practices (Lascano and Pezo, 1994). Advantages of grazing in plantations include increased and diversified of income, improvement of soil conditions, and weed control, but disadvantages are damage to the trees by animals, tree diseases transmitted by pastures, limited species selection, etc. In general, the use of shade tolerant pasture species, lower tree densities and lower stocking rates are the main characteristics of this type of silvopastoral system. Couto et al. (1994) observed Eucalyptus plantations in Brazil and suggested that there was no differences in tree survival between grazing and no grazing. Sharrow et al. (1992) also found limited tree mortality from sheep grazing in *Psedotsuga menziessi* plantations. Grazing can simply be utilized as weed control in plantations starting at early stages after trees reach a certain height and continue until the canopy closes.

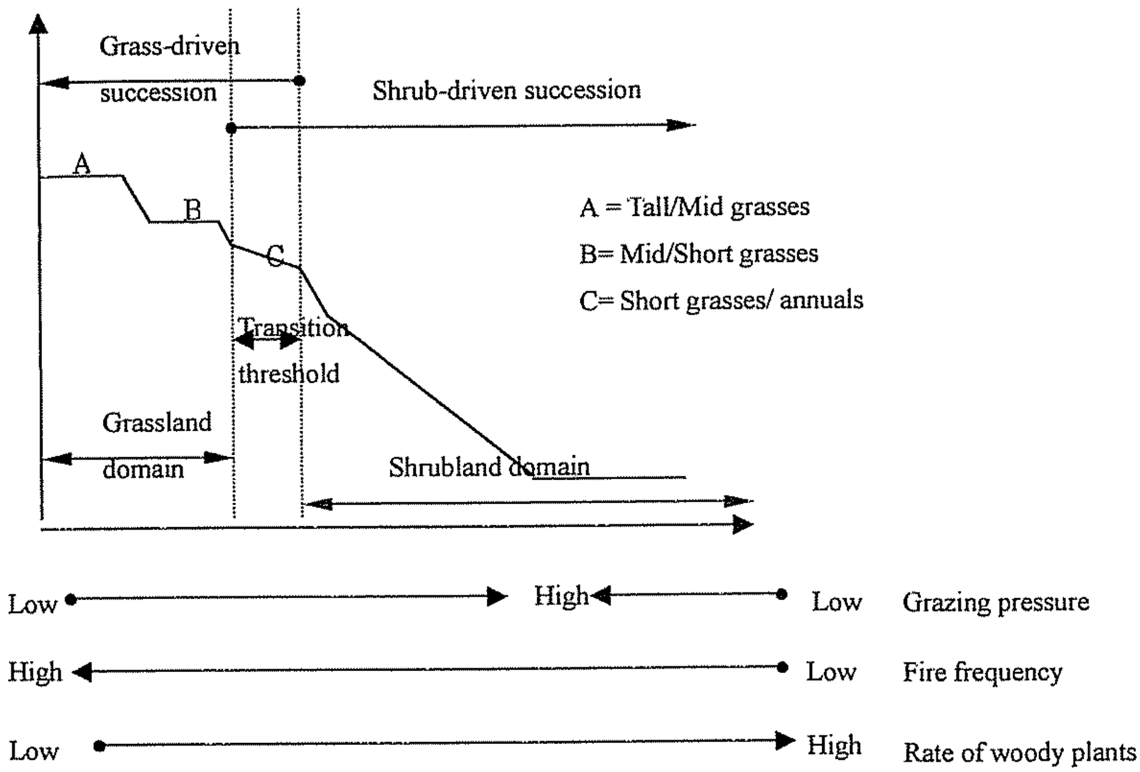
Wind breaks can be established for protection against cold wind and rain for animals and for pasture. Wind breaks are particularly important for seasonally dry areas since it may lengthen the availability of forage in the dry season (Pezo and Ibrahim, 1999). Wind breaks can be established as live fences thus utilizing their forage, fruits, fuelwood, posts, etc. but need to be protected from excessive browsing by animals in order to prevent wind from passing.

2.9.2 Dispersed trees in pastures

Dispersed trees in pastures are considered to be one type of silvopastoral system with relatively extensive management using natural regeneration. The establishment of dispersed trees in pastures depends upon farming practices for grazing and tree stand management, climatic and topographic site conditions, and the physiological characteristics of the trees species. Farmers maintain trees in pastures as shelter for cattle; a source of future timber; fence post; fuelwood and fruits; maintenance of humidity in grass during the dry seasons; wind protection; organic inputs; and soil fertility (Harvey and Haber; 1999). Farmers manage the density and spatial arrangement of trees through selective thinning, site enclosure to promote natural regeneration, tree planting, changing animal pressure, the use of herbicides and the introduction of exotic pastures or tree species (Pezo and Ibrahim, 1999). The use of low stocking rates may encourage successional recovery of woody plants, while high stocking rates may decrease above and below ground herbaceous biomass thus lowering the capacity of palatable herbaceous plants (Archer, 1996). Nepstad et al. (1991) found that forest growth on abandoned pastures is restricted by low propagule availability, seed and seedling predation, seasonal drought and root competition. He also found that forest growth was the slowest on pasturelands where bulldozers have been used.

The formation of dispersed trees in pastures are related to farm types. On farms under extensive management, dispersed trees may grow better due to lower stocking rates. In Colombia, Cajas-Giron and Sinclair (2001) found higher density of dispersed trees in pastures in drier areas with lower soil fertility where the production system is more extensive. However, when cattle grazing is combined with annual crop production, farmers may remove more trees. Souza de Abreu et al. (1999) observed in Costa Rica that dairy farms, which are more concentrated on livestock production, have more trees than farms with crop production. Archer (1995) illustrated the conceptual model of grass and woody plant interactions in grazing ecosystems (Figure 2.3). The model predicted the existence of transition thresholds between grasslands and woody plants. It should be noted that lower grazing pressure supports both forest and grasslands formation, thus higher stocking rates may support the establishment of woody plants on pasturelands by removing pressure from palatable grasses. Pezo and Ibrahim (1999) summarized the utilization of dispersed trees in pastures in Central America (Table 2.4).

Figure 2.3 Conceptual model of grass and woody plant interactions



Source: Archer, 1995.

Table 2.4
Dispersed trees in pastures and their utilization in the semi-humid tropics of Central America

Species	Local name	Fodder	Fuel	Timber	Shade
Acacia farnesiana	Espino blanco	XX	X		
Acacia mangium		X		XX	
Albizia guachipele	Guayaquil			XX	X
Cedrella odorata	Cedro			XX	
Cordia alliodora	Laurel			XX	
Croton gossyfolius			XX		
Enterolobium cyclocarpum	Guanacaste	X		X	XX
Ficus spp.	Higueron	X			XX
Gliricidia sepium	Madero negro	XX	X		
Guazuma ulmifolia	Guacimo	XX	X		
Hymanaea courbirol	Guapinol				XX
Inga spp.			XX		
Leucaena spp.	Leucaena	XX		X	
Mangifera indica	Mango	X			XX
Pithecellobium saman	Cenicero	X		XX	XX
Psidium guajaba	Guayaba	XX	X		X
Swietenia macrophylla	Caoba			XX	
Tabebuia rosea	Roble de sabana		XX	XX	
Tabebuia ochracea	Cortez Amarillo	XX		X	
Terminalia ivorensis				XX	
Vochysia ferruginea	Chancho Colorado			XX	

Modified from Pezo and Ibrahim, 1999.

Chapter 3 (Article 1)

Characterization of dual-purpose cattle production systems in the Matiguas region of central Nicaragua

Key words: Land use, farmer objectives, herd characteristics, productivity

Abstract

In order to characterise the socio-economic conditions of farmers, herd management, and productivity of dual-purpose cattle production systems in the Matiguas region of central Nicaragua, results from 43 farmer interviews were analysed. The study results showed that farmers were rather new in the area (10.3 years on average), and were largely engaged in cattle production combined with crop production (corn and beans). Family members (average of 6.2 members) were the main labour resources, but farmers frequently employ permanent and seasonal labour. Farmers preferred to increase the number of animals than to improve or increase fencing, pastures, or land area. On average, farms had 33.4 heads of cattle, 66% of which were cows, and the average stocking rate was 0.98 LU/ha. *P. maximum* and *H. rufa* were the main cultivated pastures, but natural pastures occupied approximately half of the pasturelands. *B. brizantha* and *Pennisetum spp.* for cut and carry systems were recently sown pasture species. Ninety five percent of farms used salt and 65 % of farms used molasses as supplementary feeds for cattle, but the amount of molasses fed seemed to be limited. Eighty eight percent of the farms had Brahman x Brown Swiss crossbred animals, mostly 1/2 to 3/4 European blood. The sales from cattle

production was US$6,840/year/farm (net income US$4.1/day per family labour), 65% of which comes from milk production. Average milk production was estimated as 1,056 litres/lactation, with gross margins for cattle production of US$205/LU and US$164/ha. Gross margins were higher than expected, given the low average milk yield, but it is explained by the low average variable costs (US$ 476/year), which were equivalent to only 7% of the annual sales from cattle production. The proportion of cut and carry forage had positive effects on daily milk production and the annual gross margin per hectare ($P<0.001$ in both cases) as well as annual animal sales ($P<0.05$). The proportion of area of *B. brizantha* was positively correlated to annual sale of animals per hectare ($P<0.001$), suggesting that pasture improvement supported higher cattle production. Considering higher milk price in the dry season and the obstacles to obtain locally available supplements, producing cut and carry forage may be an acceptable option for farmers, particularly for middle sized farms which have available farm lands though labour may be a constraint for the implementation. Further studies are recommended on the feasibility of pasture improvement with special attention to labour and land availability as well as the use of credit.

3.1 Introduction

Conversion of land from tropical forest to pastures has been criticised as a cause of deforestation in the humid tropics of Central America (Parsons, 1976; Myer, 1981; Kaimowitz, 1996). Cattle production in the humid tropics is constrained by the low productivity and low nutritional value of pasture and is commonly conducted with low labour and capital inputs; therefore, pasture areas are commonly degraded after years of grazing (Minson, 1981; Kaimowitz, 1996; Sunderlin and Rodriguez, 1996; Szott et al., 2000). On the other hand, extensive cattle production is an important activity in the rural economy due to its advantages compared to other forms of agricultural production: low requirements of skill and labour, low risk, daily income in the case of milk, cattle as savings, and easy transfer of products to the market (Hecht, 1992; Muchagata and Brown, 1999).

Dual-purpose cattle production (milk and meat) systems have been preferred by small and medium sized farms due to the following advantages: 1) reduced risk from changes in the price of milk and meat, 2) higher economic benefit per unit of area than meat production, 3) adaptation to the climatic conditions in the lowland tropics, 4) less capital investment and technical support required than for specialized milk production, 4) lower mastitis incidence because of calf suckling (Sere and De Vaccaro, 1985; Holmann, 1989; Souza de Abreu, 2002).

Nicaragua is considered to be one of the poorest countries in Latin America. It has a population of 5.3 million, a per capita GNI of US$720/year, and 48% of the population is under the national poverty line (World Bank, 2004). The agriculture sector comprises 32 % of the GDP. Cattle production is an important economic activity in Nicaragua. The cattle population in Nicaragua has increased in the last few years reaching more than 3.3 million heads in 2001 (FAO, 2003). In particular milk exports have increased 30 times in the last 10 years reaching US$ 3.5 million in 2001 (FAO, 2003).

At the old agricultural frontier in central Nicaragua, large cattle ranches that had been abandoned during the civil war in the 1980s were divided into small and medium sized farms in the early 1990s (Levard et al., 2001). As a result, small farms comprise most of the total area and presently 90 % of accessible cultivated land in the lowlands is occupied by pastures (NITLAPAN, 1995; Szott, 2000). In order to take advantage of family labour, and being constrained by limited land and capital, such small and medium sized farms in the region are largely engaged in dual-purpose cattle production. Existing dual-purpose cattle farms were recognized as one of the key targets for intensification of cattle production in Central America (Nicholson et al., 1995). In order to increase productivity, it is important to understand the farming systems of dual-purpose cattle production. The objective of this study is to characterise dual-purpose cattle production systems in the Matiguas region of central Nicaragua. The study first provides a description of the dual-purpose cattle production farms (land use, objectives, herd and pasture characteristics, and production indicators), then examines the effects of pasture improvement and herd parameters on productivity by correlation and multiple regression analysis.

3.2 Materials and methods

3.2.1 Study area

The study area is located in Matiguas Municipality in Matagalpa Department, central Nicaragua: Latitude 12^0 50' North and 85^0 27' Longitude East at the town of Matiguas. The altitude is 200-500m above sea level. The climate of the study area is semi-humid tropical with a well-defined dry season between February and May (savanna (Aw) by Koppen climate classification). Annual rainfall varies from 1,300 to 2,000 mm, while temperature fluctuates between 28 and 32^0C. Topographically, the land is generally flat with modest slopes (0-30%) but with small areas of steep slopes (> 30 %) (INTA, 1998).

The population density in the study area was approximately 29 inhabitants/km^2 (Levard et al., 2001). Seventy seven percent of the families live in the rural areas, and the illiteracy rate is approximately 40% (INIFOM, 1996). Cattle production is the main economic activity in the region and pastures dominate the lowland areas (altitude <400m) (Maldidier and Marchetti, 1996). Eighty four percent of the cultivated area in Matiguas is occupied by pasture, and corn/bean and coffee cultivation occupy only 14% and 2%, respectively (Levard et al., 2001). The soils are generally heavy clayey, which are difficult to cultivate with light equipment and are thus more suitable for cattle production than for crop cultivation (Levard et al., 2001).

The Matiguas region is considered to be "the old agricultural frontier" where large immigration, with people seeking land for extensive grazing to meet the demands of the international meat market, occurred in the late 1940s after World War II (Maldidier and Marchetti, 1996). Due to the political pressure during the civil war in the 1980s, large cattle ranches were abandoned and in the early 1990s these lands were divided into small and medium sized farms and made available to landless farmers (Levard et al., 2001). Since the second half of 1990s, the production of coffee, cattle and cacao have increased through the increased sales to El Salvador and technical assistance by the government and NGOs.

3.2.2 Farm selection

This study was based on farm interviews conducted as a baseline survey for the

"Regional integrated silvopastoral approaches to ecosystem management" project, undertaken by CATIE and NITLAPAN under the scheme of the Global Environment Facility (GEF) of the World Bank.

The Matiguas region is divided into four zones based on agro-ecological conditions: 1) relatively flat areas near the town of Matiguas where medium scale cattle farm enterprises are present (annual precipitation 1200-1600mm); 2) the south-eastern part of Matiguas where medium scale cattle farms are present under more humid condition (>2000mm p.a.), 3) north-western Matiguas where intensive farms are present in the highlands (>500m above the sea level); 4) the central part of the municipality and north of the town of Matiguas with steeper slope (30-50%) and moderate precipitation (1600-2000mm) (Levard et al., 2001). Sample farms were selected from two micro-watersheds: Limas and Paiwas covering three of the four agro zones (1, 2, and 4 of the classification above), which were considered to be important for cattle production. The town of Matiguas is located at the northern side of Limas. The distance between the two watersheds is approximately 20 km.

Participatory workshops were carried out with the farmers for each watershed in order to gather information about farm and herd size and distribution of farms in each watershed based on the database of the rural credit banks (FDL = fondo desarrolo local) along with interviews with key informants. The geographical distribution of the farms in the watersheds were mapped during the workshops. Approximately 190 farms were listed in the database for the watersheds and 43 farms were selected based on farm size (between 15 and 250 hectares), herd size (more than 5 cattle), and accessibility.

3.2.3 Farm interviews and questionnaires

Structured questionnaires were prepared by local experts to gather biophysical and socio-economic data of the farms. The farm interviews were carried out by technical staff of NITLAPAN in July 2001. Questionnaires consisted of 7 parts: 1) general characteristics of farms, 2) characteristics of farmers and their families, 3) farm description, 4) farm management, 5) production and sales, 6) production cost, 7) constraints and improvement measures of the farms (Appendix 3.1).

Some of the attributes included in the questionnaire are summarised as follows:

1) General characteristics of the farm: total area, access, infrastructure, land tenure, historical background of farm development, etc.

2) Characteristics of farmers and their families: sex, age, education, income and work outside the farms, etc.

3) Farm description: farm land sketch, existing and recent changes in land use, equipment and infrastructure, use of labour, etc.

4) Farm management: details of herd size and structure, change in herd inventory, cattle breeds, herd movements, reproduction methods, pasture management, labour and supplementary feeding, etc. Cattle breeds were classified based on the proportion of European breeds (*Bos taurus*) into 5 classes: 0, 25, 50, 75 and 100%. Farmers were asked the proportion of their herds for each class.

5) Production and sales: prices and amount of sales of timber, fuelwoods, crops, fruits, and cattle products (milk and animals).

6) Production costs: cost of supplements, fertilizers, herbicides, wire, transportation, veterinary services, seasonal labour, etc. for cattle production.

7) Constraints and potential improvement measures of farms: Farmers were asked about their constraints and potential improvement measures of their farms. The answers for the problems were chosen from a) security of land tenure, b) violence, c) lack of credit, d) lack of technical assistance, e) lack of support for marketing, f) low price of products and others. Those for potential improvement measures were chosen from a) move to farms located more inland, b) expand farms by land purchase in the same district, c) expand cultivation area for grains and increase the number of pigs for fattening, d) increase coffee production, e) increase number of cattle, f) make more pasture divisions, g) change pasture species, h) introduce irrigation, i) work for other activities, j) emigrate, k) off-farm work, and others.

3.2.4 Data analysis

The data obtained in the survey were summarized and production indicators (calving rates, calf and adult mortality rate,s culling rates of cows, and milk production per cow, farm and hectare), as well as economic indicators (annual gross margin on cattle and milk production and annual sales from cattle production) were estimated.

Major variables to describe farm characteristics [the number of permanent labourers per hectare (man/ha), stocking rates (LU/ha), proportion of steers (LU basis), calving rates, proportion of area for cut and carry forage and *B. brizantha* for entire grazing areas, and health costs per head], and economic indicators (gross margin, animal/milk sales per hectare) were compared by size of grazing area (<15ha, 15-30ha and >30ha). Kruscal-Wallis tests were carried out for the size of grazing area. Correlation analysis was carried out among grazing areas (ha), stocking rates, number of permanent labourers per hectare, the proportion of cows and steers for the entire herd (LU basis), annual sales from animal and milk production (US$/ha/year), health costs (US$/head), and variables related to recently sown pastures (proportion of area in cut and carry forage and *B. brizantha* for the grazing areas).

In order to quantify the effects of inputs on production, multiple regression analyses by backwards elimination were carried out against productivity parameters [annual gross margin per hectare (US$/ha/year), annual sales from cattle production per hectare (US$/ha/year), and mean daily milk production per hectare (litres/ha/day)] using stocking rates, calving rates, the proportion of steers in the herds, and the proportion of area with cut and carry forage and *B. brizantha* for grazing area, as explanatory variables. The maximum accepted P value was 0.1, rather than P=0.05, in order to avoid the danger of eliminating important variables at an early stage in the stepwise procedure. MINITAB 13 was used for statistical analysis (MINITAB, 2000).

3.2.5 Estimation of indicators

Indicators were calculated based on the questionnaires as follows:

Labour

Permanent farm labourer was estimated by the sum of family and permanent labourers. Family labourers were estimated by the number of family member whose primarily work is farming weighted by age (older than 15 years old as one labourer, 10-14 years old as half a labourer).

Herd size and structure

Farmers were asked for the number of lactating and dry cows, bulls, steers in fattening and rearing stages, and replacement heifers. The number of calves was ignored for calculating stocking rates and production/cost parameters per head since the questionnaire did not include the animal type.

Stocking rate

Stocking rates were calculated based on livestock units (Upton, 1993) using the following equivalents (400kg of liveweight equivalent to one livestock unit), cows 1.0, bulls 1.25, steers in fattening stage 1.0, steers in rearing stage 0.75, and replacement heifers 0.75.

The stocking rates were calculated by the following equation.

$$\text{Stocking rate (LU/ha)} = \frac{\text{Total herd size (LU)}}{\text{Grazing area (ha)}} \qquad (1)$$

where Grazing area (ha)= pasture area (ha) + fallow (ha)

Milk production

Total milk production was estimated based on daily farm yields in the wet and dry season by equation (2). The period of each season was assumed to be 8 months for the wet season (June to December) and 4 months for the dry season (February to May). Milk sales (US$/farm/year) was estimated by milk prices and amount of milk produced in each season. The values per cow and per hectare were calculated by dividing by the number of lactating cows and the size of the grazing areas as defined above respectively.

$$\text{Milk production (litres/farm/year)} = \text{MYW/F/D} \times 30\text{days} \times 8 \text{ months} + \text{MYD/F/D} \times 30 \text{ days} \times 4 \text{ months} \qquad (2)$$

where MYW/F/D= Daily milk yield per farm per day in the wet season (litres/ farm/day)

MYD/F/D= daily milk yield per farm in the dry season (litres/ farm/day)

Cattle production

Sales from cattle production was calculated based on the sales of all types of animals by the following equation:

$$\text{Sales of cattle production (US\$/farm/year)} = \sum_{i=1}^{n} (\text{PCTL}) \times (\text{NCTL}) \quad i = \text{Cattle categories} \qquad (3)$$

Where

PCTL = Price of each category of cattle (US$/head)

NCTL = Number of each type of animal sold in the last year

Production indicators

The production indicators were estimated based on the number of animals at the start of the year since the questionnaires asked for details of changes in herds during the last year.

Number of cattle at the start = actual number of cattle

+ number of cattle sold or died in the last year

– number of cows purchased in the last year (4)

Calving rates, mortality rates and culling rates were calculated by the following equations:

Calving rate (%) = (Calves born in the last year /(number of cows at the start)*100 (5)

Mortality rate (%)

= (Number of cattle died in the last year / number of cattle at the start)*100 (6)

Culling rate (%)

= (Number of slaughtered cows in the last year / number of cattle at the start)*100

(7)

Production costs

Farmers were asked about variable cost for cattle production (prices paid for the total amount of inputs including casual labourer) used for the last one year period. Categories used in the questionnaires were salt and minerals, herbicides, fertilizers, medicines and vaccination, cereals, concentrates and other supplements, transportation, veterinary services, seasonal labourer, and others. In addition, permanent labour costs were calculated based on permanent labourer hired multiplied by averaged monthly salary.

Gross margin and net income for cattle production

Gross margin of a farm is defined as farm outputs less its variable costs (Nix, 1999). Gross margins based on cattle production were estimated based on the product sales (cattle and milk), cattle purchases, and the variable costs. Calculations for unit value were per cow (lactating and dry cows) and per hectare (grazing area including fallow lands). Net incomes per farm and per family labourer were estimated by the following formulas:

Gross margin on cattle production (US$/year/farm)

= Cattle sales + Milk sales – Cattle purchases – Variable costs

Net income on cattle production per farm (US$/year/farm)

= Gross margin – Permanent labour costs

Net income on cattle production per family labourer (US$/year/family labourer)

= Net income on cattle production per farm / Number of family labourer

3.3 Results

3.3.1 General characteristics of the sample farms

All farmers interviewed were the owners of the farms. The farms in Limas were larger in size in total and in terms of pasture land, but had lower stocking rates (Table 3.1). The occupation periods of the farms were relatively short (63% of the farms less than 10 years, 13% less than 4 years). The average family size was 6.2 members (older than 16 years 3.7, 10-16 years 1.0). Education levels of family heads were: only up to 1st grade (one farmer 2.3%), up to 3rd grade (12 farmers, 27.9%), complete primary school (8 farmers, 18.6%), partial or complete secondary school (4 farmers, 9.3%), and none (11 farmers, 25.6%).

Almost all the farms were engaged in both cattle and crop production. Pasture occupied 80% of the total farm land (Table 3.2). Corn (*Zea mays*) and beans (*Phaseolus spp.*) were the main agricultural products while cassava (*Manihot esculenta)* was planted in some farms. Forest resources were exploited from their land and used mainly for domestic consumption (posts and fuelwood). Sales of fruits (mango, cacao, avocado and banana) were reported by seven farms.

Almost all the farms had horses (3.6 horses per farm on average), 38 farms had chicken and 32 farms had pigs (4.5 pigs per farm on average). Corrals, fences, salting places and manual backpack sprayers were the main equipment. Nine farmers (20.9%) owned cars and 5 farms had wells.

Table 3.1

Main characteristics of sample farms by district

District	Farm number	Farm Area ha	Cattle number	Stocking rate LU/ha	Pasture lands[1] %
Limas	24	51.2±6.9	36±5.0	0.94±0.12	79.5±0 3.2
Paiwas	19	42.9±11.4	31±7.2	1.03±0.12	72.2±3.0
Total	43	47.5±6.3	33.8±4.2	0.98±0.09	76.3±2.3

Note: Mean ± Standard errors, [1] Percentage of pasture lands for entire farm land.

Table 3.2

Size and percentage of each land use type of the sample farms

Land use type /Unit	Area ha	Minimum[1] ha	Maximum[1] ha	Percentage[2] %
Annual crop	2.6±0.4	0	11.4	5.4
Perennial crop	0.7±0.2	0	6	1.5
Pasture	38.1±5.7	5.6	205.5	80.1
Fallow	3.6±0.9	0	31.5	7.5
Forest	2.6±0.6	0	16.1	5.4
Total	47.5±6.3	9.1	224	100

Note: Mean ± Standard errors, n=43,

[1]Minimun and maximum areas of the land use type.

[2]Percentages of the mean of each land use for the mean total farm land.

Table 3.3

Distribution of farm size

Farm size	Frequency	%
Less than 20 ha	10	23.3
Between 20 – 50ha	17	39.5
Between 50-100ha	12	27.9
Above 100 ha	4	9.3
Total	43	100.0

3.3.1.1 Labour and residency of the owners

Permanent labourer of the farms was estimated by the sum of family labourer and hired permanent labourer. Average permanent labour was 3.7 labourers/farm composed of 2.3 family labourers and the rest from hired labourer. Twenty-seven farms (63%) had 1-3 permanent farm labourers. Thirty three farms (77%) were resident farms, and the rests were non-resident farms (Table 3.4). In resident farms, family members were the main source of labour (2.7 labourers/farm), but 45% of which (15 farms) had permanent labourers. One farm had a woman as the head of the household.

Most of the non-resident farms (9 out of the 10 farms) had farm managers, but it seemed that owners were closely involved with the farm practices. Twenty-three farms had permanent labourers (2.4 labourers on average) and 31 farms had casual labourers. Casual labour was used for agricultural cultivation (18 farms) and cattle production (22 farms). Salaries were approximately US$ 60/month for permanent labourer and US$ 2.4/day for casual labourer.

Table 3.4
Farm type based on owner's residency/work and labour

Farm types	Frequency	%
Resident farmers	33	76.7
Without permanent labourer	18	41.9
With permanent labourer	15	34.9
Non resident farmers	10	23.2
Hired farm manager + owner visit [1]	9	20.9
Without hired farm manager + owner daily visit	1	2.3
Total	43	100.0

[1] Frequencies of owner visits were daily (5 farms), 2 to 3 times/week (3), 2 to 3 times/month (1).

3.3.1.2 Tree planting activities

Trees were actively planted in the farms (34 farms, 79%) mainly for live fences (32 farms, 74%), but also for conservation of water resources (7 farms, 16%), as dispersed trees inside paddocks (7 farms, 16%), and for timber, fuelwood and windbreaks (2 farms each). The main species mentioned by the farmers were gliricidia (*Gliricidia sepium*, 13 farms), pochote (*Bombacopsis quinatum*, 12 farms), cedro (*Cedrela odorata*, 11 farms), caoba (*Swietenia macrophylla*, 9 farms), teca (*Tectona grandis*, 6 farms), and genízaro (*Albizia saman*, 5 farms).

3.3.2 Objectives and constraints of cattle production

The main problems and objectives of the farms are presented in Table 3.5. Farmers were interested in increasing the number of animals. Technical assistance and support for marketing were mentioned as factors that would help them. Very few farmers considered moving inland.

Table 3.5

Problems and improvement measures presented by farmers

Problems	Frequency	%
Lack of credit	25	58.1
Lack of technical assistance	17	39.5
Lack of support for marketing	12	27.9
Low price of products	11	25.6
Measures for improvement		
Increase number of animals	28	65.1
More divisions of paddocks	15	34.9
Improve pasture	15	34.9
Expansion of farm land in vicinity	7	16.3
Increase grain and pig production	5	11.6
Start other activities	4	9.3
Immigrate to agriculture frontier	2	4.7
Look for credit	2	4.7
Buy pasture chopper	2	4.7

Note: n= 43, multiple answers were accepted.

3.3.3 Cattle production

3.3.3.1 Herd size and structure

Average herd size of the farms was 33 heads per farm, 66% of which were cows (Table 3.6). Steers were owned by 18 farms (42%). One farm had a high proportion of steers, higher than 80%. Nine farms kept cattle of other farmers. The actual stocking rate on a livestock unit basis was 0.88±0.07 LU/ha (Mean ± Standard error) with 56% having a stocking rate between 0.6 and 1.0 (Table 3.7).

Table 3.6
Mean herd structure of the dual-purpose cattle farms in the Matiguas region

Type of cattle	Actual number	SE (Number)	Actual (LU[1])	%[2]
Lactating cows	13.2	1.7	13.2	42.1
Dry cows	7.5	1.6	7.5	23.8
Heifers	6.2	1.3	4.6	14.7
Bulls	1.0	0.2	1.2	3.9
Oxen	0.5	0.2	0.6	2.0
Steers in rearing stage	3.5	1.7	2.6	8.4
Steers in fattening stage	1.6	0.5	1.6	5.0
Total	33.4	4.1	31.3	100.0

Note: n=43. [1]LU: cow 1.0, heifers 0.75, bulls and oxen 1.25, steers in fattening stage 1.0, steers in rearing stage 0.75. [2]Based on livestock unit.

Table 3.7
Distribution of stocking rates

LU/ha	Frequency	%
0-0.5	7	16.3
0.5-1.0	24	55.8
1.0-2.0	10	23.3
>2.0	2	4.7
Total	43	100.0

3.3.3.2 Pasture management

The composition of pasture species are presented in Table 3.8. The sample farms had

38.1 ha of grazing area on average (47.5% natural pastures, 48.3% cultivated pastures for grazing and 4.1 % of cut and carry pastures). On average, farms own 3.3 paddocks for natural pastures; 3.3 paddocks for cultivated pastures and 1.7 paddocks for cut and carry pastures. Average paddock sizes for each pasture type were 6.3 ha, 4.1 ha, and 1.4 ha respectively. Major cultivated pastures were Asia (*Panicum maximum*, 27 farms), Brizanta (*Brachiaria brizantha*, 22 farms), Estrella (*Cynodon nlemfluensis*, 15 farms), King grass (*Pennisetum purpureum* x *P. typhoides*, 12 farms), Taiwan (*Pennisetum purpureum*, 10 farms), and Jaragua (*Hyparrhenia rufa*, 10 farms). Grama (*Paspalum notatum*) and Ratana (*Ischaemun ciliare*) were the main natural pasture species. *Pennisetum spp.* were the main species for cut and carry. In the last four years, *B. brizantha* and *Pennisetum spp.* were more commonly sown after fallows or in natural grasslands. Seven farms (16.3%) did not sow any pasture in the last four years.

Farmers carried out weeding 2.1 times per year on average. Weeding methods were mainly by hand (39 farms, 90.7 %) while 13 farms (30.2%) used herbicides. Only 2 farms (4.7%) reported the use of fertilizer for pastures where lactating cows were grazed.

Table 3.8
Average composition of pasture species by sown areas in the dual-purpose cattle farms in the Matiguas region

Pasture species	Mean area (ha)	Standard errors (ha)	%[1]
Panicum maximum	8.1	1.7	21.3
Hyparrhenia rufa	4.8	2.2	12.5
Brachiaria brizantha	3.4	1.5	8.9
Cynodon nlemfluensis.	2.1	0.7	5.6
Pennisetum spp. and other species for cut and carry	1.6	0.4	4.1
Natural pasture and others	18.1	4.5	47.5
Total	38.1	5.6	100

Source: n=43. [1] Percentage based on entire pasturelands.
Natural pastures include *Paspalum notatum*, *Ischaemun ciliare*, etc.

3.3.3.3 Grazing management

The sample farms typically had two or three cattle groups: lactating cows, calves, and dry cows and heifers. Almost all of the farms practiced a partial-suckling system. Lactating cows and calves tended to be grazed in cultivated pastures with short rotation systems (typically 2-20 days for grazing and 15-30 days for resting during the wet season). In the dry season, longer rotation periods and continuous grazing in open paddocks were commonly practiced. One fourth of the farms (10 farms) moved their animals to other farms due to poor pasture conditions in the dry season and mating of cows and heifers. It seemed that leaders and followers system (grazing dry cows or steers after lactating cows) was common in the study area.

3.3.3.4 Supplementation

The use of supplements is summarised in Table 3.9. Most of the farms (41 farms, 95.3%) used supplementary feeding for cattle. Common salt and molasses were the most commonly used supplements, followed by minerals mix, whereas the use of crop residues and chicken manure were very limited. A quarter of the farmers used cut and carry forages.

Table 3.9
Use of supplements for cattle in the sample farms

Type of supplementation	Frequency	%
Common salt	33	76.7
Minerals mix	25	58.1
Molasses	28	65.1
Cut and carry forages	11	25.6
Others	6	14.0

Others include crop residue(3), chicken manure (2), and silage(1).

3.3.3.5 Cattle breeds and reproduction

Brahman x Brown Swiss crossbreds were the major breed type. Ninety-three percent of the farms had crossbreed animal Brahman x Brown Swiss (38 farms, 89%), and a few Brahman x Holstein (2 farms, 5%). Among the farms which had crossbred cattle, 17 farms answered that all their cattle were 3/4 Europeans. One farm (2.3%), had pure zebu cattle and two farms owned purebred European cattle (Brown Swiss and Holstein). Only 3 farms reported the use of artificial insemination.

3.3.4 Production indicators

3.3.3.4.1 Calving, mortality and culling rates

Calving rates calf and adult mortality rates, and culling rates of cows are presented in Table 3.10. The study showed relatively low calving rates (45% on average, 33% of the farms less than 25%) (Table 3.13). Calf mortality rates were 16% on average, half of the farms had less than 5%. Adult mortality rated were 1.5% on average (n=43), but it should be noted that adult mortality was reported only by 11 farms. Two farms reported an adult mortality rate greater than 10 %. The average culling rate of cows was 10.3%, but half of the farms had less than 5%.

Table 3.10

Calving, mortality and culling rates in sample farms

Items	Mean (%)	SE (%)
Calving rate	48.4	3.5
Calf mortality rate	14.7	4.3
Adult mortality rate	1.5	0.5
Culling rate	10.1	1.9

Note: n=43, SE: Standard error mean, For calculation methods see 3.2.5.

3.3.4.2 Milk production

Daily milk production by season is presented in Table 3.11. On average, farms milked 14.3 and 11.1 cows in the wet and dry seasons respectively. Milk production in the dry season was nearly half that produced in the wet season, 37 and 73 litres/day respectively. Milk production per cow was 5.1 litres/day/cow and 3.2 litres/day/cow in the dry and wet season respectively; milk production per hectare was 2.2 litres/day/ha and 1.2 litres/day/ha in the dry and wet seasons respectively. Mean farm gate prices for milk were US$0.19 /litre in the wet season and US$0.25/litre in the dry season. Mean farm gate prices of animals were US$105 for a calf, US$228 for a culled cow, US$182 for a steer.

Table 3.11

Comparison of daily milk production by season

Calculation basis	Unit	Wet season	Dry season	Annual mean[1]
Per cow	litres/cow/day	5.1±0.18	3.2± 0.21	4.4±0.16
Per hectare	litres/hectare/day	2.2±0.18	1.2±0.13	1.8±0.15
Per farm	litres/farm/day	73±10.5	37±5.2	61±8.3

Note: n=43, Means ±Standard errors.

[1] weighted annual mean calculated based on 8 month wet season and 4 month dry season.

3.3.5 Economic indicators

Mean annual sales from cattle production per farm was estimated to be US$ 6,814, 65% of which was from milk production (Table 3.12). One third of the farms (35%) had annual sales from cattle production lower than US$3,000 per year. Production of steers were reported by 15 farms ranging from 30 to 100% of the entire cattle production of the farms. Animal and milk sales on a per hectare of grazing lands and livestock unit basis are summarised in Table 3.13. Total annual value of cattle production were US$190/ha and US$236/LU. Moreover, cattle purchases were US$663 on average reported by 7 farms.

Table 3.12

Annual sales from animal and milk production per farm

Type of products	Number of farms reported	Value[1] (US$)	%[2]
Animal[3]		2,366 ±631	34.6
Calves	39	956 ±213	14.0
Cows	21	424 ±140	6.2
Steers	15	987 ±520	14.4
Milk	42	4,472 ±665	65.4
Total		6,839 ±1095	100.0

[1] Mean ±Standard errors. n=43.

[2] Percentages of the mean values for annual total income from cattle production.

[3] Sum of all types of animals.

Table 3.13

Annual sales from animals and milk production

Category	Basis	Sale (US$/year)
Animal sales	/ha	58.2±8.9
	/LU	72.5±13.7
Milk sales	/ha	131.3±11.1
	/LU	163.2±14.2
Total sales	/ha	189.5±15.7
	/LU	235.7±20.9

Note: n=43. Mean± Standard error.

3.3.5.1 Production costs of cattle production

Total annual variable costs for cattle production was estimated to be US$ 477 per farm costs for cattle production per farm were health care of cattle (US$168/farm), casual labour (US$108/farm), common salts and mineral mixtures (US$66/farm), wire for fencing (US$64/farm). Herbicides and fertilizers were reported by ten and one farms respectively. The amount spent for supplements was small (US$27/farm), suggesting that the use of other supplements beside common salt and mineral mixtures (e.g. molasses) was limited. Moreover, the cost of permanent labour was estimated as US$938 (number of labourer x US$60/month/labourer x 12 months) reported by 23 farms.

3.3.5.2 Gross margin and net income for cattle production

The annual gross margin and net income (gross margin minus permanent labour costs) based on cattle production averaged US$5,698 and US$4,760 per farm respectively (Table 3.15). On a per unit basis, the annual gross margin per LU and per hectare were US$205/LU and US$164/ha respectively. The average daily net income per family labourer was US$4.1/day.

Table 3.14

Annual production costs for cattle production per farm

(US$)	Mean (US$)	SE (US$)	%
Variable costs			
Vaccination and medical care	168	51	35.1
Casual labour	108	42	22.7
Salts and mineral mixtures	66	17	13.8
Other supplements	27	10	5.6
Fencing	64	19	13.4
Herbicides	32	13	6.7
Others[1]	13	11	2.7
Total	477	87	100.0
Permanent labour costs	938	177	

Note: N=43. SE: Standard errors of means.

[1] Others include transportation of animals and products, fertilizers, pasture seeds, etc.

Permanent labour costs = Number of labourers x US$60/month x 12 months.

Table 3.15

Gross margin and net income from cattle production (Unit US$)

Category	Value	Standard error
Gross margin/year/farm	5,698	937
Net income/year/farm	4,760	851
Net income/day/family labourer	4.1	0.67
Gross margin/year/LU	205	20
Gross margin/year/hectare	164	14

Note: n=43 except for net income per family labourer (n=42).

Gross margin = Milk sales + Animal sales – Animal purchases – Variable costs.

Net income = Gross margin – Permanent labour costs.

3.3.6 Farm characteristics by size

Major variables to describe farm characteristics (Number of permanent labourer, stocking rates, percentage of steers, calving rates, percentages of total areas with cut and carry forage and *B. brizantha*) and economic indicators (gross margin, animal/milk sales per hectare, health costs per head) are compared by the size of grazing areas in Table 3.16. The number of permanent labourer per hectare decreased with increasing grazing areas ($P<0.001$). As the size of grazing areas increased, stocking rates tended to decrease, whereas the proportion of steers tended to increase. The farms in the middle sized class (15-30ha) tended to have the highest proportion of cut and carry forage for grazing area and the lowest health costs per animal. Regarding economic indicators, gross margin, animal sales and milk sales per hectare tended to be higher for the farms in the 15-30 ha class.

Table 3.16

Farm characteristics by size

Size of grazing area	No.	Permanent labour	Stocking rates	Steers	Calving rates	Cut & carry forage	*B. brizantha*	Health costs	Gross margin	Animal sales	Milk sales
		Man/ha		%	%	%	%	US$ /animal	US$/ha /year	US$/ha /year	US$/ha /year
<15 ha	11	0.31±0.04	1.12±0.20	4.5±2.6	46.0±10.6	2.8±1.5	13.5±5.6	5.8±2.8	160.3±23.3	49.8±11.1	133.6±22.9
15-30 ha	13	0.16±0.03	0.90±0.11	6.0±2.7	54.5±9.3	7.9±4.3	8.5±4.1	2.6±0.87	189.7±30.8	63.6±12.6	149.8±21.5
>30ha	19	0.069±0.01	0.73±0.06	14.3±4.7	46.5±6.3	3.3±11.4	9.5±5.3	4.5±0.97	147.4±21.3	59.2±17.3	115.0±16.3

3.3.7 Correlation analysis

The results of correlation analysis for the major parameters are presented in Table 3.17. The results showed that larger farms had significantly lower stocking rates ($r=-0.320$ $P<0.05$), less permanent labour per hectare ($r=-0.541$, $P<0.001$), and have lower daily milk production per hectare ($r=-0.358$, $P<0.05$). Farms with higher stocking rates had more permanent farm labour per hectare ($r=0.340$, $P<0.05$) and had higher milk production per hectare ($r=0.393$, $P<0.01$). Annual sales of animals was positively related to the proportion of steers ($r=0.604$, $P<0.01$) and to the proportion of area planted with *B. brizantha* ($r=0.479$, $P<0.001$). Increasing the proportion of cut and carry forage increased gross margin ($r=0.527$, $P<0.001$) through increased daily milk production ($r=0.621$, $P<0.001$), while *B. brizantha* increased annual sales of animals ($r=0.509$, $P<0.001$), but not gross margin.

Table 3.17
Correlation matrix of the selected variables

		Grazing Area (ha)	Perm. labour	Stocking rate	Steers	Calving rate	Cut & carry forage	*B. brizantha*	Health costs
Permanent labour	Man /ha	**-0.541*** (<0.001)**							
Stocking rate	LU/ha	**-0.320* (0.037)**	**0.340* (0.028)**						
Steers		0.281 (0.068)	-0.257 (0.101)	0.036 (0.819)					
Calving rate		0.004 (0.979)	-0.007 (0.967)	-0.070 (0.658)	-0.082 (0.604)				
Cut & carry forage		-0.104 (0.508)	0.046 (0.773)	0.135 (0.387)	-0.061 (0.698)	0.126 (0.428)			
B. brizantha		-0.099 (0.528)	0.256 (0.101)	0.011 (0.946)	**0.479*** (<0.001)**	-0.082 (0.607)	-0.120 (0.443)		
Health costs	US$/animal	0.094 (0.548)	0.125 (0.431)	0.222 (0.152)	0.099 (0.528)	-0.114 (0.471)	-0.000 (0.999)	-0.135 (0.386)	
Gross margin	US$/ ha/year	-0.247 (0.111)	0.204 (0.194)	**0.327* (0.032)**	0.143 (0.362)	0.350 (0.023)	**0.527*** (<0.001)**	0.225 (0.146)	-0.115 (0.464)
Animal sale	US$/ha/year	0.013 (0.936)	-0.011 (0.945)	**0.316* (0.039)**	**0.604*** (<0.001)**	0.125 (0.432)	0.245 (0.114)	**0.509*** (<0.001)**	-0.056 (0.720)
Daily milk production	litres/ha/day	**-0.358 (0.019)**	0.279 (0.073)	**0.393** (0.009)**	-0.160 (0.307)	0.228 (0.147)	**0.621*** (<0.001)**	0.011 (0.946)	0.075 (0.634)

Note: Cell Contents: Pearson correlation: below: (P-Value). * P<0.05, ** P<0.01, ***P<0.001
Perm: Permanent.

