Exploring the Potential of Sound Management of Forest and Tree Resources on Cattle Farms Located in Tropical Dry Forest of Guanacaste, Costa Rica

By

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DEDICATION

To my wife Jenny Patricia Flores Godoy

To my children, Jinny Regina Flores Godoy, Juan David Flores Godoy and Jose Carlos Flores Godoy

To my parents, Juan Flores and Olga Lopez

To my brother Edwin David Flores López and sister Olga Larissa Flores López

To my nieces Paola Larissa Flores Larco and Leticia Isabel Flores Larco.

DECLARATION

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

Signed .... (Candidate)

Date 15/01/06 ....

This thesis is the result of my own investigations, except where otherwise stated.

Other sources are acknowledged by footnotes giving explicit references. A bibliography is appended.

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ABSTRACT

The main objective of this research was to contribute to a better understanding of the cultural, economic, social, political and biophysical factors underlying land use trends in the dry forest zone of Costa Rica, aiming at the identification of economically viable options to increase forest and tree cover. The specific objectives were: to develop and test a predictive model of biophysical and spatial factors underlying land use change as identified by census, spatial and time series data; to analyse the economic, social, political and cultural factors that also influence land use changes and to understand farmer preferences about spatial arrangements of trees on cattle farms.

With these objectives, the research was guided by the following 7 questions. 1) What are the biophysical and spatial factors underlying farm characteristics in Costa Rica? 2) Which cattle production, dairy or beef, has a better location rent? 3) Which land use changes can be identified and quantified in Cañas over the past decade? 4) Which exogenous farm factors have influenced the decisions on land use change? 5) Which endogenous farm factors have influenced the decisions on land use change? 6) What are the main reasons for tolerating, stimulating or managing forest and tree resources on cattle farms? 7) What is the potential for introducing new agroforestry and silvopastoral technologies on cattle farms?

The hypotheses were: Question 1) elevation and rainfall are the main biophysical forces underlying the type of cattle production, dairy or beef; Question 2) dairy farms have a better location rent compared to beef farms; Question 3) the main land use change up to the early 1990's was the conversion of dry forest into cattle pastures. As cattle prices plummeted after 1994, forest regeneration areas have expanded at the expense of cattle pastures; Question 4) beef prices, in addition to government subsidies and incentives which are the key external factors underlying land use change can be rejected; Question 5) the opportunity cost of forest and tree resources management, as well as farmers' socio-economic characteristics, are the main internal factors that influence land use change; Question 6) the main reason for forest patches on cattle farms is the low marginal utility of maintaining these areas as pastures can not be rejected and Question 7) the demand for new technologies rises with decreasing

opportunity costs of sound management of forest and tree resources on cattle farms was accepted.

Question 1 was addressed in Chapter 3, using a Logit model. According to the Logit model, spatial and geographic factors have important effects on the type of cattle production. The main factor is elevation, followed by irrigation systems; both factors having a direct relationship to the probability of having dairy farms. These farms are more influenced by spatial and geographic characteristics, especially elevation and if the conditions are suitable for dairy production, the farmer will chose this type of production, and not beef production.

Although Guanacaste had a good water supply, with rainfall higher than 1400 mm/year, it was found that water supply was an important issue determining cattle production activity, essential for dairy cattle. On the other hand, elevation had a direct relationship with dairy production activity. Higher elevation implies lower temperatures, resulting in better adaptability of dairy cattle.

Question 2 was also discussed in Chapter 3. It was found that beef production is less profitable than dairy production because it occurs in places unsuitable for dairy production. Thus, beef farms are spread over the country while dairy farms are concentrated around suitable site. Consequently, transportation costs for dairy production tend to be lower. Not only geographic factors influence the transportation cost, but also the type of product. Milk is a bulk product, so farmers send the milk to plant processors at least twice a week, thus farms and markets are located as close as possible to each other to minimize transportation costs.

Although Tobit models were not significant, they show that dairy production is more intensive than beef; the technological variables had a higher effect on dairy farms. Nevertheless, this study did not consider the financial aspect of cattle production, but this finding lends support to the assumption that beef production is less profitable than diary, and that beef farms are based on the use of natural resources. Farmers would only tend to invest in technology if it had a positive profit effect. The value of this variable shows that beef farmers are less motivated to improve the level of technology.

Then, 80% of the beef farms in Costa Rica have extensive production systems based on the use of pasturelands with low capital investment like irrigation systems and wells.

Based on the discussion in Chapter 3, it is possible to conclude that forest cover in the dry forest zone of Costa Rica has increased since 1961. Most of the increase of forest cover was at expense of pasture without tree cover which was converted into pasture with tree cover.

Chapter 3 also addressed Question 4. It was found that the reason for the increase of forest and tree resource cover is the economic condition of the country, especially the rapid urbanisation process. Then, a change in this tendency is not expected. Therefore, forest and tree resources do not appear to be in danger. Forest cover seems inelastic to change in the international and national beef prices.

Question 5 was discussed in Chapter 4. Forest and tree resources on cattle farms exist because of their low opportunity cost. Farmers use these resources as inputs for cattle production, and a few of them saw the forest and tree resources as an investment. However, the likelihood of change in the pattern of land cover in the area is low, implying that forest cover is not in danger. It was found that livestock is not the main income source in farmer livelihoods, which instead appear more linked to non-farm activities.

Question 6 is discussed in Chapter 5 using a livelihood approach. Forest and tree resources were on cattle farms as an input for cattle production especially for forage production. It was found that forest patches can support one third the Animal Stocking Rate supported by pasturelands, confirming that forest resources are important in livestock production. Therefore, the main spatial tree distribution in cattle farms is dispersed in pasturelands. These trees contributed with the production of forage and shade for livestock. For this reason, tree management is a function of cattle management.

Finally, Question 7 is discussed in Chapter 5. Forest and tree resource management has potential to be included in cattle farms because forest resources on cattle farms are used in cattle production as a strategy to reduce production costs, and any strategy to introduce the management of this resource must consider this fact. Although silvopastoral systems might appear to be an option, more research to understand the relationship between pasture and trees, livestock and trees and the management of this relationship is required.

Most farmers in the area have a least 20% of their area under forest cover, and most of the pastures have trees. Considering that most of these forest areas are younger than 20 years old, the potential to improve the forest production is high.

As main conclusion from this research, it was found that farmers are not interested in investing in forest and tree resource management. Farmers demand a payment for the presence of forest cover on their farms; they demand 11 US$ for every one percent increase in forest and tree resource cover. However, at initial stages, forest and tree resources can have positive effects on grasses cover with externalities to cattle production. Therefore, payments should begin where tree and grass trade-off start. It is not well defined when this trade-off begins; therefore, more resources on defining the biological relation between trees and grasses is necessary.

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Chapter 1

INTRODUCTION

1.1 ORGANISATION OF DISSERTATION

The document consists of 7 chapters. The current chapter presents the problems statement, justification, goals, guiding research questions, hypotheses and the study area.

Chapter 2 describes the methodology applied in the study. Chapter 3 analyzes the current cattle farming in Costa Rica and presents typology of cattle ranchers as well as the current situation of forest and tree resources on cattle farms in the dry forest zone of Costa Rica. The chapter explores the relationship between cattle production and biophysical and technological factors influencing the type of cattle production: beef, dual-purpose or dairy.

Chapter 4 analyzes the main endogenous driving forces affecting cattle production in Costa Rica. The chapter