3.3.8 Multiple regression analysis

Estimates of the relationships between inputs and productivity parameters [annual gross margin (US$/ha/year), annual sales of cattle production (US$/ha/year) and mean daily milk production (litres/ha/day)], both before and after backwards elimination, are presented in Table 3.18, 3.19 and 3.20. The results show that cut and carry forage made a significant contribution to milk production ($P<0.001$), sales from cattle production ($P<0.01$), and gross margin ($P<0.001$). areas of *B. brizantha* contributed to gross margin ($P<0.05$), and sales from cattle production ($P<0.001$). Stocking rates significantly influenced gross margin, milk production and sales of cattle production ($P<0.05$). Calving rates were significantly related to the gross margin and cattle production, but not milk production per hectare. The proportion of steers significantly increased sales from cattle production ($P<0.001$) and tended to decrease milk production. The stepwise regression did not remove any variables for sales of cattle production.

Table 3.18

Results of regression analysis for annual gross margin of cattle production per hectare (US$/ha/year)

Predictor	Constant	Stocking rate	Calving rate	Steer	Cut & carry forage	*B.brizantha*
Unit		LU/ha				
Before elimination						
Coefficient	26.53	**54.93**	**103.35**	30.87	**481.6**	**135.51**
SE Coefficient	32.4	**24.70**	**36.38**	78.09	**116.6**	**63.52**
P value	0.417	**0.033**	**0.007**	0.695	**<0.001**	**0.040**
After elimination						
Coefficient	28.44	**55.09**	**102.67**		**481.3**	**147.27**
SE Coef.	31.62	**24.41**	**35.93**		**115.2**	**55.47**
P value	0.374	**0.030**	**0.007**		**<0.001**	**0.012**

Note: R^2 : 51.7% before elimination and 51.5% after elimination.

Maximum accepted p value was 0.1.

Table 3.19

Results of regression analysis for annual cattle sales per hectare (US$/ha/year)

Predictor	Constant	Stocking rate	Calving rate	Steer	Cut & carry forage	*B.brizantha*
Unit		LU/ha				
Coefficient	-24.3	**36.3***	34.1	**173.3*****	**156.7***	**98.5****
SE Coef.	18.0	**13.7**	20.2	**43.3**	**64.6**	**35.2**
P value	0.184	**0.012**	0.099	**<0.001**	**0.020**	**0.008**

Note: SE Coefficients (Standard error coefficient), R^2 : 61.5%.

Maximum accepted p value was 0.1.

With all initial variables and backwards elimination, results were the same.

Table 3.20

Results of regression analysis for daily milk production per hectare (litres/ha/day)

Predictor	Constant	Stocking rate	Calving rate	Steers	Cut&carry forage	*B. brizantha*
Unit		LU/ha				
Before elimination						
Coefficient	**0.757**	**0.670**	0.558	-1.367	**5.789**	0.942
SE Coef.	**0.325**	**0.248**	0.365	0.784	**1.170**	0.637
P value	**0.025**	**0.010**	0.136	0.136	**<0.001**	0.148
After elimination						
Coefficient	**0.972**	**0.674**			**5.978**	
SE Coef.	**0.243**	**0.246**			**1.186**	
P value	**<0.001**	**0.009**			**<0.001**	

Note: R^2 54.5% before elimination and 48.3% after elimination.

Maximum accepted p value was 0.1.

3.4 Discussion

3.4.1 Herd size, structure and farm type

The study results showed that larger farms had fewer permanent labourers per hectare (P<0.01) and lower stocking rate (P<0.05, Table 3.17), suggesting that the larger farms are more extensive. On the other hand, farms which were more dedicated to raising steers tended to have larger total grazing area (p=0.068, Table 3.17). The results of the correlation analysis showed that in those farms with a higher proportion of steers, there is also a larger proportion of pasture planted with *B. brizantha* (P<0.001) and increased the annual sales of animals (P<0.01) (Table 3.17). It is generally considered that farms specialising in meat production are more extensive than dual-purpose cattle farms (NITLAPAN, 1995;

Corporación Ganadera, 2000). However, these results may suggest that fattening steers pays for pasture improvement, thus they are more intensive in terms of pasture improvement. Although a relatively high proportion of sales of steers was recorded (14.5% of total cattle sales of the farms), in fact only 18 farms owned steers and 15 farms reported steer sales. It seems that planting *B. brizantha* which is dry tolerant species (Peters et al., 2003), and raising steers during the dry season is one of the accepted farmers' strategies.

3.4.2 Productivity of cattle production

The average calving rate was 48%, which is considered to be low compared with the national census of Costa Rica (64%, Corporación Ganadera, 2000), but similar to the national average in Venezuela (45%, Plasse, 1992) and on the lower limit of the range presented by Sere and De Vaccaro (1985) (50-70%) for Honduras, Colombia, Panama and Brazil. Ideally, calving should occur once a year with a dry period of two months (Ramirez, 2002). However, in the study area, calving rates may be lowered due to malnutrition during the dry season, presence of calves and low availability of bulls particularly in small farms. The average culling rate was 10%, which is also considered to be low. Since the variation in milk production between individual cows is high, frequent culling was suggested by Llamozas and Vaccaro (2002). However, farmers seemed to think that they do not have sufficient cattle (Table 3.5), thus they possibly tend to retain cows even with poor milk yields. Improving feeding systems in the dry season may increase calving rates as well as potential overall production. Further studies are needed to consider potential intensification through increasing calving rates and culling rates, including technical assistance on herd management issues.

Average calf mortality rate was 15%, which is higher than the results reported by Sere and de Vaccaro (1985) and Vaccaro et al. (1992) (6-12%) for dual-purpose systems in Brazil, Costa Rica, Panama, and Venezuela, whereas the adult mortality rate was lower (1.5%) than the values reported by the same authors. Mortality rates were particularly high in some farms (nine farms with higher than 25% calf mortality rates and two farms had adult mortality rates higher than 10%). High mortality may be caused by poor animal nutrition and health care practices. Further studies are needed in order to clarify the causes of the animal losses (e.g. malnutrition, diseases or accidents).

3.4.3 Milk production and economic performance

The mean annual milk production was 4.4 litres/cow/day, which results in 1,056 litres milk production per lactation, assuming that the lactation period is 8 months (Levard et al., 2001). The results were within the range of comparable systems presented by Sere and de Vaccaro (1985) (3-5 litres/day) in Panama, Colombia and Brazil and by Vaccaro, et at. (1992) in Venezuela (700-1,100 litres/lactation), but lower than the target yield using improved tropical pasture suggested by Wilkins et al. (1979) (1,300 litres sold per lactation with 700 litres consumed by the calf). The daily milk production per hectare (annual mean 1.8 litres with 2.2 litres in the wet season and 1.2 litres in the dry season) were also lower than the results reported by Nicholson (1994) (3.7 litres/day) for similar cattle production systems in Mexico.

However, the gross margin per livestock unit (US$205/LU/ha) was similar to the results (US$218/cow/year adjusted by consumer price index) reported for the humid lowlands of

Venezuela by Holmann (1989). This is mainly due to the low annual variable cost, which was only 7.0% of the annual cattle sales of the farms (10.6% of the annual milk sales), which is much lower than the case in Mexico (42% of milk sales) as reported by Nicholson (1995). The variable costs reported by farmers were total values for one year, which may not reflect the total cost of farming practices as they do not keep records. In particular the cost of permanent labourers, which was reported as 1.4 labourers/farm on average, was included in the gross margin estimation but not included in variable costs, may be substantial.

On average, the annual gross margin and net income per farm (excluding only permanent labour costs) on cattle production was US$5,698 and US$4,760 respectively with 3.7 labourers (2.3 family labourers and 1.4 hired labourers). The annual net income per family labourer excluding the permanent labour costs is estimated as US$1,483 (US$4.1/day). On average, it is probably acceptable for farmers though they still need to pay the other fixed costs but share housing and do not have to buy most of the food since they are produced in the farms. The distribution of the net income per family labour and farm size are presented in Table 3.21. It should be noted that the average net income per family labour was raised by larger farms and that 37% of sample farms (16 farms) had the daily net income per labour lower than US$2, which was the average daily salary of casual labourer. It suggests that the situation of smaller farms are unstable because daily income per labourer is better to be a casual labourer than working in the farm.

Table 3.21

Net income per family labour and farm size

Net income/family labourer (US$)	Number of farms	%	Farm size (Mean ± SE)
< US$2	16	37.2	33.8±8.5
US$2 - 4	12	27.9	36.0±6.3
> US$4	14	32.6	74.7±13.5
No answer	1	2.3	
Total	43	100.0	

3.4.4 Supplementary feeding and potential for pasture improvement

Supplementary feeding is practised in the study area. Supplementation may be an attractive option for farmers during the dry season when milk prices are high. However, in the study area, locally available supplements are limited due to the following reasons: 1) utilization of molasses is common (65%), but it seems that the amount is limited due to its high and unstable price; 2) the use of crop residues is limited due to the large number of cattle relative to the area used for crop cultivation; 3) the price of chicken manure is high since it needs to be transported from Managua.

Regression analysis showed that the use of cut and carry forage had a positive impact on daily milk production ($P<0.001$ Table 3.18), annual cattle sales ($P<0.05$, Table 3.19), and gross margin per hectare ($P<0.001$, Table 3.18). Considering the obstacles to obtain locally available supplement and the farmers' tendency to avoid cash outlays (Kaimowitz, 1996), it seems that producing fodder for the dry season by using cut and carry forage may be an acceptable option for farmers. It should be noted that cut and carry forage tended to be more frequently present in the middle sized dual-purpose cattle farms (15-30ha) (Table 3.16). It may suggest that these farms have available land to sow the pasture and that farmers need to intensify production without expanding farm size. However, the permanent labourer per hectare of these farms was a half of the smaller farms (<15 ha) (Table 3.16), suggesting that number of farm labourer did not increase by expanding the farm size. It may imply that labour may be a main obstacle to increase cut and carry practices in these farms. In addition, cultivated pasture, *B. brizantha*, was also positively associated with annual sales of animals ($P<0.001$, Table 3.17). It should be also noted that these two types of pastures occupied only a limited area on the surveyed farms: 4.7% for cut and carry forage and 8.9% for *B. brizantha*. This suggests that it is possible to implement pasture improvement technologies in dual-purpose cattle farms. However, lack of labour availability as well as high interest and short payback periods in the bank system may be obstacles for pasture improvement (Nicholson, 1994; Holmann, 1999). Further studies are needed on the feasibility of pasture improvement with regard to labour availability and the use of credit.

3.4.5 Potential and obstacles of intensification

It has been argued that additional labourer tends not to be employed in cattle farms in Latin America due to the farmers' preference to avoid cash outlays and the need for supervision (Kaimowitz, 1996). The study results showed that although larger farms had less labourer per hectare, farmers were eager to intensify their production by means of increasing the number of animals, constructing more fencing around paddocks and pasture improvement rather than by expanding their farms (Table 3.5). Under the present conditions of the study availability may be limited or expensive (US$509/ha to buy or US$42/hectare/year to rent on average). It was likely that in the medium-term, the goal of farmers was to intensify their production by increasing the herd size, which may contribute to maximizing the return per unit of labour (Kaimowitz, 1996). This assumes that they believe there is adequate soil and pasture resources (in their farms or by renting pasture lands in other farms) to support this strategy. Therefore, farmers expressed a desire for credit to purchase more animals (Table 3.5). When farmers have sufficient animals, they have an option to sell more animals and invest in farm land or intensification (e.g. pasture improvement, more use of supplements, etc.). However, it should be noted that in addition to the advantages of land using technologies (Nicholson et al, 1995) when land is available, farmers may prefer to use more land to increase production rather than intensifying the current systems so that they can leave the lands to their children in the long term (Ruiz, 1994; Kaimowitz, 1996). This implies that the farming systems could move from extensive to intensive management in the short-term if herd sizes are increased without an increase in land area, but it may not intensify the systems in the long-term.

It should be emphasised that one of the most important characteristics of this farming system is risk averse as the costs for inputs may fluctuate after farmers accept the intensive system. Sere and de Vaccaro (1985) suggested that "land and cattle constitute the main capital investments in dual-purpose cattle production systems, thus very small allowance for depreciation is needed". Nicholson et al. (1995) indicated that "empirical evidence in Latin America suggests that land using technologies have lower total costs per unit of milk than land saving technologies". Considering the easiness, stability, flexibility, and daily income which are determinant factors for developing production systems in tropical conditions, this farming system, with low feed costs and based on grazing has low productivity, but is economically system, with low feed costs and based on grazing has low productivity, but is economically feasible and socially acceptable for farmers, allowing them to survive (Martinez, 1992).

3.5 Conclusions

The study described dual-purpose cattle farms in the study area, which were owned and managed mainly by families that immigrated to the area during the last decade. The study results provided evidence that farms were managed extensively in terms of production levels on a per cow and per hectare basis. Reasonable gross margins were achieved due to the low feeding costs, based mainly on grazing.

The study results also showed that introducing *B. brizantha* and cut and carry forage had significant positive impacts on farm productivity. Considering the limited area presently occupied by these pastures, improvement of other grazing areas is potentially important and probably acceptable for farmers in order to increase productivity. Particularly, cut and carry forage seems to be accepted by the middle sized farms which have available farm land, though labour may be an obstacle for the implementation. Further studies are recommended on the feasibility of pasture improvement with regard to labour availability and use of credit systems.

References

Corporación Ganadería. 2000. Análisis de Censo Ganadero 2000. http://www.corfoga.org/pdf/proyecto/censo2000.pdf.

FAO.2003. FAOSTAT.

Hecht, SB. 1992. Logics of livestock and deforestation: The case of Amazonia. *In* Downing, TE; Hetcht, SB; Pearson HA; Garcia-Downing, C. eds. Development or Destruction. Westview press. p.7-25.

Holmann, F. 1989. Economic evaluation of dairy and dual-purpose cattle production systems in Venezuela. Ph.D. Dissertation. Cornell University.

Holmann, F. 1999. Ex ante analysis of new forage alternatives for faros with dual-purpose cattle in Peru, Costa Rica and Nicaragua. Livestock research for rural development. 11(3) CIPAV. http://www/cipav.org.co/lrrd/lrrd11/3/holl13.htm.

INIFOM (Instituto Nicaragüense de Fomento Municipal). 1997. Matiguas.

INTA (Instituto Nicaragüense de Tecnología Agropecuaria). 1998. Zonificación agro socioeconómica agencia Matiguas. 72p.

Kaimowitz, D. 1996. Livestock and Deforestation: Central America in the 1980s and 1990s: A Policy Perspective. CIFOR Special Publication. 88p.

Levard, L; Lopez, YM; Navarro, I. 2001. Municipio de Matiguas: potencialidades y limitantes del desarrollo agropecuario. UCA/FIDA/NITLAPAN. 83p.

Llamozas, JA; Vaccaro, L. 2002. Correlations of part and total lactations and the prediction of lactation milk yield in Venezuelan dual-purpose cows hand milked with calf at foot. Livestock Research for rural development. 14(5) http://www.cipav.org.co/lrrd/lrrd14/lrrd14.htm.

Maldidier, C; Marchetti, R. 1996. El Campesino-Finquero y el potencial económico del campesinado nicaragüense. NITLAPAN. 174p

Martinez, JC. 1992. Los sistemas de producción. *In* Ganadería mestiza de doble propósito. González-Stagnaro, C. Eds. Universidad del Zulia. p.27-40.

MINITAB. 2000. MINITAB User's Guide 1 and 2.

Minson, DJ. 1981. Nutritional differences between tropical and temperate pastures. *In* Morley, FHW. Eds. Grazing animals. Disciplinary approach. World Animal Science 1(B1): 143-157.

Muchagata, M; Brown, K. 1999. A Literature Review and Annotated Bibliography. Small Farming Systems in Amazonia: Livestock Production and Sustainability. Appendix 8. ODG. University of East Angolia.

Myers, N. 1981. The Hamburger Connection: How Central America's Forest Became North America's Hamburgers. AMBIO 10: 3-8.

Nicholson, CF; Lee, DR; Boisvert, RN; Blake, RW. 1994. An optimization model of the dual-purpose cattle production system in the humid lowlands of Venezeuela. Agricultural systems 46(3): 311-334.

Nicholson, CF; Blake, RW; Lee, DR. 1995. Livestock, deforestation, and policy making: intensification of cattle production systems in Central America revisited. Journal of Dairy Science 78(3): 719-734.

NITLAPAN. 1995. Diagnostico de la Producción Agropecuaria en el Interior del País. Análisis de Encuesta Rural. Proyecto de Tecnología Agraria y Ordenamiento de la Propiedad Agraria.

Nix, J. 1999. Farm Management Handbook. 30th Edition. University of London. 244p.

Palase, D. 1992. Presente y futuro de la producción bovina en Venezuela. *In*

González-Stagnaro, C. eds. Ganadería mestiza de doble propósito. Universidad del Zulia. p.1-23.

Parsons, J. 1976. Forest to Pasture: Development or Destruction? Revista de Biología Tropical 24(1): 121-138.

Peters, M; Franco, LH; Schmidt, A; Hincapié, B. 2003. Especies Forrajeras Multipropósito: Opciones para productores de Centroamérica. CIAT. 113p.

Ramirez, AC. 2002. Ganadería de leche: Enfoque empresarial. Editorial Universidad Estatal a Distancia. 289p.

Ruiz, A. 1994. Tenencia y Uso de la Tierra en Matiguas-Matagalpa, Nicaragua. FAO Land Tenure Working Paper. 79p.

Sere, C; De Vaccaro, L. 1985. Milk production from dual-purpose systems in tropical Latin America. *In* Smith, AJ. Eds. Milk production in Developing Countries. Centre for Tropical Veterinary Medicine. University of Edinburgh. p.459-475.

Souza de Abreu, MH. 2002. Contribution of trees to the control of heat stress in dairy cows and the financial viability of livestock farms in humid tropics. Ph.D. dissertation. CATIE.

Sunderlin, WD; Rodríguez, JA. 1996. Cattle, Broadleaf Forests and the Agricultural Modernization law of Honduras: The case study of Olancho. CIFOR Occasional Paper No. 7 (S). 28p.

Szott, L; Ibrahim, M; Beer, J. 2000. The hamburger connection hangover: Cattle pasture land degradation and alternative land use in Central America. Serie Técnica No.313. CATIE. 71p.

Upton, M. 1993. Livestock productivity assessment and modeling. Agricultural Systems 43: 459-472.

Vaccaro. L; Vaccaro, R; Verde, O; Alvarez, R; Mejias, H; Rios, L; Romero, E. 1992.

Características productivas en la evaluación de explotaciones y vacas en sistemas de doble propósito. Turrialba 42(1): 14-22.

Wilkins, JV. Pereyra, G; Ali, A; Ayola, S. 1979. Milk production in the tropical lowlands of Bolivia. World Animal Review 32: 25-32.

World Bank. 2004. Nicaragua at a glance 2004.

Chapter 4 (Article2)

Evaluation of trees and grass covers of dual-purpose cattle farms at the semi-humid old agricultural frontier in central Nicaragua

Key words: grass cover, tree cover, slope, dual-purpose cattle farms, Nicaragua

Abstract

Dual-purpose cattle production systems have been described as traditional cattle production systems on family farms in Latin America. The existence of trees in grazing areas may support cattle production in various ways: 1) improving chemical and physical soil conditions, 2) improving pasture quality, 3) improving the physical condition of animals and 4) providing additional fodder for animals by leaves and fruits. In the lowland tropics, shade in pastures is especially needed in the systems using crossbreds with a high proportion of European breeds that require cooler temperatures. In order to evaluate the grass cover in grazing areas, grass cover were surveyed by stratified samplings based on grass types (natural or cultivated), tree cover class, and slope class at 153 plots in 31 dual-purpose cattle farms in the semi-humid lowland tropics of central Nicaragua.

The results showed that the grass cover differed by grass type ($P<0.01$), dominant grass species ($P<0.01$), and tree cover ($P<0.05$), but not by slope. Tree cover greater than 30% reduces grass cover under existing conditions. On average, cultivated grass species showed higher grass cover than natural grass species except for *I. ciliare* and *P. maximum,* potentially due to heavy grazing, roughness of the dry season, and higher requirements in terms of soil fertility. Bare soil cover was increased by increased slope ($P<0.01$), which

had larger negative impacts on cultivated grass than natural grass species. Tree cover had larger negative impacts on natural grass species than on cultivated grass species.

In addition, the study identified the major tree species in the grazing areas: useful trees for cattle production, *G. ulmifolia*, *E. cyclocarpum,* and *A. saman* (mean DBH approximately 20cm), and timber production, *T. rosea, C. alliodora,* and *P. pleosthachyum* (mean DBH <15cm). The stand density of *G.ulmifolia* and *A. saman* decreased by slope ($P<0.01$), but those of *C. alliodora* and *P. pleosthachyum* were high on moderate slopes ($P<0.001$) and on steeper slopes (>30%) ($P<0.01$), suggesting the potential use of these species in sloped areas. The findings of the study suggest that generally a large proportion of the grazing area has low grass cover, especially those areas dominated by natural grasses. Further research on the relationships between soil fertility and pasture conditions, natural pasture management and actual utilization by cattle and on the feasibility of pasture improvement are recommended.

4.1 Introduction

Conversion of land from tropical forest to pastures has been criticised and identified as a cause of deforestation in the humid tropics of Central America (Parsons, 1976; Myer, 1981; Kaimowitz, 1996). Farmers have moved to less populated areas seeking new lands (Maldidier and Marchetti, 1996), resulting in pasture expansion from the dry areas of the Pacific and central regions towards more humid area of the Atlantic plains (Kaimowitz, 1996). In the old agricultural frontier in central Nicaragua, large cattle ranches that had been abandoned during the civil war in the 1980s, were divided into small and medium sized farms in the early 1990s (Levard et al., 2001). Consequently, small farms, which are largely engaged in dual-purpose cattle production (milk and meat), comprise most of the farms, and 90 % of the accessible cultivated lands of the lowlands are occupied by pastures (NITLAPAN, 1995; Szott, et al., 2000). These existing dual-purpose cattle farms were recognized as one of the key targets for intensification of cattle production in Central America (Nicholson et al., 1995).

In small and medium sized farms in central Nicaragua, cattle are traditionally produced under extensive management with low inputs (Chapter 3). Grazing areas largely consist of natural or naturalized grass species as well as cultivated pastures with naturally regenerated trees, thus forming variable pasture conditions and tree densities. It is generally agreed that in silvopastoral systems, the level of shade is an important factor to determine pasture growth (Smith and Whiteman, 1983; Shelton et al., 1987); however, it has been observed that biomass production of grass could be higher or similar under shade as in open grassland especially when growth is restricted by nitrogen deficiencies (Wilson and Ludlow, 1990; Wong 1990; Cruz, 1997; Durr and Rangel, 2000; Durr and Rangel, 2002). In addition, many pasture species in the study areas, including *B. brizantha, P. maximum*, and *P. notatum/conjugatum,* are shade tolerant (Wong, 1990). Dispersed trees in pastures are assumed to be beneficial for cattle farmers since they maintain trees in pastures for shelter, forage and fruits, increased grass production during the dry seasons for cattle, a source of timber, fence posts, fuel woods and fruits for human use (Harvey and Haber, 1999). In the dual-purpose cattle production in the lowland tropics, tree cover in pastures is particularly needed in order to facilitate the use of crossbred animals with a higher proportion of European breeds that require cooler temperatures (Souza de Abreu, 2002).

In order to analyze the effects of the different land uses of grazing areas on cattle production, it is important to examine how the pasture conditions are influenced by tree shading. This study evaluated the grazing areas of dual-purpose cattle farms with regard to grass cover, tree cover and slope. In addition, in order to understand the general characteristics of grazing areas, the relationships between grass cover and tree cover for dominant grass species, the percentages of basal area of the dominant tree species by the tree cover class, and the effects of bare soil cover on other measured variables were also analysed.

4.2 Materials and Methods

4.2.1 Site

The study area is located in Matiguas Municipality in Matagalpa Department, central Nicaragua: Latitude 12^0 50' North and 85^0 27 Longitude East. The altitude is 200-500m above sea level. The climate of the study area is sub-humid tropical with a well-defined dry season between February and May (savanna (Aw) by Koppen climate classification). Annual rainfall varies from 1,300 to 2,000 mm, while temperature fluctuates between 28 and 32^0C. Topographically, the land is generally flat with modest slopes (0-30%) but with small areas of steep slopes (> 30 %) (INTA, 1998).

The population density of the study area is approximately 29 inhabitants/km^2 (Levard et al., 2001). Cattle production is the main economic activity in the region where pastures dominate the lowland areas (altitude <400m) (Maldidier and Marchetti, 1996). The soils are generally heavy clayed, which are difficult to cultivate with light equipment and are thus more suitable for cattle production than for crop cultivation (Levard et al., 2001).

The Matiguas region is considered to be "the old agricultural frontier" where large immigration, with people seeking land for extensive grazing to meet the demands of the international meat market, occurred in the late 1940s after World War II (Maldidier and Marchetti, 1996). Due to the political pressure during the civil war in the 1980s, large haciendas were abandoned and in the early 1990s these farms were divided into small and medium sized farms and made available to landless farmers (Levard et al., 2001).

4.2.2 Farm selection

This study was based on data of the project, "Regional integrated silvopastoral approaches to ecosystem management project", undertaken by CATIE and NITLAPAN under the scheme of Global Environment Facility (GEF) of the World Bank.

The Matiguas region is divided into four zones based on agro-ecological conditions: 1) relatively flat areas near the town of Matiguas where medium scale cattle farm enterprises are present (annual precipitation 1,200-1,600mm); 2) the south-eastern part of Matiguas where medium scale cattle farms are present under more humid condition (>2,000mm p.a.), 3) north western Matiguas where intensive farms are present in the highlands (>500m above sea level); 4) the central part of the municipality and north of in the town of Matiguas with steeper slopes (30-50%) and a medium level of precipitation (1,600-2,000mm) (Levard et al., 2001). Sample farms were selected from two watersheds: Limas and Paiwas in order to cover 1), 2), and 4) of the four agro-zones which were considered to be important for cattle production. There were approximately 190 farms in the study area, and 31 farms were selected from project participants for the survey based on the following criteria: (1) farm size (10-140 ha); (2) farms with more than 3 cattle; (3) willingness to cooperate with the project, (4) accessibility and (5) geographical distribution. The distance between the two watersheds was approximately 20km.

4.2.3 Sampling

Following interviews with farmers, farms were sketched with farmers based on the main land uses (primary forest, secondary forest, pastures and crop cultivation). As for pasture lands, farmers were asked questions regarding grass species and abundance of trees in paddocks. The paddocks for the measurements were chosen based on stratified sampling based on: dominant grass types (cultivated grass species: *Panicum maximum, Brachiaria brizantha, Hyparrhenia rufa, Cynodon nlemfluensis and Pennisetum spp.*, and natural and naturalized grass species: *Paspalum notatum/conjugatum, Ischaemun ciliare, Digitaria sp., Paspalum virgatum/fasciculatum*, and others); abundance of dispersed trees (i.e. tree cover less than 10%, 10-30% and above 30%) and slope (less than 10%, 10-30% and above 30%). Cultivated grasses were introduced species which are generally planted (either by sowing or controlled seeding) by farmers and are suitable for cattle production, while natural grass species are all other species native to the area or naturalized.

The sites where the measurements were taken in the selected paddocks were chosen based on uniform vegetation and steepness, following the criteria defined for stratified samplings in this study (grass type, abundance of trees, and slope). Paddocks that were recently subjected to weed control after grazing were avoided. The measurements were taken between December 2002 and February 2003 in 153 plots, with four to six plots per each farm. In small and medium sized dual-purpose cattle farms in the study area, grazing areas show high variation with regard to pasture conditions and abundance of trees. Therefore, in order to cover sufficient variability, an effort was made to take samples for different strata within each farm.

4.2.4 Data recorded

For the sampling plots, a square of land was defined. Initially 50m x 50m were used, but due to difficulties finding plots of this size with consistent vegetation (it occurred in 5 plots out of the initial 40 plots), 40m x 40m square plots were used for the remaining 113 plots. All sampled plots were included in the analysis because the shape of the plots does not affect the results, even though the distance between the measurements became shorter in the smaller plots. Trees of lesser known species were identified by a local specialist based on local names given by farmers. For each plot, the measurements were as follows:

1) Tree measurements

Species and diameter at breast height (DBH) (1.3 meters height) for all trees with DBH>5cm in the sample plots were measured. The diameter of the tree was defined by the following formula (Hidalgo, et al., 2002):

$$D \text{ (Diameter of the tree)} = (\Sigma\, Di^{2})^{1/2}$$

Where Di (Diameter of each stem) = C (Circumference at breast height) $/\pi$

i = Ordinal number of stems

The basal area of each tree was calculated by the following formula:

BA (Basal area of the tree) $= \pi/4 \ \Sigma \ Di^2$

2) Slope measurements

Slope was measured between the representing points within the plots using a clinometer.

3) Grass cover measurements

Botanical composition was measured at 36 points within each plot. The measurement points were distributed throughout the plots at 8 m intervals using 6 lines with 6 points on each line (10m intervals in the case of 50m square plots). At each point, quadrates of 0.25 m^2 were placed on the ground for the measurements. Within each quadrate, the percentage of area covered by (1) grass species (for each species for the major species), (2) legume species, (3) bare soil (denuded areas), and (4) other broadleaf plants and dry materials were visually estimated. The mean of the 36 observations was taken as representative of each plot.

4) Tree cover measurements

Tree cover was measured in the same points where the grass measurements were taken by using a vertical densitometer (whether under tree cover or not). The percentages of tree cover were calculated based on probability of the points under the tree cover by the following equation:

Percentage of tree cover (%) = Points under tree cover x 100

4.2.5 Data analysis

The survey data were summarized for each plot as grass cover, tree cover, stand density, basal area of trees, bare soil cover and slope. The plots were classified by dominant grass types (cultivated or natural, based on more than 50% of grass cover), grass species (the species of the largest grass cover), and the tree cover and slope class as described above.

Kruscal Wallis tests (Wheater and Cook, 2000) were carried out for grass cover of the entire samples by grass type, tree cover class and slope class in order to examine the differences between the dominant grass species. Correlation analyses were carried out between grass covers (of total and of the species) and tree covers.

Tree data were summarized for all plots. Six major tree species were specified based on the total number of stands found. In order to examine the species composition by tree cover, Kruscal Wallis tests were carried out for the percentages of basal area for the six most common species by tree cover class. Also, in order to examine the effects of slope on each tree species, Kruscal Wallis tests were performed for basal areas and stand densities of the six most common species by slope class.

Lastly, correlation analyses were carried out for all of the samples in order to examine the relationships between bare soil cover and tree cover/slope/stand density/basal area. In addition, in order to examine the difference between cultivated and natural grasses, correlation analyses between bare soil cover and total grass cover of the plots with each dominant grass type (cultivated and natural grass) were performed.

4.3 Results

4.3.1 Distribution of plots and descriptive statistics of major variables

Distributions of the sample plots by grass type, tree cover and slope class are presented in Table 4.1. Sixty percent of the plots (91 plots) were dominated by natural grass species. Approximately one third of the plots were located in open lands (tree cover less than 10%) and 40% of the plots were in the flat lands (the slope class <10%). Descriptive statistics of stand density and basal area of tree species are presented in Table 4.2. On average, grass cover, tree cover and slope were 42%, 25%, and 16%, respectively. The results showed that on average a large number of trees (103 trees per hectare), with $24m^2$/hectare basal area, were found in the sample plots.

Table 4.1
Distribution and tree/grass cover by sample class

	Class	Frequency	%	Tree cover (%)	Grass cover (%)
Dominant type	Cultivated grass	61	40.5	21.9±2.65	51.5±3.66
	Natural grass	92	59.5	26.4±2.35	35.0±2.71
Tree cover	0-10%	51	33.3	3.4±0.45	51.3±3.61
	10-30%	50	32.7	19.9±0.88	46.5±3.98
	>30%	52	34.0	49.9±2.18	27.6±3.48
	Total	153	100.0	24.6±1.76	41.7±2.28
				Slope (%)	Grass cover (%)
Slope	0-10%	61	39.9	2.0±0.36	40.0±3.5
	10-30%	59	38.6	18.4±0.73	47.6±3.7
	>30%	33	21.6	38.0±1.1	34.2±4.6
	Total	153	100.0	16.1±1.2	41.7±2.28

Note: Means ±Standard errors

Table 4.2
Means and ranges of stand density/basal area of trees and bare soil cover

Variables	Unit	Minimum	Maximum	Mean	SE Mean
Stand density	number/ha	0	788	103	9.22
Basal area	m^2/ha	0	171.3	23.9	2.23
Bare soil cover	%	0	21.8	2.22	0.30

Note: n=153.

4.3.2 Pasture survey

4.3.2.1 Total grass cover by tree cover, slope class and dominant grass type

Grass cover as a function of tree cover along with slope classes for each grass type is presented in Table 4.3. Grass cover differed by grass type ($P<0.01$) and tree cover class

(P<0.05). The plots dominated by cultivated grass showed higher grass cover than those with natural grass (51% against 35%). Grass cover differed significantly between tree cover classes 10-30% and over 30% (P<0.01, 47% against 28%), but did not differ between tree cover classes 0-10% and 10-30%. The slope class over 30% tended to have lower grass cover, but it did not differ significantly. On average, plots dominated by cultivated grass species had lower tree cover (21% against 26%) than those of natural grass.

Total grass cover of each dominant grass type is compared by tree cover and slope class in Table 4.3. Total grass cover of the plots dominated by cultivated grass did not differ by tree cover class (P<0.05), but those dominated by natural grass differed by tree cover class (P<0.001). In the plots dominated by natural grass, the tree cover class higher than 30% had lower total grass cover than the low and moderate classes (P<0.001). In the plots dominated by cultivated grass, the tree cover class higher than 30% tended to have lower grass cover. Total grass cover of both cultivated and natural grass did not differ by slope class (P<0.05). For both grass types, the slope class between 10-30% had the highest grass cover, and the slope class higher than 30% showed the lowest grass cover.

Table 4.3
Total grass cover by dominant grass type, tree cover and slope class

	Dominant grass type			
	Cultivated grass		Natural grass	
Classification	Frequency on plots	Total grass cover (%)	Frequency on plots	Total grass cover (%)
Tree cover class				
<10%	23	55.0±5.4	28	48.2±4.9
10-30%	21	57.8±6.1	29	38.3±4.8
>30%	17	40.6±7.7	35	21.3±3.1
Slope class				
<10%	20	50.2±6.7	41	35.0±4.0
10-30%	28	55.9±5.2	31	40.0±5.0
>30%	13	46.2±8.3	20	26.5±4.8
Total	61	51.5±3.7	92	35.0±2.7

Note: Means±Standard errors

4.3.2.2 Grass cover by dominant grass species

Grass cover, total herbage cover and tree cover by dominant grass species are presented in Table 4.4. Grass cover differed significantly by dominant grass species ($P<0.01$). As a whole, grass species are classified into high grass cover [*Pennisetum spp.* (mean 75%), *B. brizantha* (65%), and *I. ciliare* (65%)], medium grass cover *H.rufa* (49%), and low grass cover [*P. maximum* (30%), *P. notatum/conjugatum* (31%) and *Digitaria sp.* (26%)]. It should be noted that the cultivated grass species, *P. maximum, H. rufa* and *C. nlemfluensis* were dominant in less than half of the plots found.

On average, 42% of the sample plots were covered by grass (graminea) and 56% were covered by broadleaves species and dry materials, comprising 98% of the total herbage cover (Table 4.4). Natural grass species were found in 94% of the evaluated plots, but were the dominant species in 68% of the plots. Leguminosae such as *Mucuna pruriens*, *Vigna vexillata* and *Desmodium sp.* were found in 72% of the plots, covering approximately 5% of the area (mean 1.4%, n=153). Bare soil was observed in approximately half of the plots covering 4% of the area (mean 2.2%, n=153).

Table 4.4

Herbage, grass and tree cover by dominant grass species in the Matiguas region, central Nicaragua

Dominant grass species[1]	Local name	Frequency in plot found	Frequency in dominant plots	Herbage cover[2] (%)			Tree cover[2] (%)
				Total grass cover	Grass cover by the dominant species	Total herbage cover[3]	
Cultivated grass		107	61	51.5±3.66			21.9±2.65
P. maximum	Asia	49	17	30.8±4.72	24.4±3.76	97.1±0.76	25.4±6.74
B.brizantha	Brizanta	26	19	64.6±6.87	52.2±6.68	99.2±0.37	23.2±4.11
H. rufa	Jaragua	45	16	48.7±5.93	38.2±5.11	98.8±0.45	14.8±4.15
C. nlemfluensis	Estrella	14	2	56.3±12.5	43.2±16.8	100.0	33.4±30.6
Pennisetum spp	King grass/ Taiwan	8	7	75.4±9.54	65.9±9.63	99.8±0.22	22.2±5.02
Natural grass		144	92	35.0±2.71			26.4±2.35
P. notatum/conjugatum	Grama	85	31	30.7±4.46	25.7±3.98	95.1±1.26	29.7±3.57
Digitaria sp.	Manga larga	71	14	23.7±3.41	17.1±2.54	99.1±0.19	31.2±6.62
I. Ciliare	Ratana	30	13	66.9 ±6.90	50.4±6.69	99.4±0.18	28.0±5.82
Others			34	31.0±3.78	16.9±2.54	97.7±0.74	21.8±4.07
All plots			153	41.7±2.28		97.8±0.34	24.6±1.76

Note: Means± Standard errors.
[1]Dominant grass species are the largest occupants of the entire grass cover.
[2] Mean of dominant plots. [3] includes dry material.

4.3.2.3 Correlation analysis between grass and tree cover by dominant grass species

Correlations between grass cover (total and that of the specific species) and tree cover by dominant grass species are shown in Table 4.5. Tree cover and total grass cover were significantly correlated only in those plots dominated by natural grass species (*P. notatum/conjugatum*, *Digitaria* sp. and *I. ciliare*, $P<0.05$), suggesting that cultivated grasses were more tolerant to tree cover except for *H. rufa*, whose correlation coefficient was close to being significant ($r=0.467$, $p=0.068$). However, correlations between tree cover and grass cover were significant only for *Digitaria sp.*, suggesting that grass cover of the other natural grass species was not significantly influenced by tree cover.

Table 4.5
Correlations between tree cover and total and species' grass cover by dominant species

Variables	*P. maximum*	*B. brizantha*	*H. rufa*	*P. notatum/ conjugatum*	*Digitaria sp.*	*I. ciliare*
Number[1]	17	19	16	31	14	13
Total grass cover	-0.258	-0.062	-0.467	-0.359*	-0.688*	-0.638*
Grass cover of the species	-0.112	-0.013	-0.349	-0.222	-0.654*	-0.473

Note: Pearson correlation, P<0.05* P<0.01**

[1]Number of the plots where the species were dominant.

4.3.3 Tree survey

Common tree species found in the grazing areas are shown in Table 4.6. A total of 2,828 trees of 76 species were found in 153 plots with a total cover area of 27.6 hectares. The six most common species represented 71% and 64% of the total number of stands and the total basal area, respectively. *G. ulmifolia* was the most frequent species and was found in 63% of the plots (96 plots) occupying approximately 31% of the total basal area and 26% of the total number of stands. The average DBH of *G. ulmifolia*, *E. cyclocarpum*, and *A. saman* were relatively large (19-23cm), while the average DBH of *T. rosea*, *C. alliodora*, and *P. pleosthachyum* were relatively small (11-14cm). *G. sepium* was not a frequently found species; only 89 trees in 19 plots were found.

Table 4.6:

Common tree species in grazing areas in the Matiguas region, central Nicaragua

Species	Local Name	Number of trees[1]	Stand density	Number of plots found	Basal area[1]	Avg. DBH/tree
			Trees/ha		cm^2	cm
Guazuma ulmifolia	Guacimo	718	26.0	96	12378	22
Tabebuia rosea	Roble	366	13.3	64	1592	11
Cordia alliodora	Laurel	358	13.0	70	2614	14
Platymiscium parviflorum	Coyote	236	8.5	50	1839	13
Enterolobium cyclocarpum	Guanacaste	203	7.4	64	3560	19
Albizia saman	Genizaro	137	5.0	56	2883	23
Gliricidia sepium	Madero negro	89	3.2	19	1988	25
Psidium guajava	Guayaba	61	2.2	28	345	13
Cupania sp.	Cola de pava	48	1.7	9	272	13
Tabebuia ochracea	Cortez	43	1.6	15	333	15
Leucaena shannonii	Frijolillo	40	1.4	15	294	15
Cassia grandis	Carao	39	1.4	21	848	25
Genipa americana	Jagua	37	1.3	14	193	12
Spondias mombin	Jobo	29	1.1	24	1036	30
Inga vera	Guaba	26	0.9	12	507	22
Cordia bicolor	Muneco	24	0.9	17	358	20
Vochisia ferruginea	Zopilote	22	0.8	16	250	18
Lysiloma auritum	Quebracho	20	0.7	8	846	31
Elaeis oleifera	Corozo	19	0.7	2	1576	53
Albizzia longapedata	Gavilan	18	0.7	12	171	15
Others		351	12.7		5218	22
Total		2,828	102.5		39,102	22

Source: Based on the measurements in 153 plots for 27.6hectares total.

[1]Sum of all plots.

4.3.3.1 Distribution of major tree species by tree cover class

The percentage of basal area associated with the six major tree species are presented by tree cover class in Table 4.7. Statistically significant differences were shown by 1) *T. rosea* ($P<0.05$) and *E. cyclocarpum* ($P<0.01$) between tree cover classes <10% and 10-30%, 2) *P. pleosthachyum* ($P<0.05$) between tree cover classes 10-30% and >30%, and 3) *G. ulmifolia* ($P<0.05$), *T. rosea* ($P<0.01$), *P. pleosthachyum, E. cyclocarpum* ($P<0.001$) and *A. saman* ($P<0.01$) between tree cover classes <10% and >30%. The results suggest that the basal area of *G. ulmifolia, P. pleosthachyum, E. cyclocarpum* and *A. saman* increases, and *T. rosea* decreases as total tree cover increases. *C. alliodora* tended to show higher percentages of basal area in the tree cover class <10%, but it was not statistically significant.

Table 4.7
Percentage of basal area of six major tree species by tree cover class

Tree cover	*N*	*G. ulmifolia*	*T. rosea*	*C. alliodora*	*P. pleosthachyum*	*E. cyclocarpum*	*A. saman*
<10%	44	24.6±5.6	7.9±3.0	17.3±4.9	4.4±2.5	3.4±2.2	8.2±3.5
10-30%	50	30.1±4.6	6.6±1.5	9.8±2.4	5.1±2.3	11.4±3.0	7.8±2.6
>30%	52	30.8±3.9	4.3±1.2	8.2±2.4	6.1±1.4	10.9±2.4	8.8±1.8
Total	146[1]	28.7±2.7	6.2±1.1	11.5±1.9	5.2±1.2	8.8±1.5	8.3±1.5

[1] Seven plots had no tree cover.

4.3.3.2 Basal area and stand density of major tree species by slope class

Basal area and stand density of six major tree species by slope class are presented in Table 4.8. Regarding basal area, *G. ulmifolia* ($P<0.01$) and *C. alliodora* ($P<0.001$)

differed between the slope classes <10% and 10-30%, while *P. pleosthachyum* differed between the slope classes 10-30% and >30% (P<0.001). Regarding stand density, *G. ulmifolia* (P<0.01), *C. alliodora* (P<0.001), and *A. saman* (P<0.05) differed between the slope classes 10% and 10-30%, while *P. pleosthachyum*, (P<0.01) differed between the slope classes 10-30% and >30%. *T. rosea* did not differ significantly between slope classes.

Basal area and stand density of *G. ulmifolia* (and stand density of *A. saman*) increased but stand density of *C. alliodora* decreased as slope decreased (10-30% to <10%), but basal area and stand density of *P. pleosthachyum* increased at higher slope (>30%).

Table 4.8
Basal area and stand density of six major tree species by slope class

Slope level	*N*	*G. ulmifolia*	*T. rosea*	*C. alliodora*	*P. pleosthachyum*	*E. cyclocarpum*	*A. saman*
				Basal areas (Unit cm^2)			
<10%	61	3,281±528	196±40	131±56	124±38	597±177	708±195
10-30%	59	1,284±342	372±149	773±232	239 ±79	497±159	486±165
>30%	33	1,996±832	304±104	562±139	882±271	988±360	229±113
Total	153	2,234±313	287 ±64	472 ±99	332±71	642±122	519±104
				Stand density (number of trees/hectare)			
<10%	61	7.2±1.2	1.2±0.2	0.8±0.3	1.0±0.4	1.0±0.2	1.5±0.3
10-30%	59	3.0±1.1	3.9±2.6	3.8±1.1	1.4±0.6	1.2±0.4	0.5±0.1
>30%	33	3.0±1.1	2.0±0.6	2.7±0.6	2.8±0.8	2.2±0.7	0.5±0.1
Total	153	4.7±0.7	2.4±1.0	2.3±0.5	1.5±0.3	1.3±0.2	0.9±0.2

Mean ±Standard errors.

4.3.4 Analysis related to bare soil cover

Correlations between bare soil cover and tree cover, slope level, stand density, basal area, and total bare soil cover are presented in Table 4.9. The results show that slope level significantly increased bare soil cover (P<0.01), and that increasing total grass cover significantly decreased bare soil cover ($P<0.001$). The percentage of bare soil cover was positively correlated with tree cover ($P<0.05$), slope level ($P<0.01$) and basal area ($P<0.05$), but not with stand density ($P<0.05$).

The percentage of bare soil cover was negatively correlated with total grass cover in the plots dominated by both cultivated ($P<0.001$) and natural grasses ($P<0.01$). However, a larger negative coefficient and smaller p value were observed for cultivated grass ($r=-0.505$, $P<0.001$) than for natural grass ($r=-0.313$, $P<0.01$).

Table 4.9
Correlations between bare soil cover and other measured variables

Variables	Tree cover	Slope level	Tree density	Tree basal area	Dominant grass types		
	(%)	(%)	(number /ha)	(cm^2)	Cultivated grass (%) (n=92)	Natural grass (%)(n=61)	Total (%)
Bare soil cover (%)	0.163* (0.045)	0.269** (0.001)	0.152 (0.060)	0.164* (0.043)	-0.519*** (<0.001)	-0.313** (0.002)	-0.368*** (<0.001)

Pearson correlation (p value), * $P<0.05$ **$P<0.01$, ***$P<0.001$. n=153.

4.4 Discussion

4.4.1 Grass cover by grass type and tree cover

The results showed that grass cover differed by grass type ($P<0.01$). Grass cover percentages for the plots dominated by cultivated grass were not affected by tree cover, but those dominated by natural grass differed by tree cover class ($P<0.001$). These results may suggest that cultivated grasses are generally more tolerant of tree cover. Natural grass species were found in more plots than cultivated grass species (144 vs. 107 plots, Table 4.4). It is suggested that natural grass species were important to maintain grass cover, although they were not dominant species in many plots. *P. notatum/conjugatum* were the most commonly found species in the study (85 plots, 56% of the sample plots, Table 4.4). Cultivated grass species accounted for 70-80% of the total grass cover (Table 4.4), the rest being represented mainly by *P. notatum/conjugatum*.

Grass cover differed between the tree cover classes 10-30% and >30% ($P<0.01$), but it did not differ between the tree cover classes less than 10% and 10-30% (Table 4.1). It may suggest that the tree cover higher than 30% generally affects grass cover under existing pasture conditions of grazing areas in the study area.

4.4.2 Grass cover by slope class

The results show that grass cover was not affected by slope class ($P<0.05$). However, the correlation between the total bare soil cover and slope was positive ($P<0.001$, Table 4.9). The loss of vegetative cover increases peak and volume of stream flow during intensive rain and significantly increases sedimentation in runoff water (Hamilton and Pearce, 1987), thus causing soil degradation. Greater bare soil cover was observed in particular on slopes steeper than 40%. It may suggest that soil degradation is occurring on that level of slopes. Decreasing grass cover of both natural and cultivated grasses, which was potentially related to soil conditions due to slope ($P<0.01$), increased bare soil cover ($P<0.01$, Table 4.9). It should be noted that the correlations with bare soil cover by the plots dominated with cultivated grass had larger negative coefficients with smaller p values than those of natural grass, suggesting that bare soil cover had larger negative impacts on cultivated grass species than natural grass species (r=-0.505, P<0.001 against r= -0.313, P<0.01 in Table 4.9). On the other hand, tree cover had larger negative impacts on natural grass species than cultivated grass species (Table 4.5). It may be suggested that some natural grasses can do better under degraded soil conditions than cultivated grass species, but cultivated grass species are more tolerant to tree shade. However, it should be noted that the most common natural grass species in the study area, *P. notatum/conjugatum,* are considered to be shade tolerant (Wong, 1990). Therefore, it is likely that natural grasses had less grass cover under shade due to weed invasion. It is possible that farmers weed more intensively in open lands than under shade in order for natural grasses to recover, causing more severe weed invasion in shade conditions.

4.4.3 Grass cover by grass species

The results suggest that grass cover differed by species (P<0.01). The plots dominated by *B. brizantha* and *Pennisetum spp.* showed high grass cover (65% and 75% respectively, Table 4.4) with relatively moderate tree cover (23% and 22% respectively), while *P. maximum* and *H. rufa* (especially *P. maximum*) were had relatively low to medium grass cover (31% and 49%, respectively) and moderate to low tree cover (25% and 15%, respectively). According to Wong (1990), pasture yields for high yield species such as *B. brizantha* and *P. maximum* are not affected by light disturbance up to 25% especially when nitrogen is not supplied. The percentage of tree cover in the plots of *B. brizantha* and *Pennisetum spp.* and *P. maximum* were close to the acceptable light disturbance level suggested by Wong (1990). In addition, *B. brizantha* showed higher grass cover due to its recent establishment. Moreover, it should be noted that grass cover was calculated as total grass cover (the sum of natural and cultivated grass species) and classified by dominant grass species. Therefore, grass cover was calculated only by those plots "dominated" by a species even though the species were present in other plots as non-dominant species.

Among natural grass species, *I. ciliare* showed high grass cover (67%, Table 4.4). It may be caused by alelophatic effects (Arosemena, 1990). The plots dominated by *P. notatum/conjugatum,* and *Digitaria sp.* had a high percentage of tree cover (30% and 26%, respectively, Table 4.4) and low grass cover (35% and 26% respectively). *P. notatum/conjugatum* are considered to be highly tolerant species to shade (Wilson et al., 1990; Wong, 1990), but the study results showed a negative correlation with tree cover (Table 4.5) probably suggesting that *P. notatum/conjugatum* plots are largely invaded by weeds due to their slow growing nature (Duke, 1983). One potential reason for the predominance of these species over other species is their high resistance to heavy trampling (Garcia, 1996).

4.4.4 Other natural grasses and other plants

Natural grass species except for *Paspalum notatum/conjugatum, Ischaemun ciliare,* and *Digitaria sp.*, were summarized as "others". In fact, Zacaton (*Paspalum virgatum/fasciculatum)* and Peludo (*Ixophorus onisetus*) were commonly found in the study area. Both species were generally treated as weeds by farmers and their consumption by cattle appeared to be very limited. However, in the dry season these grass species may support cattle when other forages are in shortage. Some farmers suggested that *P. virgatum/fasciculatum* have hard textured leaves; therefore, cattle probably consume less than *I. onisetus* which has softer leaves. Other species like *Digitaria sanguinalis, Eleusine indica,* and *Rotboellia spp.* were also found during the survey but only in limited quantities.

The use of legumes may mitigate seasonal reduction in forage production because legumes often grow during the drier periods (Bayer and Waters-Bayer, 1998). The results showed that leguminous species such as *Mucuna pruriens*, *Vigna vexillata* and *Desmodium sp.* were found in approximately half of the plots covering 5% of the area. However, utilization of these species by cattle is probably limited due to the low coverage of the area. Further studies are recommended on the role of less palatable grasses and other broadleaves plants as cattle forage in the dry season.

4.4.5 Low grass cover of *P. maximum*

In the study area, *P. maximum* and *H. rufa* were the major traditional cultivated grass species. Among cultivated grass species, it was found that *P. maximum* had low grass cover, only 31%. *P. maximum* was found in 49 plots, but dominated only 18 plots (Table 4.4), highlighting the fact that there were many plots in which *P. maximum* was present with low cover.

P. maximum has high crude protein and digestibility, but requires high soil fertility (Peters et al., 2003). Therefore, it is possible that the importance of *P. maximum* decreased due to the lowered soil fertility after years of grazing. Without fertilization, weed competition is severe in the wet tropics because it is perennial bunch grass allowing other plants to grow in between (Skerman and Riveros, 1990). *P. maximum* responds very well to fertilization (Peters et al., 2003); therefore, application of fertilizers may be recommended in order to maintain the cover of the species.

In addition, it was observed that *P. maximum* tended to be drier than *B. brizantha* which is a drought tolerant species (Peters et al., 2003), resulting in lower grass cover in the early dry season. *P. maximum* produces seeds throughout the year, while *H. rufa* produces seeds at the end of the wet season. It was observed that farmers kept cattle out of the paddocks of *H. rufa* at the end of wet season in order to ensure the seeding of the species. Contrary to *P. maximum, H. rufa* requires lower soil fertility and can compete successfully with weeds (Skerman and Riveros, 1990). It is possible that grass cover of *H. rufa* was higher than *P. maximum* due to its adaptation to lower soil fertility, seasonal seeding control, and less weed invasion.

It is also important to consider the effects of pasture conservation and cattle grazing. It is generally considered that conserved pastures are maintained in well-fenced small paddocks. In fact, the mean paddock size of plots dominated by *B. brizantha* was much smaller than those of *P. maximum* (1.4 ha against 6.7 ha). Since the survey was undertaken between December and February, between the end of the wet season and the beginning of the dry season, *B. brizantha* and *Pennisetum spp.* were probably conserved for dry season fodder. On the contrary, it was possible that areas of *P. maximum* were heavily grazed during this period in order to maintain the areas of *B. brizantha*. Further studies are recommended regarding seasonal changes of grazing management for different grass species.

4.4.6 Major tree species in grazing areas

G. ulmifolia, the most abundant tree found in the grazing areas, is a pioneer species used for tree cover, forage and fruits for cattle feeding, posts and firewood (CATIE, 1991).

G. ulmifolia showed the highest percentage of basal area in all of the tree cover classes (Table 4.7). The abundance of *G. ulmifolia* is probably because the seeds can be distributed by large animals (Jansen, 1982). It was observed that farmers collected the fruits of *G. ulmifolia* to feed cattle. Studies by Bressani et al. (1981) suggested that up to 30% of the flour made from fruits of *G. ulmifolia* does not affect performance of calf growth. A higher percentage of basal areas for *G. ulmifolia* was observed in the higher tree cover classes, but a statistical difference was found only between the tree cover classes <10% and >30%, suggesting that *G. ulmifolia* is most commonly found in clustered stands. However, 25% of the basal area for the tree cover class <10% was associated with *G. ulmifolia*, suggesting that this species is also spread throughout the grazing areas as individual trees. Both larger basal areas and higher stand density of *G. ulmifolia* were observed at the slope class <10% than at 10-30% ($P<0.01$), suggesting better establishment of the species on flat areas.

C. alliodora, P. pleosthachyum and *T. rosea*, pioneer species which produce timber with little tree cover for animals, were found as relatively small trees (DBH <15 cm on average, Table 4.6). *C. alliodora* was one of the most common species and is largely planted and utilized for furniture in Costa Rica (CATIE, 2004). *C. alliodora* is not tolerant to poor drainage or compaction, and requires high fertility to be able to grow well. *P. pleosthachyum* has hard and heavy timber but is rarely planted in the region (CATIE 2004). The basal area and stand density of *C. alliodora* were higher at the slope class >30% than 10-30% ($P<0.001$), while stand density of *P. pleosthachyum* was higher at the slope class >30% than 10-30% ($P<0.01$). It suggests that both species performed better on sloped land. *C. alliodora* performed better on moderate slopes of 10-30% while *P. pleosthachyum* performed best on steeper slopes (>30%). It is possible that poor growth of these species on flat areas with compacted soil caused by higher grazing pressure and poor drainage due to the heavy clayey textures (CATIE, 1994) resulted in smaller size and better growth of these species on slopes.

T. rosea did not differ significantly by slope class, suggesting its potential on slopes. However, it was observed that *T. rosea* produced dense tree cover due to its large leaves and dense natural regeneration. Therefore, in order to maintain grass cover, they probably need to be thinned though for timber production purposes it is better to maintain dense plantations since stems tend to separate in open area in the first few years of growth (CATIE, 2004). Accordingly, *T. rosea* can be produced densely at specific areas on slopes avoiding interaction with grass production. Further studies are recommended for these species regarding potential production in grazing areas, especially on slopes.

E. cyclocarpum and *A. saman,* which were found as relatively large sized trees (DBH approximately 20cm on average, Table 4.6), are nitrogen fixing legume species that improve soil fertility and produce valuable timber and shade for animals. Stand density of *A. saman* was higher at slopes less than <10% ($P<0.05$), while *E. cyclocarpum* tended to have increased basal area and stand density by slope (Table 4.8). A possible reason is that *A. saman* grows better on the bottom of valleys due to its high water demand. In fact, it was observed that *A. saman* had greener leaves than other trees at the end of the dry season. The other reason is that seeds are distributed by cattle manure and cattle spend more time on flat lands (Jansen, 1982). Further studies are needed to determine the causes of tree growth under different ecological and cattle related conditions.

In particular, *A. saman* was preferred by farmers since the pods, which are useful for cattle feeding, drop from trees at the end of the dry season (Jansen, 1982). The pods had value in local markets. The fruits contain protein and carbohydrates and can increase daily milk production at the end of the dry season (CATIE, 2004). *E. cyclocarpum* is considered to be a dry zone species known as one of the largest canopy trees in pasture lands in the Pacific region. The pods fall gradually over a period of two months in the dry season, and they are therefore available as feed for cattle over a prolonged period (Hughes and Stewart, 1990). However, local farmers indicated that the seeds of *E. cyclocarpum* affect fertility. Thus, it was observed that *E. cyclocarpum* were cut for timber. Further studies regarding animal performance, especially the influence of supplementary feeding with *E. cyclocarpum* on calving are recommended.

4.5 Conclusions

The study evaluated grazing areas of dual-purpose cattle farms with regard to grass cover, tree cover and slope. The results showed that grass cover differed by grass types, grass species and tree cover class. Grass cover differed significantly only for the highest tree cover class (> 30%), suggesting that tree cover over 30% reduces grass cover under existing conditions.

The study results also suggested that as a whole grass cover was not affected by slope. However, bare soil cover increased with slope whilst grass cover declined. This is probably a result of soil degradation. Increasing bare soil cover had larger negative impacts on cultivated grass species than natural grass species.

On average, the plots dominated by cultivated grass species showed higher grass cover than natural pastures except for those with *I. ciliare* and *P. maximum.* Low cover of

P. maximum may be caused by low soil fertility caused by years of grazing without fertilization.

Common tree species found in grazing areas in the study area were *G. ulmifolia*, *E. cyclocarpum*, and *A. saman* with mean DBH approximately 20cm, and *T. rosea C. alliodora*, and *P. pleosthachyum* with mean DBH smaller than 15cm. *G. ulmifolia* and *A. saman* were found most commonly in flat areas. *C. alliodora* and *P. pleosthachyum* were found most commonly on slopes. The abundance of *P. pleosthachyum* was strongly influenced by slopes >30%, suggesting that it may be possible to produce these trees on slopes.

Further research is recommended on the following topics: natural pasture management; relationships between weeding intensity, stocking rates and sward composition; feasibility of pasture improvement by cultivated grass species (especially *B. brizantha*); and causes of pasture degradation of *P. maximum*; potential utilization of non-graminae species including leguminosa for cattle production.

References

Arosemena, 1990. Determinación de mecanismos de interferencia por alelopatia y requerimientos externos e internos de fósforo en pasto ratana (*Ischaemun ciliare* Merrill). Master Thesis. CATIE. 124p.

Bayer W; Waters-Bayer, A. 1998. Forage husbandry. Tropical Agriculturalist. ICTA/GTZ. Macmillan Education Ltd. 198p.

Bressani, R; Gonzalez, JM; Brenes, RG. 1981. Evaluación del fruto del Caulote (*Guazuma ulmifolia*, Lam) en la alimentación de terneros. Turrialba 31(4): 281-285.

CATIE (Centro Agronómico Tropical de Investigación y Enseñanza) 1991. Guacimo: Especie de árbol de uso múltiple en América Central. Informe Técnico No.165. 71p.

CATIE(Centro Agronómico Tropical de Investigación y Enseñanza) 1994. Laurel: Especie de árbol de uso múltiple en América Central. Informe Técnico No.239. 41p.

CATIE(Centro Agronómico Tropical de Investigación y Enseñanza) 2004. Árboles de Centroamérica. Manual para extensionistas.

Cruz, P. 1997. Effects of shade on the growth and mineral nutrition of a C_4 perennial grass under field conditions. Plant and Soil 188(1): 227-237.

Duke, JA. 1983. Handbook of Energy Crops. Unpublished. http://www.hort.purdue.edu/newcrop/duke_energy/Panicum_maximum.html

Durr, PA; Rangel J. 2000. The response of *Panicum maximum* to a simulated subcanopy environment 1. Soil x tree cover interaction. Tropical Grasslands 34(2): 110-117.

Durr, PA; Rangel J. 2002. Enhanced forage production under *Samanea saman* in a sub-humid tropical grassland. Agroforestry Systems 54(2): 99-102.

Garcia, EG. 1996. Manual de forrajes en Nicaragua.

Hamilton, LS; Pearce, AJ. 1987. Biophysical aspects in watershed management. In Watershed resources management: An integrated framework with studies from Asia and the Pacific. Studies in Water Policy and Management. No.10. Westview press.

Harvey, CA; Haber, WA. 1999. Remnant trees and the conservation of biodiversity in Costa Rican pasture. Agroforestry Systems 44(1): 37-68.

Hidalgo, DM; Kleinn, C; Kunth, S. 2002. Manual de campo para el censo de árboles en potreros. Project Fragment. University of Gottingen. 26p.

Hughes, CE; Stewart, JL. 1990. *Enterolobium cyclocarpum*: The ear pod tree for pasture, fodder and wood. NFTA Highlight. 90-05. Nitrogen Fixing Tree Association. Waimanalo, Hawaii.

INTA (Instituto Nicaragüense de Tecnología Agropecuaria). 1998. Zonificación agro socioeconómica agencia Matiguas. 72p.

Jansen, DH. 1982. Costa Rican natural history. Jansen, DH. Eds. The University of Chicago Press. 816p.

Kaimowitz, D. 1996. Livestock and Deforestation: Central America in the 1980s and 1990s: A Policy Perspective. CIFOR Special Publication. 88p.

Levard, L; Lopez, YM; Navarro, I. 2001. Municipio de Matiguas: potencialidades y limitantes del desarrollo agropecuario. UCA/FIDA/NITLAPAN. 83p.

Maldidier, C; Marchetti, R. 1996. El Campesino-Finquero y el potencial económico del campesinado nicaragüense. NITLAPAN. 174p.

Myers, N. 1981. The Hamburger Connection: How Central America's Forest Became North America's Hamburgers. AMBIO 10: 3-8.

Nicholson, CF; Blake, RW; Lee, DR. 1995. Livestock, deforestation, and policy making :intensification of cattle production systems in Central America revisited. Journal of Dairy Science 78(3): 719-734.

NITLAPAN. 1995. Diagnostico de la Producción Agropecuaria en el Interior del País. Análisis de Encuesta Rural. Proyecto de Tecnología Agraria y Ordenamiento de la Propiedad Agraria.

Parsons, J. 1976. Forest to Pasture: Development or Destruction? Revista de Biología Tropical 24(1): 121-138.

Peters, M.; Franco, LH; Schmidt, A; Hincapié, B. 2003. Especies Forrajeras Multipropósito: Opciones para productores de Centroamérica. CIAT. 113p.

Shelton, HM; Humphreys, LR; Batello, C. 1987. Pasture in the plantations of Asia and the Pacific: performance and prospect. Tropical Grasslands 21(4): 159-168.

Skerman, PJ; Riveros, F. 1990. Tropical grasses. FAO. 832p.

Smith MA; Whiteman. PC. 1983. Evaluation of tropical grasses in increasing shade under coconut canopies. Experimental Agriculture 19(2): 153-161.

Souza de Abreu, MH. 2002. Contribution of trees to the control of heat stress in dairy cows and the financial viability of livestock farms in humid tropics. Ph.D. thesis. CATIE.

Szott, L; Ibrahim, M; Beer, J. 2000. The hamburger connection hangover: Cattle pasture land degradation and alternative land use in Central America. Serie Técnica No.313. CATIE. 71p.

Wheater, CP; Cook, PA. 2000, Using statistics to understand environment. Routledge. 245p.

Wilson, JR; Ludlow, MM. 1990. The environment and potential growth of herbage under plantations. *In* Shelton, HM; Stur, WW. Eds. Forages for plantation crops, ACIAR

Proceedings No. 32. Canberra. ACIAR. p.10-24.

Wilson, JR; Hill, K; Cameron, DM., Shelton HM. 1990. The growth of *Paspalum notatum* under the shade of *Eucalyptus grandis* plantation canopy or in full sun. Tropical Grasslands 24(1): 24-28.

Wong, CC. 1990. Shade tolerance of tropical forages: a review. *In* Shelton, HM; Stur, WW. Eds. Forages for plantation crops. ACIAR Proceedings No. 32:Canberra. p.64-69.

Chapter 5 (Article 3)

Herd management, productivity, and tree covers in grazing lands of dual-purpose cattle farms at the semi-humid old agricultural frontier in central Nicaragua

Key words: dual-purpose cattle production, pasture type, silvopastoral system, herd dynamics, milk production

Abstract

Cattle production in the humid lowland tropics has been criticised for its extensive management system, low productivity and high burden on the environment. Dual-purpose cattle production systems have been preferred by small and medium sized farms in such regions due to low capital and technical demands with low risk for farmers. Intensification of existing dual-purpose cattle farms has been recognized as a key target to reduce deforestation in Central America. Herd management was monitored seasonally and relations with land use patterns based on grass cover and tree density were examined for 74 farms based on satellite images in semi-humid regions of central Nicaragua.

The results showed that grazing lands were largely covered by tree cover (23% on average), degraded pasture (32%) and pastures with low and moderate tree densities (42%). Although cattle were frequently moved from and to the farms, stocking rates did not differ by season ($P<0.05$). The maintained stocking rates as well as significantly higher occurrences of calving ($P<0.05$) seemed to cause serious fodder shortage for cattle in the dry season,

to have higher adult mortality rates. In addition, smaller farms tended to have higher stocking rates, natural pasture with lower tree density (LTNP) ($P<0.05$), and a tendency to have less degraded pastures. It is suggested that smaller farms were more intensive in terms of animals and amount of weeds, but more extensive in terms of pasture species. Further research is recommended on improvement of calving rates, fodder availability in the dry season, effects of land use pattern on production, the feasibility of pasture improvement, and cattle movement and sharing.

5.1 Introduction

Conversion of land use from tropical forest to pasture has been criticised as one of the causes of deforestation in the humid tropics of Central America (Parsons, 1976; Myer, 1981; Kaimowitz, 1996). At the old agricultural frontier in central Nicaragua, due to the political pressure during the civil war in 1980s, large cattle farms that had been abandoned during the civil war in 1980s were divided into small and medium sized farms in the early 1990s (Levard et al., 2001). Presently, 90% of accessible cultivated lands in lowland are occupied by pastures, and small farms comprises most of the total farms (NITLAPAN, 1995). In order to take advantage of family labour and to overcome constraints by limited land and capital, such small and medium sized farms are largely engaged in dual-purpose cattle production systems. Dual-purpose cattle production systems have been preferred by small and medium scaled farms due to the following advantages: 1) reduced risk from price changes of milk and meat, 2) higher economic productivity per area than meat production, 3) adaptation of dual-purpose cattle to the climate condition of lowland tropics, 4) less capital investment and technical support required than for specialized milk production, and 5) reduction of mastitis incidence due to calf suckling (Holmann, 1989; Souza de Abreu, 2002).

Nicaragua is considered to be one of the poorest countries in Latin America. It has a population of 5.3 million, a per capita GNI of US$720, and 48% of the population is under the national poverty line (World Bank, 2004). Cattle production is an important activity of the agricultural sector in Nicaragua. In the last few years cattle population has increased reaching more than 3.3 million head in 2001 (FAO, 2003). In particular milk export has increased since 1996 reaching US$3.5 million in 2001, which is 30 times larger than 10 years ago (FAO, 2003). In order to reduce the effects of deforestation, intensification of existing dual-purpose cattle farms was recognized as a key target in Central America (Nicholson et al., 1995).

Dual-purpose cattle production systems of lowland tropics are of intermediate intensity, are very efficient in the use of medium and poor quality forage resources, and have low calving rates and milk production per hectare per annum (Sere and De Vaccaro, 1985). The quantity and quality of products vary adjusting to the local conditions and the prices. Land and cattle constitute the main capital investment in the system and mating is natural or uncontrolled. Rotational grazing and some form of weed control is being conducted (Chapter 3). Dual-purpose cattle farms in central Nicaragua have higher stocking rates than larger farms (Ruiz, 1994) and grazing areas are largely occupied by natural pastures and naturally regenerated trees (Chapter 3). Many of these trees are beneficial for cattle production, particularly in the dry season. Simultaneously, in order to improve productivity and maintain cattle in the dry season, cultivated pastures, including those for cut and carry, were sown to a certain extent in the region (Chapter 3). On the other hand, as a feature of the dual-purpose cattle production systems, herds are composed of various types of cattle: lactating and dry cows, heifers, bulls, and calves, whose nutritional requirements are different from one another. As a results, farmers need to control pasture lands with a variety of pasture conditions and tree densities, stocking rates composed of different cattle types, and supplemental feedings within economic constraints. The objective of this chapter is to assess land use patterns of grazing areas by satellite images, and herd management of dual-purpose cattle farms and to examine the relationships between them. In order to contribute to knowledge for potential modification, the emphasis was placed on examining the level of intensification for the indicators of herd management and land use patterns by classifying the farm types.

5.2 Materials and Methods

5.2.1 Site

The study area is located in Matiguas Municipality in Matagalpa Department, central Nicaragua: Latitude 12^0 50' north and 85^0 27' Longitude east. The altitude is 200-500m above sea level. The climate of the study area is sub-humid tropical with a well-defined dry season between February and May (savanna (Aw) by Koppen climate classification). Annual rainfall varies from 1,300 to 2,000 mm, while temperature fluctuates between 28 and 32^0C. Topographically, the land is generally flat with modest slopes (0-30%) but with small areas of steep slopes (> 30 %) (INTA, 1998).

Population density of the study area is approximately 29 inhabitants/km^2 (Levard et al., 2001). Cattle production is the main economic activity in the region where pasture dominates lowland (altitude <400m) areas (Maldidier and Marchetti, 1996). The soils are generally heavy clayey, which are difficult to cultivate with light equipment and are thus more suitable for cattle production than for crop cultivation (Levard et al., 2001).

The Matiguas region is considered to be a part of "the old agricultural frontier" where large immigration occurred in the late 1940s seeking land for extensive grazing to meet the demands of the international meat market (Maldidier and Marchetti, 1996). Due to the political pressure during the civil war in the 1980s, large haciendas were abandoned and in the early 1990s were divided into small and medium sized farms and made available to landless farmers (Levard et al., 2001).

5.2.2 Farm selection

This study was based on data from the project "Regional integrated silvopastoral approaches to ecosystem management project" undertaken by CATIE and NITLAPAN under Global Environment Facility (GEF) of World Bank.

The Matiguas region is divided into four zones based on agro-ecological conditions: 1) relatively flat areas near the town of Matiguas where medium scale cattle farm enterprises are present (annual precipitation 1200-1600mm); 2) the south-eastern part of Matiguas where medium scale cattle farms are present under more humid condition (>2000mm p.a.), 3) north-western Matiguas where intensive farms are present in the highlands (>500m above the sea level); 4) the central part of the municipality and north of the town of Matiguas with steeper slope (30-50%) and moderate precipitation (1600-2000mm) (Levard et al., 2001). Sample farms were selected from two micro-watersheds: Limas and Paiwas covering three of the four agro zones (1, 2, and 4 of the classification above), which were considered to be important for cattle production. The town of Matiguas is located at the northern side of Limas. The distance between the two watersheds is approximately 20 km. Both areas are served by milk collectors.

In each watershed, initially all the farmers were invited to participate in the project. Information about the project was disseminated by project staff of NITLAPAN through visits to those farms in the NITLAPAN data base. After several workshops and farmer interviews, the farms were selected based on the criteria: (1) farm size (10-140 ha); (2) farms with more than 3 cattle; (3) willingness to participate in the project and (4) accessibility.

According to the database owned by NITLAPAN, there were approximately 190 farms in the watersheds and 130 farms were initially selected by the project at the beginning of 2003. The intention was to complete farm surveys using farm visits and project meetings. Farmers were provided with financial incentives to participate in the project. However, due to difficulties encountered when trying to meet farmers (e.g. selling or abandoning the farms, poor attendance at meetings, or high water level of the river during the rainy season) collection of both land use and herd data was completed for only 74 farms by the end of 2003.

5.2.3 Land use survey

Satellite images taken by Quick Bird (Resolution 0.7m with three natural colours) in January 2003 were used for land analysis. Farm boundaries were mapped out with farmers' participation using satellite photos based and on-site geo-referencing with GPS. After the farm mapping, boundaries of land use types inside each farm were specified in the satellite images. Land use types in the farms were classified into annual and perennial crop cultivations, pasture land, forage bank, fallows and forests based on the observations of tree density. Grazing lands were classified into nine types based on the conditions of dominant pastures and tree densities (Table 5.1). Pasture in the grazing areas were classified into three types: (a) degraded pasture (more than 50% are covered by herbaceous and woody broadleaves); (b) cultivated pasture (introduced pasture species under management which are generally considered as suitable for cattle production, e.g., Asia (*Panicum maximum*), Brizanta (*Brachiaria brizantha*), Jaragua (*Hyparrhenia rufa*), Estrella (*Cynodon nlemfluensis*), and Gamba (*Andropogon gayanus*); (c) natural pasture (all other pasture species including native and naturalised species). The tree density was classified into three groups: high (more than 30 trees (DBH>10cm)/hectare), low (less than 30 trees (DBH>10cm)/hectare) and none. Hereinafter the four types of land use types, natural and cultivated pastures with low and moderate tree densities are called silvopastoral areas. A tree density of 30 trees/hectare was used because tree density over 30 trees/hectare is generally considered to affect grass cover (Murgueitio et al., 2003). In addition to the pasture in the grazing areas, the supplementary forages for cut and carry [King grass (*Pennisetum purpureum x P.typhoides*), Taiwan (*Pennisetum purpureum*) and Sugar cane (*Saccharum officinarum*)] are sown in forage banks.

Cattle were grazed mainly on pasture lands, but they also had access to fallow and forests. Fallows and riparian forest were included, but secondary and primary forests were excluded from grazing areas since generally cattle did not graze in these areas. Types and conditions of pastures (natural, cultivated or degraded) and tree densities were verified during the wet season in 2003 by field observations for all land uses of all the sample farms.

Table 5.1
Land use types of grazing lands

Land use types	Abbre.[1]	Grass cover	Tree density
Degraded pasture	DGPS	< 50%	N.A.
Natural pastures with no trees	NTNP	> 50%	Nominal
Cultivated pasture with no trees	NTCP	> 50%	Nominal
Natural pasture with low tree density	LTNP	> 50%	<30 trees/ha
Cultivated pasture with low tree density	LTCP	> 50%	<30 trees/ha
Natural pasture with moderate tree density	MTNP	> 50%	>30 trees/ha
Cultivated pasture with moderate tree density	MTCP	> 50%	>30 trees/ha
Fallow	FAL	None	N.A.
Riparian forests[2]	FRST	None	N.A

N.A. Not available.

[1]These abbreviations were used for variables of the proportion of the land use types for grazing areas.

[2]Forest area excluding secondary and primary forests.

Table 5.2
Classification of land use types based on dominant cover and tree density

	Dominant cover		
Tree density	Broadleaf plants	Natural pasture	Cultivated pasture
None	DGPS	NTNP	NTCP
<30 trees/ha	DGPS	LTNP	LTCP
>30 trees/ha	DGPS	MTNP	MTCP
High	FAL	-	-
Very high	FRST	-	-

In addition to the nine types of grazing areas, areas of recently sown pasture species (supplemental cut and carry forages, mainly *Pennisetum spp.*, and *Brachiaria brizantha*) were carefully considered since these pasture species may have a significant influence on cattle production (Section 3.3.7). Hence, the proportions of these two pasture species within grazing areas were recorded.

5.2.4 Tree cover study

Tree cover was recorded for each land use type. Estimation of tree cover was carried out on the images with the 1:5,000 scale since one tree cover as large as 56 m^2 (equal to the size of 7.5m^2, approximately 8.5m in diameter of trees) is seen as a point. The individual trees smaller than this size were ignored. Tree cover was analysed by ARC VIEW 3.3 as follows.

1) Forest areas where lands were totally covered by trees were manually drawn on the satellite image for each farm.

2) On the images with a 1:5000 scale, large dispersed trees as large as 56 m^2 (equal to the size of $7.5m^2$, approximately 8.5 m in diameter of tree cover) or groups of trees were manually replaced by points based on visually estimation by placing the number of points in proportion to the size of the tree cover. Thus, one point was equivalent to the size of 7.5 m square on the images, which was approximately 8.5 m in diameter of trees.

3) The points placed (one $7.5m^2$ on the images) were converted into nine $2.5m^2$ pixels (2.5m interval grid on 7.5 m^2) so that one tree cover in more than two land use types were counted for each land use type by dividing the tree cover by $2.5m^2$ square pixels.

5.2.5 Herd survey

Data for herd size and structures, as well as changes in herd inventory (number of animals sold/bought and born/died), daily saleable milk yields (milk produced minus calf suckling and family consumption) and supplementary feeding were collected by structured farmer interviews (Appendix 5.1). Farmers were asked for information about the actual number of cattle on the farm at the time of the interviews and occurrences of calving, mortality, animal sales and purchases in the previous three months (i.e. since the last interview). Cattle were classified into lactating and dry cows, heifers, bulls and oxen (castrated male cattle for draft purpose), steers in the fattening stage (male cattle older than 2.5 years old), steers in the rearing stage (male cattle between 1.5 and 2.5 years old), and calves (before and after weaning).

The interviews were conducted for 74 farms every 3 months for one year period in 2003:

1) between the end of January and the beginning of February (the beginning of the dry season), the end of April and the beginning of May (the end of the dry season), the end of July and the beginning of August (the beginning of the wet season) and the end of October and in the beginning of November (the end of the wet season), (hereinafter Jan./Feb., Apr./May, Jul./Aug. and Oct./Nov.). During the survey it was observed that some farmers did not correctly explain the number of cattle on the farm due to the complexities of their herd management: for example, confusion between the cattle owned by the farmers and the cattle kept on the farm. Therefore, in the last set of interviews, farmers were specifically asked regarding overall herd movement during the one year period and herd size was subsequently adjusted by removing or adding the number of cattle which were or were not on the farm for a certain period. Also, in some cases farmers had additional lands where their cattle can graze, but these areas were outside the project area. Stocking rates were adjusted by adding the additional lands to the farms.

5.2.6 Data analysis

The data were analysed by using MINITAB 13 (MINITAB 2000) using correlation analysis to examine the relationships between land use and herd management variables. One way analysis of variance were used for statistical analysis for stocking rates and milk production per hectare since they were normally distributed. Kruskal-Wallis tests were used for statistical analysis for all other data, both non-parametric data and non-normally distributed parametric data.

5.2.6.1 Land use types and tree cover

Mean areas and percentages of each land use type were calculated and presented for entire farm lands and for grazing areas by the classification shown in Table 5.1. Mean tree cover for the land use types of grazing areas were also calculated. The percentages of the land use types for grazing areas were compared by the size of grazing areas (<15ha, 15-30ha and >30ha).

5.2.6.2 Herd size and structure

Herd sizes were estimated based on livestock units (LU) (one livestock unit is equivalent to 400kg of liveweight). As weighing animals were not possible, the following equivalencies were used: 1.0 for lactating and dry cows, 0.75 for heifers (1.5-3 years), 1.0 for steers in the fattening stage (older than 3 years), 1.25 for bulls and oxen, 0.75 for steers in the rearing stage (1.5-3 years old), 0.5 for weaned calves, and 0.25 for calves before weaning. Herd sizes and compositions were calculated for four seasons with adjustment for cattle movement using the following equation.

$$\text{Annual mean herd size (LU)} = 1/4 \times \Sigma^{4}_{i=1} \textit{Herd} \quad (\text{i=Seasons,1,2,3,4})$$

$$\text{Where Herd}_{1,2,3,4}\ (\text{LU}) = 3\ (\text{months}) \times \text{Actual number of cattle in the farm (LU)}$$

- Number of cattle removed (LU) x Removed period (month)

+ Number of cattle placed (LU) x Placed period (month)

5.2.6.3 Stocking rates

Stocking rates were estimated by dividing an total herd size (LU basis) by the estimated grazing area (pasture lands, fallows and riparian forests, see land use survey above 5.2.3) based on satellite images. Where farmers used additional land used for grazing cattle, the stocking rates were adjusted by adding the additional land to the farms (8 farms, 5.3% of total grazing areas added). Calculations were undertaken for four seasons and the means of the four values were used as the annual stocking rates. The formula used to estimate stocking rate was as follows.

$$\text{Stocking rate} = \frac{\text{Herd size (LU)}}{\text{Grazing areas (hectare)} + \text{Additional grazing areas (hectare)}}$$

5.2.6.4 Calving and mortality rates

Seasonal and annual calving and mortality were monitored and compared by season. These were calculated by the following equations:

Annual/seasonal calving rates = (Frequency of calving through the year or of the period)

/ (Annual mean or seasonal total number of lactating and dry cows) x 100

Annual/seasonal adult mortality rates

= (adults died throughout the year or of the period) / (annual mean or seasonal total number of adults) x 100

Annual/seasonal calf mortality rates

= (calves died throughout the year or the period) / (total number of calvings throughout the year or the period) x 100

5.2.6.5 Cattle sales and purchase

Sales and purchases of all categories of cattle, and daily saleable milk production per farm, per lactating cow and per hectare of grazing areas (as defined in 5.2.3) were calculated and statistically compared by season. Annual/seasonal sales and purchases of the cattle were presented by the percentages of the animal type (cow, steer and calf) sold or purchased in relation to the annual means or seasonal number of the animal type. Total annual income from animal and milk sales was calculated based on the mean prices obtained in the general farm survey (Chapter 3).

5.2.6.6 Analysis of cattle movement

In the last interviews, farmers were specifically asked about cattle movement between the sample farms and other farms. Herd data based on livestock units for each season were summarised for all sample farms and farms were classified into three groups on the basis of the annual data: (1) farms which receive cattle from other farms, (2) farms which send cattle to other farms, and (3) farms which did not receive or send cattle from/to other farms. The number of cattle moved out and placed in were summarised. The size of the grazing areas, the stocking rates, the percentage of areas covered by degraded pasture and cultivated pasture, and the percentage of areas with moderate tree density were compared between the farm types based on cattle movement (1-3).

5.2.6.7 Analysis of supplementary feeding

The sample farms were classified based on the use of supplementary feeds including salt, molasses, supplementary forages by cut and carry, and concentrates. The same variables (except for the percentage of area with moderate tree density) used for the analysis of cattle movement (Section 5.2.6.6) were applied to analyse the effects of the type of supplements used in the sample farms.

5.2.6.8 Correlation analysis

Correlations were determined between land use parameters, size of grazing areas and herd parameters. The selected variables for the analysis were land use parameters (proportion of the land use types for entire grazing area), herd parameters [stocking rates (LU/ha); proportion of both milking and dry cows, milking cows and steers for the herds (LU base); and mean daily saleable milk production per hectare of grazing area (litres/ha/day); and annual income from cattle production (US$/ha/year)], and pasture parameters (proportion of recently sown areas with *B. brizantha* and cut and carry forages in relation to the entire grazing areas).

5.3 Results

5.3.1 Land use and tree cover

Land use and tree cover of sample farms are summarized in Table 5.3. On average, farm size was 26.5 hectares of which grazing lands occupied approximately 80%. Grazing areas were largely composed of nine types of land use types largely occupied by degraded pasture (32 %), natural pasture with moderate tree density (17%), natural pasture with low tree density (10%), and riparian forests (17%) (Table 5.4). Pastures with no trees occupied only 3.3% of the grazing areas. Areas occupied by cultivated pastures were smaller than those of natural pastures (14.8% against 29.9%). As a whole, the results suggest that grazing areas were largely occupied by silvopastoral areas where trees were present with pastures, and natural and degraded pastures were more common than cultivated pastures.

Grazing areas had 23% tree cover on average (Table 5.4). It should be noted that degraded pasture had 18.8% tree cover which was close to the range of moderate tree density (19.6% for cultivated pasture with moderate tree density); therefore, it is included in silvopastoral areas.

Table 5.3

Mean land use of dual-purpose cattle farms in the Matiguas region, central Nicaragua

Land use type	Area (ha)	Standard error	Percentage (%)
Annual crop cultivation	2.0	7.67	7.7
Perennial crop cultivation	0.5	2.0	2.0
Forage bank	0.8	3.0	3.0
Pasture lands[1]	16.4	1.42	61.8
Fallow	1.4	0.28	5.1
Forest[2]	5.4	0.66	20.2
Others	0.1	0.02	0.2
Grazing area[3]	21.3	2.00	80.0
Mean per farm	26.5	2.06	100.0

Source: Satellite images based on Quick Bird, January 2003, n=74

[1]Pasture lands were classified into seven land use types (Table 5.1).

[2] Forest is composed of riparian forest, secondary and primary forests.

[3]Grazing area is composed of seven land use types of pasture lands, fallow and riparian forest.

Table 5.4

Description of land use types of grazing areas in the Matiguas region, central Nicaragua

Land use type	Abbrev.	Mean (ha)	Standard error (ha)	Percentage for grazing area (%)	Tree cover (%)
Grazing areas					
Degraded pasture[1]	DGPS	6.9	1.15	32.2	18.8
Natural pasture with no trees[1]	NTNP	0.5	0.17	2.4	7.0
Cultivated pasture with no trees[1]	NTCP	0.2	0.09	0.9	4.6
Natural pasture with low tree density[1]	LTNP	2.2	0.36	10.4	12.1
Cultivated pasture with low tree density[1]	LTCP	1.5	0.33	7.0	12.5
Natural pasture with moderate tree density[1]	MTNP	3.7	0.57	17.2	24.8
Cultivated pasture with moderate tree density[1]	MTCP	1.5	0.40	6.9	19.6
Fallow[1 2]	FAL	1.4	0.28	6.4	42.6
Riparian forest[1 2]	FRST	3.5	13.52	16.6	84.8
Total		21.3	2.06	100.0	23.2
Land use types of specific pasture species					
Cut and carry forages[4]	CCF	0.8	0.15	3.0	
B.brizantha[5]	BB	0.4	0.14	1.6	

Source: Satellite images based on Quick Bird, January 2003, n=74.

[1]These land use types form grazing areas.

[2]These land use types were not included in pasture lands, but included in grazing areas.

[3]Tree cover was calculated by estimation at 1:5,000 scale (see method section 5.2.4).

[4] Outside of grazing areas (equivalent to Forage bank in Table 5.3).

[5] Included in grazing areas (within cultivated pastures)

5.3.2 Land use and farm size

The percentages of land use types by different sizes of grazing areas are presented in Table 5.5. Larger farms tended to have more degraded pasture, but less natural pasture with low tree density. Cultivated pasture with no trees (NTCP) and moderate tree density (MTCP) were larger on medium sized farms ($P<0.05$ for MTCP between <15ha and 15-30ha, tendency for NTCP), but those with low tree density did not differ by farm size. Cultivated pasture with no trees showed high standard errors for all farm types, which were larger than 60% of the mean values.

Table 5.5
Percentages of land use types by size of grazing area in the Matiguas region, central Nicaragua

Land use types	Category Abbrev.	< 15 ha	15-30 ha	> 30 ha
Degraded pasture	DGPS	21.8±4.1	30.0±6.1	37.7±7.3
Natural pasture with no trees	NTNP	1.6±0.7	1.8±0.9	2.9±1.4
Cultivated pasture with no trees	NTCP	0.3±0.2	1.6±1.0	0.8±0.7
Natural pasture with low tree density	LTNP	18.0±3.0	10.7±2.9	6.9±2.8
Cultivated pasture with low tree density	LTCP	7.7±2.7	8.4±2.6	5.8±2.4
Natural pasture with moderate tree density	MTNP	20.5±3.6	16.3±4.6	16.2±4.7
Cultivated pasture with moderate tree density	MTCP	5.4±1.6	11.5±3.3	5.7±4.4
Fallow[1]	FAL	10.8±3.6	4.3±1.6	5.9±2.1
Riparian forests[1]	FRST	13.9±1.8	15.3±1.8	18.2±2.1
Total	Total	100.0	100.0	100.0

Note: Means ±Standard errors, Unit : %.

5.3.3 Herd size and structure

Seasonal and annual herd structures and stocking rates are summarized in Table 5.6. The results show that stocking rates and herd sizes did not differ by season ($P<0.05$). Herd size was at its largest at the beginning of the dry season and lowest at the end of the dry season. In fact, stocking rates tended to be lower at the beginning of the wet season than the end of the dry season, but herd size tended to be at its lowest at the end of dry season, indicating that cattle were concentrated in larger farms in the beginning of the wet season.

The numbers of lactating cows in the herds increased toward the end of the dry season and the beginning of the wet season. The number of dry cows and steers in the fattening stage differed between seasons ($P<0.05$ for dry cows and $P<0.01$ for steers in fattening stages). The results of the comparison between seasons suggested that the number of dry cows was significantly higher at the beginning of the dry season than at the end of the dry season ($P<0.01$) and the beginning of the wet season ($P<0.01$). The number of steers in the fattening stages at the beginning of dry season was greater than at the end of the dry season ($P<0.05$) and the end of the wet season ($P<0.05$). The results suggest that herd sizes were influenced by dry cows and steers in the fattening stage (at some farms), but they did not significantly change the stocking rates of the entire farm.

Table 5.6

Herd structure and stocking rate for each season

Season	Month	Lactating cows	Dry cows	Heifers	Steers under rearing	Steers under fattening	Oxen	Calves	Total [1]	Stocking rate[1]
Dry	Jan./Feb	7.5 ± 0.74	5.2 ± 0.57	3.3 ± 0.68	1.3 ± 0.66	0.5 ± 0.28	0.2±0.06	8.4±0.93	19.8±1.91	0.95±0.06
	Apr./May	8.0 ±0.93	3.6 ± 0.48	3.4 ± 0.63	0.9 ± 0.38	0	0.2±0.07	9.7±1.10	18.8±1.89	0.90±0.05
Wet	July/Aug	8.4 ± 0.83	3.3 ± 0.47	3.3 ± 0.71	1.2 ± 0.68	0.1 ± 0.12	0.2±0.08	9.3±0.88	18.9±1.78	0.87±0.04
	Oct./Nov.	7.3 ± 0.83	4.4 ± 0.47	4.2 ± 0.71	1.6 ± 0.68	0	0.2±0.08	8.8±0.88	19.7±1.90	0.93±0.05
Annual Mean		7.81 ± 0.73	4.11 ± 0.43	3.55 ± 0.57	1.25 ± 0.51	0.15 ± 0.07	0.20±0.07	9.04±0.81	19.3±1.68	0.92±0.04

Note: Means ±Standard Errors. n=74, Unit: number of animals per farm (except for Total and Stocking rates by livestock unit)[1].

5.3.4 Calving and mortality

Percentages of calving and mortality for each animal type are summarized in Table 5.7. The results show that a greater number of calves were born in the dry season (Jan/Feb and Apr/May) than in the wet season (July/Aug and Oct/Nov) (P<0.01). Whilst the percentages of calf mortality was higher in the end of the wet season, the percentages of adult mortality tended to be higher at the end of the dry season. The mean annual calving rate, adult death rate and calf death rate (±SE) were 47.0±4.13 %, 1.0±0.36 % and 15.8±4.23 % respectively.

Table 5.7
Calving and mortality for each season

Season	Month	Calving (% of cow)	Adult mortality (% of adults)	Calf mortality (% of calvings)
Dry	Jan./Feb.	14.5 ±1.65 (31)	0	4.6 ±1.78 (29)
	Apr./May	15.8 ±2.61 (34)	0.57±0.30 (57)	1.5 ±0.70 (9)
Wet	July/Aug.	8.0±1.91 (17)	0.21±0.20 (21)	3.0 ±1.70 (19)
	Oct./Nov.	7.9 ±1.60 (17)	0.21±0.16 (21)	6.1 ±3.12 (39)
Annual mean		47.0±4.13	1.0±0.36	15.8±4.23

Note: Means ± Standard Errors (% of annual mean), unit: %, n=74.
Calculated by the number of occurrences in relations to annual mean and seasonal number of the animal type.

5.3.5 Sales and purchases of cattle

Percentages of sales and purchases of cattle are summarized in Table 5.8. Calf/steer sales and calf/cow/heifer purchases did not differ by season (P<0.05), while cow sales

(P<0.05) and steer purchases (P<0.05) differed by season. Higher percentages of cows were sold at the end of the dry season than the beginning of dry season (P<0.01), and at the beginning of wet season than the beginning of dry season (P<0.05), while steers were purchased only at the beginning of dry season. Steer sales and purchase were reported from only four and six farms respectively. On average, 11% of cows and 19% of calves were sold annually.

Table 5.8

Cattle sales and purchases for each animal type for each season

Season	Month	Sales			Purchases		
		Cows	Steers	Calves	Cow/Heifer	Steers	Calves
Dry	Jan./Feb.	1.9+0.9	0.2±0.2	5.2±1.4	0.5±0.3	5.2±2.3	0.3±0.3
	Apr./May	5.6+1.5	2.5±1.8	7.1±1.9	0.4±0.2	0	3.4±1.7
Wet	July/Aug	2.9+0.7	0	5.3±1.2	0.5±0.2	0	5.3±2.4
	Oct./Nov.	3.9+1.6	0	6.8±2.0	3.3±1.6	0	1.9±1.4
Annual mean[1]		10.8+1.8	4.2±2.2	19.1±2.6	4.5±1.7	6.6±2.9	10.1±3.7

Note: Means ± Standard Errors, Unit: %, n=74.

[1]Number of occurrences divided by mean number of the cattle types.

5.3.6 Milk production

Daily saleable milk production for each season is presented in Table 5.9 and Figures 5.1 and 5.2. The results show that saleable milk production differed significantly between seasons on a per cow (P<0.01) and per hectare (P<0.05) basis, but did not differ on a per farm basis.

Saleable milk production per cow was significantly lower at the end of the dry season than other seasons (P<0.01) and it was also lower at the beginning of the dry season than the beginning of the wet season (P<0.01). It should be noted that saleable milk production per cow at the end of the dry season was not only low on average but was also extremely low on some farms (see lower whisker in Figure 5.1).

Saleable milk production per hectare at the end of the dry season was significantly lower than the beginning of the wet season (P<0.01). It should be noted that saleable milk production per hectare did not change between the end of the wet season and the end of the dry season (P<0.05), but upper whiskers became lower as dry climate became more severe (Figure 5.2).

Saleable milk production per farm tended to be at its lowest level at the end of the dry season and highest at the beginning of the wet season. It should be noted that daily saleable milk production per farm was likely to be higher at the beginning of the dry season than the end of wet season though milk yield per cow was lower at the beginning of dry season, indicating that more lactating cows were present in the farms in the dry season. Moreover, estimated milk yield per cow, excluding the farms with no saleable milk production were 3.62±0.15 litres/cow (n=67), 3.08±0.15 litres/cow (n=65), 4.05±0.12 litres/cow (n=70), and 3.88±0.14 litres/cow (n=68) for Jan./Feb. Apr./May, Jul./Aug., and Oct./Nov. respectively.

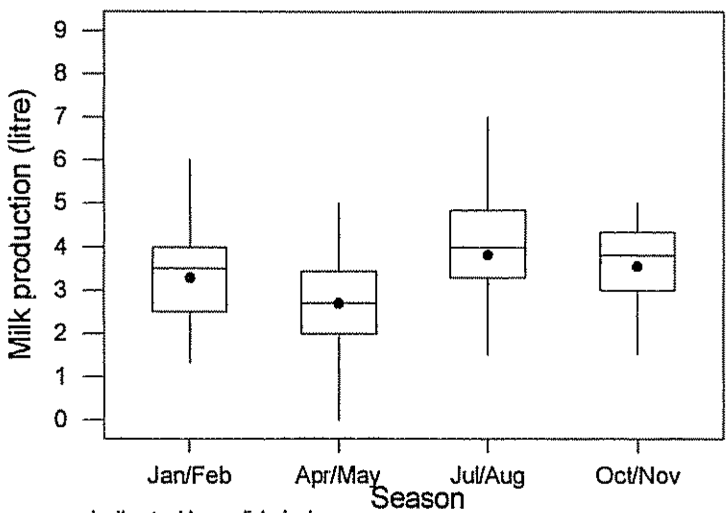
Table 5.9

Daily saleable milk production for each season

Season	Dry		Wet		
Category/Month	Jan./Feb.	Apr./May	Jul./Aug.	Oct./Nov.	Annual Mean
Per farm (litres/farm)	28.0 ± 3.21	22.8 ± 2.80	33.2 ± 3.40	25.6± 2.69	27.4± 2.71
Per lactating cow (litres/cow)	3.33 ± 0.18	2.70 ± 0.17	3.83 ± 0.15	3.56± 0.18	3.35± 0.10
Per hectare (litres/ha)	1.33 ± 0.11	1.20 ± 0.09	1.65 ± 0.13	1.35± 0.12	1.38± 0.08

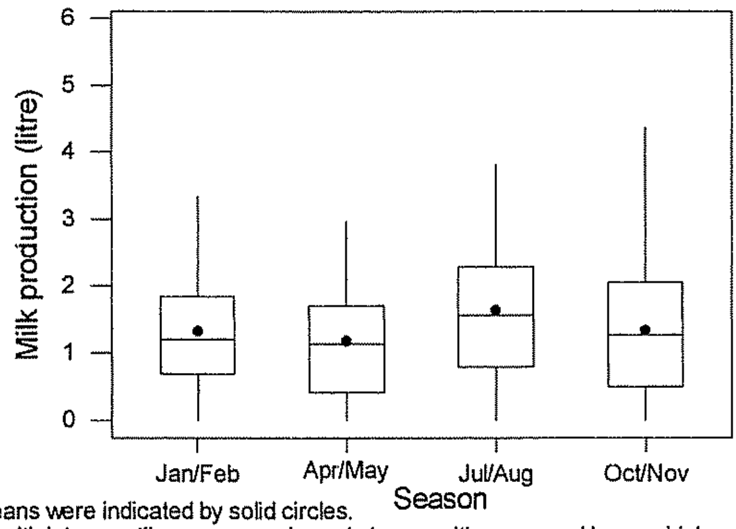
Note: Means ± Standard Errors, n=74.

Figure 5.1 Milk production per cow for each season



Note: Means were indicated by solid circles.
Medians with interquartile range are shown in boxes with upper and lower whiskers in line (MINITAB 2001).

Figure 5.2 Milk production per hectare for each season



Note: Means were indicated by solid circles.
Medians with interquartile range are shown in boxes with upper and lower whiskers in line (MINITAB 2001).

5.3.7 Annual income from cattle production

Annual income from cattle is shown in Table 5.10. The results showed that on average milk contributed to 73% of the income on the farms. On average sales of cows and calves contributed 51% and 44% of the total income from animal sales. Cow and calf sales were reported by approximately half of the sample farms (36 and 40 farms respectively), but steer sales were reported by only 4 farms, resulting in large standard errors.

Table 5.10

Total annual farm income from cattle production

Category		Animals				Milk	Total
	Unit	Cow	Steer	Calf	Total		
Value	US$	410±80	39±27	353±73	802±128	2,179±218	2,981+300
Percentage	%	13.7	1.3	11.9	26.9	73.1	100

Note: Means ± Standard errors. N= 74.

Based on mean numbers of cattle and amount of milk sold and producer prices from Chapter 3: milk price U$0.19/litre in the wet season, US$ 0.25/litre in the dry season, cow (US$228), steer (US$182), calf (US$105).

5.3.8 Cattle movement

Cattle movement between the farms is summarised in Table 5.11; numbers and change in numbers for each season are shown in Table 5.12. The results show that keeping others' cattle (cattle receiver, 24%) or keeping cattle at others' farms (cattle remover, 35%) was a very common practice. Cattle were removed from or placed in the farms throughout the year. As a whole, cattle tended to be removed in the dry season and the beginning of the wet season, and received at the end of the wet season. It appears that there are three types of schemes for cattle movement: short term for one to two months, medium-term for approximately six months, and long term for longer than six months. It was observed that cattle were removed from the farms at the end of dry season due to shortage of forage, but also at the beginning of the wet season for pasture recuperation. Long term transfer of animals tended to start in the wet season. The large number of animals removed at the end of the wet season (Table 5.12) resulted from the long term removal from large farms.

Table 5.11

Annual summary of cattle movement

Movement type	No.	Mean[1] (LU)	Percentage of total farms (%)
Cattle receiver	19	4.6±0.90	25.6
Cattle remover	27	-13.8±0.87	36.5
No movement	28	0	37.8
	74 farms		100.0

Note: Mean± Standard Error.

[1] Calculated based on the total number of farms in the categories.

Table 5.12

Cattle removal and placement from/to sample farms

/Movement types	Receipt[2]		Removal[2]		All samples[2]	Change
Season[1]	Mean (LU)	Frequency	Mean (LU)	Frequency	Mean±SE (LU)	
Nov-Jan	4.6	7	-8.7	7	-0.39±0.43	-0.39
Feb-Apr	8.3	9	-8.1	14	-0.52±0.63	-0.13
May-Jul	6.3	12	-8.3	15	-0.65±0.71	-0.13
Aug- Oct	7.0	12	-10.2	15	-0.55±0.79	+0.10

[1]Seasons were divided into three month periods before the farm interviews.

[2]Calculated by total cattle placed and/or removed on/from the farms during the period divided by the number of farms (n=74).

Comparison by farm types based on cattle movement of grazing areas and stocking rates as well as percentages of degraded pasture, cultivated pasture and moderate tree density for grazing areas are presented in Table 5.13. Percentages of cultivated pastures differed ($P<0.01$), but other variables did not differ by the farm types based on cattle movement. Cattle receivers had higher percentages of cultivated pastures than cattle removers ($P<0.05$) and farms without movement ($P<0.01$). It was also observed that cattle receivers tended to have smaller farms, lower stocking rates, and less grazing areas with moderate tree density than cattle removers.

Table 5.13
Comparison of grazing area characteristics and stocking rates by farm type based on cattle movement

Farm types	No.	Grazing area (ha)	Stocking rates LU/ha	Degraded pasture %	Cultivated pasture[1] %	Moderate tree density %
Cattle receiver	19	17.0±2.75	0.82±0.094	26.9±6.1	28.1±5.9	23.2±4.2
Cattle remover	27	25.6±4.29	0.98±0.052	26.4±5.0	12.6±3.0	30.2±5.2
No movement	28	20.2±2.47	0.92±0.064	29.2±5.7	10.8±3.5	23.3±4.4

[1] Statistically significant difference between farm types ($P<0.01$).

5.3.9 Supplementary feeding

Sample farms are classified into six categories on the basis of supplementary feeding. Size of grazing areas, stocking rates, and percentage of degraded/cultivated pastures are compared in Table 5.14. All the farms used supplementary feeding for cattle. Two thirds of the farmers used salt with minerals, half of the farms used supplementary forages by cut and carry system. The use of concentrates was limited (5.4% of the sample farms). The amount of cut and carry forages offered to animals varied among the farms from less than 4 to 32 kg/head/day depending upon the availability and number of cattle. The supplementary pastures were minced manually or by machine depending upon the availability of machinery and labour. Some farmers fed entire plants to cattle. The amount of molasses used also varied, but most of the farmers gave a very limited amount (approximately 1-2 litres/day/farm). Farms which only used salt as a supplement and farms which used supplementary pastures represented 33.8% and 64.8% of the total, respectively. Size of grazing areas, stocking rates, and proportion of degraded/cultivated pastures did not differ significantly by farm types based on supplementary feeding ($P<0.05$).

Table 5.14
Characteristics of grazing areas and stocking rates by farm type based on supplementary feeding

Farm types	No.	%	Grazing area ha	Stocking rates LU/ha	Degraded pastures %	Cultivated pastures %
Natural/mineral salt only	25	33.8	21.0±2.9	0.80±0.06	20.3±3.8	21.9±5.0
Salt and supplementary pastures	14	18.9	19.6±3.8	0.89±0.09	31.7±8.5	14.1±5.4
Salt, supplementary pastures and molasses	30	40.5	21.0±2.9	0.95±0.07	29.7±5.4	13.5±3.3
Salt and molasses without supplementary pasture	1	1.4	27.0	0.72	6.97	16.9
Mineral salt, supplementary pasture and concentrates	4	5.4	52.4±17.1	0.92±0.11	51.1±17.4	2.7±2.0
Total	74	100				

Note: Means ±Standard Errors. Fr. Frequency.

5.4 Correlation analysis

5.4.1 Correlations between proportions of land use parameters

Correlations between size of grazing areas and land use parameters (the proportions of land use types for grazing areas) are presented in Table 5.15. The results show negative correlations between size of grazing areas and the proportion of natural pastures with low tree density (LTNP) ($P<0.05$) and significant negative correlations between degraded pasture (DGPS) and many land use types (DGPS-NTNP r=-0.28 P<0.05, DGPS-LTNP r=-0.51 P<0.001, DGPS-MTNP r=-0.51 P<0.001, DGPS-LTCP r=-0.24 P<0.05). The correlations between no trees and low tree density of both natural and cultivated pastures were significant (NTNP-LTNP, r=0.40 P<0.001 and NTCP-LTCP, r=0.32 P<0.01), suggesting that these land uses were developed in a similar pattern in the sample farms. However, cultivated pasture with moderate tree density (MTCP) was not significantly correlated with any other land use types, indicating that this land use type was independently developed in the farms. Regarding pasture variables, cut and carry forages and LTNP (CCF-LTNP r=0.26 P<0.05) as well as *B. brizantha* and MTCP (BB-MTCP r=0.25 P<0.05) were significantly correlated.

Table 5.15

Correlation matrix between size of grazing areas, land use and pasture parameters

Variables	Grazing area	DGPS	NTNP	NTCP	LTNP	LTCP	MTNP	MTCP	FAL	FRST	CCF
DGPS[1]	0.194 (0.098)										
NTNP[1]	0.097 (0.412)	**-0.279*** **(0.016)**									
NTCP[1]	0.031 (0.795)	-0.117 (0.321)	-0.114 (0.333)								
LTNP[1]	**-0.277**** **(0.017)**	**-0.509**** **(0.000)**	**0.400**** **(0.000)**	-0.081 (0.493)							
LTCP[1]	-0.069 (0.558)	**-0.242*** **(0.037)**	-0.111 (0.347)	**0.322**** **(0.005)**	-0.144 (0.221)						
MTNP[1]	-0.039 (0.740)	**-0.505**** **(0.000)**	0.018 (0.879)	-0.051 (0.666)	0.157 (0.183)	-0.197 (0.093)					
MTCP[1]	0.014 (0.907)	-0.194 (0.097)	-0.119 (0.314)	0.128 (0.279)	-0.173 (0.141)	0.007 (0.953)	-0.141 (0.232)				
FAL[1]	-0.129 (0.273)	-0.125 (0.289)	0.041 (0.726)	-0.073 (0.537)	-0.150 (0.202)	-0.052 (0.658)	-0.174 (0.139)	-0.178 (0.129)			
FRST[1]	**0.240**** **(0.039)**	0.090 (0.444)	-0.057 (0.630)	-0.224 (0.055)	0.001 (0.992)	-0.050 (0.671)	-0.225 (0.053)	0.018 (0.881)	**-0.358**** **(0.002)**		
CCF[1]	-0.047 (0.691)	-0.023 (0.847)	0.086 (0.468)	-0.101 (0.391)	**0.263*** **(0.024)**	-0.112 (0.341)	-0.124 (0.294)	0.294 (0.734)	-0.057 (0.627)	0.212 (0.070)	
BB[1]	0.039 (0.740)	-0.183 (0.118)	-0.097 (0.410)	-0.101 (0.394)	0.191 (0.103)	-0.026 (0.823)	-0.045 (0.704)	**0.253*** **(0.030)**	-0.060 (0.613)	0.161 (0.172)	0.070 (0.551)

Note: n=74, Cell Contents: Pearson correlation/(P-Value). * P<0.05, ** P<0.01, *** P<0.001, Significant correlations are presented in bold.

[1]Land use and pasture parameters are based on the proportions for grazing areas, DGPS (degraded pasture), NTNP (natural pasture with no trees), NTCP(cultivated pasture with no trees), MTNP(natural pasture with moderate tree density), MTCP(cultivated pasture with moderate tree density), FAL(fallow), FRST (riparian forests). CCF(cut and carry forages), BB (*B. brizantha*).

5.4.2 Correlations between size of grazing areas and herd parameters

Correlations between size of grazing areas and herd parameters are presented in Table 5.16. The results showed that size of grazing areas was highly correlated with herd size ($r=0.856$ $P<0.01$), but not with other herd parameters. Proportions of cows and steers were negatively correlated ($r=-0.575$ $P<0.001$), indicating that these cattle types substituted for one another. In addition, the correlation between the proportion of cows and lactating cows for herds were positive ($r=0.667$ $P<0.001$). Stocking rate was correlated with both annual income from cattle production per hectare ($r=0.468$ $P<0.001$) and milk production per hectare ($r=0.642$ $P<0.001$), while the proportion of milking cows was correlated only with milk production (0.514 $P<0.001$), not with annual income.

Table 5.16

Correlation matrix between farm size and herd parameters (n=74)

Variables /unit	Grazing area ha	Herd size LU	Stocking rate LU/ha	COW	STEER	MCOW	CTL/Y/H US$/year/ha
Herd size	0.856*** (<0.001)						
Stocking rate	-0.210 (0.072)	0.221 (0.059)					
COW	-0.148 (0.208)	-0.157 (0.182)	-0.108 (0.359)				
STEER	0.176 (0.133)	0.140 (0.233)	-0.003 (0.980)	-0.575*** (<0.001)			
MCOW	-0.154 (0.191)	-0.138 (0.240)	-0.007 (0.955)	0.667*** (<0.001)	-0.435*** (<0.001)		
CTL/Y/H	-0.175 (0.135)	0,067 (0.569)	0.468 (<0.001)	0.055 (0.641)	-0.059 (0.619)	0.121 (0.305)	
Milk production (litres/ha/day)	-0.235 (0.044)	0.086 (0.464)	0.642 (<0.001)	0.263 (0.023)	-0.217 (0.063)	0.514 (<0.001)	0.682 (<0.001)

Note: above: Pearson correlation, (P-Value) below.

*P<0.05, **P<0.01, ***P<0.001, Significant correlations are presented in bold.

COW: proportion of cows for herd, MCOW: proportion of milking cow for herd,

STEER: proportion of steers for herd, CTL/Y/H: annual income from cattle production per hectare.

5.4.3 Correlations between land use and herd parameters

The correlations between land use, pasture and herd parameters are presented in Table 5.17. Correlations were significant between stocking rates and the proportion of natural pastures with low tree density (SR-LTNP, r=0.356 P<0.01), between cultivated pasture with low tree density and the proportion of steers (LTCP-STEER, r=0.362 P<0.01), and between the proportion of cut and carry forages and saleable milk production/stocking rate (CCF-MEMLK, r=0.336 P<0.01; CCF-SR, r=0.391 P<0.01). In addition, farms with higher stocking rates tended to have less degraded pasture (r=-0.201 P=0.086). The results suggest that farms with higher stocking rates had more natural pasture with low tree density (P<0.01) and cut and carry forages (P<0.01), and they tended to have less degraded pasture. In contrast, farms with more steers had more cultivated pasture with low tree density (P<0.01).

Table 5.17

Correlation matrix between land use and herd parameters (n=74)

Land use type	Annual income	Daily milk production	Stocking rate	Milking cow/herd	Steer /herd
Unit	US$/ha	litres/day/ha	LU/ha		
Abbrev.	CTL/Y/H	MEMLK/D/H	SR	MCOW	STEER
DGPS	0.045 (0.701)	-0.015 (0.899)	-0.201 (0.086)	0.001 (0.990)	0.013 (0.915)
NTNP	-0.170 (0.147)	-0.039 (0.739)	0.177 (0.132)	-0.126 (0.284)	0.162 (0.168)
NTCP	-0.067 (0.569)	-0.016 (0.892)	-0.168 (0.152)	0.093 (0.433)	-0.080 (0.497)
LTNP	-0.002 (0.985)	0.082 (0.488)	**0.356**** **(0.002)**	0.048 (0.687)	-0.051 (0.669)
LTCP	0.037 (0.756)	-0.066 (0.574)	-0.042 (0.724)	-0.140 (0.233)	**0.362**** **(0.002)**
MTNP	0.010 (0.933)	0.040 (0.733)	0.110 (0.350)	-0.044 (0.710)	-0.130 (0.268)
MTCP	-0.015 (0.896)	-0.003 (0.979)	-0.167 (0.156)	0.082 (0.488)	-0.093 (0.429)
FAL	-0.035 (0.767)	0.069 (0.560)	0.020 (0.862)	0.125 (0.288)	-0.119 (0.313)
FRST	-0.023 (0.847)	-0.179 (0.128)	-0.019 (0.871)	-0.089 (0.452)	0.103 (0.381)
CCF	0.223 (0.057)	**0.336**** **(0.003)**	**0.391**** **(0.001)**	0.195 (0.096)	-0.050 (0.671)
BB	0.048 (0.682)	0.164 (0.163)	0.026 (0.828)	0.141 (0.232)	0.134 (0.256)

Cell Contents: Pearson correlation (P-Value),*P<0.05, ** P<0.01. Significant correlations are presented in bold. DGPS (degraded pasture), NTNP (natural pasture with no trees), NTCP(cultivated pasture with no trees), LTNP(natural pasture with low tree density), LTCP(cultivated pasture with low tree density), MTNP(natural pasture with moderate tree density), MTCP(cultivated pasture with moderate tree density), FAL(fallow,) FRST(riparian forests), CCF(cut and carry forages), BB(*B. brizantha*).

5.5 Discussion

5.5.1 Tree cover, stocking rates, and land use types

The results show that on average tree cover represented 23% of the grazing lands (Table 5.4). Pasture occupied 62%, while forest occupied 20% of the total farm area (Table 5.3). The most frequent land use types (degraded pasture (DGPS) and natural pasture with moderate tree density (MTNP)), occupied almost half of the grazing areas with moderate tree cover accounting for approximately 20%, while pastures with no trees occupied only 12% of the grazing areas. It suggests that the farms largely utilize silvopastoral areas for cattle grazing. Stocking rates were 0.91 on average, (Table 5.6) and pastures were largely composed of degraded and natural pastures rather than cultivated pastures. This suggests that the farms are under extensive management.

Correlations were significant between stocking rates and natural pasture with low tree density ($r=0.356$ $P<0.01$, Table 5.17) and close to being significant between stocking rates and degraded pasture ($r=-0.201$ $P=0.086$) (Table 5.17). These suggest that higher stocking rates tend to reduce degraded pasture and reduce lower tree density by disturbing natural regeneration of trees. However, even though potentially higher financial resource per hectare is expected for farms with higher stocking rates, pasture improvement was not observed in those farms. Since farms with higher stocking rates were rather small ($r=-0.210$ $P=0.072$, Table 5.16), these farms may not have sufficient financial resources to reduce degraded pasture. On the other hand, the farms with higher proportion of steers had higher proportion of cultivated pasture with low tree density ($P<0.01$, Table 5.17). It may indicate that farms with more emphasis on rearing steers have greater financial resources, and therefore they improve pasture lands.

5.5.2 Herd structure and farm types

Regarding herd structure, the proportion of cows and steers were negatively correlated ($P<0.01$) and the correlations between the proportion of milking cows for the entire herd and the proportions of both milking and dry cows were significant ($P<0.001$) (Table 5.13). This suggests that there are two types of farms: ones that rear steers and ones with more emphasis on milk production. Saleable milk production generates daily cash for living which is essential for farmers, but steer production generates income in the medium-term. In addition, as mentioned above, the proportion of steers was positively correlated with the proportion of cultivated pasture with low tree density ($P<0.01$, Table 5.17). Therefore, it may be considered that farmers who concentrated on rearing steers had greater financial resources. They were able to sell the steers at the end of dry season when cattle prices were at their highest.

5.5.3 Calving and cattle mortality

The study results showed that calving frequencies were significantly higher in the dry season than in the wet season ($P<0.01$, Table 5.9) and that saleable milk production per cow was significantly lower at the end of the dry season than in other seasons ($P<0.01$, Table 5.8). Also adult death rates were higher at the end of the dry season (Table 5.7). Considering the fact that one third of the farms did not use any supplementary fodder in the dry season (Table 5.14), it may suggest that stocking rates at the end of dry season are higher than the carrying capacity of the grazing areas thus causing low milk yield per cow and high adult death rates.

The average calving rate (47%) is low compared with the national census of Costa Rica, 64% (Corporacion Ganadera, 2000) and with the ranges presented by Sere and de Vaccaro (1985) (50-70%) in Honduras, Panama and Colombia, but similar to the national average of Venezuela (45%, Plasse, 1992). Ideally, calving interval should be 12 months with a dry period of two months (100% calving rate) (Ramirez, 2002), which is higher than any of these ranges. In the study area, calving rates may be generally lowered due to malnutrition during the dry season, presence of calves and low availability of bulls particularly in small farms. It was possible that calving records were not reported correctly due to difficulties associated with specifying frequencies for three months periods and because some farmers simply brought milking cows after calving to the sample farms which are conveniently located to sell milk to milk collectors. It is also possible that low calving rates were caused by the farmers' tendency to keep unproductive cows (Chapter 3). Since the variation in milk production between individual cows is high in dual-purpose cattle farms, frequent culling was suggested by Llamozas and Vaccaro (2002). On average, calf mortality rate was 16%, which is higher than the results presented by Sere and de Vaccaro (1985) and Vacarro et al. (1992) (6-12%) in Brazil, Costa Rica and Panama, and

Venezuela. The average adult mortality rate was 1.0%, which is relatively low compared with the range presented by Sere and de Vaccaro (1985). Further studies are recommended on the improvement of calving rates, the timing of calving, and the cause of the death (e.g. nutritional problems, disease or accidents).

5.5.4 Milk production

It is to be expected that milk production is lower in the dry season. However, the results show that daily saleable milk production did not differ per farm by season ($P<0.05$, Table 5.9). The number of calvings were higher in the dry season ($P<0.01$) and the number of milking cows did not differ by season ($P<0.05$) (Table 5.7). It is probably because more cows conceive at the beginning of the wet season when physical conditions are improved by better fodder. It seems that since most of the farms were at locations accessible to milk collectors, they tended to bring more milking cow to the farms to sell milk.

In contrast, saleable milk production by season differed significantly per cow ($P<0.01$) and per hectare ($P<0.05$) (Table 5.9). Clearly the conditions of grazing areas in the dry season restrict milk yield. Common pasture species in the study area, such as *P. notatum* and *H.rufa,* which covered large grazing areas, do not maintain their nutritional values in the dry season (Peters et al., 2002). This could cause low milk yields per cow and per hectare. Since there were more milking cows during the dry season (Table 5.6), as confirmed by the higher number of calvings ($P<0.01$, Table 5.7), milking cows which were intentionally kept in the farms in the dry season may also have caused low milk yield per cow and per hectare. Clearly, greater demand by calves, as a consequence of the higher number of calvings, also caused the lower saleable milk production per cow in the dry season. Further studies are recommended to consider fodder availability in the dry season as well as the feasibility and effects of pasture improvement.

Based on the data of seasonal saleable milk production per cow (Table 5.9), it can be estimated from all sample farms that true saleable milk production was 804 litres/cow/lactation [daily estimated milk yields per cow, 3.35 litres/day/cow multiplied by 8 month lactation period (Lavard et al., 2001)]. This yield result is similar to those presented by Sere and de Vaccaro (1985) in Colombia and Panama (749 and 956 litres/cow/lactation), Vaccaro et al., (1992) in Venezuela (700-1,100 litres/cow/lactation), and by Wilkins et al. (1979) in Bolivia (600-1,200 litres/cow/year).

Tropical grasses in general have poorer feeding value than temperate grasses due to lower voluntary intake and dry matter digestibility (Minson, 1981). Stobbs and Thompson (1975) concluded that by using improved tropical pasture it was possible to produce 2,000kg of milk per lactation. The sample farms were family farms engaged in dual-purpose cattle production, thus milk is partly consumed by calves and family members. Wilkins et al. (1979) estimated that maximum milk production per cow with improved pastures without concentrates was approximately 2,000 litres (1,300 litres sold per lactation with 700 litres consumed by a calf). This target yield is comparatively higher than the results of the present study. The grazing areas in the study area are highly covered by natural pastures (30% Table 5.4), which have limited potential for cattle production in the tropics (Humphreys, 1987). Stobbs and Thompson (1975) suggested that "the early lactation stage is the most important phase of the whole cycle: the cow's potential is being established". However, in the study area, the high potential may not be achieved due to the fodder restriction in the dry season when the majority of calvings occur. Based on these findings, the study concludes that there is considerable potential to increase saleable milk production per cow and per hectare in the study area.

5.5.5 Stocking rates and cattle movement

It is generally considered that in the semi-humid tropics, farmers move their cattle to areas with shorter dry season in order to have better forage for cattle. In fact cattle were commonly moved from farm to farm (62% of total farms, Table 5.11). However, the study results showed that herd sizes and stocking rates did not differ by season ($P<0.05$) (Table 5.6). It seems that this misconception occurred due to overlooking several important points: 1) needs of cattle removal in the beginning of the wet season for pasture recuperation, 2) farmers' limited capacity to move cattle, 3) existence of large farms with a small number of cattle, 4) farmers' annual perspectives for cattle feeding, 5) increased calving in the dry season, and 6) cattle removal for long-term cattle entrusting in the wet season.

It is apparent that natural forage for cattle is in shortage in the dry season. Farmers need to move their cattle from their farm, but in the beginning of the wet season. Farmers also need to remove their cattle for pasture recuperation in order to make pasture cover the grazing areas. It was observed that when the rain starts, some farmers remove weeds in their grazing areas and keep cattle out for a few months. These characteristics are probably more common in natural pasture species since natural pastures are rather susceptible to weed invasion. In the wet season, it is probably easier and cheaper for cattle owners to rent other pasture lands to keep the cattle when cattle can consume good forage.

In fact, it seemed difficult for many farmers (especially with small farms) to take their cattle to other farms far from their farms. It is probably because this practice is very costly or the number of cattle is not sufficient to make it worthwhile. If farmers have strong connections based on their family, it may be easier to control stocking rates by removing cattle in the dry season. However, the period of settlement in the study area was rather short (60% of farms less than 10 years, Section 3.3.1); therefore, it seems that farmers do not have reliable contacts to others where cattle can be kept in the dry season. Many of farmers in the area are probably not in a stabilization stage but in a survival stage.

Forty one % of the farms did not move their cattle probably because they have large farms compared with the number of cattle (Table 5.11). When cattle are grazed on other farms, cattle owners may need to watch the conditions of their cattle because cattle may consume low quality feed. Supervision are required in this culture when hiring others (Kaimowitz, 1996) and some farmers showed negative feelings about keeping cattle in other farms due to bad experiences. Moreover, farmers may plan dry season fodder from the wet season, thus some farmers may remove their cattle in the wet season for a long-term basis in order to keep their own pasture in the dry season.

For farmers who have excessive cattle with respect to the forage supply, one option is to sell animals. However, it seemed that they want to increase the number of cattle and are rather reluctant to sell the cattle (Section 3.3.2). Cattle are clearly an important investment for them; therefore, it seems that they do not sell their cattle even if they have to pay other farmers for caretaking.

In order to reduce the number of cattle for a long period of time, farmers were entrusting their cattle (their young heifers) to other farmers until they calved and their calves had been weaned (long term caretaking contracts). In general, cows returned to the owners with calves after weaning [usually half of the calves born, therefore this system is called "sistema media" (half system)]. The caretakers of the cattle take the milk produced and half of the calves born on the farm. It seemed that the system was less costly than using credits, which was not financially viable due to high interest rates (Holmann, 1999). The system has relatively low risks provided that there are reliable relationships between the two farmers. In the system, they share the risks because the cattle keepers take greater care of the cattle since they receive direct benefit from them. It was observed that cattle were moved on a long-term basis in the wet season when forage was abundant. Further studies are recommended on cattle movement and the role of local cattle sharing systems compared with credit systems available from local banks.

Finally, it is important to point out that sample farms were selected by accessibility, located near the road, where milk collectors can come most of the year. In fact, there were many farms inaccessible to milk collectors and these farms were probably available to keep cattle. On the contrary, the farmers may bring cows to the farms (possibly from others' farms) when they start producing milk to sell milk, resulting in maintaining large number of milking cows in the dry season when calving rates were rather high ($p<0.01$).

5.5.6 Estimation of herd dynamics

The herd dynamics of the sample farms were estimated for a farm with a mean herd size and structure (Table 5.18). The results demonstrated that gains of livestock units during the year were 71% from growth and 29% from purchase. The cattle removed at the end of the year represented approximately 15% of the total livestock units reduced during the year (including sold and dead) from the farm. Since sample farms were located on the route of milk collectors, it is possible that the amount of livestock unit in error (0.13) could partly come from a gradual increase in the number of milking cows from neighbouring farms.

Table 5.18

Estimated annual summary of herd dynamics at the farm with mean herd size and structure

Types of changes	Cattle types	Base (number)	Change (LU)	Division Total	% within gain and loss
Growth	Heifer	3.30 [a]	0.15 [c]		
	Calves born	6.18 [b]	1.55 [f]		
	Calves grown	8.40 [a]	0.79 [d]		
	Steers	1.30 [a]	0.20 [e]	2.69	70.7
Sale	Cows	1.80 [b]	-1.80 [f]		
	Steers	0.22 [b]	-0.17 [f]		
	Calves	3.36 [b]	-0.84 [f]	-2.81	-76.6
Purchase [b]	Heifer	0.65 [b]	0.49 [f]		
	Steer	0.55 [b]	0.41 [f]		
	Calves	0.85 [b]	0.21 [f]	1.11	29.2
Death [b]	Adult	0.12 [b]	-0.12 [f] [h]		
	Calves	0.77 [b]	-0.19 [f]	-0.31	-8.4
Removal [c]			-0.55	-0.55	-15.0
Total (error)			0.13	0.13	0.0

a) Number of animals in Jan/Feb (Table 5.4)

b) Annual means of calves born, animal sales, purchases and deaths (Table 5.5 and 5.6)

c) Assuming that 25% of heifers become cows in one year. Number of heifers in Jan./Feb. x 0.25 (LU) x 0.75 [in the last nine month period (0.75 year)]].

d) Assuming that 25% of calves become heifers in one year. Number of calves in Jan./Feb. x 0.5 (LU) x 0.75 [in the last nine month period (0.75 year)]].

e) Assuming that all the steers which were not sold become steers in fattening stages (gained 0.25 LU) in one year.

f) Multiplied by amount of livestock unit (for cows 1.0, calves 0.25, steers 0.75).

g) Assuming that all dead adults were cows.

h) Total cattle removed to other farms at the end of the year.

5.5.7 Supplementary feeding and farm types

Size of grazing areas, stocking rates and the percentages of degraded/cultivated pastures did not differ significantly by classification based on supplementary feeding ($P<0.05$, Table 5.14). However, farms that used supplementary feeds, such as supplementary forages and molasses, tended to have higher stocking rates, more degraded pastures and less cultivated pastures in the grazing areas. It may indicate that some farmers with higher stocking rates prefer to invest in supplementary feeding than pasture improvement in the grazing areas.

5.6. Conclusions

The study results show that tree cover represented a large proportion of the land area on the dual-purpose cattle farms that were surveyed. Silvopastoral areas (approximately 73% of the grazing areas) were largely utilized for grazing. Cattle in the dual-purpose cattle farms were frequently moved between local farms, but stocking rates did not differ by season ($P<0.05$). In addition, the frequency of calving was significantly higher in the dry season ($P<0.01$) and saleable milk production per cow was lower at the end of the dry season ($P<0.01$). It was concluded that lack of forage, accompanied by high stocking rates and high calving rates in the dry season, caused low saleable milk production and high mortality rates of adult cattle at the end of the dry season. In addition, farms with higher stocking rates had more natural pasture lands with low tree density ($P<0.01$) and less degraded pasture (P=0.086), but they seemed to be reluctant to improve pasture by introducing cultivated pasture species. Further research is recommended on the improvement of calving rates, fodder availability in the dry season, effects of land use patterns on production at the farm level, the feasibility of pasture improvement, and cattle movement and herd sharing.

References

Corporación Ganadería. 2000. Análisis de Censo Ganadero 2000. http://www.corfoga.org/pdf/proyecto/censo2000.pdf.

FAO (Food and Agricultural Organization). 2003. FAOSTAT.

Holmann, F. 1989. Economic evaluation of dairy and dual-purpose cattle production systems in Venezuela. Ph.D. Dissertation. Cornell University.

Holmann, F. 1999. Ex ante analysis of new forage alternatives for farms with dual purpose cattle production in Peru, Costa Rica and Nicaragua. Livestock research for rural development 11(3) 24p.

Humphreys, LR. 1987. Tropical pastures and fodder crops. Intermediate Tropical Agriculture Series. Longman Science and Technical. 115p.

INTA.1998. Zonificación agro socioeconómica agencia Matiguas. 72p.

Kaimowitz, D. 1996. Livestock and Deforestation: Central America in the 1980s and 1990s: A Policy Perspective. CIFOR Special Publication. 88p.

Llamozas, JA.; Vaccaro, L. 2002. Correlations of part and total lactations and the prediction of lactation milk yield in Venezuelan dual purpose cows hand milked with calf at foot. Livestock Research for rural development 14(5) http://www.cipav.org.co/lrrd/lrrd14/lrrd14.htm.

Levard, L; Lopez, YM; Navarro, I. 2001. Municipio de Matiguas: Potencialidades y limitantes del desarrollo agropecuario. UCA/FIDA/NITLAPAN. 83p.

Maldidier, C; Marchetti, R. 1996. El Campesino-Finquero y el potencial económico del campesinado nicaragüense. NITLAPAN. 174 p.

MINITAB. 2000. MINITAB User's Guide 1 and 2.

Minson, DJ. 1981. Nutritional differences between tropical and temperate pastures. Morley, FHW. eds. Grazing animals. Disciplinary approach. World Animal Science B1: 143-157.

Murgueitio, E; Ibrahim, M; Ramirez, E; Zapata, A; Eduardo, C; Casasola, F. 2003. Usos de la tierra en fincas ganaderas: Guía para el pago de servicios ambientales en el proyecto Enfoques Silvopastoriles Integrados para el Manejo de Ecosistemas. CIPAV. 97p.

Myers, N. 1981. The Hamburger Connection: How Central America's Forest Became North America's Hamburgers. AMBIO 10: 3-8.

Nicholson, CF; Blake, RW; Lee, DR. 1995. Livestock, deforestation, and policy making :intensification of cattle production systems in Central America revisited. Journal of Dairy Science 78(3): 719-734.

NITLAPAN. 1995. Diagnostico de la Producción Agropecuaria en el Interior del País. Análisis de Encuesta Rural. Proyecto de Tecnología Agraria y Ordenamiento de la Propiedad Agraria.

Peters, M; Franco, LH; Schmidt, A; Hincapié, B. 2003. Especies Forrajeras Multipropósito: Opciones para productores de Centroamérica. CIAT. 113p.

Plasse, D. 1992. Presente y futuro de la producción bovina en Venezuela. *In* González-Stagnaro, C. Eds. Ganadería mestiza de doble propósito. Universidad del Zulia. p.1-23.

Parsons, J. 1976. Forest to Pasture: Development or Destruction? Revista de Biología Tropical 24(1): 121-138.

Ramirez, AC. 2002. Ganadería de leche: Enfoque empresarial. Editorial Universidad Estatal a Distancia. 289p.

Ruiz, A. 1994. Tenencia y Uso de la Tierra en Matiguas-Matagalpa, Nicaragua. FAO Land Tenure Working Paper. 79p.

Sere, C; De Vaccaro, L. 1985. Milk production from dual-purpose systems in tropical Latin America. *In* Smith, AJ. Eds. Milk production in Developing Countries. Centre for Tropical Veterinary Medicine. University of Edinburgh. p.459-75.

Souza de Abreu, MH 2002. Contribution of trees to the control of heat stress in dairy cows and the financial viability of livestock farms in humid tropics. Ph.D. dissertation. CATIE.

Stobbs, TH; Thompson, PAC. 1975. Milk production from tropical pastures. World Animal Review 13: 27-31.

Vaccaro. L; Vacarro, R; Verde, O; Alvarez, R; Mejias, H; Rios, L; Romero, E. 1992. Características productivas en la evaluación de explotaciones y vacas en sistemas de doble propósito. Turrialba 42(1): 14-22.

Wilkins, JV; Pereyra, G; Ali, A; Ayola, S. 1979. Milk production in the tropical lowlands of Bolivia. World Animal Review 32: 25-32.

World Bank. 2004. Nicaragua at a glance.

Chapter 6 (Article 4)

Effects of silvopastoral areas on milk production at dual-purpose cattle farms at the semi-humid old agricultural frontier in central Nicaragua

Key words: dual-purpose cattle production, silvopastoral system, stepwise regression, principal components analysis, milk production

Abstract

In extensive cattle production systems, the composition of grazing areas may significantly influence productivity. In dual-purpose cattle production systems in the lowland tropics, pasturelands with trees, so-called silvopastoral areas, are considered as being important, particularly to facilitate the management of crossbred European native cattle. The aim of the study was to quantify the effects of silvopastoral areas on production at dual-purpose cattle farms in the semi-humid lowlands of central Nicaragua. The relationships between seasonal milk production and herd data, and the proportions of land use types for size of grazing areas were examined for 74 farms by stepwise regression, principal components analysis and principal component regression.

The results showed significant positive effects on saleable milk production of degraded pastures (DGPS) ($P<0.001$), natural and cultivated pastures with moderate tree density (MTCP and MTNP) ($P<0.05$), and cultivated pastures with low tree density (LTCP). However, negative effects of land use types under natural pasture with low tree density (LTNP) ($P<0.01$) was also observed, suggesting that on smaller farms, high stocking rates resulted in overgrazing. Analysis by season confirmed the positive effects of degraded pastures (DGPS)

on saleable milk production at the end of dry season ($P<0.01$), and of natural pasture with moderate tree density (MTNP) at the beginning of wet season ($P<0.05$). This suggests that degraded pasture may be important as cattle feed at the end of the dry season whilst natural pastures with moderate tree density are particularly important at the beginning of the wet season. The area of *B. brizantha* had positive effects on saleable milk production at the end of the dry season ($P<0.01$), suggesting that the use of this species is an important option for farmers.

Regression analysis with principal components of land use parameters selected three principal components; the largest component (23% of variance, $P<0.05$) related to grazing pressure and land capacity, the second (18% of variance) related to the use of cultivated pastures, and the fourth (12% of variance) related to silvopastoral areas under natural conditions. The results suggest that in order to have positive effects from land use patterns, farms need to be large in size and small in stocking rate, but also use of cultivated pastures and silvopastoral areas with natural pastures support milk production.

Further studies are recommended concerning the feasibility of the proposed land use change and on the contribution of broadleaf plants to milk production at the end of the dry season.

6.1 Introduction

Conversion of natural forest to pasture in the humid tropics of Central America has been criticized as the main cause of deforestation (Parsons, 1976; Myer, 1981; Kaimowitz, 1996). Cattle managed extensively in tropical pastures with low nutrient values (Minson, 1981) and low labour and capital inputs are exploitative on nutrients accumulated in the soil by the original vegetation (Kaimowitz, 1996; Sunderlin and Rodriguez, 1996). However, extensive cattle production is an important activity in the rural economy due to its comparative advantages against other agricultural production, namely, its low requirement for skill and labour, its low risk, and the fact that products can be transferred easily to markets (Hecht, 1992; Muchagata and Brown, 1999). Dual-purpose cattle production systems have been traditionally preferred by family farms in the lowland tropics due to low risk of price changes, higher economic benefit per unit of area than meat production, adaptation to the climatic conditions in the lowland tropics, and less capital investment and technical support required than for specialized milk production (Sere and De Vaccaro, 1985; Halmann, 1989).

The existence of trees in grazing areas may support cattle production in various ways: 1) improvement of chemical and physical soil conditions (Horne and Blair, 1991; Belsky, 1992; Belsky et al., 1993; Young, 1997), 2) stabilization of soil by protecting the soil surface from intensive rainfall (Pereira, 1989), 3) supporting higher amount of grass production in the dry season by increasing soil water holding capacity and reducing moisture loss (Wilson and Wild, 1991;Young, 1997), 4) improvement of pasture quality (Wilson, 1982; Wilson and Ludlow, 1991; Smith and Whiteman, 1983), 5) increased production by improving the condition of animals and 6) provide leaves and fruits as fodder for animals (Pezo et al., 1990; Pezo and Ibrahim, 1999). In particular, Zebu and European crossbred cattle, which are the most common cattle types in dual-purpose cattle farms in the lowland tropics (Section 3.3.3), can benefit from shading because they are less tolerant of high temperatures than purebred Zebu cattle (Souza de Abreu, 2002). Common tree species in the grazing areas in the study area, *G. ulmifolia*, *E. cyclocarpum*, and *P. saman*, produce fruits and leaves which are an important source of fodder in the dry season (Zamora et al., 2001; Section 4.3.3).

However, published evidence of positive contributions of trees to cattle production have mostly been based on limited scale investigations or experiments. The effects of silvopastoral areas on production in existing farming systems have not been quantified at the farm level due to the high variation between farms and seasons, and technical difficulties obtaining land data for entire farms. The objective of this chapter is to quantify the effects of silvopastoral areas on milk production in dual-purpose cattle farms and to develop a production model, based on data gathered from farms, in order to predict the effects of changes in land use.

6.2. Materials and methods

6.2.1 Site

The study area is located in the Matiguas Municipality in the Matagalpa Department, central Nicaragua: Latitude 12^0 50' North and 85^0 27' Longitude East. The climate of the study area is semi-humid tropical with a well-defined dry season between February and May. Annual rainfall varies from 1,300 to 2,000 mm, while temperature fluctuates between 28 and 32 ^{0}C. Altitude from sea level is between 200-500 m. Topographical conditions are largely flat and modest slopes (0-30%) and small areas with steep slopes (> 30 %) (INTA, 1998). See Section 5.2.1 for more details.

6.2.2 Farm selection

This study was based on data from an independent survey and the project "Regional integrated silvopastoral approaches for ecosystem management project" undertaken by CATIE and NITLAPAN, under the scheme of Global Environment Facility (GEF) of the World Bank.

Seventy-four farms were selected among the project participants based on the following criteria: (1) farm size (10-140 ha); (2) farms with more than 3 cattle; (3) willingness to cooperate with the project and (4) accessibility. Please see Section 5.2.2 for more details.

6.2.3 Land use survey

The satellite images of Quick Bird (Resolution 0.7m with three natural colours) taken in January 2003 were used for the land analysis. Grazing lands were classified into nine types based on the types and conditions of dominant pastures (natural, cultivated or degraded), and tree densities (Reproduced in Table 6.1). Types and conditions of pastures and tree densities were verified in 2003 by field observations for all land uses on all the sample farms. See Section 5.2.3 for more details.

Table 6.1

Land use types of grazing lands

Land use types	Abbrev.[1]	Grass cover	Tree density	Tree cover (%)[2]
Degraded pasture	DGPS	< 50%	N.A.	18.8
Natural pasture with no trees	NTNP	> 50%	None	7.0
Cultivated pasture with no trees	NTCP	> 50%	None	4.6
Natural pasture with low tree density	LTNP	> 50%	<30 trees/ha	12.1
Cultivated pasture with low tree density	LTCP	> 50%	<30 trees/ha	12.5
Natural pasture with moderate tree density	MTNP	> 50%	>30 trees/ha	24.8
Cultivated pasture with moderate tree density	MTCP	> 50%	>30 trees/ha	19.6
Fallow	FAL	None	N.A.	42.6
Riparian forests	FRST	None	N.A	88.8

N.A. Not available.

[1]These abbreviations are used for variables of regression model (proportion of the land use types for grazing area).

[2] Source: Chapter 5.

6.2.4 Herd survey

Data for herd size and structures, changes in herd inventory (number of animals sold/bought and born/died), and daily milk yields were seasonally collected by using structured interviews. The interviews were conducted for 74 farms every 3 months for a one year period: the beginning of the dry season (between the end of January and the beginning of February), the end of the dry season (the end of April and the beginning of May), the beginning of the wet season (the end of July and the beginning of August) and the end of the wet season (the end of October and in the beginning of November) in 2003. See Section 5.2.5 for more details.

6.2.5 Model specification

6.2.5.1 Selection of variables

The objective of this study was to quantify the effects of silvopastoral areas on milk production in dual-purpose cattle farms and to develop a model based on variables collected from commercial farms. In dual-purpose cattle farms, milk and live cattle (calves, cows and steers) are the products. In the study area, 70% of the annual income coming from cattle production was produced by milk sales (Section 3.3.5). In the regression model, therefore, daily saleable milk production was used as the dependent variable. In order to adjust for differences in land areas between farms, the model was developed on a per hectare basis.

Milk production of a dual-purpose cattle farm is largely determined by 1) number of cattle (particularly lactating cows), 2) types of cattle (breeds, health conditions, etc.), 3) feed, and 4) management. It is assumed that feed was adequately covered in the model by having land types as independent variables (as explained later in this section). Herd structure parameters were covered by including stocking rates (LU/ha) and the proportion of lactating cows as independent variables. In the study area, cattle on the dual-purpose farms were mainly crossbreeds of Brown Swiss and Brahman (mostly 50-70% Brown Swiss - Section 3.3.3); therefore, breed was not included in the model. Regarding management, there was no difference between farms in terms of milk consumption by calves since almost all of the farms practiced a partial-suckling system (Section 3.3.3.3). Other factors related to management (e.g. milking practices) were ignored since the farm data were not collected in the survey.

Grazing areas were defined as areas that farmers could use for cattle grazing throughout or for parts of the year. For the model, these were composed of pasture lands with different tree densities, fallow and forest (riparian forest). The proportions of each land use type (i.e the area of each land type relative to the total area used for grazing) were used as independent variables. The land use types included in the analysis are as defined in Table 6.1.

In the dual-purpose cattle farms in the study area, several types of supplementary feeds were used, but the amounts were limited except for supplemental pasture (mainly *Pennisetum spp.*) fed by means of cut and carry (Section 5.3.9). Supplementary pastures were sown in forage banks (Table 5.3). In addition, recently sown pasture, *Brachiaria brizantha*, was shown to be important (Section 3.3.7). Therefore, the proportions of these two types of pastures (*B.brizantha* and cut and carry forage) in grazing areas were treated as independent variables.

Milk production was calculated by the following equations:

Mean daily saleable milk production per hectare (MLK/D/H (litres/day/hectare)

$$= \frac{\sum_{i=1}^{4} \text{Daily saleable milk production (litres/day)}}{4 \times \text{Size of grazing area (hectares)}} \qquad (1)$$

where i=1, 2, 3, 4, different seasons

The selected variables are presented in Table 6.2.

Table 6.2

List of selected variables

Variable	Description (Unit)
Dependent variable	
MLK/D/H[1]	Daily saleable milk production per hectare (litres/day/ha)
Independent variables	
SR[1 2 3]	Stocking rate (LU/ha)
MCOW[1 2]	Proportion of milking cows in relation to entire herd
CCF[3]	Proportion of area of cut and carry forage in relation to total grazing area
BB[3]	Proportion of area of *B. brizantha* in relation to total grazing area
DGPS[4]	Proportion of area of degraded pasture in relation to total grazing area
NTNP[4]	Proportion of area of natural pasture with no trees in relation to total grazing area
NTCP[4]	Proportion of area of cultivated pasture with no trees in relation to total grazing area
LTNP[4]	Proportion of area of natural pasture with low tree density in relation to total grazing area
LTCP[4]	Proportion of area of cultivated pasture with low tree density in relation to total grazing area
MTNP[4]	Proportion of area of natural pasture with moderate tree density in relation to total grazing area
MTCP[4]	Proportion of area of cultivated pasture with moderate tree density in relation to total grazing area
FAL[4]	Proportion of area of fallow in relation to total grazing area
FRST[4]	Proportion of area of riparian forests in relation to total grazing area

[1] The annual mean of four seasons were used for annual analysis and original data were used for seasonal analysis.

[2] LU: livestock unit was based on 400kg of liveweight: 1.0 for lactating and dry cows, 0.75 for heifers, 1.0 for steers in the fattening stage, 1.25 for bulls and oxen, 0.75 for steers in the rearing stage, 0.5 for calves after weaning, and 0.25 for calves before weaning.

[3] Pasture parameters with recently sown species.

[4] Composition of grazing areas.

6.2.5.2 Description of selected variables

Descriptive statistics of saleable milk production, herd parameters (stocking rates and proportion of milking cows, both annual means and seasonal values), pasture parameters (proportion of cut and carry forage, and *B. brizantha*), mean size of grazing areas, and land use parameters (proportions of each land use type) are presented in Table 6.3 and 6.4 from the survey results described in Chapter 5. *B. brizantha* and cut and carry forage were sown at a limited number of farms (21 and 31 farms, respectively), resulting in large standard deviations. The proportions of the land use types varied considerably. DGPS occupied 28% of the grazing area, which was 35 times larger than the area occupied by NTCP.

Table 6.3
Description of dependent variables and cattle/pasture variables

Variable	Unit	Mean	Standard Deviation	Median
MLK/D/H[1]	litres/day/ha	1.382	0.731	1.447
MLK/D/H1-2 [2]	litres/day/ha	1.334	0.918	1.205
MLK/D/H4-5 [3]	litres/day/ha	1.198	0.910	1.143
MLK/D/H7-8 [4]	litres/day/ha	1.647	1.078	1.560
MLK/D/H10-11[5]	litres/day/ha	1.350	1.002	1.265
SR[1]	LU/ha	0.916	0.337	0.875
SR1-2 [2]	LU/ha	0.949	0.480	0.880
SR4-5 [3]	LU/ha	0.903	0.463	0.875
SR7-8 [4]	LU/ha	0.873	0.376	0.880
SR10-11 [5]	LU/ha	0.927	0.422	0.900
MCOW[1]		0.426	0.14	0.442
MCOW1-2 [2]		0.391	0.199	0.390
MCOW4-5 [3]		0.434	0.211	0.444
MCOW7-8 [4]		0.476	0.220	0.501
MCOW10-11 [5]		0.401	0.228	0.400
Cut & carry forage		0.0362	0.0451	0.0192
B. brizantha		0.0202	0.0496	0.0000

Note: n=74. MLK/D/H and SR are reproduced from Table 5.9 and 5.6, respectively.

[1]Annual mean values based on data from four seasons.

[2,3,4,5]Mean values based on data in Jan/Feb, Apr./May, Jul./Aug., and Oct./Nov., respectively.

MLK/D/H (Saleable daily milk production), SR (Stocking rate), MCOW (Proportion of milking cows for the entire herd),

Table 6.4

Size, proportion, and tree cover of land use types for grazing lands

Land use types	Proportion		Size		Tree cover
	Mean	SD	Mean (ha)	SD (ha)	(%)
DGPS	0.276	0.274	6.86	1.15	18.8
NTNP	0.019	0.0467	0.50	0.17	7.0
NTCP	0.008	0.0315	0.20	0.09	4.6
LTNP	0.134	0.160	2.21	0.36	12.1
LTCP	0.076	0.138	1.50	0.33	12.5
MTNP	0.183	0.210	3.66	0.57	24.8
MTCP	0.075	0.137	1.47	0.40	19.6
FAL	0.077	0.160	1.36	0.28	42.6
FRST	0.152	0.094	3.59	0.54	84.3
Total	1.000		21.36	1.97	23.3

Source: Data based on Quick bird satellite images, January 2003, n=74

Note: SD: Standard deviation.

DGPS (degraded pasture), NTNP (natural pasture with no trees), NTCP (cultivated pasture with no trees), LTNP (natural pasture with low tree density), LTCP (cultivated pasture with low tree density), MTNP (natural pasture with moderate tree density), MTCP (cultivated pasture with moderate tree density), FAL (fallows), FRST (riparian forests).

6.2.5.3 Data analysis

The effects of land use parameters on milk production were examined by regression analyses. In addition to the regression analyses with original variables, principal components for land use parameters were used since it was expected that the effects were rather weak compared with herd parameters (stocking rates and proportion of milking cows).

6.2.5.3.1 Stepwise regression analysis on saleable milk production

In order to examine the effects on saleable milk production of the independent variables (as defined in Section 6.2.5.1 and 6.2.5.2.), two forms of stepwise regression analysis were performed: (1) backwards elimination (remove variables one at a time) and (2) standard stepwise regression with forward entrance and backwards elimination (add and remove variables) (MINITAB, 2000). The analyses were performed on an annual and seasonal basis. The analysis by season assumed that that the proportions of each land type per farm did not change during the study period. MINITAB 13 was used for the statistical analysis (MINITAB, 2000).

A threshold P value of 0.15 was used for both types of regression analysis. This was the default value in MINITAB and was chosen, rather than P=0.05, in order to avoid the danger of eliminating important variables at an early stage in the stepwise procedure. In order to maintain independency of land use parameters, the proportion of riparian forests was excluded from the predictors.

The regression model is described as follows:

MLK/D/H (Saleable milk production, litres/ha/day)

$$= b_1\,SR + b_2\,MCOW + b_3\,CCF + b_4\,BB + b_5\,DGPS + b_6\,NTNP + b_7\,NTCP + b_8\,LTNP$$
$$+ b_9\,LTCP + b_{10}\,MTNP + b_{11}\,MTCP + b_{12}\,FAL \qquad (2)$$

where $b_{1\text{-}12}$ = Regression coefficients and the variables are as defined in Sections 6.2.5.1.

6.2.5.3.2 Principal components analysis for land use parameters

Principal components analysis (PCA) is a technique to identify a new set of orthogonal axes so that the first few components account for a large proportion of the total variance in the data (Sharma, 1996). Principal components regression (PCR) can be a powerful technique when principal components are used as new practical variables (Draper and Smith, 1980). When multicollinearity is present among the predictors, principal components regression is an appropriate alternative to the ordinary least squares regression (Chatterjee and Price, 1991).

In this study, partial use of principal components, only for land use parameters, was applied in order to examine the gradients related to land use patterns while avoiding unnecessary interference by other variables. All other predictors (i.e. except for land use parameters) were standardised before the analysis by subtracting the means and dividing by standard deviations.

The principal component scores of land use parameters are described as:

$$PCi = Z_{1i}\,DGPS + Z_{2i}\,NTNP + Z_{3i}\,NTCP + Z_{4i}\,LTNP + Z_{5i}\,LTCP + Z_{6i}\,MTNP + Z_{7i}\,MTCP + Z_{8i}\,FAL + Z_{9i}\,FRST \quad (i= 1,2,3,4,5,6,7,8,9,) \qquad (2)$$

where $Z_{h,i}$ (h, i = number of land use parameters and principal components) = Coefficients of principal components for land use parameters.

6.2.5.3.3 Stepwise regression analysis by principal components of land use parameters

Stepwise regression was performed by using both backwards elimination and a standard selective procedure (forward selection to add variables and backwards elimination to remove variables) (MINITAB, 2000). The analyses were performed on an annual and seasonal basis. As used with the original land use parameters, a threshold P value of 0.15 was used for the regression analysis. Only the principal components which made a substantial contribution to variance (>0.1) were considered as predictors. Thus, the five principal components with the largest contribution to variance were selected as initial variables for the stepwise regression.

The regression model is described as follows.

Saleable milk production (litres ha^{-1} day^{-1}) = $\alpha_1 \, SR^{ST} + \alpha_2 MCOW^{ST} + \alpha_3 CCF^{ST}$

$+ \alpha_4 BB^{ST} + \Sigma^9_{i=1} \; (\beta i * PCi)$ (3)

where $\alpha_{1\text{-}4}$ = Regression coefficients

βi = Regression coefficients for principal components

ST Standardized variables by subtracting the mean and dividing by standard deviations.

Hence, the final coefficients for the nine land use parameters (DGPS, NTNP, NTCP, LTNP, LTCP, MTNP, MTCP, FAL, FRST) for the saleable milk production are described by putting PCi (2) in equation (3).

$\Sigma^9_{i=1} \;\; \beta i \, Zji$ (j = 1, 2, 3, 4, 5, 6, 7, 8, 9 for each land use parameter) (4)

6.2.5.3.4 Assessment of collinearity between predictors

Collinearity between independent variables were analysed by cluster analysis with distance based on one minus absolute values of Pearson correlation coefficients. Values smaller than 0.55 are considered to have a collinearity problem (Johnson and Wichern, 1998). In this study, DGPS and LTNP had a collinearity problem (Appendix 6.1); however, they were not selected together in the final model. Therefore, the model was considered to be sensible. Infostat (Infostat, 2004) was used for this analysis. Correlations between explanatory variables with principal components were also examined and proved to be low (Appendix 6.2).

6.2.5.3.5 Economic prediction by regression model

In order to examine the changes in profit of the farms as a consequence of land use change, an economic model was developed based on the models derived by stepwise regression with original variables. The model was applied to a hypothetical farm with parameters equal to the mean values of data from all the farms (stocking rates, proportion of milking cows, size of grazing area, and proportion of land use types along with recently installed pastures). It was assumed that without changing herd variables (stocking rates and proportion of milking cows), the proportions of land use types for grazing were changed. Milk price were calculated as a weighted mean from values for the wet and dry seasons.

6.3 Results

6.3.1 Multiple regression analysis with initial variables

Results of the multiple regression analysis against daily saleable milk production are presented in Table 6.5. The stocking rate (SR) and the proportion of milking cows (MCOW) ($P<0.001$), the proportions of area of *B. brizantha* (BB), degraded pastures (DGPS), cultivated pastures with low tree density (LTCP), and natural/cultivated pasture with moderate tree density (MTNP and MTCP) ($P<0.05$) showed significant positive effects on milk production. Among the four land use types, P values of degraded pasture (DGPS) ($P=0.010$) and natural pasture with moderate tree density (MTNP) ($P=0.014$) were smaller than the other land use types. The proportion of fallow (FAL) showed positive effects on saleable milk production close to significant level ($P=0.059$). The R^2 value was 76%.

Table 6.5

Results of regression analysis for saleable milk production with initial variables

Predictor	Abbre.	Coefficient	SE Coefficient	T	P
Constant		-2.2989***	0.5047	-4.54	<0.001
Stocking rate	SR	1.5475***	0.1603	9.65	<0.001
Milking cow	MCOW	2.5046***	0.3467	7.22	<0.001
Cut and carry forage	CCF	0.765	1.204	0.64	0.527
B.brizantha	BB	2.274*	1.038	2.19	0.032
Degraded pasture	DGPS	1.6018*	0.6051	2.65	0.010
Natural pasture with no trees	NTNP	1.598	1.345	1.19	0.239
Cultivated pasture with no trees	NTCP	1.887	1.629	1.16	0.251
Natural pasture with low tree density	LTNP	0.4271	0.6778	0.63	0.531
Cultivated pasture with low tree density	LTCP	1.4804*	0.6868	2.16	0.035
Natural pasture with moderate tree density	MTNP	1.4665*	0.5775	2.54	0.014
Cultivated pasture with moderate tree density	MTCP	1.4394*	0.6663	2.16	0.035
Fallow	FAL	1.0555	0.5492	1.92	0.059

R^2 = 75.9%, *** P<0.001, * P<0.05.

6.3.2 Stepwise regression analysis using forward and backwards procedures

Results of stepwise regression for daily saleable milk production by forward entrance and backwards elimination are presented in Table 6.6 and equation (3). Stocking rates (SR), the proportion of milking cows (MCOW), the proportion of *B. brizantha* (BB), and the proportion of natural pastures with low tree density (LTNP) were selected as predictors, of which SR and MCOW (P<0.001) and LTNP (P<0.01) showed significant positive effects on saleable milk production. Positive effects of BB (P=0.079) were observed. Variables entered the model in the order SR, MCOW, LTNP and BB. R^2 of final model was 73%. The model with the first two variables (SR and MCOW) had an R^2 of 68%, which was already 93% of that of final model. In contrast to the results of multiple regression with all variables, no positive effects, except for BB (pasture variable), were obtained for land use and pasture parameters.

$$MEMK/D/H = -1.06 + 1.57\ SR + 2.61\ MCOW + 1.70\ BB - 1.01\ LTNP \text{ ------------ } (3)$$

Table 6.6

Results of stepwise regression analysis for saleable milk production by forward and backwards procedures

Predictor	Abbrev.	Coefficient	SE Coefficient	T	P
Constant		-1.0588***	0.1913	-5.54	<0.001
Stocking rate	SR	1.5654***	0.1463	10.70	<0.001
Milking cow	MCOW	2.6054***	0.3226	8.08	<0.001
B. brizantha	BB	1.7029	0.9536	1.79	0.079
Natural pasture with low tree density	LTNP	-1.0142**	0.3142	-3.23	0.002

$R^2 = 72.7\%$, * $P<0.05$, ** $P<0.01$, *** $P<0.001$. Maximum accepted P value = 0.15.

6.3.3 Stepwise regression analysis by backwards elimination

Results of the stepwise regression analysis on saleable milk production by backwards elimination are presented in Table 6.7 and equation (4). Stocking rates (SR) and the proportion of milking cows (MCOW) ($P<0.001$); the proportions of degraded pasture (DGPS) ($P<0.001$), cultivated pasture with low tree density (LTCP) ($P<0.05$), natural pasture with moderate tree density (MTNP) ($P<0.01$), cultivated pasture with moderate tree density (MTCP) ($P<0.05$), and fallow (FAL) ($p=0.68$) from land use parameters; and the proportion of *B. brizantha* (BB) ($p=0.067$) retained as predictors. Thus the significant positive effects of DGPS, LTCP, MTNP, and MTCP were ascertained, but the effects of fallows and *B. brizantha* were not significant. Among land use parameters, P values for DGPS ($P<0.001$) and MTNP

(P=0.005) were smaller than the other land use parameters. As in the forward and backwards procedures, the variables entered the model in the order of SR, MCOW at first. R^2 for the final model was 75%. The model with the first two variables (SR and MCOW) had R^2 of 68%, which was already 91% of that of the final model.

$$\begin{aligned}MEMK/D/H = &- 1.85 + 1.58\ SR + 2.58\ MCOW + 1.04\ DGPS + 1.02\ LTCP \\ &+ 0.947\ MTNP + 0.966\ MTCP + 0.620\ FAL + 1.84\ BB \text{ ------------(4)}\end{aligned}$$

Table 6.7

Results of stepwise regression analysis for saleable milk production by backwards elimination

Predictor	Abbrev.	Coefficient	SE Coefficient	T	P
Constant		-1.8514***	0.2856	-6.48	<0.001
Stocking rate[1]	SR	1.5750***	0.1565	9.80	<0.001
Milking cow[1]	MCOW	2.5782***	0.3175	4.06	<0.001
Degraded pasture	DGPS	1.0358***	0.2659	3.90	<0.001
Cultivated pasture with low tree density	LTCP	1.0212*	1.052	2.06	0.043
Natural pasture with low tree density	MTNP	0.9466**	0.3286	2.88	0.005
Cultivated pasture with moderate tree density	MTCP	0.9660*	0.4006	2.41	0.019
Fallow	FAL	0.6204	0.3340	1.86	0.068
B.brizantha	BB	1.8374	0.9853	1.86	0.067

Note: R^2 = 74.8%, * P<0.05, ** P<0.01, *** P<0.001, Maximum accepted P value = 0.15. Regression analyses by the initial variables are in Table 6.6.

[1]Annual means.

6.3.4 Effects of predictors on saleable milk production by season

The coefficients of the selected predictors by stepwise regression by backwards elimination for saleable milk production are presented by season in Table 6.8. The results showed that stocking rates and the proportion of milking cows (MCOW) remained as significant predictors in all seasons. A larger proportion of R^2 was accounted for by stocking rates in the wet season, and it had a larger coefficient indicating that it had greater effects on saleable milk production in the wet season than in the dry season. Regarding pasture variables, the proportion of *B. brizantha* (BB) showed positive effects only at the end of the dry season (4.9, $P<0.01$), suggesting that this pasture species is important for saleable milk production in this season. The proportion of degraded pastures (DGPS) also had positive impacts on saleable milk production at the end of the dry season ($P<0.01$), suggesting that this land use type is important for saleable milk production in this season. On the other hand, cut and carry forage tended to have positive effects at the end of the wet season (2.5, $P=0.098$). Moreover, R^2 values were much lower in the dry season (41.9% at the end of the dry season) than wet season (72.7% at the beginning of the wet season), suggesting that the influence of other factors are greater in the dry season. In fact, the contributions by cattle parameters (stocking rates and proportion of milking cows) were much smaller at the end of the dry season than the beginning of the wet season (R^2 only with the two variables were 33.6% and 70.1%, respectively), suggesting that cattle parameters had greater influence on saleable milk production in the wet season.

Table 6.8

Regression coefficients of predictors by season (backwards elimination)

/Season Predictor/Month	Dry Jan./Feb.	 Apr./May	Wet Jul./Aug.	 Oct./Nov.
Constant	-0.7582	-1.145	-1.811	-1.223
SR	**1.03*** **	**1.11*** **	**1.67*** **	**1.35*** **
MCOW	**2.36*** **	**1.37** **	**3.23*** **	**2.74*** **
CCF	N.S.	N.S.	N.S.	2.5
B.brizantha	N.S.	**4.9** **	N.S.	N.S.
DGPS	0.43	**1.16** **	0.57	0.48
NTNP	N.S.	N.S.	N.S.	N.S.
NTCP	N.S.	1.06	N.S.	N.S.
LTNP	N.S.	N.S.	N.S.	N.S.
LTCP	0.99	N.S.	0.88	N.S.
MTNP	N.S.	0.89	**1.00* **	N.S.
MTCP	N.S.	1.11	N.S.	N.S.
FAL	N.S.	N.S.	0.77	N.S.
R^2	54.68	41.90	72.67	70.24

* P<0.05, ** P<0.01. *** P<0.001. Maximum accepted P value = 0.15,

N.S. Not significant: variables not retained after stepwise procedure.

SR(stocking rate, values for each season), MCOW (proportion of milking cows for entire herd, values for each season), DGPS (degraded pasture), NTNP (natural pasture with no trees), NTCP (cultivated pasture with no trees), LTNP (natural pasture with low tree density), LTCP (cultivated pasture with low tree density), MTNP (natural pasture with moderate tree density), MTCP (cultivated pasture with moderate tree density), FAL (fallows), CCF (cut and carry forage).

The regression coefficients of the selected predictors by stepwise regression using forward entrance and backwards elimination for saleable milk production are presented by season in Table 6.9. Stocking rates and the proportion of milking cows (MCOW) showed significant positive effects on saleable milk production for all seasons (P<0.001 except for MCOW in

Apr/May), which had similar trends (in terms of P values and larger coefficients in wet seasons) as occurred with backwards elimination. On the other hand, the proportion of *B.brithanta* (BB) showed significant positive effects at the end of the dry season, while the proportion of cut and carry forage showed a tendency to have positive effects at the end of the wet season, which was also similar to the trends observed in the results of backwards elimination. However, the proportions of land use parameters were quite different from the results by using backwards elimination. The proportion of natural pasture with low tree density (LTNP) had a negative impact on saleable milk production at the end of the dry season ($P<0.05$) and at the beginning of the wet season ($P<0.05$). The R^2 values were much lower in the dry season (43.4 % at the end of the dry season) than wet season (72.7% at the beginning of the wet season), which also occurred in backwards elimination, suggesting that the influence of other factors are greater in the dry season.

Table 6.9

Regression coefficients of predictors by season (forward and backwards procedures[1])

/Season	Dry		Wet	
Predictor/Month	Jan./Feb.	Apr./May	Jul./Aug.	Oct./Nov.
Constant	-0.4968	-0.3145	-1.388	-1.223
SR	**1.12*** **	**1.10*** **	**1.73*** **	**1.35*** **
MCOW	**2.29*** **	**1.34** **	**3.28*** **	**2.74*** **
CCF	N.S.	N.S.	N.S.	2.5
B. brizantha	N.S.	**5.1** **	N.S.	N.S.
DGPS	N.S.	N.S.	N.S.	0.48
NTNP	N.S.	N.S.	N.S.	N.S.
NTCP	N.S.	N.S.	N.S.	N.S.
LTNP	-0.93	**-1.26* **	**-0.99* **	N.S.
LTCP	N.S.	N.S.	N.S.	N.S.
MTNP	N.S.	N.S.	0.53	N.S.
MTCP	N.S.	N.S.	N.S.	N.S.
FAL	N.S.	N.S.	N.S.	N.S.
R^2	54.19	43.44	72.67	70.24

[1]Forward entrance and backwards elimination with maximum accepted P value = 0.15.
*P<0.05, ** P<0.01. ***P<0.001.

N.S. Not significant: variables not retained or selected after stepwise procedure

DGPS (degraded pastures), NTNP (natural pastures with no trees, NTCP (cultivated pasture with no trees), LTNP (natural pastures with low tree density), LTCP (cultivated pastures with low tree density), MTNP (natural pastures with moderate tree density), MTCP (cultivated pastures with moderate tree density), FAL (fallows), CCF (cut and carry forage).

6.3.5 Principal components analysis of land use parameters

The results of the principal components analysis (PCA) of the land use parameters are presented in Table 6.10. The PCA produced five principal components that explained 79% of the total variance (23% by PC1, 18% by PC2, 15% by PC3, 13% by PC4 and 11% for PC5, respectively). The proportion of variance of PC6 was 0.09 (<0.1) and the eigenvalue of PC5 was 0.97 (approximately 1.0), suggesting that placing five components in the model is sensible.

Degraded pasture (DGPS) and natural pasture with low tree density (LTNP) largely determined PC1 (accounting for 23% of the variance) with negative and positive contributions, respectively. DGPS was negatively correlated with LTNP ($r=-0.509$, $P<0.001$, Table 5.15). In addition, LTNP was negatively correlated to size of grazing areas ($r=-0.277$, $P<0.05$, Table 5.15) and positively correlated to stocking rates ($r=0.356$, $P<0.01$, Table 5.17), while DGPS was positively correlated to size of grazing areas ($r=0.194$, tendency with $P=0.098$, Table 5.15) and negatively correlated to stocking rates ($r=0.201$, tendency with $P=0.086$, Table 5.17). Hence, PC1 was interpreted as a gradient related to land capacity to produce biomass and consumption of biomass from grazing pressure: larger farms with lower stocking rates which can produce more biomass vs. smaller farms with higher stocking rates.

Cultivated pasture with no trees (NTCP) and cultivated pasture with low tree density (LTCP) largely determined PC2 (accounting for 18% of the variance) with negative contributions, while PC3 (accounting for 16% of the variance) was largely determined by positive contribution of fallows (FAL) and by negative contribution of riparian forests (FRST). The correlation between FAL and FRST was negative ($r=-0.358$, $P<0.01$, Table 5.15). It is, therefore interpreted as a gradient related to woodlands in grazing areas, whether the woodlands are fallow or forest. It is probably related to farm size since larger farms have more forest in grazing area ($r=0.240$ $P<0.05$, Table 5.15), and some small farms have high proportion of fallow.

Natural pasture with moderate tree density (MTNP) and natural pasture with no trees (NTNP) largely determined PC4 (accounting for 12% of the variance) with positive and negative contributions, respectively. PC4 was interpreted as a gradient related to the proportion of silvopastoral areas (moderate tree density against no trees) with natural pasture, which moves positively with MTNP and negatively with NTNP. Cultivated pasture with moderate tree density largely determined PC5.

Table 6.10

Coefficients and proportions of variance of the principal components for land use parameters

Land Use Category	Abbre.	PC1	PC2	PC3	PC4	PC5
Degraded pasture	DGPS	**-0.564**	0.313	0.145	0.018	0.161
Natural pasture with no trees	NTNP	0.406	0.180	0.071	**-0.474**	-0.185
Cultivated pasture with no trees	NTCP	-0.048	**-0.587**	-0.096	-0.068	0.184
Natural pasture with low tree density	LTNP	**0.535**	0.157	-0.154	-0.261	0.061
Cultivated pasture with low tree density	LTCP	-0.078	-0.531	-0.145	-0.394	0.339
Natural pasture with moderate tree density	MTNP	0.432	-0.039	-0.031	**0.671**	0.236
Cultivated pasture with moderate tree density	MTCP	-0.102	-0.265	-0.380	0.143	**-0.807**
Fallows	FAL	0.014	-0.105	**0.704**	-0.164	-0.275
Forests	FRST	-0.160	0.369	**-0.529**	-0.222	0.075
Eigenevalues		2.022	1.592	1.404	1.121	0.971
Proportion of variance		0.225	0.177	0.156	0.124	0.108
Cumulative proportion		0.225	0.402	0.558	0.682	0.790

Note: PC1-5: Principal components of land use parameters.

6.3.6 Stepwise regression with principal components

The results of the regression analysis for saleable milk production with all variables and those retained after the stepwise procedure are presented in Tables 6.11 and 6.12. Initially, stocking rates (SR), and the proportion of milking cows (MCOW) were significant ($P<0.05$) and P values for PC1, PC2 and PC4 were lower than the threshold ($P<0.15$). The results by using forward and backwards procedure and backwards elimination were the same. SR ($P<0.001$), MCOW ($P<0.001$), PC1 ($P<0.05$), PC2 ($P=0.133$) and PC4 ($P=0.104$) were retained after the stepwise regression. SR and MCOW contributed to 94% of R^2 ($R^2= 68\%$ only with two variables), and R^2 increased 1.9 %, 1.0% and 1.0 % when adding PC1, PC2 and PC4, respectively. The P values of SR and MCOW were much smaller than those of the PCs. In addition, the regression coefficient of PC1 had the largest absolute value among the PCs, but those of SR/MCOW were 6.4/4.6 times larger. These findings suggest that SR and MCOW had much larger impacts than land use parameters on saleable milk production. The regression coefficient of PC1 ($P<0.05$) was negative, suggesting the combined effects of DGPS and LTNP (the former having a positive effect and the later a negative effect) in PC1 on milk yield. The coefficient of PC2 was also negative, suggesting the combined positive effects of cultivated pasture with no trees and low tree density (NTCP and LTCP). The coefficient of PC4 was positive, suggesting the combined effects of natural pasture with moderate tree density (MTNP) and natural pasture with no trees (NTNP) (the former having a positive effect and the latter a negative effect) on milk yield.

Table 6.11

Results of regression analysis for daily saleable milk production per hectare by initial variables

Predictor	Coefficient	SE Coefficient	T	P
Constant	1.382***	0.04675	29.56	<0.001
$SR^{SI\ 1}$	0.517***	0.05461	9.47	<0.001
$MCOW^{SI\ 1}$	0.346***	0.04996	6.93	<0.001
CCF^{SI}	0.0185	0.05507	0.34	0.738
B. brizantha^{SI}	0.0813	0.05031	1.62	0.111
PC1	-0.0838*	0.03513	-2.38	0.020
PC2	-0.0617	0.03853	-1.60	0.114
PC3	0.0509	0.04181	1.22	0.228
PC4	0.0781	0.04557	1.71	0.091
PC5	0.00001	0.04935	0.00	1.000

R^2 = 73.4 % * P<0.05, ** P<0.01, *** P<0.001

[1]Annual means.

[SI]Standardised values (subtracting means and dividing by standard deviations).

Table 6.12

Results of stepwise regression analysis for daily saleable milk production per hectare with selected principal components

Predictor	Coefficient	SE Coefficient	T	P
Constant	1.382***	0.0466	29.68	<0.001
SR^{SI}	0.525***	0.0503	10.45	<0.001
$MCOW^{SI}$	0.367***	0.0471	7.80	<0.001
PC1	-0.0802*	0.0349	-2.30	0.025
PC2	-0.0573	0.0376	-1.52	0.133
PC4	0.0737	0.0447	1.65	0.104

R^2 = 72.0 %. * P<0.05, *** P<0.001.

Note: SR (annual mean stocking rate), MCOW (annual mean proportion of milking cows for entire herds), PC1, 2, and 4 (principal components based on land use parameters).

Standard stepwise procedure (forward selection and backwards elimination) and backwards elimination with maximum accepted P value = 0.15.

[SI] Standardised values (subtracting means and dividing by standard deviations).

6.3.7 Estimation of the coefficients of land use parameters

The coefficients of land use parameters calculated based on equation (4) with selected principal components after the stepwise procedure are presented in Table 6.13. Degraded pasture (DGPS), cultivated pasture with moderate tree density (MTCP), and natural pasture with moderate tree density (MTNP) accounted for 71% of the positive effects on milk yield (26%, 30% and 15%, respectively), while natural pasture with low tree density (LTNP) and natural pasture with no trees (NTNP) accounted for 86% of the negative effects on milk yield (41% and 45% respectively).

The coefficients of the land use parameters are also demonstrated in Figure 7.1. The model (equation 5) indicated that the negative effects of natural pasture with no trees and low tree density (NTNP and LTNP) were larger than the positive effects of DGPS, NTCP and MTCP. With the mean values of cattle/pasture and land use parameters, the mean saleable milk production per hectare was 1.38 litres/ha/day which was the same as the value from the herd survey (Section 5.3.6).

$$
\begin{aligned}
\mathrm{MLK/D/H} &= 1.38 + 0.525\ \mathrm{SR}^{SI} + 0.367\ \mathrm{MCOW}^{SI} \\
&+ 0.029\ \mathrm{DGPS} - 0.078\mathrm{NTNP} + 0.032\mathrm{NTCP} - 0.071\ \mathrm{LTNP} + 0.008\ \mathrm{LTCP} \\
&+ 0.017\ \mathrm{MTNP} + 0.034\ \mathrm{MTCP} - 0.007\ \mathrm{FAL} - 0.025\ \mathrm{FRST} \qquad (5)
\end{aligned}
$$

Table 6.13

Coefficients of land use parameters for daily saleable milk production per hectare by selected principal components[1]

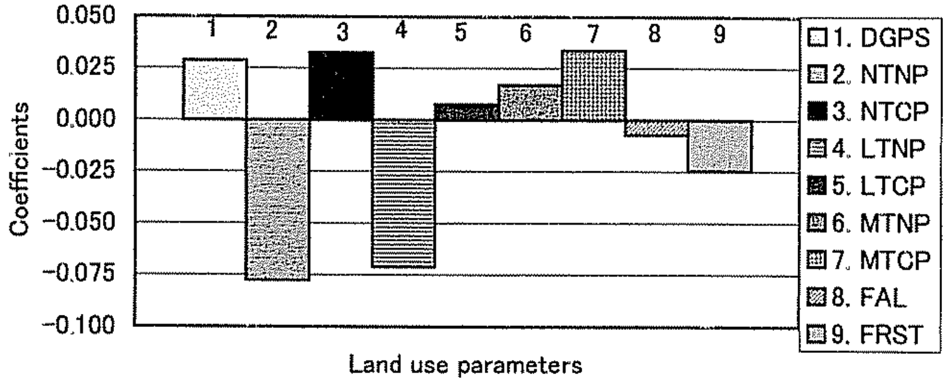
	Variables of coefficients				
Land use parameter	PC1	PC2	PC4	Total	%[2]
DGPS	0.045	-0.018	0.001	0.029	25.5
NTNP	-0.033	-0.010	-0.035	-0.078	-44.9
NTCP	0.004	0.034	-0.005	0.032	29.0
LTNP	-0.043	-0.009	-0.019	-0.071	-41.1
LTCP	0.006	0.030	-0.029	0.008	4.4
MTNP	-0.035	0.002	0.049	0.017	15.2
MTCP	0.008	0.015	0.011	0.034	30.2
FAL	-0.001	0.006	-0.012	-0.007	-4.2
FRST	0.013	-0.021	-0.016	-0.025	-14.2
Total					0.0

[1]Coefficients were calculated by the coefficients of land use parameters for principal components scores multiplied by the coefficients of principal components for the regression model (Section 6.2.5.3.3).

[2]Percentage for the sums of negative and positive coefficients.

Note: DGPS (degraded pasture), NTNP (natural pasture with no trees, NTCP (cultivated pasture with no trees), LTNP (natural pasture with low tree density), LTCP (cultivated pasture with low tree density), MTNP (natural pasture with moderate tree density), MTCP (cultivated pasture with moderate tree density), FAL (fallows), FRST (riparian forests).

Figure 6.1: Coefficients of land use parameters for the regression model



Note: DGPS (degraded pasture), NTNP (natural pasture with no trees), NTCP (cultivated pasture with no trees), LTNP (natural pasture with low tree density), LTCP (cultivated pasture with low tree density), MTNP (natural pasture with moderate tree density), MTCP (cultivated pasture with moderate tree density), FAL (fallows) FRST (riparian forests).

6.3.8 Regression analysis with principal components for each season

The results of the regression analysis on saleable milk production for each season by the initial variables are presented in Table 6.14. Stocking rates (SR) and the proportion of milking cows (MCOW) were significant and positive for all seasons ($P<0.001$) except for MCOW at the end of dry season ($P<0.01$), suggesting that MCOW were less important for milk production at the end of the dry season. Regarding pasture parameters, positive effects were shown by the proportion of *B. brizantha* (BB) at the end of dry season ($P<0.01$) and cut and carry forage at the end of wet season ($P<0.05$). The effect of PC1 was close to being significant at the end of the dry season ($P=0.057$). Moreover, R^2 values were much lower in the dry season than in the wet season (45% at the end of the dry season and 73% at the beginning of the wet season).

The results of the stepwise regression for saleable milk production for each season with the selected predictors are presented in Table 6.14. The results by backwards elimination and forward and backwards procedure were the same. Stocking rates (SR) and the proportion of milking cows (MCOW) were significant and positive for all seasons ($P<0.001$) except for MCOW at the end of the dry season ($P<0.01$), suggesting that MCOW is less important for saleable milk production in this season. A larger R^2 value was observed at the beginning of the wet season, because R^2 obtained by SR and MCOW were much larger in this season (R^2 =34% at the end of the dry season compared with R^2 =70% at the beginning of the wet season), suggesting that these variables were more important in the wet season for milk production. Positive effects of the proportion of *B. brizantha* (BB) on milk yield were found at the end of the dry season ($P<0.01$). The proportion of cut and carry forage was retained in the model at the end of the wet season but it was not significant ($P=0.093$). No PCs were retained in the model except for PC1 at the end of the dry season ($P=0.064$).

Table 6.14

Results of regression analysis for daily milk production for each season by initial variables

/Season	Dry		Wet	
Predictor/Month	Jan./Feb.	Apr./May	Jul./Aug.	Oct./Nov.
Constant	**1.334***** **(<0.001)**	**1.198***** **(<0.001)**	**1.647***** **(<0.001)**	**1.350***** **(<0.001)**
SR^{SI}	**0.512***** **(<0.001)**	**0.510***** **(<0.001)**	**0.597***** **(<0.001)**	**0.573***** **(<0.001)**
$MCOW^{SI}$	**0.434***** **(<0.001)**	**0.263**** **(0.003)**	**0.685***** **(<0.001)**	**0.594***** **(<0.001**
CCF^{SI}	-0.0035 (0.972)	0.0113 (0.904)	0.0955 (0.207)	**0.154*** **(0.039)**
B. brizantha^{SI}	0.0985 (0.243)	**0.242**** **(0.009)**	-0.0307 (0.680)	0.0267 (0.709)
PC1	-0.0813 (0.157)	-0.1169 (0.057)	-0.0203 (0.684)	-0.0646 (0.229)
PC2	-0.0366 (0.566)	-0.0643 (0.358)	-0.0954 (0.103)	-0.00737 (0.895)
PC3	0.0016 (0.981)	0.0692 (0.354)	0.0850 (0.172)	0.0916 (0.134)
PC4	0.0044 (0.953)	0.11036 (0.180)	0.107 (0.114)	0.0911 (0.168)
PC5	0.0473 (0.584)	-0.0244 (0.783)	0.0251 (0.733)	0.0377 (0.597)
R^2	54.6 %	45.0 %	73.4 %	71.2 %

Note: Regression coefficients above and (P values) below.

^{SI} Standardised values (subtracting means and dividing by standard deviations) were used.

Table 6.15

Results of stepwise regression analysis for each season with selected principal components[1]

/Season	Dry		Wet	
Predictor/Month	Jan./Feb.	Apr./May	Jul./Aug.	Oct./Nov.
Constant	**0.469**** **(0.006)**	**1.198***** **(<0.001)**	**1.647***** **(<0.001)**	**1.350***** **(<0.001)**
SR	**0.489***** **(<0.001)**	**0.491***** **(<0.001)**	**0.613***** **(<0.001)**	**0.528***** **(<0.001)**
MCOW	**2.21***** **(<0.001)**	**0.285**** **(<0.001)**	**0.706***** **(<0.001)**	**0.622***** **(<0.001)**
CCF	N.S.	N.S.	N.S.	0.117 (0.093)
B. brizantha	N.S.	**0.224**** **(0.009)**	N.S.	N.S.
PC1	N.S.	-0.112 (0.064)	N.S.	N.S.
R^2	51.8	42.0	70.1	68.7

[1]Maximum accepted P value = 0.15, * P<0.05, ** P<0.01, *** P<0.001.

Note: Regression coefficients above and (P value) below.

N.S. Not significant (excluded from the model by stepwise procedure).

[SI] Standardised values (subtracting means and dividing by standard deviations) were used.

No significant effects of PC2-PC5 were observed.

6.4 Discussion

6.4.1 The positive effects of land use parameters on saleable milk production

The four land use parameters [degraded pasture (DGPS) (P<0.001), cultivated pasture with low tree density (LTCP) (P<0.05), natural pasture with moderate tree density (MTNP) (P<0.01), and cultivated pasture with moderate tree density (MTCP) (P<0.05)] remained, with positive coefficients, in the stepwise regression analysis for saleable milk production by backwards elimination (Table 6.7). The land use types with positive regression coefficients (DGPS, MTNP, MTCP) had moderate tree cover (19 -25%), except for cultivated pasture with low tree density (LTCP) (12.5%). Tree cover can provide positive effects on grass production due to leaf drops, better nutrition cycling, higher soil organic matter and improved physical soil structure and nitrogen fixing by trees (Young, 1989; Wilson and Wild, 1991). Seasonal analysis by backwards elimination suggested that these land use types tended to have positive effects on milk production at the end of the dry season. It may suggest that these land use types generally supported milk production through tree cover (approximately 20%), providing fruits and leaves from trees and/or contributing to maintaining pasture production particularly at the end of the dry season

Seasonal analysis provided evidence that DGPS had positive effects on saleable milk production at the end of the dry season ($P<0.01$) (Table 6.8). This may suggest that broadleaf plants which were generally considered as weeds and not consumed by cattle during the wet season, remaining in DGPS, supported saleable milk production at the end of the dry season. Some broadleaf plants are considered to be important forage in the dry season with higher selectivity due to the shortage of grass (Bayer and Waters-Bayer, 1998; Nyaata et al., 2000). In contrast, positive effects on saleable milk production of MTNP were observed at the beginning of the wet season ($P<0.05$) (Table 6.8), suggesting that natural pastures grow during this period and support saleable milk production. Moreover, both LTCP and MTCP had positive effects on milk production, but the effects of MTCP were found at the end of the dry season while those of LTCP seemed to be spread out throughout the year (Table 6.8). It may suggest increased grass production by shade in the dry season (Wilson and Ludow, 1991) and fruit production by common tree species found in grazing areas, (e.g. *Guazuma ulmifolia*, *Enterolobium cyclocarpum*, and *Albizia saman*) supported milk production in particular in the dry season (Section 4.3.3; Esquivel, 2004). Further studies are recommended regarding the botanical composition and nutritional values of broadleaf plants in the dry season.

6.4.2 The negative effects of land use parameters on saleable milk production

According to the stepwise regression analysis with original variables by forward and backwards procedure, natural pasture with low tree density (LTNP) had a negative effect on saleable milk production ($P<0.01$) (Table 6.5). In addition, seasonal analysis showed that LTNP had negative coefficients at the end of the dry season and the beginning of the wet season ($P<0.05$). It may suggest that the land use type does not have sufficient pasture to support saleable milk production at the end of the dry season and that the areas were conserved for pasture recuperation at the beginning of the wet season as described in Chapter 5. It should be noted that the correlation between the annual mean stocking rate (SR) and LTNP was positive ($r=0.356$, $P<0.01$, Table 5.17) and that the correlation between the size of grazing area and LTNP was negative ($r=-0.277$, $P<0.01$, Table 5.15). These findings suggest that LTNP was overgrazed, resulting in the negative effects on saleable milk production due to lack of biomass at the end of the dry season. The associations with the size of grazing area imply that this overgrazing problem is likely to be found in smaller farms.

However, it should be also noted that at the beginning of the wet season, natural pasture with moderate tree density (MTNP) had a positive coefficient ($P<0.05$). It may suggest that MTNP had stronger pasture growth under better soil conditions supported by tree cover, thus did not require pasture recuperation, while LTNP needed pasture recuperation due to pasture degradation caused by overgrazing. It is not entirely clear whether the difference between two land use types were caused by higher tree cover of MTNP or overgrazing on LTNP because both tree cover and stocking rates historically formed two land use types over time. The results of the regression analysis suggest that in addition to the effects of actual stocking rates (one of the predictors), the land use types with moderate tree cover contributed to milk production but the land use type with low tree density did not. Further studies are recommended to compare milk production on these land use types under similar stocking rates.

6.4.3 The effects of introduced pasture species on saleable milk production

The regression coefficient of *B. brizantha* was at its largest at the end of the dry season ($P<0.01$) (Table 6.8). The results suggest that this species is an important forage source particularly at the end of the dry season due its drought tolerance (Peters et al., 2003). The positive coefficients of the proportion of cut and carry forage (*Pennisetum spp.*) at the end of the wet season are noteworthy (Table 6.8 and 6.9). It seems that supplementary forage was cut and used as cattle fodder at the end of the wet season in order to make it available in the dry season (60 days after cutting, Peters, et al., 2003), simultaneously keeping other pasture for grazing in the dry season. Cut and carry forage is provided to cattle in the dry season, but positive coefficients were not observed in the regression analysis. It is probably because the cut and carry forage was over mature and mainly used in limited amounts from February to May (Section 5.3.9). Hence it was primarily used for maintenance of cattle rather than contributing to milk production.

6.4.4 Role of cattle management on saleable milk production by season

In the regression model, stocking rates (SR) and the proportion of milking cows (MCOW) were demonstrated to be important variables affecting saleable milk production (R^2 of 68%) based on the data of annual means. However at the end of the dry season, R^2 was much smaller (R^2 of 33.6%) (Table 6.8). It may suggest that due to the shortage of fodder in general at the end of the dry season, since higher stocking rates and the proportion of milking cows resulted in a higher fodder requirement, these variables did not contribute to milk production as much as they did in the wet season.

6.4.5 Regression analysis based on annual data with principal components

In the stepwise regression with principal components based on annual data, PC1, PC2 and PC4 were retained in the model as predictors. PC1 ($P<0.05$) and PC2 were retained negatively, and PC4 positively. Since PC1 had a gradient of less degraded pasture and higher grazing pressure, it suggests that lower grazing pressure with more degraded pasture result in higher saleable milk production. This result may suggest that in order to have very efficient use of medium and poor quality forage resources, which is one of the main characteristics of the dual-purpose cattle farms (Sere and de Vaccaro, 1985), the farms need to have sufficiently low stocking rates and large size. These characteristics may be comparable to the conditions to use "the land-using technologies", which have lower total costs per unit of milk production than land saving technologies (Nicholson et al., 1995).

Cultivated pasture with low tree density (LTCP) made a large negative contribution to PC2, suggesting that cultivated pasture supported milk production. PC4, which was interpreted as a gradient of silvopastoral areas with natural pasture, had a positive coefficient, suggesting that increased proportion of silvopastoral areas (with 25% tree cover of natural pasture with moderate tree density) increases milk production. On the other hand, PC3 and PC5 were not retained in the model. PC3 had coefficients for fallows and forests with opposite signs, the effects of woodlands were therefore potentially eliminated. PC5, to which cultivated pasture with moderate tree density (MTCP) made a large contribution, was not selected probably because cultivated pasture with low tree density had the opposite signs; therefore, the effects of cultivated pasture were eliminated.

The regression coefficients for land use parameters highlighted positive effects of degraded pasture (DGPS), cultivated pasture with no trees (NTCP), cultivated pasture with moderate tree density (MTCP) and natural pasture with moderate tree density (MTNP). They highlighted large negative effects of natural pasture with no trees (NTNP) and natural pasture with low tree density (LTNP) (Table 6.13, Figure 6.1). These results were similar to the significant effects obtained with original variables (Section 6.3.2 and 6.3.3); positive effects of DGPS, LTCP, MTNP and MTCP and negative effects of LTNP. The negative effect of NTNP and the positive effect of NTCP on milk production were not observed in the regression analysis of original variables, probably because these variables represented a small proportion of the area, with large standard deviations, on the sample farms; therefore, standardisation of variables allowed the effects of these land use parameters to be identified. Moreover, FAL, which had a positive coefficient in the model by backwards elimination (Section 6.3.1), had a small negative coefficient in the model, probably because the effects of this land use type were eliminated by PC3.

Fifty-two percent of the variance were accounted by PC1, PC2 and PC4. Initial multiple regression showed that P values of PC3 and PC5 were much larger than those of PC1, 2 and 4, particularly PC5 ($P=1.0$ Table 6.11). PC3 had 15% of variance of the data set, but was largely composed of FAL and FRST (Table 6.10). It indicates that the model including PC1, 2 and 4 was sensible except for the coefficients of FAL and FRST whose variances were excluded by eliminating PC3.

6.4.6 Regression analysis based on seasonal data with principal components

Separate analysis by season did not detect any significant effects of principal components except for PC1, which was retained in the model, albeit with $P>0.05$, at the end of the dry season. In contrast, regression analysis of the original variables identified effects of land use parameters in several seasons. These were the positive coefficients for MTCP at the beginning of the wet season and for DGPS at the end of the dry season. Negative coefficients were estimated for natural pasture with low tree density at the end of the dry season and at the beginning of the wet season. The positive effects of the proportion of *B. brizantha* (BB) at the end of the dry season ($P<0.01$) and the proportion cut and carry forage at the end of the wet season were observed, and were the same as the results of regression analysis with original variables.

It seemed that the effects of land use parameters were weakened by using principal components. It is probable that since principal components are composed of a combination of variables, the variables may counteract each other resulting in non-significant effects of the principal component.

6.4.7 Economic prediction based on the regression model

Economic prediction by the regression model was performed by regression models by the original variables (3) and (4). Scenarios presented here were to increase saleable milk production by changing 10% of the grazing areas to one with higher effects on saleable milk production. By using regression model (3), 10% of the grazing areas were removed from LTNP and by using regression model (4), the same size of land were added to MTCP. The results showed that daily milk yield per hectare became almost the same, 1.48 litres/ha/day for both models. The results indicate that either by increasing cultivated pasture with moderate tree density (MTCP) or reducing the natural pasture with low tree density (LTNP) by 10% of the grazing areas, the farm can increase production by 0.1 litres/ha/day (7% increase) (Table 6.16). By the same land use change additionally using *B. brizantha,* the farm can increase milk production by 0.28 litres/ha/day, (20 % increase). The results imply that for a farm with the mean size grazing area (21.4 ha), the farm income can be increased by US$459 by changing 10% of the land use to more productive types.

Table 6.16

Economic prediction of saleable milk production by land use change

Condition of change	Milk production	Milk production	Difference	Difference
/unit	litres/ha/day	litres/ha/year	US$/ha/year	%
Current condition	1.38	504	0	0
10% land with MTCP	1.48	540	7.4	7.0
10% land with MTCP and *B. brizantha*	1.66	606	21.5	20.3

[1]Milk price: US$0.21/litre (based on weighted mean milk price of wet and dry season (Section 3.3.5) by the following equation):

Mean milk price (US$/litre) = [(Milk price in the wet season x 8 months) + (Milk price in the dry season x 4 months)] x 1 / 12 months

MTCP (cultivated pasture with moderate tree density).

6.5 Conclusions

This study examined by stepwise regression the effects of land use patterns of dual-purpose cattle farms on cattle production in central Nicaragua. The regression model by using original variables demonstrated that significant positive effects of natural and cultivated pastures with moderate tree density ($P<0.01$ for MTNP and $P<0.05$ for MTCP), degraded pastures, ($P<0.001$), cultivated pasture with low tree density ($P<0.05$), and negative effects by natural pasture with low tree density ($P<0.01$) on saleable milk production.

Also, the area of *B. brizantha* made a significant contribution to saleable milk production at the end of the dry season ($P<0.01$), suggesting that this pasture species is important in this season. Although stocking rates and the proportion of milking cows were demonstrated as important variables for saleable milk production through the year, their importance was smaller at the end the dry season.

The regression model using principal components selected the three principal components for annual saleable milk production; the largest component (23% of variance, $P<0.05$) related to grazing pressure and land capacity, the second (18% of variance) related to the use of cultivated pasture, and the fourth (12% of variance) related to silvopastoral areas under natural conditions. The results suggest that in order to have positive effects from the largest components, farms need to be large in size and small in stocking rates, but also the use of cultivated pasture and silvopastoral area under natural pasture support milk production.

The study generally concluded that silvopastoral areas, especially pasturelands with moderate tree density (tree cover approximately 20%) have significant positive impacts on annual milk production and that the land use change from natural pasture with low tree density (LNTP) to cultivated pasture with moderate tree density (MTCP) using *B. brizantha* is the most productive land use change. However, it can be concluded that the smaller farms with higher stocking rate, and higher proportion of LTNP were overgrazed and therefore degraded, thus having negative effects on saleable milk production at the end of the dry season. If further degradation proceeds, such farms may have to be sold, and farmers would have to move further east into the agricultural frontier where land is available at a lower price. Such movement would probably cause further deforestation in the Atlantic side of Nicaragua. Therefore, intervention is suggested as an appropriate policy for these farms. Further studies are recommended on botanical composition of broadleaf plants in the grazing areas and their nutritional values in the dry season, as well as the relationship between farm types and potential land use change for increasing saleable milk production.

References

Bayer W; Waters-Bayer, A. 1998. Forage husbandry. Tropical Agriculturalist. ICTA/GTZ. Macmillan Education Ltd. 198p.

Belsky. AJ. 1992. Effects of trees on nutritional quality of understorey gramineous forage in tropical savannas. Tropical Grasslands 26(1): 12-20.

Belsky, AJ; Mwonga, SM; Duxbury, JM. 1993. Effects of widely spaced trees and livestock grazing on understory environments in tropical savannas. Agroforestry systems 24(1): 1-20.

Chatterjee, S; Price, B. 1991. Regression analysis by example. John Wiley and Sons. NY.

Draper N; Smith H. 1980. Applied regression analysis. 2nd edition. John Wiley and Sons.

Esquivel, H. 2004. Relationship between tree cover on farm and pasture productivity of silvopastoral systems in dry ecosystems. Draft. Ph.D. dissertation. CATIE.

Hecht, SB. 1992. Logics of livestock and deforestation: The case of Amazonia. *In* Downing, TE; Hetcht, SB; Pearson, HA; Garcia-Downing, C. Eds. Development or Destruction. Westview press. p.7-25.

Holmann, F. 1989. Economic evaluation of dairy and dual-purpose cattle production systems in Venezuela. Ph.D. dissertation. Cornel University.

Horne, PM; Blair, GJ. 1991. Forage tree legumes. IV. Productivity of Leucaena/grass mixture. Australian Journal of Agricultural Research 42(7): 1231-1250.

Infostat. 2004. Manual para usuario. Versión 1 2004. Grupo Infostat. FCA. Universidad Nacional de Cordoba. Primera edición Editorial Brujas. Argentina.

INTA (Instituto Nicaragüense de Tecnología Agropecuaria). 1998. Zonificación agro socioeconómica agencia Matiguas. 72p.

Johnson, RA; Wichern, DW. 1998. Applied multivariate statistical analysis. 4th edition.

Prentice Hall. NJ.

Kaimowitz, D. 1996. Livestock and Deforestation: Central America in the 1980s and 1990s: A Policy Perspective. CIFOR Special Publication. 88p.

MINITAB 2000. MINITAB User Guide 2 Data analysis and quality tool.

Minson, DJ. 1981. Nutritional differences between tropical and temperate pastures. Morley, FHW. Eds. Grazing animals. Disciplinary approach. World Animal Science B1: 143-157.

Muchagata, M; Brown, K. 1999. A Literature Review and Annotated Bibliography. Small Farming Systems in Amazonia: Livestock Production and Sustainability. Appendix 8. ODG. University of East Angolia.

Myers, N. 1981. The Hamburger Connection: How Central America's Forest Became North America's Hamburgers. AMBIO 10: 3-8.

Nicholson, CF; Blake, RW; Lee, DR. 1995. Livestock, deforestation, and policy making :intensification of cattle production systems in Central America revisited. Journal of Dairy Science 78(3): 719-734.

Nyaata, OZ; Dorward, PT; Keatinge, JD; H; O'Neill, MK. 2000. Availability and use of dry season feed resources on smallholder dairy farms in central Kenya. Agroforestry Systems 50(3): 315-33.

Parsons, J. 1976. Forest to Pasture: Development or Destruction? Revista de Biología Tropical. 24(1): 121-138.

Pereira, HC. 1989. Policy and practice in the management of tropical watersheds. Westview press. 237p.

Peters, M; Franco, LH; Schmidt, A; Hincapié, B. 2003. Especies Forrajeras Multipropósito: Opciones para productores de Centroamérica. CIAT. 113p.

Pezo, DM; Kass, J; Benavides, F; R; Chaves, C 1990. Potential of legume tree fodders as animal feed in Central America. In Shrubs and Tree fodders for farm animals. Proceedings of a workshop in Denpasar, Indonesia, 24-29 July. 1989. IDRC. Ottawa.

Pezo, D; Ibrahim, M. 1999. Sistema Silvopastoriles. Modulo de Enseñanza. No.2. CATIE. Turrialba. 275p.

Sere, C; De Vaccaro, L. 1985. Milk production from dual-purpose systems in tropical Latin America. *In* Milk production in Developing Countries. Smith. AJ. Eds. Centre for Tropical Veterinary Medicine. University of Edinburgh. p.459-75.

Sharma, S. 1996. Applied multivariate techniques. John Wiley and Sons. Inc.

Smith, MA; Whiteman, PC. 1983. Evaluation of tropical grasses in increasing shade under coconut canopies. Experimental Agriculture 19(2): 153-161.

Souza de Abreu, MH. 2002. Contribution of trees to the control of heat stress in dairy cows and the financial viability of livestock farms in humid tropics. Ph.D. dissertation. CATIE.

Sunderlin, WD; Rodríguez, JA. 1996. Cattle, Broadleaf Forests and the Agricultural Modernization law of Honduras: The case study of Olancho. CIFOR Occasional Paper No. 7 (S). 28p.

Wilson, JR. 1982. Environmental and nutritional factors affecting herbage quality. *In* Hacker. JB. Eds. Nutritional limits to animal production from pasture. CAB. p.111-131.

Wilson, JR; Ludlow, MM. 1991. The environmental and potential growth of herbage under plantations. Shelton, HM; Stur, WW. Eds. Forages for plantation crops. ACIAR Proceedings No. 32. ACIAR. Canberra. Australia. p.10-24.

Wilson, JR; Wild, DWM. 1991. Improvement of nitrogen nutrition and grass growth under shading. *In* Shelton, HM; Stur, WW. Eds. Forages for plantation crops. ACIAR Proceedings

No. 32. ACIAR. Canberra. Australia. p.77-82.

Young, A. 1997. Agroforestry for soil management. 2nd Edition. CAB International. 320p.

Zamora, S; Garcia, J; Bonilla, G; Aguilar, H; Harvey, CA; Ibrahim, I. 2001. Como utilizar los frutos de guanacaste (*Enterolobium cyclocarpus*), guacimo (*Guazuma ulmifolia*), genezaro (*Pithecellobium saman*)y jicaro (*Crecentia alata*) en alimentacion animal? Agroforesteria en las Americas 8(31): 45-49.

Chapter 7

General Discussion and Conclusions

7.1 Evaluation of methodological framework

7.1.1 Comparison between experiments and farm monitoring

The study has five components: 1) general farm survey (Chapter 3), 2) pasture and vegetation survey (Chapter 4), 3) land survey (Chapter 5), 4) herd survey (Chapter 5), and 5) analysis of the relationships between land use patterns of grazing areas and production parameters (Chapter 6). The objective of the study is to examine the effects on production of silvopastoral areas in the "existing" dual-purpose cattle production systems in the Matiguas region of central Nicaragua. It is possible to examine the effects of silvopastoral areas on production on an experimental basis by comparing the production from cattle grazed on silvopastoral areas with that of cattle grazed on pastures without trees under the same conditions in terms of cattle production systems. However, since variability between individual cattle is large (Llamozas and Vaccaro, 2002), in order to obtain statistically significant results, a large number of samples is needed. It is difficult to have similar conditions in grazing areas across a large number of samples. The experiments would be large and very costly.

In contrast, the present study was undertaken using "existing" farming systems on commercial farms. Farm management varied between farms; therefore, variability is expected to be much higher than in field experiments. Consequently, a greater number of samples than experiments is needed. However, the study is less expensive than a comparable experimental approach since production costs are met by the farmers. The study farms were monitored for a one year period. One hundred and thirty farms were initially identified and the study attempted to monitor 100 farms. However, 74 farms were surveyed due to farmers' attitudes toward the project, harsh field conditions in the agricultural frontier, and time constraints.

The experiment results are considered to be technical results; therefore, in order to apply the results, the other factors including farm management, socio-economic conditions of farmers, etc. have to be considered. In contrast, the results of this study, based on existing farming systems, provide useful information for policy design in the region. However, it should be noted that since farm management decisions will have influenced the data, the study may not be able to determine whether silvopastoral areas themselves directly have positive effects on production or whether the positive effects were due to the impact of farmers' decisions.

7.1.2 Analytical approach of the study

In this dissertation, there are three chapters that characterise the surveyed farms in terms of general farming systems (Chapter 3), grazing areas (Chapter 4), and land use patters along with herd management (Chapter 5). The main objective, "To examine the effects of silvopastoral areas on production", was analysed in Chapter 6. The effects of silvopastoral systems were analyzed by only using data obtained for land and herd surveys (Chapter 5).

The general farm survey (Chapter 3) provided general information about the farming systems including socio-economic conditions by using existing data, and the pasture and tree survey (Chapter 4) provided information of existing conditions of grazing areas. The data from these two surveys were not directly used in the final analysis, but they played a very important role in planning the final stage of the analysis and discussion of the results of the last two chapters.

7.1.3 Selection of study site

The study area was selected because it was considered the most probable site to observe positive effects of silvopastoral areas on cattle production. Three characteristics were considered to be important to ascertain the positive effects. First, tree cover is particularly important in the farming systems in the study area in order to facilitate crossbred cattle which require cooler temperature. Secondly, tree cover is also important in semi-humid conditions for dry season fodder. Thirdly, an important proportion of the grazing areas were covered by tree cover. It is probable that the positive effects of silvopastoral areas on milk production were ascertained due to these conditions of the study area. It should be noted that the effects of natural and cultivated pasture with no trees were observed only by regression analysis with principal components, suggesting that the certain proportions of the land use types were needed in order to show the significant effects by regression analysis with the original variables. Further studies on the effects of land use patterns on cattle production in different farming systems (e.g. intensive milk production, meat production) and climate conditions (e.g. area with a longer dry season, higher altitude) are recommended.

7.1.4 Selection of variables for regression analysis

The effects of silvopastoral areas on cattle production were expected to be rather weak compared to other factors such as stocking rates, number of lactating cows, and supplementary feeding. In order to examine the effects of silvopastoral areas on cattle production, the study needed to remove the effects of other factors. Stocking rates and the proportion of milking cows were included in the regression predictors. The general survey (Chapter 4) concluded that supplementary pastures significantly influence the gross margin and milk production, but the use of molasses and concentrates were limited. The level of supplementary forage was, therefore, estimated by the proportion of areas of cut and carry forage for grazing areas. Accordingly, the study obtained the results for the main objective, the significant effects of silvopastoral areas by the regression analysis with original variables (Chapter 6).

Productivity can be examined by cow basis, but it was observed that the productivity per cow basis was strongly influenced by farm size. Variability between farms was large. Farm size is the largest factor influencing the total variability of the farms. Therefore, the study examined productivity per hectare.

In the regression analysis of Chapter 6, the dependent variable was daily saleable milk production per hectare. It was considered that daily saleable milk production was the easiest and most accurate variable for farmers to answer. In the regression analysis, the errors of the dependent variables are very sensitive to results.

Due to the resource and time constraints of the study and the number of samples needed for multivariate analysis, it was not possible to directly monitor cattle production. However, the study ascertained the effects of silvopastoral areas by selecting daily saleable milk production as the dependent variable.

7.2 Efficiency of cattle production

The dual-purpose cattle farms in the study area are under extensive management. On average, tree cover represented 23% of the grazing lands (Section 5.3.1). The stocking rate was 0.91 LU/ha on average, (Section 5.3.3). The estimated mean milk production was low (804 litres per lactation and 1.38 litres per hectare per day) (Chapter 5). However, these results were similar to the production data presented by other studies in Latin American countries (Sere and de Vaccaro, 1984; Vaccaro et al., 1992; Wilkins et al., 1979), but lower than the target yield suggested by Wilkins et al. (1979).

Grazing areas were largely dominated by natural pastures, fallows and forests with low grass cover (Chapter 4 and 5). The farms largely utilized silvopastoral areas for cattle grazing. The two large land use types, degraded pasture (DGPS) and natural pasture with moderate tree density (MTNP) occupied almost half of the grazing areas with moderate tree cover (accounting for approximately 20%), while pastures with no trees occupied only 12% of grazing areas. Supplementary feeding was common in the dry season but rather for maintenance purposes and use of concentrates was not common (Section 5.3.9). Variable costs were estimated to be low, approximately 7% of the annual income from cattle production, but it is questionable whether higher amounts of inputs are economically feasible. Nicholson et al. (1995) suggested that the empirical experiences of dual-purpose cattle production systems in Latin America showed that land-using technologies have lower total costs per unit of milk than land saving technologies. Holmann (1989) concluded that dual-purpose cattle production systems with crossbred cattle in lowlands is more economical than specialized dairy systems in the highlands of Venezuela.

Economic productivity indicators suggested that the gross margin was estimated to be US$150/ha/year from cattle production (mean annual income from cattle production US$161/ha minus 7% of the variable cost), which was rather low compared with other data presented by Holmann (1989) in Venezuela and Sere and de Vaccaro (1985) in Panama. In addition, the average net income per family labourer was US$4.1/day. In fact, the average net income per family labourer was raised by larger farms and that 37% of the sample farms had the daily net income per labourer lower than US$2, the average daily salary of a casual labourer (Chapter 3).

The economic situation of Nicaragua is, GNP per capita US$720, 48% of the population under national poverty line (World Bank 2004), land price US$509/ha, and few available jobs in the study area. This farming system requires a very small allowance for depreciation since most investments are associated with land and cattle (Sere and de Vaccaro, 1985), thus it may be characterized as being risk averse, as it is generally agreed that farmers are willing to forgo some income in order to avoid risk (Upton, 1996). Sere and de Vaccaro (1985) observed that in dual-purpose cattle farms in Panama, land and cattle comprised 91% of the total capital investment. In addition, this farming system has an advantage of producing most of the food for human consumption (corn, bean, pigs, chickens, etc.) on the farms.

Hence, it is possible to conclude that this farming system is low in productivity, but it is economical, low risk involved, and provides an acceptable option for farmers who have relatively large farms (>60 ha, Table 3.21). For smaller farms, intensification may be essential in order to survive with current family members; otherwise, they may need to emigrate to the current agricultural frontier. Further studies are recommended on economic analysis of the farming systems, particularly feasibility studies on different ways of intensification for various farm types (e.g. size, labour).

7.3 Stocking rates and farmer strategies

Cattle were frequently moved between local farms, while many problems related to temporal cattle movement were observed (Chapter 6). Farmers with small holdings in the tropics may pursue neither high production per animal nor area, but rather high production from locally available resources (Bayer and Waters-Bayer, 1998). Thus, they may be more interested in achieving acceptable reproduction rates rather than high production per animal. Farmers feed animals with high quality forage when it is available, but when forage is in short supply they use low quality feeds to meet maintenance requirements.

The study results showed that farmers want to have more cattle in their farms (Section 4.3.2). Ninety percent of R^2 value of the regression analysis on milk production per hectare was explained by stocking rates and the proportion of milking cows (Section 6.3.2). This indicates that the number of milking cattle was the most important variable affecting milk production, and farmers preferred to have more animals on the farms. In the dual-purpose cattle systems, reproduction is essential for production. It seems that farmers are interested in intensifying their production systems, but tend to simply believe that having more cattle makes more opportunities for reproduction and produces more milk and calves.

7.4 Farm size and land use to support cattle production

The principal components analysis, based on the proportion of land use types in grazing areas, showed that the largest component (PC1) had a gradient related to production capacity and consumption of biomass. The regression analysis showed that PC1 had significant effects on milk production (P<0.05), providing the estimation that farms which have larger degraded pasture (DGPS), smaller natural pasture with low tree density (LTNP), and lower stocking rates can take advantage of these components to support milk production (Chapter 6). Further analysis provides evidence that smaller farms have larger natural pasture with low tree density causing negative effects on saleable milk production, and they tend to have smaller degraded pasture which can contribute to milk production (Section 5.4.1). It probably indicates that for larger farms, having low stocking rates and more degraded pasture is one of appropriate options (in a sense to use PC1 for production), which takes advantage of "land using technology" as suggested by Nicholson et al. (1994).

In contrast, smaller farms with less degraded pasture, but that need to graze cattle at rather higher stocking rates, have more natural pasture with low tree density (LTNP) (P<0.01) where soil fertility is lowered and amount of biomass production is declining. As mentioned above, smaller farms have lower net income per family labourer. Such farms eventually may need to be sold and farmers may have to move towards the current agricultural frontier where lands are less expensive or adopt other economic activities. It was observed that farmers considered moving towards the east, to have a larger farm, as one possible option. This movement may cause deforestation and pasture development from natural forest towards the more humid area of the Atlantic plains (Kaimowitz, 1996). Alternative measures for such farms, including diversification of the production system need to be considered.

The study results showed that medium sized farms (15-30 ha of grazing areas) tended to have more areas for cut and carry forage for dry season fodder (Chapter 3). Such farms are likely to be more eager to intensify their farming systems because they do not have sufficiently large land to use "land using technology" but they may have small available lands. Accordingly, it can be concluded that these farms can be targeted for political intervention to intensify production.

7.5 Availability of dry season fodder

The study results show that daily saleable milk production per farm did not differ by season (Chapter 5). The study results also showed that calving were more frequent in the dry season than in the wet season ($P<0.05$, Section 5.3.4) probably because more cows conceive at the beginning of the wet season when physical conditions are improved by better fodder. In addition, even though fodder conditions are very severe, stocking rates did not decline in the dry season, resulting in significantly low milk production per cow ($P<0.01$) and there was a tendency to have higher adult mortality rates at the end of the dry season. It seems that since most of the farms were at locations accessible to milk collectors, they tended to bring more milking cows to the farms to sell milk. The evidence suggests that this farming system places a large burden on the environment, especially in the dry season.

Supplementary feeding, especially with salt and molasses, were practiced in the study area (42% of the farms used molasses, Section 5.3.9). However, it seemed that the amount of molasses was limited due to its high and unstable price. The use of crop residues as animal feedstuffs was also limited due to the small area of crop cultivation compared to the number of cattle on the farms. Considering the obstacles to obtain locally available supplements, higher milk prices in the dry season and farmer tendency to avoid cash outlays (Kaimowitz, 1996), it seems that producing supplemental pasture by cut and carry system is an acceptable option for farmers. The study results suggested that the proportion of area of cut and carry forage for the entire grazing area was positively correlated with the annual gross margin from cattle production, cattle sales and milk production per hectare (Section 3.3.7). However, since the cut and carry system is labour intensive, the expansion of the system may be limited to a certain extent by using currently available labour (3.7 farm labourers on average, Section 3.3.1.1).

7.6 Pasture conditions and soil fertility

7.6.1 Conditions of natural pastures

Sixty-two percent of the grazing areas were occupied by areas dominated by either natural grass (natural pasture with no, low or moderate tree density) or broadleaf plants (degraded pasture) (Section 5.3.1). Natural pasture with low tree density (LTNP) showed negative effects on milk production at the end of the dry season ($P<0.05$, Section 6.3.4). Natural pasture species (e.g. *Paspalum notatum/conjugatum)* are low in yield and their production is limited in the dry season (Duke, 1983; Peters et al., 2003). Therefore, natural pastures require frequent weeding to cover larger areas especially in the beginning of the wet season when pastures start to grow. The study results showed that degraded pasture had positive effects on milk production at the end of the dry season ($P<0.01$, Section 6.3.4), suggesting that broadleaf plants are not "weeds", but an important forage in the dry season when production of natural pasture is limited.

Herbaceous leguminous plants such as *Mucuna pruriens*, *Vigna vexillata* and *Desmodium sp*. were found in approximately half of the parcels covering 5% of the area (Section 4.3.2.2). However, utilization of these species by cattle is probably limited due to low coverage of the area. In general, creeping tropical pasture legumes are unstable under commercial stocking rates (Minson et al., 1993), but manipulation under lower stocking rates may be applicable in the study area. In addition, farmers suggested that some herbaceous plants found in the grazing areas are consumed by cattle. Moreover, it should be noted that the consumption of broadleaf plants by cattle at the end of the dry season may support growth of natural grass at the beginning of the wet season, thus lowering the burden of weeding. Therefore, some farmers may consider that higher grazing pressure at the end of the dry season is sensible. Further studies are recommended regarding the nutritional values of broadleaf plants and their utilization for cattle production, especially in the dry season.

7.6.2 Conditions of cultivated pastures

Cultivated pastures covered only a limited proportion of the grazing areas. *H. rufa* and *P. maximum* are the traditional cultivated pasture species and *B. brizantha* and *Pennisetum spp.* are recently sown pasture species in the study area (Section 3.3.3.2). *H. rufa* produces abundant seeds and requires low to medium soil fertility, but it loses nutritional value in the dry season, thus supporting lower stocking rates (Peters et al., 2003). In the study area, pasture enclosure for seed production of this species was observed at the end of the wet season.

The study results showed that *P. maximum* was very low in grass cover, only 31%

(Section 4.3.3.2). It was found in 49 parcels, but dominated only in 18 parcels. *P. maximum* is one of the most productive forage grasses in tropical America with high nutritional values, but it requires medium to high soil fertility (Peters et al., 2003). It is known to lack good seed production and rotational grazing is essential for the species, otherwise it dies rapidly under continuous grazing (Duke, 1983), but the size of paddocks of *P. maximum* were rather large compared to those with *B. brizantha*. Several studies suggested that grass cover and productivity of *P. maximum* were not maintained without fertilization (Humphreys, 1987; Jones et al., 1995). Therefore, low pasture cover of *P. maximum* was probably caused by 1) lowered soil fertility without fertilization, 2) lack of seed production and/or sowing, and 3) continuous grazing with longer occupancy period.

In contrast, the study found high grass cover in *B. brizantha* dominated pastures (Section 4.4.3). Regression analysis against milk production per hectare showed the positive coefficient of the proportion of *B. brizanntha* for the grazing area at the end of dry season ($P<0.05$, Section 6.3.4). *B. brizantha* has been sown more recently occupying 1.6% of the grazing areas (Section 5.3.1). *B. brizanntha* may be more useful than *P. maximum* under the present conditions of the grazing areas in the study area since *B. brizantha* requires medium soil fertility which is lower than *P. maximum* (Peters et al., 2003). In addition, *B. brizantha* maintains yield and nutritive values during the dry season and produces high quality seeds so that it is easier for farmers to propagate.

7.6.3 Pasture productivity and soil fertility

It is generally agreed that lowering pasture productivity is inevitable in extensive livestock production systems in the humid tropics in the absence of fertilization or symbiotic nitrogen fixation by legumes (Humphrey, 1994; Fisher et. al., 1996). Soil nitrogen is the first constraint for pasture production (Wong 1990; Humphreys, 1994), but it was argued by Serrao (1978) that pasture productivity fell as a consequence of overgrazing due to the loss of P in the soil, particularly when the clay content of the soil was high (da Veiga, 1995). Boddey et al. (2000) reviewed the process of pasture degradation and suggested the importance of applying 25 kg P and 15 kg K/ha/year in order to maintain pasture productivity. In order to maintain the productivity of *Pennisetum purpureum*, N, P and K should be applied at 50-75, 20 and 50 kg/ha/year respectively (Peters et al., 2003).

However, because of high costs, fertilization is rarely practiced for pasture lands in the study area (Chapter 4). In addition, in order to make the system with fertilization profitable, stocking rates need to be sufficiently high (Hernandez-Garay et al., 2004), but this farming system is rather extensive with relatively low stocking rates. In fact, *B. brizantha* and *Pennisetum spp*. respond well to fertilization (Peters et al., 2003) and seemed to be cultivated in small paddocks in the study area (Chapter 3). Considering the economic status of the farmers and the large size of the grazing areas, fertilization should probably be concentrated in small areas where more productive species are sown under a regime of well controlled higher stocking rates.

The study observed pasture degradation by three ways: natural pasture with low tree density which is more common in smaller farms, low grass cover of *P. maximum,* and the loss of grass cover on slopes especially for cultivated pasture. However, most farms continuously produce cattle products mainly by grazing without the use of fertilizer. Twenty three percent of the grazing areas are covered by trees and the silvopastoral areas occupy 74% of the grazing areas. The study results showed that grass cover under tree cover class 10-30% did not significantly differ from tree cover class less than 10% ($P<0.05$), particularly for cultivated pasture species (Chapter 4). Leguminous trees can derive nitrogen without any cost in a sustainable way. Accordingly, silvopastoral areas are largely utilized for maintaining soil fertility under extensive management in the study area.

7.7 Effects of silvopastoral areas on cattle production

7.7.1 Effects of silvopastoral areas for dry season fodder

The regression analysis showed positive effects on milk production of three types of silvopastoral areas at the end of the dry season [degraded pasture ($P<0.01$) and tendencies by natural and cultivated pasture with moderate tree density]. Common tree species found in the study area, *G. ulmifolia*, *E. cyclocarpum,* and *P. saman* are commonly found in other grazing areas in Latin America and are preferred by farmers for cattle fodder (Marrison et al, 1996; Toral et al., 2001; Cajas-Giron and Sinclair, 2001). These trees produce fruits in the dry season which are useful for cattle feeding. They have high in vitro digestibility (70-80%) and crude protein (7-30%) (Zamora et al., 2001). Fanidino (1998) found that milk production per cow increased by 0.5 to 1.1 litres and showed higher values of total solids, protein and fat in milk as a consequence of supplementing with *P. saman* fruits. Studies by Bressani et al. (1981) observed that feeding calves maiz silages supplemented with concentrates containing up to 30% of the flour of *G. ulmifolia* did not affect calf growth. Cattle can also assist seed distribution in grazing areas. Jansen (1982) observed that seeds of *P. saman* are eaten by horses or cattle within a few days of falling, but intact hard dormant seeds can pass through the digestive system and are found in dung, thus expanding seed germination and protecting them from other predators.

Tree leaves may also be important forage in the dry season. The nutritional quality of tree leaves tends to be better maintained from season to season than that of grasses (Pezo et al., 1990). Palma et al. (1999) found no seasonal difference in crude protein, crude fibre, and organic matter digestibility of leguminous trees. Tree leaves from most tree species found in the study including *G. ulmifolia*, *E. cyclocarpum, P. saman, Gliricidia sepium Psidium guajava, Tabebuia ochracea Spondias mombin*, *Vochisia ferruginea* etc. are found to be useful for cattle feeding (Hernandez and Benavides, 1995; Pezo and Ibrahim, 1999).

Farmers can probably record daily milk production by cows easier than calving rates which need proper recordkeeping over a long period of time, thus they may lack attention of calving rates. It should be noted that the potential for milk production is established in early lactation (Stobbs and Thompson, 1975). Therefore, higher calving frequency in the dry season due to forage conditions not only prolongs the dry period of cows, but also lowers production over the whole lactation period. In other words, improvement of dry season fodder will not only shorten the dry period, but will also potentially increase milk production per lactation including the amount produced in the wet season.

7.7.2 Effects of silvopastoral areas on soil fertility and cattle production

Regression analysis showed that one type of silvopastoral area (natural pasture with moderate tree density) had positive effects on milk production at the beginning of the wet season ($P<0.05$) (Chapter 6). It may suggest that natural pasture with moderate tree density had more vigorous pastures as a consequence of better soil conditions supported by tree cover, and thus did not require pasture recuperation.

Leguminous trees such as *E. cyclocarpum*, *P. saman* *G. sepium*, etc. were commonly found in the grazing areas. Leguminous trees occupied approximately a quarter of the total basal area found in the study. Leguminous plants not only stabilize soil nitrogen and organic carbon content, but also provide higher animal production through increased crude protein content of herbage and voluntary intake of cattle. They also mitigate seasonal reductions of forage production due to maintained growth during drier periods (Crowder, 1985; Humphreys, 1987; Crowder and Chheda, 1987). The positive effects of shading by leguminous trees on pasture growth and nutrient uptake are observed when nitrogen and water are limiting factors (Cruz, 1997). Alley cropping of *G. sepium*, and *Leucaena leucacophala* can derive 100-300 kgN/ha/year from the atmosphere (Sanginga et al., 1995). Compared with N application by fertilizer, N fixed by trees is more useful for pasture since nitrogen released from biomass sources is retained in the topsoil, thus avoiding leaching (Lehmann and Schroth, 2003). In addition, it should be noted that compared with agroforestry systems with crop production, using tree leaves from nitrogen fixing trees as cattle fodder can avoid nitrogen loss through leaching, volatilization, and denitrification since tree leaves are directly consumed by cattle.

However, nitrogen fixation is sensitive to nutrient deficiency, especially with phosphorus (Giller, 2003). Overgrazing may potentially remove phosphorous from the soil (Serrao, 1978). However, Kass et al. (1999) reported that applying cattle manure increases the readily available P fraction significantly more than mineral P application, suggesting that cattle under light stocking rates with leguminous trees may support nitrogen fixation of leguminous trees.

7.8 Conclusions

Dual-purpose cattle production systems are low in productivity, but economical and risk aversive, and provide an acceptable option for farmers who have relatively large farms in the study area. The study results showed that 23% of the grazing areas were covered by trees, thus silvopasotral areas are largely utilized. Grass cover of silvopastoral areas with moderate tree cover (accounting for approximately 20%) did not significantly differ from those of areas with less tree cover under existing pasture conditions ($P<0.01$). The study concludes that silvopastoral areas have positive effects on milk production through shade for crossbred cattle, producing leaves and fruits in the dry season and improving soil fertility particularly by nitrogen fixing leguminous trees.

Cattle were frequently moved between local farms, but stocking rates did not differ by season ($P<0.05$). In addition, the study found higher occurrences of calvings ($P<0.01$) in the dry season due to seasonal nutritional availability. The lack of fodder, together with the relatively high level of stocking rates at the end of the dry season caused low milk productivity per cow ($P<0.01$), and high adult mortality rates. Improvement of dry season fodder not only increases production in the dry season, but may also shorten calving rates and potentially increase milk production for the entire lactation period.

Low grass cover of *Panicum maximum* was observed probably due to lowered soil fertility after overgrazing without fertilization. In contrast, recently sown *B. brizantha* made a significant contribution to milk production at the end of the dry season ($P<0.01$). However, in order to maintain productivity of high yielding pastures, silvopastoral techniques in smaller paddocks under controlled stocking rates are recommended.

The study results suggested positive effects of degraded pasture ($P<0.01$) and negative effects of natural pasture with low tree density ($P<0.05$) on milk production at the end of the dry season. Smaller farms had higher stocking rates, higher proportions of natural pasture with low tree density, but lower net income per family labourer. Such farms may eventually need to move towards the agricultural frontier in order to have larger farms. Alternative measures to support this type of farming are important in the context of development in the study area. On the other hand, production of supplementary forage by cut and carry are accepted particularly by medium sized farms (15-30 ha of grazing areas), which have small available lands. Accordingly, these farms can be targeted for political intervention to intensify production.

Further studies are recommended on the following topics.

- Stocking rates and change of sward composition,
- Feasibility study of pasture improvement by desirable pasture species (*B. brizantha*), use of fertilization and application of silvopastoral techniques with leguminous plants under existing levels of grazing pressure,
- Feasibility study on cut and carry forage for dry season fodder with regard to labour availability, use of fertilization and application of silvopastoral techniques with leguminous plants,
- Availability and nutritional values of broadleaf species including legumes in the dry season,
- Cattle movement and the role of local cattle sharing systems,
- Analysis of socio-economic conditions of small farms.

References

Aber, JD; Melillo, JM. 1991. Terrestrial ecosystems. Sunders College Publishing. 429p.

Agüero, JM; Alvarado, A. 1983. Compactación y compactabilidad de suelos agrícolas y ganaderos de Guanacaste, Costa Rica. Agronomía Costarricense 7 (1/2): 27-33.

Alfaro, M; Rojas, I. 1992. Sistemas agroforestales en la cuenca superior del rio Nosara. *In* Montagnini, F. Eds. Sistemas agroforestales: principios y aplicaciones en los trópicos. OTS. San José. p.277- 330.

Aragon, M. 1981. Evaluación bioeconomica de un hato de doble propósito en el tropical monzonico de Costa Rica. Master thesis. CATIE/UCR. 52p.

Archer, S. 1995. Herbivore mediation of grass-woody plant interactions. Tropical Grasslands. 29(4): 218-235.

Archer, S. 1996. Assessing and interpreting Grass-Woody plant dynamics. *In* Hodgson J.; Illus, AW. Eds. The ecology and management of grazing systems. CAB International.

Asner, GP; Townsend, AR; Bustamante, MMC; Nardoto, GB; Olander, LP. 2004. Pasture degradation in the central Amazon: linking changes in carbon and nutrient cycling with remote sensing .Global Change Biology, 10(5): 844-862.

Arnon, I. 1987. Modernization of Agriculture in developing countries. 2nd edition John Wiley and Sons.

Arosemena, 1990. Determinación de mecanismos de interferencia por alelopatia y requerimientos externos e internos de fósforo en pasto ratana (*Ischaemun ciliare* Merrill). Master Thesis. CATIE. 124p.

Bayer W; Waters-Bayer, A. 1998. Forage husbandry. Tropical Agriculturalist. ICTA/GTZ. Macmillan Education Ltd. 198p.

Belsky. AJ. 1992. Effects of trees on nutritional quality of understorey gramineous forage in tropical savannas. Tropical Grasslands 26(1): 12-20.

Belsky, AJ; Mwonga, SM; Duxbury, JM. 1993. Effects of widely spaced trees and livestock grazing on understory environments in tropical savannas. Agroforestry Systems 24(1): 1-20.

Benavides, J; Roberto, AR; Borel, R. 1994. Producción y calidad del forraje de King grass (*Pennisetum purpureum* x *P. Typhoides*) y Poro (*Erythrina poeppigiana*) en asociación. Árboles y arbustos forrajeros en América Central. CATIE. Serie Técnica, Informe Técnico 236(1): 117-133.

Boddey, RM; Alves, BJR; Oliveira, OC; Urquiaga, S. 2000. Pasture degradation and nitrogen cycling. Documentos - Embrapa Agropecuária Oeste, No. 26. p.110-124.

Bolívar. D; Ibrahim, M; Kass, D; Jiménez, F; Camargo, JC. 1999. Productividad y calidad forrajera de *Brachiaria humidicola* en monocultivo y en asocio con *Acacia mangium* en un suelo ácido en el trópico húmedo. Agroforestría en las Américas 6(23): 48-50.

Brady, NC. 1990. The nature and properties of soils. Tenth edition. Macmillan publishing. 621p.

Bressani R; Gonzalez, JM; Brenes RG. 1981. Evaluación del fruto del Caulote (*Guazuma ulmifolia*, Lam) en la alimentación de terneros. Turrialba 31(4): 281-285.

Bustamante, J; Ibrahim, M; Beer, J. 1998. Evaluación agronómica de ocho gramíneas mejoradas en un sistemas silvopastoral con poró (*Erythrina poeppigiana*) en el trópico húmedo de Turrialba. Agroforestería en las Américas 5(19): 11-16.

Cajas-Giron, YS; Sinclair, FL. 2001. Characterization of multistrata silvopastoral systems on seasonally dry pastures in the Caribbean Region of Colombia. Agroforestry Systems 53(2): 215-225.

CATIE (Centro Agronómico Tropical de Investigación y Enseñanza) 1991. Guacimo: Especie de árbol de uso múltiple en América Central. Informe Técnico No.165. 71p

CATIE(Centro Agronómico Tropical de Investigación y Enseñanza) 1994. Laurel: Especie de árbol de uso múltiple en América Central. Informe Técnico No.239. 41p.

CATIE (Centro Agronómico Tropical de Investigación y Enseñanza) 2004. Árboles de Centroamérica. Manual para extensionistas.

Chatterjee, S; Price, B. 1991. Regression analysis by example. John Wiley and Sons. New York.

Chen, CP. 1990. Cattle productivity under oil palm in Malaysia. *In* Shelton, HM; Stur, WW. Eds. Forages for plantation crops, ACIAR Proceedings No. 32. Canberra. ACIAR. p.97-101.

Chesworth, J. 1992. Ruminant nutrition, Macmillan/CTA. London. 170p.

Chong, DT; Tajuddin, I; Abd.Sumat, M.S.. 1990. Stocking rate effect on sheep and forage productivity under rubber in Malaysia. *In* Shelton, HM; Stur, WW. Eds. Forages for plantation crops, ACIAR Proceedings No. 32. Canberra. ACIAR.

Corporación Ganadería. 2000. Análisis de Censo Ganadero 2000. http://www.corfoga.org/pdf/proyecto/censo2000.pdf.

Couto, L; Roath, RL; Betters, DR; Garcia, R; Almeida, JCC. 1994. Cattle and sheep in eucalyptus plantations: a silvopastoral alternative in Minas Gerais, Brazil. Agroforestry Systems 28(2): 173-185.

Cowan, RT; Moss, RJ; Kerr, DV. 1993. Northern dairy feedbase 2001.2. Summer feeding systems. Tropical Grasslands 27(3): 150-161.

Crowder, LV; Chheda, HR. 1982. Tropical Grassland Husbandry. Longman.562p.

Crowder, LV. 1985. Pasture management for optimum ruminant production. *In* McDowell, LR. Eds. Nutrition of grazing ruminants in warm climates. Academic press. p.103-128.

Cruz, P. 1997. Effects of shade on the growth and mineral nutrition of a C4 perennial grass under field conditions. Plant and Soil 188: 227-237.

Draper N; Smith H. 1980. Applied regression analysis. 2nd edition. John Wiley and Sons.

Duke, JA. 1983. Handbook of Energy Crops. unpublished http://www.hort.purdue.edu/newcrop/duke_energy/Paspalum_notatum.html

Durr, PA; Rangel J. 2000. The response of *Panicum maximum* to a simulated subcanopy environment 1. Soil x tree cover interaction. Tropical Grasslands 34(2): 110-117.

Durr, PA; Rangel J. 2002. Enhanced forage production under *Samanea saman* in a sub-humid tropical grassland. Agroforestry Systems 54(2): 99-102.

Esquivel, H. 2004. Relationship between tree cover on farm and pasture productivity of silvopastoral systems in dry ecosystems. Draft. Ph.D. dissertation. CATIE.

Fanidino, BR; Velandia, ET; Sierra, M. 1998. Producción de vacas de doble propósito suplementadas con frutos de algarrobillo (*Pithecellobium saman*) durante la época de lluvia. Colombia. Primer congreso Latieamericano de Agroforestería para la producción animal sostenible. CIPAV.

FAO. 1993. Forest resources assessment, 1990. Tropical countries. FAO forestry paper. Rome. 112p.

FAO.2003. FAOSTAT.

Fisher, MJ; Rao, IM; Thomas, RJ; Lascano, CE. 1996. Grasslands in the well-watered tropical lowlands. *In* Hodgson J; Illius.AW. Eds. The ecology and management of grazing systems. CAB International. p.393-425.

Flores-Rauna, OI. 1994. Caracterización y evaluación de follajes arbóreos para la alimentación de rumiantes en el Departamento de Chiquimula, Guatemala". *In* Benavides, J.E. Eds. Árboles y arbustos forrajeros en América Central. CATIE. Serie Técnica, Informe Técnico 236(1): 117-133.

Garcia E.G. 1996. Manual de forrajes en Nicaragua. 179p.

Gartner, JA. 1966. Proceedings. 10th International Grassland Congress. Helsinki. p.123.

Giller, KE. 2003. Biological nitrogen fixation. *In* Schroth, G; Sinclair, FL. Eds. Trees, crops and soil fertility: concepts and research methods. CABI Publishing. P.259-270.

Giraldo, VL; Boteo, J; Saldarriega, J; David, P. 1995. Efecto de tres densidades de árboles en el potencial forrajero de un sistema silvopastoril natural en la región Atlántica de Colombia. Agroforestería de las Américas 2(8): 14-19.

De Groot, JP; Ambrogi, R; Jimenez, ML. 1996. Sistemas de producción en el trópico húmedo de Nicaragua: una comparación de dos áreas de colonización. *In* Frontera agrícola en Nicaragua. UNAN. Managua.

Golding, EJ. 1985. Providing energy-protein supplementation during the dry season. *In* . McDowell, L.R. Eds. Nutrition of grazing ruminants in warm climates. Academic press.

p.129-163.

Gutierrez, MA. 1996. Pastos y forrages en Guatemala. Universidad de San Carlos de Guatemala.

Hamilton, LS; Pearce, AJ. 1987. Biophysical aspects in watershed management. *In* Watershed resources management: An integrated framework with studies from Asia and the Pacific. Studies in Water Policy and Management. No.10, Westview press.

Harvey, CA; Haber, WA. 1999. Remnant trees and the conservation of biodiversity in Costa Rican pasture. Agroforestry Systems 44(1): 37-68.

Hecht, SB. 1992. Logics of livestock and deforestation: The case of Amazonia. *In* . Downing, TE; Hetcht, SB; Pearson HA; Garcia-Downing, C. Eds. Development or Destruction Westview press. Boulder. P.7-25.

Heitschmidt, RK; Tayor, CA. 1991. Livestock production. *In* Heitschmidt, RK; Stuth, JW. Eds. Grazing management: An ecological perspective. Timber press. p.161-177.

Hernández Garay, A; Sollenberger, LE; McDonald, DC; Ruegsegger, GJ; Kalmbacher, RS; Mislevy, P. 2004, Nitrogen fertilization and stocking rate affect stargrass pasture and cattle performance. Crop Science 44(4): 1348-1354.

Hidalgo, DM; Kleinn, C; Kunth, S. 2002. Manual de campo para el censo de árboles en potreros. Project Fragment. University of Gottingen. 26p.

Holmann, F. 1989. Economic evaluation of dairy and dual purpose cattle production systems in Venezuela. Ph.D. dissertation. Cornel University.

Holmann, F; Romero, F; Montenegro, J; Chana, C; Oviedo, E; Banos, A. 1992. Rentabilidad de los sistemas silvopastoriles con pequeños productores de leche en Costa Rica:

primero aproximación. Turrialba 42(1): 79-89.

Holmann, F. 1999. Ex ante analysis of new forage alternatives for farms with dual purpose cattle production in Peru, Costa Rica and Nicaragua. Livestock Research for Rural Development 11(3) 24p.

Horne, PM; Blair, GJ. 1991. Forage tree legumes. IV. Productivity of Leucaena/grass mixture. Australian Journal of Agricultural Research 42(7): 1231-1250.

Hughes, CE; Stewart, JL. 1990. *Enterlobium cycloccarpum*: The ear pod tree for pasture, fodder and wood. NFT Highlight. 90-05. Nitrogen Fixing Tree Association. Waimanalo, Hawaii.

Humphreys, LR. 1987. Tropical pastures and fodder crops. Intermediate Tropical Agriculture Series. Longman Science and Technical. 115p.

Humphreys, LR. 1994. Tropical Forages: Their role in sustainable agriculture. Longman Science and Technical.

Ibrahim, MA; Mannetje, L't. 1998. Compatibility, persistence and productivity of grass-legume mixture in the humid tropics of Costa Rica. 1. Dry matter yield, nitrogen yield and botanical composition. Tropical Grasslands 32(2): 96-104.

Ibrahim, MA. 2000. Contribution of *Erythrina* protein banks and rejected bananas for improving cattle production in the humid tropics. Agroforestry Systems 49(3): 245-254.

INIFOM (Instituto Nicaragüense de Fomento Municipal). 1997. Matiguas.

Infostat. 2004. Manual para usuario. Versión 1 2004. Grupo Infostat. FCA. Universidad Nacional de Cordoba. Primera edición Editorial Brujas. Argentina.

INTA (Instituto Nicaragüense de Tecnología Agropecuaria). 1998. Zonificación agro socioeconómica agencia Matiguas. 72p.

Jansen, DH. 1982. Costa Rican natural history. *In* Jansen, DH. Eds. The university of Chicago press. Chicago and London. 816p.

Johnson, RA; Wichern, DW. 1998. Applied multivariate statistical analysis. 4th edition. Prentice Hall. NJ.

Jones, RJ; Sandland RL. 1974. The relation between animal gain and stocking rate: deviation of the relation from the results of grazing trials. Journal of Agricultural Science 83(2): 335-341.

Jones, RM; McDonald, CK; Silvey, MW. 1995. Permanent pastures on a brigalow soil: the effect of nitrogen fertilizer and stocking rate on pastures and liveweight gain. Tropical Grasslands 29(4): 193-209.

Kaimowitz, D. 1996. Livestock and Deforestation: Central America in the 1980s and 1990s: A Policy Perspective. CIFOR Special Publication. 88p.

Kass, DCL; Foletti, C; Szott, LT; Landaverde, R; Nolasco, R. 1993. Traditional fallow systems of the Americas. Agroforestry Systems 23: 207-218.

Kass, DCL; Somarriba, E; Vasconcelos de Macedo. 1999. Soil phosphorus fractions in agroforestry systems: effect of soil depth and sampling time. Agroforestry Forum 9(4): 42-49.

Lal, R; Hall, GF; Miller, FP. 1989. Soil degradation: I Basic processes. Land Degradation and Rehabilitation 1(1): 51-69.

Lascano, CE; Pezo, D. 1994. Agroforestry systems in the humid forest margins of tropical America from a livestock perspective. *In* Copeland, JW; Djajanegara, A; Sabrani, M.

Eds. Agroforestry and animal husbandry for human welfare. ACIAR. Proceedings. No. 55, p.17-24.

Lehmann J; Schroth, G. 2003. Nitrogen leaching. *In* Schroth, G; Sinclair, FL. Eds. Trees, crops and soil fertility: concepts and research methods. CABI Publishing. P.151-166.

Levard, L; Lopez, YM; Navarro, I. 2001. Municipio de Matiguas: potencialidades y limitantes del desarrollo agropecuario. UCA/FIDA/NITLAPAN. 83p.

Librero, HF; Benavides, JE; Kass, D; Pezo, D. 1994. Productividad de una plantación asociada de poro (*Erythrina poeppigiana*) y King grass (Pennistetum purpureum x P.typhoides). I. Efecto de la adición de follaje al suelo sobre la producción y calidad de la biomasa. *In* Benavides, JE. Eds. Árboles y arbustos forrajeros en América Central. CATIE. Serie Técnica Informe Técnico 236(2): 453-474.

Lilienfein, J; Wilcke, W. 2003. Element storage in native, agri-, and silvicultural ecosystems of the Brazilian savanna. I. Biomass, carbon, nitrogen, phosphorus, and sulfur. Plant and Soil 254(2): 425-442.

Llamozas, JA; Vaccaro, L. 2002. Correlations of part and total lactations and the prediction of lactation milk yield in Venezuelan dual purpose cows hand milked with calf at foot. Livestock Research For Rural Development 14(5) http://www.cipav.org.co/lrrd/lrrd14/lrrd14.htm.

Loker, WM. 1994. Where's the beef ?: Incorporating Cattle into Sustainable Agroforestry systems in the Amazon Basin. Agroforestry Systems 25(3): 227-241.

Maldidier, C. 1993. Tendencias actuales de la frontera agrícola en Nicaragua. Managua: NITLAPAN-UCA.

Maldidier, C; Marchetti, R. 1996. El Campesino-Finquero y el potencial económico del campesinado nicaragüense. NITLAPAN. 174p.

Martinez, JC. 1992. Los sistemas de producción. *In* Ganadería mestiza de doble propósito. González-Stagnaro, C. Eds. Universidad del Zulia. P.27-40.

Martinez, A; Ibrahim, M; Pezo, D; L. Mannetje. 1993. Selectividad de *A. Pintoi* asociado con *B.brizantha* y *B.humidicola* por bovinos en pastoreo en condiciones del tropical seco. CATIE/MAG/UAW. Field Report. No. 92, 20p.

Matson, PA; Parton, WJ; Power, AG; Swift, MJ; 1997. Agricultural intensification and ecosystem properties. Science 277(5325): 504-508.

MINITAB 2000. MINITAB User Guide 2 Data analysis and quality tool.

Minson, DJ. 1981. Nutritional differences between tropical and temperate pastures. *In* Morley. FHW. Eds. Grazing animals. Disciplinary approach. World Animal Science B1: 143-157.

Minson, D.1993. Northern dairy feedbase 2001. 1. Summer pasture and crops. Tropical Grasslands 27(3): 131-149.

Montagnini, F; Sancho, F. 1994. Net nitrogen mineralization in soils under six indigenous tree species, and abandoned pasture and a secondary forest in the Atlantic lowlands of Costa Rica. Plant and Soil 162(1): 117-124.

Morrison, BJ; Gold, MA; Lantagne, DO. 1996. Incorporating indigenous knowledge of fodder trees into small-scale silvopastoral systems in Jamaica. Agroforestry Systems 34(1): 101-117.

Muchagata, M; Brown, K. 1999. A Literature Review and Annotated Bibliography. Small

Farming Systems in Amazonia: Livestock Production and Sustainability. Appendix 8. ODG. University of East Angolia.

Müller, MML; Guimarães, MF; Desjardins, T; Mitja, D. 2004. The relationship between pasture degradation and soil properties in the Brazilian Amazon: a case study. Agriculture, Ecosystems & Environment 103(2): 279-288.

Murgueitio, E. 1990. Intensive sustainable livestock production: An Alternative to Tropical Deforestation. AMBIO 19(8): 397-400.

Murgueitio, E; Ibrahim, M; Ramirez, E; Zapata, A; Eduardo, C; Casasola, F. 2003. Usos de la tierra en fincas ganaderas: Guía para el pago de servicios ambientales en el proyecto Enfoques Silvopastoriles Integrados para el Manejo de Ecosistemas. CIPAV. 97p.

Myers, N. 1981. The Hamburger Connection: How Central America's Forest Became North America's Hamburgers. AMBIO 10: 3-8.

Myers, N. 1994. Tropical deforestation: rates and patterns. *In* Brown K; Pearce, DW. Eds. The causes and deforestation. UCL press.

Nyaata, OZ; Dorward, PT; Keatinge, JD; H; O'Neill, MK. 2000. Availability and use of dry season feed resources on smallholder dairy farms in central Kenya. Agroforestry Systems 50(3): 315-33.

Nepstad, DC; Uhl, C; Serrão, EAS. 1991. Recuperation of Degraded Amazonian Landscape: Forest Recovery and Agricultural Restoration. AMBIO 20(6): 248-255.

Nicholson, CF; Lee, DR; Boisvert, RN; Blake, RW. 1994. An optimization model of the dual purpose cattle production system in the humid lowlands of Venezuela. Agricultural Systems 46(3): 311-334.

Nicholson, CF., Blake, RW; Lee, DR. 1995. Livestock, deforestation, and policy making :intensification of cattle production systems in Central America revisited. Journal of Dairy Science 78(3): 719-734.

NITLAPAN. 1995. Diagnostico de la Producción Agropecuaria en el Interior del País. Análisis de Encuesta Rural. Proyecto de Tecnologia Agraria y Ordenamiento de la Propiedad Agraria.

Nix, J. 1999. Farm Management Handbook. 30th Edition. University of London. 244p.

Norton, BW. 1994. Anti-nutritive and toxic factors in forage tree legumes". *In* Gutteridge RC; Shelton, HM. Eds. Forage tree legumes in tropical agriculture. CAB International.

Nyaata, OZ; Dorward, PT; Keatinge, JD; H; O'Neill, MK. 2000. Availability and use of dry season feed resources on smallholder dairy farms in central Kenya. Agroforestry Systems 50(3): 315-33.

Palase, D. 1992. Presente y futuro de la producción bovina en Venezuela. *In* González-Stagnaro, C. eds. Ganadería mestiza de doble propósito. Universidad del Zulia. p.1-23.

Palma, JM; Aguirre, M; Cadenas, C; Moya, A. 1999. Nutritive value of three tree legumes in the dry topics of Mexico. Pastos y Forrajes 22(1): 353-358.

Parsons, J. 1976. Forest to Pasture: Development or Destruction? Revista de Biología Tropical 24(1): 121-138.

Payne, WJA; Wilson, RT. 1999. An introduction to animal husbandry in the tropics. Blackwell Science.

Pereira, HC. 1989. Policy and practice in the management of tropical watersheds. Westview press. 237p.

Peters, M; Franco, LH; Schmidt, A; Hincapié, B. 2003. Especies Forrajeras Multipropósito: Opciones para productores de Centroamérica. CIAT. 113p.

Pezo, D; Kass, D; Benavides, J; Romero; F; Chaves, C. 1990. Potential of legume tree fodders as animal feed in Central America. *In* Shrubs and Tree fodders for farm animals. Proceedings of a workshop in Denpasar, Indonesia, 1989. IDRC. Ottawa. p.163-175.

Pezo, D; Ibrahim, M. 1999. Sistema Silvopastoriles. Modulo de Enseñanza. No.2. CATIE. Turrialba. 275p.

Plasse, D. 1992. Presente y futuro de la producción bovina en Venezuela. *In* González-Stagnaro, C. Eds. Ganadería mestiza de doble propósito. Universidad del Zulia. p.1-23.

Ramirez, AC. 2002. Ganadería de leche: Enfoque empresarial. Editorial Universidad Estatal a Distancia. 289p.

Rao, CR; Toutenburg, H. 1999. Linear models: Second edition. Springer.

Reynolds, SG. 1996. Integration of animal production in coconut plantation. Livestock feed resources within integrated farming systems, Second FAO Electric Conference, 1996-97 on Tropical feed.

RongGui W; Bao L; Tiessen, H. 2003. Study on the dynamics of soil phosphorus in the transitional areas of grasslands and crop fields. Plant Nutrition and Fertilizer. Science 9(2): 131-138.

Ruiz, A. 1994. Tenencia y Uso de la Tierra en Matiguas-Matagalpa, Nicaragua. FAO Land Tenure Working Paper. 79p.

press. 237p.

Peters, M; Franco, LH; Schmidt, A; Hincapié, B. 2003. Especies Forrajeras Multipropósito: Opciones para productores de Centroamérica. CIAT. 113p.

Pezo, D; Kass, D; Benavides, J; Romero; F; Chaves, C. 1990. Potential of legume tree fodders as animal feed in Central America. *In* Shrubs and Tree fodders for farm animals. Proceedings of a workshop in Denpasar, Indonesia, 1989. IDRC. Ottawa. p.163-175.

Pezo, D; Ibrahim, M. 1999. Sistema Silvopastoriles. Modulo de Enseñanza. No.2. CATIE. Turrialba. 275p.

Plasse, D. 1992. Presente y futuro de la producción bovina en Venezuela. *In* González-Stagnaro, C. Eds. Ganadería mestiza de doble propósito. Universidad del Zulia. p.1-23.

Ramirez, AC. 2002. Ganadería de leche: Enfoque empresarial. Editorial Universidad Estatal a Distancia. 289p.

Rao, CR; Toutenburg, H. 1999. Linear models: Second edition. Springer.

Reynolds, SG. 1996. Integration of animal production in coconut plantation. Livestock feed resources within integrated farming systems, Second FAO Electric Conference, 1996-97 on Tropical feed.

RongGui W; Bao L; Tiessen, H. 2003. Study on the dynamics of soil phosphorus in the transitional areas of grasslands and crop fields. Plant Nutrition and Fertilizer. Science 9(2): 131-138.

Ruiz, A. 1994. Tenencia y Uso de la Tierra en Matiguas-Matagalpa, Nicaragua. FAO Land Tenure Working Paper. 79p.

Sanginga N; Vanlauwe,B; Danso, SKA. 1995. Management of biological N_2 fixation in alley cropping systems: estimation and contribution to N balance. Plant and Soil 174: 119-141.

Sere, C; De Vaccaro, L. 1985. Milk production from dual-purpose systems in tropical Latin America. *In* Smith, AJ. Eds. Milk production in Developing Countries. Centre for Tropical Veterinary Medicine. University of Edinburgh. p.459-475.

Serrao, EAS; Falesi, IC; De Veiga, JB; Neto, JFT. 1978. Productivity of cultivated pastures on low fertility soils in the Amazon of Brazil. *In* Proceeding of a seminar on Pasture production in acid soils of tropics. CIAT. p.195-226.

Serrão, EAS; Toledo, JM. 1992. Sustaining Pasture-based Production Systems for the Humid Tropics. *In* Downing, TE; Hecht, SB; Pearson, H. A; Garcia-Downing, C. Eds. Development or Destruction. The conversion of Tropical Forest to Pasture in Latin America. Westview press. Boulder. p.257-280.

Sharma, S. 1996. Applied Multivariate Techniques. John Wiley and Sons. Inc.

Sharrow, SH; Carlson, DH; Emmingham, WH; Lavender, DP; Direct impact of sheep upon Douglas-fir trees in two agrosilvopastoral systems. Agroforestry systems 19(3): 223-232.

Shelton, HM; Humphreys, LR; Batello, C. 1987. Pasture in the plantations of Asia and the Pacific: performance and prospect. Tropical Grasslands 21(4): 159-168.

Shelton, HM. 1990. Productivity of cattle under coconuts. *In* Shelton, HM; Stur, WW. Eds. Forages for plantation crops, ACIAR Proceedings No. 32. Canberra. ACIAR. p.92-96.

Simpson, JR; Conrad, JH. Intensification of cattle production systems in Central America:

Why and When. Journal of Dairy Science 76(6): 1744-1752.

Skerman, PJ; Riveros, F. 1990. Tropical grasses FAO. 832p.

Smith MA; Whiteman, PC. 1983. Evaluation of tropical grasses in increasing shade under coconut canopies. Experimental Agriculture 19(2): 153-161.

Soares, WV; Lobato, E; Sousa, DMG; Vilela, L. 2001. Maintenance phosphorus fertilization for *Brachiaria decumbens* pasture in Cerrado Region. Comunicado Técnico - Embrapa Cerrados, No. 53, 5p.

Soca, M; Simon, L; Caceres O; Francisco AG. 1999. Nutritive value of hay from tree legumes. 1. *Albizia lebbeck*. Pastos y Forrajes 22(4): 353-358.

Somarriba, E. 1988. Pasture growth and floristic composition under the shade of guava (*Psidium guajava* L.) trees in Costa Rica. Agroforestry Systems 6(2): 153-162.

Souza de Abreu, MH; Ibrahim, M; Harvey, C; Jimenez, F. Caracterización del componente arbóreo en los sistemas ganaderos de la Fortuna de San Carlos, Costa Rica. 1999. CATIE.

Souza de Abreu, MH. 2002. Contribution of trees to the control of heat stress in dairy cows and the financial viability of livestock farms in humid tropics. Ph.D. dissertation. CATIE.

Spain, JM; Gualdrón, R. 1991. Degradación y Rehabilitación de Pasturas. *In* Lascano CE; Spain, JM. Eds. Establecimiento y Renovación de Pasturas. CIAT. p.269-283.

Stobbs, TH. 1969. The influence of inorganic fertilizers upon the adaptation, persistency and production of grass and grass/legume swards in eastern Uganda. East African Agriculture and Forestry Journal. 35: 112.

Stobbs, TH; Thompson, PAC. 1975. Milk production from tropical pastures. World Animal Review 13: 27-31.

Sunderlin, WD; Rodríguez, JA. 1996. Cattle, Broadleaf Forests and the Agricultural Modernization law of Honduras: The case study of Olancho. CIFOR Occasional Paper No. 7 (S). 28p.

Szott, L; Ibrahim, M; Beer, J. 2000. The hamburger connection hangover: Cattle pasture land degradation and alternative land use in Central America. Serie Técnica No.313. CATIE. 71p.

Tainton, NM; Morris, CD; Hardy, MB. 1996. Complexity and stability in grazing systems. *In* Hodgson, J; Illius, AW. Eds. The ecology and management of grazing systems. CAB International. p.275-299.

Thiele, G. 1993. The dynamics of farm development in the Amazon: The barbecho crisis model. Agricultural Systems 42(3): 179-197.

Toral, O; Iglesias MJ; Simón, L; Shateloin, T; Albert, A. 2001. Colecta y potencialidades del germoplasma forrajero arbóreo en diferentes ecosistemas. Pastos y Forrajes 24(2): 105-113.

Torres, F. 1983. Role of woody perennials in animal agroforestry. Agroforestry Systems 1(2): 131-163.

UNEP. 2000. GEO-2000. Global Environmental Outlook. Chapter two: state of the Environment. Latin America and the Caribbean.

Upton, M. 1993. Livestock productivity assessment and modeling. Agricultural Systems 43(4): 459-472.

Upton, M. 1996. The economics of tropical farming systems. Cambridge University Press. 374p.

Vaccaro. L; Vacarro, R; Verde, O; Alvarez, R; Mejias, H; Rios, L; Romero, E. 1992. Características productivas en la evaluación de explotaciones y vacas en sistemas de doble propósito. Turrialba 42(1): 14-22.

Da Veiga, JB. 1995. Rehabilitation of Degraded Pasture Areas. Management and Rehabilitation of Degraded Lands and Secondary Forest in Amazonia. Proceedings of an International Symposium, Santarém Pará, Brazil. IITF. p.193-202.

Venator, CR; Glaeser, J; Soto, R. 1992. A Silvopastoral Strategy. *In* Downing, TE; Hetcht, SB; Pearson HA; Garcia-Downing, C. Eds. Development or Destruction, The Conversion of Tropical Forest to Pasture in Latin America, Westveiw special studies in social, political and economic development. Westview Press. p.281-292.

Vickery, PJ. 1981. Pasture growth under grazing. *In* Morley. FHW. Eds. Grazing animals. Disciplinary approach. World Animal Science B1: 55-77.

Vieira, ICG; Nepstad, DC; Brienza, S; Pereira, C. 1993. A Importância de Area Degradadas no Contexto Agrícola e Ecológico da Amazônia. Bases Científicas para Estratégias de Preservaçáo e Desenvolvimento da Amazônia. Vol.2. INPA. Manaus.

Wheater, CP; Cook, PA. 2000, Using statistics to understand environment. Routledge. 245p.

Whiteman, PC. 1980. Tropical pasture science. Oxford, UK. Oxford University Press.

Wilkins, JV; Pereyra, G;. Ali, A; Ayola, S. 1979. Milk production in the tropical lowlands of Bolivia. World Animal Review 32: 25-32.

Wilson, JR. 1982. Environmental and nutritional factors affecting herbage quality. *In* Hacker.

JB. Eds. Nutritional limits to animal production from pasture. CAB. p.111-131.

Wilson, JR; Hill, K; Cameron, DM., Shelton HM. 1990. The growth of *Paspalum notatum* under the shade of *Eucalyptus grandis* plantation canopy or in full sun. Tropical Grasslands 24(1): 24-28.

Wilson, JR; Ludlow, MM. 1990. The environment and potential growth of herbage under plantations. *In* Shelton, HM; Stur, WW. Eds. Forages for plantation crops, ACIAR Proceedings No. 32. Canberra. ACIAR. p.10-24.

Wilson, JR; Wild, DWM. 1991. Improvement of nitrogen nutrition and grass growth under shading. *In* Shelton, HM; Stur, WW. Eds. Forages for plantation crops. ACIAR Proceedings No. 32. ACIAR. Canberra. Australia. p.77-82.

Wiseman, FM. 1978. Agricultural and historical ecology of the lake region of Peten, Guatemala. Ph.D. Dissertation. University of Arizona.

Wong, CC. 1990. Shade tolerance of tropical forages: a review. *In* Shelton, HM; Stur, WW. Eds. Forages for plantation crops, ACIAR Proceedings No. 32. Canberra. ACIAR. p.64-69.

World Bank. 2004. Nicaragua at a glance. 2004.

Young, A. 1997. Agroforestry for soil management. 2nd Edition. CAB International. 320p.

Zamora, S; Garcia, J; Bonilla, G; Aguilar, H; Harvey, CA; Ibrahim, M. 2001. Como utilizar los frutos de guanacaste (*Enterolobium cyclocarpus*), guacimo (*Guazuma ulmifolia*), genezaro (*Pithecellobium saman*)y jicaro (*Crecentia alata*) en alimentacion animal? Agroforestería en las América 8(31): 45-49.

Appendix 3.1 Selected questionnaire sheet for general farm survey

I.1.1 Características de la unidad de producción y de la finca

Nota: El área se da en mzs en Nicaragua, y en ha en otros paises

De cuantas fincas se compone la unidad de producción? 1 [ ]
(bajo cualquier modalidad de acceso, incluyendo temporal)

De las cuales, en propiedad: 2 [ ]
(del jefe de familia o de cualquiera de sus miembros)

Nombre de la finca principal:	3		1.4. Nombre de la finca secundaria	12
Area total	4		Area total	13
Municipio:	5		Municipio:	14
Localidad:	6		Localidad:	

Acceso a la finca 7 [ ]
Clave: 1. Pavimento
2. Revestido
3. Tierra

Acceso a la finca 15 [ ]
Clave: 1. Pavimento
2. Revestido
3. Tierra

Distancia al centro poblado mas cerca 8 [ ]

Servicios que posee la finca: 9 [ ]
Clave: 1. Agua
2. Electricidad
3. Teléfono
0. Ninguno

Altitud: 10 [ ]
Pluviometria: 11 [ ]

Distancia al centro poblado mas cerca 16 [ ]
Distancia desde la finca principal 17 [ ]
Servicios que posee la finca: 18 [ ]
Clave: 1. Agua
2. Electricidad
3. Teléfono
0. Ninguno

Altitud: 19 [ ]
Pluviometria: 20 [ ]

Vive en la finca en forma permanente 21 [ ]
Clave: 1. Si
2. No

Si es no, cuantas veces la visita por m 22 [ ]
En este caso, tiene mandador o mayor 23 [ ]
Clave: 1. Si
2. No

A que distancia se encuentra su lugar de residencia? 24 [ ]

Que proporción de su tiempo total dedica a la finca? 25 [ ]

Appendix 3.1 Selected questionnaire sheet for general farm survey (continued)

I.1.2 Situación de la tenencia

Tipo de ocupante: 26 [1]
Clave:
1. Propietario
2. Arrendatario
3. Da en alquiler

Si es propietario:
Hace cuantos años posee la finca? 27 [10] Años

Qué tipo de documento legal posee sobre la tenencia de la finca? 28 [2]
Clave:
1. Escritura
2. Titulo de Reforma Agraria
3. En proceso
4. Carta de Venta
5. Ninguno

Cuál es el valor de la Ha. en su finca? [5.000] ~~US$~~/Ha.

Cuál es el valor de alquiler de la Ha. en su finca? [200] ~~US$~~/Ha.

Dio Ud. Tierra propia en alquiler, medieria o prestada a otros productores? 29 [2]
Clave:
1. Si
2. No

Cuantas mzs o Ha en total al año? 30 [ ]

Cuanto recibió como pago total? 31 [ ]

Si es arrendatario de finca:
Hace cuantos años arrienda esta finca? 32 [ ]
Por cuantos años más es el contrato de arriendo? 33 [ ]

Se siente seguro de poder seguir alquilando: 34 [ ]
Condiciones del arriendo: 35 [ ]
Clave:
1. Pago en efectivo.
2. Pago en animales.
3. Pago en dinero y animales
4. Otro.

Qué tipo de contrato tiene con el dueño? 36 [ ]
Clave:
1. Legal
2. Verbal
3. Otros

Monto anual del arriendo a pagar en dinero 37 [ ]
Monto anual del arriendo a pagar en animales: 38 [ ]

Si es arrendatario de parcelas :
Cuantas manzanas o hectáreas arrienda al año? 39 [5 mz]
Para qué fines? 1.
Clave:
1. Ganaderia
2. Agricultura

Monto anual del arriendo a pagar en dinero? 40 [30 $ por ha]

I.2.1 Características del productor y su familia

Nota: en el caso de los productores que viven fuera de la finca y tienen un mandador o mayordomo, se encuesta acerca de la familia de este último, es decir la que vive en la finca

Cuantas personas viven habitualmente en la vivienda principal de la finca? [ ]

Para todo el grupo familiar						Para personas mayores de 10 años de edad.			
No.	53. Sexo 1. M 2. F.	54. Edad. Años.	55. Parentesco con jefe de la familia. Clave 1.	56. Sabe leer y escribir? 1. Si 2. No.	57. Cuantos años de educación formal tiene? Clave 2.	58. El trabajo de la finca es su ocupación principal? 1. Si. 2. No.	59. Que otras actividades no agropecuarias realiza? Clave 3.	60. Cuanto gana aproximadamente en sus actividades no agropecuarias (por mes)?	61. Otros ingresos de la familia (remesas, pensiones, etc...)
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

Clave 1:
1. Jefe
2. Cónyuge
3. Hijo/a
4. Padre/Madre
5. Abuela/o
6. Hermano/a
7. Tio/a
8. Otro (especificar)

Clave 2:
1. Hasta 3° gr.
2. Primaria completa
3. Primaria activa
4. Secundaria parcial
5. Secundaria completa
6. Secundaria activa
7. Técnico básico
8. Técnico medio
9. Universitario
10. Otros

Clave 3
1. Agricultura propia
2. Ganadería propia
3. Obrero agricola
4. Obrero agricola temporal
5. Obrero industrial
6. Empleado servicio domestico
7. Negocio propio comercio
8. Artesania familiar
9. Servicios (albañil, carpintero, ...)
10. Profesional
11. Estudiante

Appendix 3.1 Selected questionnaire sheet for general farm survey (continued)

I.3.2 Uso del suelo

		Finca principal		Finca 2		Finca 3	
		1. Superficie (ha)	2. No. potreros	3. Superficie (ha)	4. No. Potreros	5. Superficie (ha)	6. No. Potreros
Cultivos anuales	67. Maiz	1 Mz					
	68. Frijoles	1/2 mz					
	69. Raices y tuberculos						
	70. Otros (especifica [illegible])	0.25					
Cultivos Perennes	71. Café						
	72. Caña de Azúcar						
	73. Cacao						
	74. Musáceas	0.25					
	75. Otros (especifica)						
Pasturas	76. Pastos "naturales"						
	77. Pastos mejoradas para pastoreo	12 mz	6				
	78. Pastos asociados con leguminosas						
	79. Pastos de corte (bancos)						
Otros	80. Area en regeneración (tacotales o charrales)						
	81. Bosques naturales	1 mz					
	82. Bosques mezclados con especies plantadas						
	83. Bosques implantados homogéneos						
Otros	84. Cercas vivas	mts lineales		mts lineales		mts lineales	
	85. Cortina rompevientos	mts lineales		mts lineales		mts lineales	
	86. Cercas muertas	mts lineales		mts lineales		mts lineales	
	87. Cercas eléctricas.	mts lineales		mts lineales		mts lineales	
Topografia % finca	88. Plana (0-15 % pendiente)						
	89. Ondulada (15-30 % pendiente)						
	90. Quebrada (+ de 30 % pendiente)	100					

Appendix 3.1 Selected questionnaire sheet for general farm survey (continued)

I.3.3 Cambios recientes en el uso del suelo: a) pasturas

91. ¿Ud. ha introducido nuevas pasturas en su finca en los últimos 4 años ? [1]

Clave:
1. Si
2. No

Si la respuesta es no, pasar a la página siguiente

	1. Especie introducida	2. Area	3. Uso anterior clave 1	4. Motivo del cambio clave 2	5. ¿Está satisfecho con el cambio? 1. Si; 2 No
92	Vin Grass	[illegible]	6.	8.	1
93	[illegible]	[illegible]	6.	5	1
94					
95					
96					

clave 1:
1. Bosque natural primario
2. Bosque secundario (tacotal)
3. Area de cultivos anuales
4. Pradera natural
5. Pradera mejorada (especifique la especie)
6. Otro (especifique: Tacotales

clave 2: Para el encuestador
1. Modificación de las condiciones socioeconómicas
2. Innovación propia
3. Por imitación directa
4. Inducido por la Asistenca técnica, sin que haya una demanda
5. Ídem, en respuesta a una demanda
6. Ídem, con demanda canalizada por alguna organización de los productores
7. Inducido por razones no técnicas (especifique)
8. Otro (especifique) Para ajustar [illegible] de los Vacas

I.3.4. Equipo de producción e infraestructura.

	Equipo de producción	Can	1. Años de uso	2. Valor nuevo de reposición	3. Costo anual de mantenimiento	4. Si alquila: cuánto gastó en alquiler?
109	Bomba de espalda (motor)					
110	Bomba de mochila manual	1	15	900 ₡	100 ₡	
111	Arados de tracción animal					
112	Tractor de ruedas					
113	Bomba de agua para riego					
114	Herramientas		12	NS		
115	Vehiculos (camión/pick up)					
116	Picadora de pastos					
117	Motosierra					
118	Camión					
119	Generador electrico					
120	Equipo procesamiento lácteo					
121	Báscula de pesar ganado					
122	Otros (especificar)					
	Infraestructura					
123	Establo o cobertizo					
124	Cercas muertas púas	4	10	1400 ₡	350 ₡	
125	cercas muertas eléctrica					
126	saladeros					
127	Caminos internos					
128	Almacenamiento y distribución agua					
129	Pozos artesianos					
130	Corrales	1	1	200 ₡	–	
131	Casa	1	2	10.000 ₡	500 ₡	
132	Galerones y bodegas					
133	Sala ordeño mecánico					
134	Silos para grano					
135	Silos para fermentación					
136	Aeromotor					
137	Otros (especificar)					

Appendix 3.1 Selected questionnaire sheet for general farm survey (continued)

I.3.5 Mano de obra asalariada permanente

Trabajadores **permanentes** de la finca (sin incluir los colonos, es decir sólo son los trabajadores que reciben un salario pero no tierra a cambio de trabajo)

	Tipo de trabajador	Salario mensual	Número	En invierno	En verano
138	Campisto o peones				
139	Ordeñadores				
140	Mandador				
141	Mozo				
142	Otro (especifique)				

Trabajadores **ocasionales** de la finca.

Número de trabajadores ocasionales contratados para actividades **agricolas** durante el último 143 [(1)] trabajadores

Número promedio de días en que cada trabajador ocasional para tareas **agricolas** fue emplad 144 [(12)] días

Número de trabajadores ocasionales contratados para actividades **ganaderas** durante el últim 145 [ ] trabajadores

Número promedio de días en que cada trabajador ocasional para tareas **ganaderas** fue emple 146 [ ] días

Forma de pago de los trabajadores ocasionales: 147 [2]
1. En dinero
2. En dinero y comida.

Si el pago es solo en dinero, indique el monto por día: 148 [ ] US $/día
Si el pago es en dinero y en comida indicar el monto total (estimando lo correspondiente a comida) 149 [40 ₡] US $/día

Colonos

Número de colonos viviendo y trabajando en la finca 150 [ ]

Si se les ha otorgado tierra a cada uno, qué area? 151 [ ] max. 152 [ ] min.

Hacen trabajo agricola a media en la finca? 153 [ ] 1. Si , 2. No En qué area? [ ] 156
Hacen trabajo agricola en la finca a cambio de empastar pot 154 [ ] 1. Si , 2. No En qué area? [ ] 157
Hacen trabajo agricola a cambio de desmontar tacotales? 155 [ ] 1. Si , 2. No En qué area? [ ] 158

Reciben tamnbién un sueldo por trabajos ademas de los ant 159 [ ] 1. Si , 2. No Por cuántos días? [ ] 160
Monto / día [ ] 161

Appendix 3 1 Selected questionnaire sheet for general farm survey (continued)

I.4.1. Las actividades ganaderas de la finca.

Estructura del Hato.

	Tipo de animales	Cantidad (cbzs)	
		Propio	Ajeno o en cuidado
162	Vacas en ordeño	5	
163	Vacas secas	5	
164	Hembras de reemplazo	10	
165	Toros reproductores		
166	Bueyes		
167	Machos de engorde		
168	Machos de desarrollo		

20

Composición genética (ganado vacuno)

Estime el grupo racial promedio de las vacas adultas.

		% vacas	Nombre raza predominante
180	100 % cebú		
181	75 % Cebú - 25 % Europeo		
182	50 % Cebú - 50 % Europeo		
183	25 % Cebú - 75 % Europeo		
184	100 % Europeo		
185	Ganado Reyna		

Otras especies

169	bestias caballares	1	
170	bestias mulares		
171	Cerdos	7	
172	Gallinas	33	
173	Otros		

En caso de haber recibido ganado ajeno en cuidado, cuanto se le pago por atenderlo? ______ 186
(Si el pago fue en animales calcular el equivalente monetario) US $

Cambios en el inventario del hato

	Categoria de animales	Cantidad	Precio prom.
174	Vacas adultas descartadas en el último año?	3	$ 3.000 c/u
175	No. terneros y terneras muertos en el último año?		
176	Animales adultos muertos en el último año?		
177	Machos adultos comprados en el último año?		
178	Hembras adultas compradas en el último año?		
179	No. nacimientos en el último año?	10	1.500 $ c/u

Appendix 3 1 Selected questionnaire sheet for general farm survey (continued)

I.4.1. Las actividades ganaderas de la finca (sigue)

Sistema de reproducción

Indique el sistema de reproducción mas común que se emplea en la finca. 187 [2.]

Clave 1. Inseminación artificial
2. Monta natural
3. Inseminación artificial + monta natural
4. Transplante de embriones.

Indique el tipo de manejo de su hato. 188 [1.]

Clave 1. Pastoreo puro
2. Semiconfinamiento
3. Estabulado o confinamiento total
4. Otro (especifique:__________)

Que sistema de ordeño utiliza? 189 [1.]

Clave 1. A mano con ternero al pie.
2. A mano sin ternero
3. A maquina con ternero al pie.
4. A maquina sin ternero.

Cria Usted el ternero macho? 190 [1.]

Clave 1. Si
2. No.

A que edad desteta sus terneros? 191 [1 1/2] meses

Qué peso alcanzan los terneros al destete? 192 [150] Kg

A qué edad vende el ternero macho? 193 [1 1/2] meses

A qué peso vende el ternero macho? 194 [No sabe] Kg. Se vende por calidad del animal

Cuanto le pagan en promedio, por un ternero mach 195 [1,500] ₡

Cuántos terneros machos vendió el año pasado? 196 [3]

Cuantas terneras hembras vendió el año pasado? 197 [0]

[illegible] la [illegible] la mayor [illegible] 198 [illegible]

Appendix 3.1 Selected questionnaire sheet for general farm survey (continued)

I.4.1. Las actividades ganaderas de la finca: Movimientos del hato

Ud. traslada su ganado a otra finca en el verano? 198 [1.]
1. Si
2. No (pasar a la sección)

Que tipo de animales traslada? 199 [3.]
1. Vacas ordeño
2. Novillos
3. Vaquillas reproductoras
4. Otro (especifique:_________)

Por que los traslada en el verano? 200 [4.]
1. Por que se secan los pastos en su finca.
2. Para dejar descansar los potreros
3. Por seguridad
4. Otros (especifique) porque no tienen la hierba suficiente en su finca para la cant de ganado

Cuántos animales trasladó el año pasado a otra fi 201 [10] animales

Cuantos grupos de animales maneja Ud. En la fin 202 [1] grupos

Cuales son estos grupos (Ej., ordeño, secas, novillos, terneros, etc), cuantos potreros le asigna a cada uno, cual es la especie predominante de pasto en cada potrero y su respectivo manejo?

	Grupo 1 Clave 1	Potreros (#)	Especie Predominante	Época de lluvia		Época seca	
				Días de descanso	Días de ocupación	Días de descanso	Días de ocupación
203	Ordeño	6	Jaragua	2 meses	1 mes	1 mes	2 meses
204							
205							
206							
207							

60	30	30	60

clave 1:
1. Ordeño
2. Vacas secas.
3. Novillas
4. Terneros
5. Otras (especifique)

Appendix 3.1 Selected questionnaire sheet for general farm survey (continued)

I.4.2. Manejo de potreros

Cuántas veces al año desmaleza sus potreros? [11 veces] 208

Cual es el método mas frecuente para desmalezar sus potreros 210 [1]
1. Manual (chapias, arranca...)
2. Quimico (herbicidas)

Los fertiliza ? [2] 209
1. Si (pasar a la siguiente pregunta)
2. No

Si fertiliza sus pastos, que grupo de animales se alimenta del pasto fertilizado? (indique todos ellos) 211 [ ]

Clave
1. Vacas de ordeño
2. Novillos de engorde
3. Terneros
4. Otro (especifique: ________________)

Quce area de pasto fertilizó el año pasado? [ ] 212

Tiene sistema de riego para los pastos? [ ] 213
1. Si 2. No

Que tipo de riego utiliza? [ ] 214
1. Por gravedad
2. Por aspersión
3. Otro (especifique:______________)

ié area de pasto riega? [ ] 215

Durante cuántos meses riega esa área? [ ] 216

Estructura de los potreros de la finca

Cual es la superficie ocupada por los diferentes tipos de pasto en su finca?

	Especie de pasto o forraje	Superficie (ha)	No. potreros	Esta satisfecho del estado actual 1. Si , 2 No.	Si no está satisfecho porqué razón? Clave 1	Cual es el problema? clave 2
217	natural					
218	estrella					
219	brachiaria					
220	caña de azucar					
221	taiwan					
222	sorgo forrajero					
223	asia	5 mz				
224	otro (esp.) [illegible]	1 MZ	1	1		
225	otro (esp.) [illegible]	11 Mz	5	1		

Clave 1
1. Alta presencia de malezas invasoras
2. Baja cobertura
3. Tardanza en el periodo de recuperación
4. Baja producción de pasto
5. Otro (especifique:__________________)

Clave 2
1. Terreno con mucha pendiente
2. Mal drenaje
3. Sobrepastoreo
4. Poca fertilidad del suelo
5. Quemas anteriores
6. Especie inadecuada a la zona
7. No sabe porque

Appendix 3.1 Selected questionnaire sheet for general farm survey (continued)

I.4.4 Alimentación complementaria del ganado

¿Qué tipo de alimentación proporciona a sus animales, además del pastoreo en su finca?

	Tipo de alimentación	Qué tipo de animales alimenta (marque con x)				Cantidad total al año		Comprado (1) o Producido (2)
		Terneros/as	Vaquillas/ novillos	Paridas	Resto del hato	Um.	Cantidad	
244	Rastrojo cosechas							
245	Concentrado							
246	Sal común	X	X	X		qq	1	(1)
247	Sales minerales							
248	Ensilaje							
249	Forraje leguminosas							
250	Pastos corte							
251	Gallinaza							
252	En los caminos							
253	Semolina							
254	Melaza			X		Ton	40	(1)
255	Otro (especifique)							
256	Otro (especifique)							
257	Otro (especifique)							

Appendix 3.1 Selected questionnaire sheet for general farm survey (continued)

I.5.1 Producción agropecuaria y forestal

Producción total a nivel de finca (excepto lácteos). En base a una producción regular por año.

	Producción	Unidad de medida	Produccion regular anual	% de producción que se consume en la finca (minimo -	máximo)	Precio unitario (precio de finca)	Precio total
258	Postes	m3/año m	50 [illegible]		100 %	5 [illegible]	250 [illegible]
259	Madera aserrada	m3/año					
260	Madera en trozo	m3/año					
261	Leña	m3/año					
262	Cítricos						
263	cacao						
264	Otros frutales						
265	Maiz	qq	20 qq		70 %	100 ₡	2,000 ₡
266	Frijoles	qq	5 qq		100 %	250 ₡	1,050 [illegible]
267	Otros granos						
268	Café						
	Producción animal						
269	Terneros	animal/año	10			1.500 ₡	[illegible] ,000 ₡
270	Vacas descarte	vacas/año					
271	Novillos/as	novillo/año					
272	Otros (especifique) [illegible]	[illegible]	14 [illegible]	[illegible]	-	14.000 [illegible]	100 [illegible]
273	Otros (especifique) [illegible]		[illegible]		100 %	30 ₡	150 [illegible]

Producción lechera

		Invierno	Verano
274	Cuántas vacas ordeñó en promedio?	4	8
275	Cuántos litros de leche obtuvo al día	15 lts	20 lts
276	Leche/Vaca/Día	4-5 lts	[illegible]

Appendix 3 1 Selected questionnaire sheet for general farm survey (continued)

I.5.2 Venta de Lácteos

Ventas en invierno

	Producto	U/M	Precio US $	Donde vende Clave 1	A quien vende Clave 2	Cómo vende Clave 3	% que se consume en la finca
277	Leche	Lt/día	100 Lts = 250 ₡	2.	1.	1.	50%
278	Queso	kg/sem					
279	Cuajada	kg/sem					
280	Mantequilla	kg/sem					
281	Crema	kg/sem					
282	Quesillo	kg/sem					

Ventas en verano

	Producto	U/M	Precio US $	Donde vende Clave 1	A quien vende Clave 2	Cómo vende Clave 3	% que se consume en la finca
283	Leche	Lt/día	[illegible] 410 ₡	2.	1.	1.	50%
284	Queso	kg/sem					
285	Cuajada	kg/sem					
286	Mantequilla	kg/sem					
287	Crema	kg/sem					
288	Quesillo	kg/sem					

clave 1:
1. Finca
2. Carretera
3. Fuera de comarca

Clave 2:
1. Empresa láctea
2. Comerciante
3. Por cuenta propia
4. Otro (especifique:__________)

Clave 3:
1. De futuro
2. Al contado
3. Ambas
4. Otro (especifique:__________)

I.6. Costos de producción

Cuánto ha gastado Ud. En la producción de granos, árboles maderables y frutales en su fina durante el último año.
Estos gastos se refieren a: 3 Ha (debe ser igual al área total dedicada a cultivar granos, maderables y frutales.

		Unidad de medida	Cantidad	Mz.	Valor Total gastado/año	% destinado a granos.	% destinado a maderables	% destinado a frutales
289	Semillas							
290	Fertilizantes							
291	Herbicidas	lts	[illegible]	1	180₡	100 %		
292	Abonos							
293	Pesticidas							
294	M. obra temporal	₡	40	1 1/2	488 ₡	100%		
295	Alquiler de equipo							
296	transporte							
297	Asistencia tecnica							
298	otros servicios							

Cuánto ha gastado Ud. en la producción ganadera de su finca durante el último año:
Estos gastos se refiere a: 12 Ha (indicar solo las dedicadas a la ganaderia)

	Concepto	Unidad de medida	Cantidad	Um	Valor Total de lo gastado $	Precio compra
299	Sales y minerales	qq	1		50₡	50₡
300	Herbicidas					
301	Fertilizantes químicos					
302	Fertilizantes orgánicos					
303	Medicamentos y vacunas	Lts	3		1,000 ₡	
304	cereales					
305	Alambre de púa y postes		4		1400₡	350₡
306	Concentrados alimenticios					
307	Otros suplementos alimenticios (pollinaza, urea, melaza...)	Lts	40		100₡	2.5₡ c/litro
308	Compra de rastrojos agricolas					
309	Transporte de animales					
310	Transporte de producción					
311	Servicios veterinarios					
312	Mano de obra temporal					
313	Otros servicios (esp)					
314	Otros servicios (esp)					

2
350₡
4
1400

Appendix 3.1 Selected questionnaire sheet for general farm survey (continued)

II.1 Aspectos gerenciales y de toma de decisión

Lleva registros del hato? [1.] 315
1. Si 2. No.

Lleva registros contables de la finca? [2.] 316
1. Si 2. No.

Ud. toma sólo las decisiones acerca de la finca?	NO	317
Si no, con quien la comparte?	Conyugue	318
Ud. Comparte son su mujer la gestión de la finca	Si	317a
Si no, con quien la comparte?		318a

Cómo hace Ud. para informarse de los precios y nuevas tecnologias ? [6.] 319

Clave para el encuestador
1. A travès de la radio (especificar:________________)
2. A travès del periodico (especificar: ________________)
3. A travès de información que dan los organismos
4. A travès del técnico privado
5. A traves de una organización de productores)
6. Otro (especificar: Hasta que [illegible]

¿Cual es el principal problema que enfrenta Ud. Y su familia que le impide mejorar? [7.] 320

Clave para el encuestador
1. seguridad de tenencia
2. violencia
3. falta de crédito
4. falta de asistencia técnica
5. falta de apoyo a la comercialización
6. malos precios
7. otro por [illegible]

¿Qué está pensando hacer para mejorar su finca y la situación de su familia?

[4.] 321
1. Vender y comprar más tierra montaña adentro
2. Comprar más tierra en la comarca
3. Vender un pedazo de la finca para financiar otras actividades
4. Sembrar más granos para vender y engordar chanchos
5. Sembrar más café
6. Aumentar el número de animales
7. Hacer mas divisiones de potreros
8. Cambiar el pasto
9. Introducir riego
1o. Dedicarse a otra actividad o rubro (especificar:______________)
11. Emigrar
12. Irse a la ciudad a trabajar
13. otros (especifique:______________)

Appendix 4.1

List of tree species in grazing areas in Matiguas region, central Nicaragua

No.	Species	Local Name	Number of trees[1]	Stand density	Frequency of parcels found	Basal area[1]	Avg DBH/tree
				Trees/ha		cm^2/ha	cm
1	*Guazuma ulmifolia*	Guacimo	718	26.01	96	12378	21.6
2	*Tabebuia rosea*	Roble	366	13.26	64	1592	10.6
3	*Cordia alliodora*	Laurel	358	12.97	70	2614	13.7
4	*Platymiscium parviflorum*	Coyote	236	8.55	50	1839	13.5
5	*Enterolobium cyclocarpum*	Guanacaste	203	7.35	64	3560	18.8
6	*Albizia saman*	Genizaro	137	4.96	56	2883	23.0
7	*Gliricidia sepium*	Madero negro	89	3.22	19	1988	25.0
8	*Psidium guajava*	Guayaba	61	2.21	28	345	12.9
9	*Cupania spp.*	Cola de pava	48	1.74	9	272	12.6
10	*Tabebuia ochracea*	Cortez	43	1.56	15	333	15.1
11	*Leucaena shannonii*	Frijolillo	40	1.45	15	294	14.5
12	*Cassia grandis*	Carao	39	1.41	21	848	24.9
13	*Genipa americana*	Jagua	37	1.34	14	193	12.1
14	*Spondias mombin*	Jobo	29	1.05	24	1036	29.6
15	*Inga vera*	Guaba	26	0.94	12	507	21.7
16	*Cordia bicolor*	Muneco	24	0.87	17	358	20.1
17	*Vochisia ferruginea*	Zopilote	22	0.80	16	250	17.8
18	*Lysiloma auritum*	Quebracho	20	0.72	8	846	30.7
19	*Elaeis oleifera*	Corozo	19	0.69	2	1576	53.4
20	*Albizzia longapedata*	Gavilan	18	0.65	12	171	14.6
21	*Maclura tinctoria*	Mora	18	0.65	8	232	17.3
22		Tamarron	18	0.65	7	82	11.9
23		Machoguite	17	0.62	1	132	16.1
24	*Bursera simaruba*	Jinocuabo	16	0.58	8	205	18.2
25	*Persea coerulea*	Aguacate	14	0.51	4	106	15.6
26	*Zuelania guidonia*	Plomo	14	0.51	9	53	10.4

Appendix 4.1

List of tree species in grazing areas in Matiguas region, central Nicaragua (Continued)

No.	Species	Local Name	Number of trees[1]	Stand density	Frequency of parcels found	Basal area[1]	Avg DBH/tree
				Trees/ha		cm^2/ha	cm
27	*Cecropia insignis*	Guarumo	13	0.47	12	195	21.8
28	*Lonchocarpus parviflorus*	Chaperno	13	0.47	7	180	19.5
29	*Muntingia calabura*	Capulin	12	0.43	3	151	18.2
30	*Citrus sp.*	Naranja	11	0.40	4	222	23.5
31	*Cedrela odorata*	Cedro	10	0.36	9	1191	108.7
32	*Capparis sp.*	Limonsillo	10	0.36	6	48	12.5
33	*Gyrocarpus americanus*	Tambor	10	0.36	4	43	11.6
34	*Erythrina sp.*	Elequeme	9	0.33	5	47	12.2
35	*Calycophyllum candidissimum*	Madrono	9	0.33	6	174	22.4
36	*Bombacopsis quinatum*	Pochote	9	0.33	6	590	44.5
37	*Pterocarpus rohrii*	Sangredrago	8	0.29	3	61	13.1
38	*Cupania guatemalensis*	Piyojillo	7	0.25	3	65	22.7
39	*Spondias sp.*	Jocote	5	0.18	3	38	14.1
40	*Crescentia alata*	Jicaro	5	0.18	5	35	14.6
41		Patacon	5	0.18	6	30	13.7
42		Llama de huevo	4	0.14	4	16	10.7
43	*Pithecellobium dulce*	Espino de playa	3	0.11	2	77	28.4
44	*Lonchocarpus minimiflorus*	Chinche	3	0.11	3	40	20.0
45	*Ceiba pentandra*	Ceiba	3	0.11	2	266	52.7
46		Cuajichote	3	0.11	1	95	33.1
47	*Acacia hindsii*	Cornizuelo	3	0.11	3	5	7.9
48		Ocote	3	0.11	2	36	20.5

Appendix 4.1

List of tree species in grazing areas in Matiguas region, central Nicaragua (Continued)

No.	Species	Local Name	Number of trees[1]	Stand density	Frequency of parcels found	Basal area[1]	Avg DBH/tree
				Trees/ha		cm^2/ha	cm
49	*Tecoma stans*	Sardinillo	3	0.11	3	24	13.0
50	*Annona purpurea*	Soncoya	3	0.11	3	5	6.9
51	*Annona reticulata*	Anona	2	0.07	2	44	24.8
52		Cacuniyo	3	0.11	2	20	16.4
53	*Curatella americana*	Chaparro	2	0.07	1	14	15.3
54	*Dalbergia tucurensis*	Granadillo	2	0.07	2	4	8.1
55	*Melicoccus bijugatus*	Mamon	2	0.07	1	257	65.6
56	*Sapium macrocarpum*	Palo de leche	2	0.07	2	101	41.5
57	*Senna atomaria*	Vainillo	2	0.07	2	33	29.9
58	*Manilkara zapota*	Nispero	2	0.07	2	10	12.7
59	*Achatocarpus*	Barazon	1	0.04	1	1	4.8
60		Camajote	1	0.04	1	9	17.8
61	*Anica venezuelana*	Canela	1	0.04	1	25	29.5
62	*Morella cerifera*	Cera	1	0.04	1	2	9.0
63		Chocojito	1	0.04	1	3	9.8
64	*Ficus sp*	Chiramate	1	0.04	1	6	14.3
65		Guanijicuil	1	0.04	1	14	20.2
66		Guapotillo	1	0.04	1	8	16.6
67	*Leucaena sp*	Leucaena	1	0.04	1	6	15.0
68		Maelmono	1	0.04	1	60	45.8
69		Ocotillo	1	0.04	1	37	36.3
70	*Combretum farinosum*	Papamiel	1	0.04	1	2	9.3
71	*Ardisia revoluta*	Pata de uva	1	0.04	1	20	26.4
72		Posoriyo	1	0.04	1	5	13.1
73		Sombra de cusco	1	0.04	1	3	10.4

Appendix 4.1

List of tree species in grazing areas in Matiguas region, central Nicaragua (Continued)

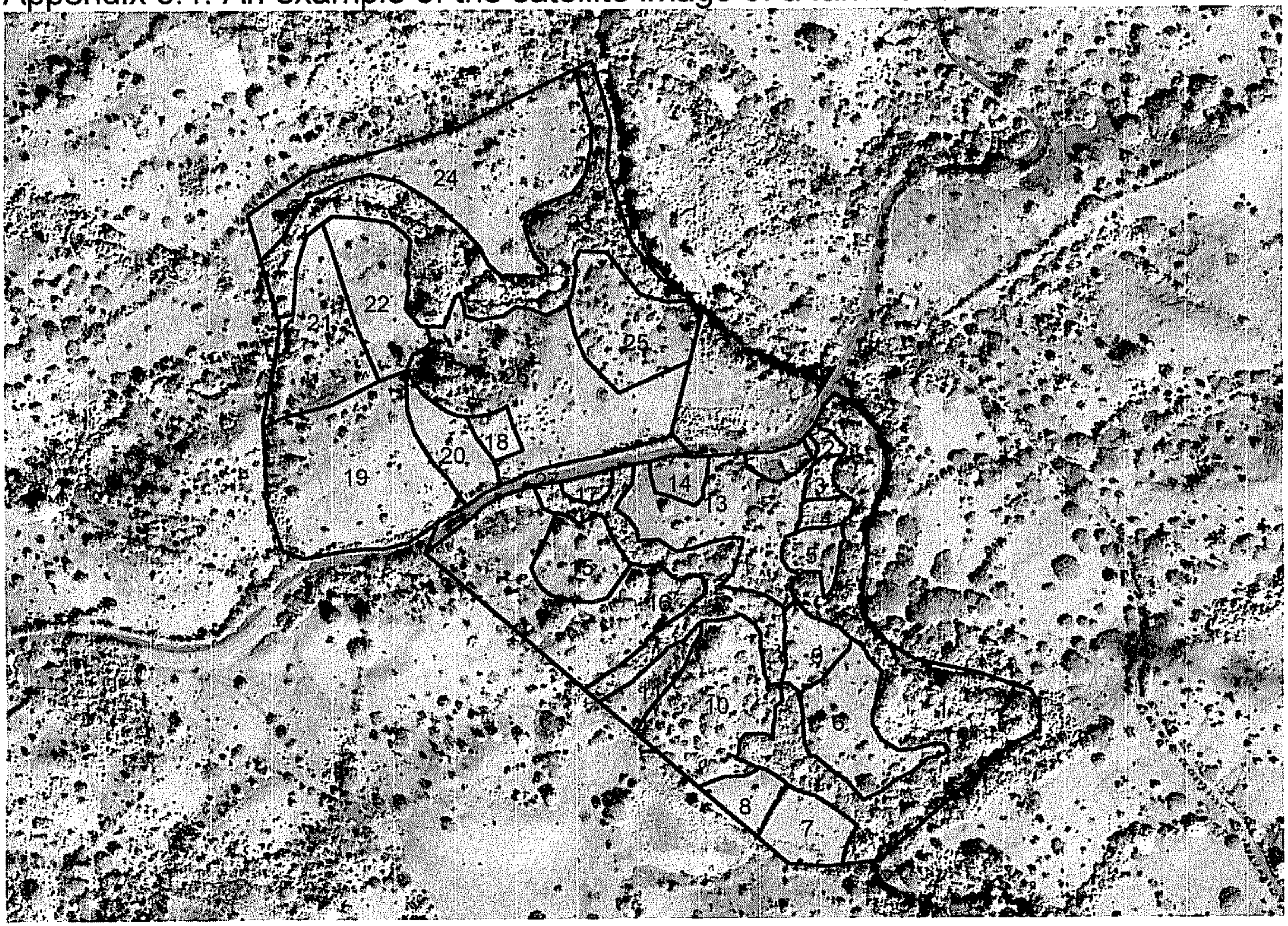
No.	Species	Local Name	Number of trees[1]	Stand density	Frequency of parcels found	Basal area[1]	Avg. DBH/tree
				Trees/ha		cm^2/ha	cm
74		Kaniwa	1	0.04	1	42	38.5
75	*Sloanea terniflora*	Tercipelo	1	0.04	1	40	37.6
76	*Eugenia sp.*	Guacuco	1	0.04	1	11	19.4
	Total		2829	102.5		39102	

Note: Based on the measurements at 153 parcels of 27.6 hectare.

In the order of number of tree found.

[1]Sum of all parcels.

Appendix 5.1: An example of the satellite image of a farm land use



Quick Bird, January 2003.

Appendix 5.1 Example of satellite images of farm land use (Continued) (Land use code and area for the image)

Site no	Land use code	Area (ha)
1	Riparian forest	5.76
2	Annual crop cultivation	0.12
3	Forage bank	0.19
4	Perennial crop cultivation	0.23
5	Natural pasture with moderate tree density	0.43
6	Natural pasture with moderate tree density	1.61
7	Weedy pasture	0.85
8	Natural pasture with low tree density	0.49
9	Weedy pasture	0.62
10	Annual crop cultivation	2.35
11	Weedy pasture	0.52
12	Riparian forest	2.08
13	Natural pasture with moderate tree density	2.35
14	Natural pasture with no tree	0.36
15	Natural pasture with moderate tree density	0.99
16	Weedy pasture	3.42
17	Weedy pasture	0.19
18	Cultivated pasture with low tree density	0.28
19	Natural pasture with low tree density	3.95
20	Weedy pasture	0.86
21	Natural pasture with moderate tree density	1.94
22	Annual crop cultivation	1.59
23	Riparian forest	4.54
24	Weedy pasture	4.15
25	Natural pasture with moderate tree density	1.84
26	Natural pasture with low tree density	4.27
27	Others	0.92

Appendix 5.2 Questionnaires Sheet for Herd Survey

Fecha / /

Nombre del Productor ______________________________

Tiene otra Finca fuera de la finca del proyecto Silvopastoriles?

Si ____________Tamano _______Mz No____________

El hato de la finca del proyecto esta rotacionando con otra finca? Tamano_____Mz

Como funciona la finca del proyecto? Vaca parida Vaca Seca Otro

La otra finca Vaca parida Vaca Seca Otro

Area de la Finca del proyecto Silvopastoriles

Area total de la finca	Mz
Cultivo anuales (Grano basico)	Mz
Cultivo Perennes (Frutales, Chaguite)	Mz
Pasturas	Mz
Tacotales/Charrales	Mz
Bosques (Secundario, primario)	Mz

Estructura del hato

	Numero total en la finca	Cuidas	Alimentacion suplementaria		
Tipo de ganado			Tipo	Cantidad por animal	Periodo
Vaca parida					
Vaca horra					
Vaquilla reemplazo					
Novillo de desarrollo					
Novillo de engorde					
Sementales					
Bueyes					
Terneros					

Sal comun(SC), Sales minerals(SM), Pasto de corte, Cana de azucar (CN), Gallinaza (GN), Concentrado (CCD), Melaza (MZ), Rastrojo cosechas (RC)

Produccion de la finca

Leche por finca ________litro/dia

Leche por vaca ________litro/vaca

Cambio de la estructura del hato de la finca

Venta de adultos en los ultimos tres meses? ________________

Venta de terneros en los ultimos tres meses? ________________

No nacimientos en los ultimos tres meses? ________________

Animales adultos muertos en los ultimos tres meses? _____________

Animales terneros muertos en los ultimos tres meses? ____________

Animales comprados en los ultimos tres meses?

Macho adulto	
Hembra adultos	
Ternero/Ternera	

Animals echados de otras fincas en los ultimos tres meses?__________

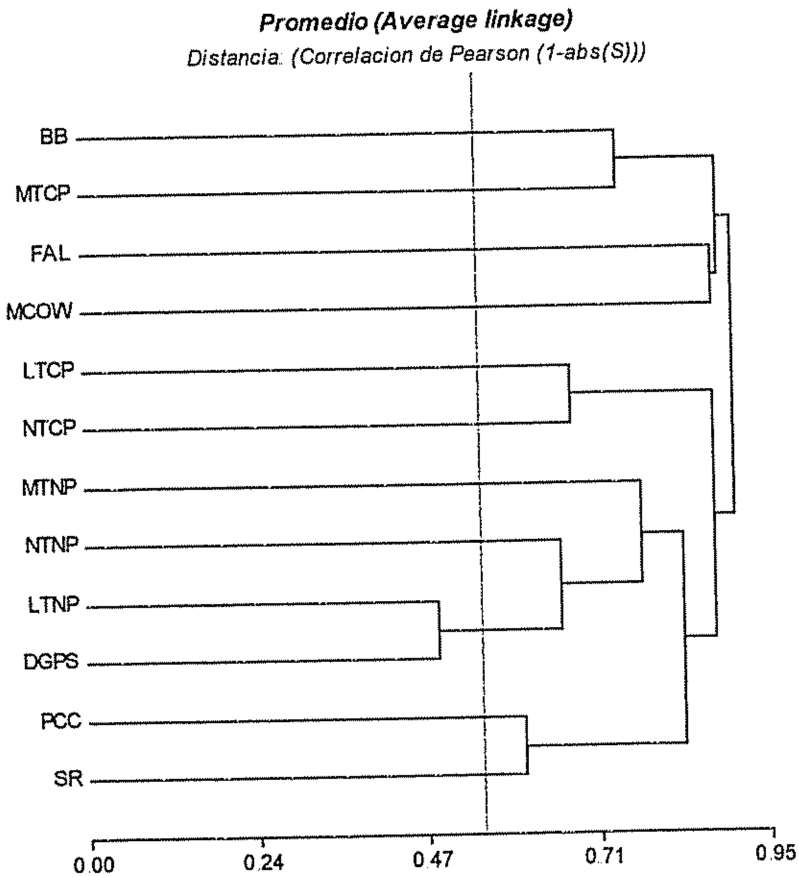
Animales quitado a otras fincas en los ultimos tres meses?__________

Cambio de la estructura del hato de la ultimo un ano

Mes	Cambio de hato (numero y tipo de Ganado)		Razon
	Echar	Quitar	
Noviembre/2002			
Deciembre/2002			
Enero/2003			
Febrero/2003			
Marzo/2003			
Abril/2003			
Mayo/2003			
Junio/2003			
Julio/2003			
Agosto/2003			
Septiembre/2003			
Octubre/2003			

Appendix 6.1

Distance between land use parameters by Pearson correlation coefficients



Appendix 6.2

Correlations between selected predictors

Correlations between dependent variables are shown in Table below. The correlations between SR^{SI} and PC1 was significant (P<0.01), but low association, indicating low degree of collinearity.

Table

Correlations between dependent variables

	SR^{ST}	$MCOW^{ST}$
$MCOW^{ST}$	-0.007	
	(0.955)	
$PC1^{1}$	**0.320****	-0.022
	(0.005)	(0.851)
$PC2^{1}$	0.140	-0.048
	(0.234)	(0.685)
$PC4^{1}$	-0.096	0.074
	(0.417)	(0.533)

Note: Cell Contents: Pearson correlation (P-Value) *P<0.05, ** P<0.01.
SR (annual mean stocking rate), MCOW(annual mean proportion of milking cow for entire herd size),
PCs (Principal components based on land use parameters).
[1]Correlations between PCs are zero.
ST Standardized variables by subtracting the means and dividing by standard deviations.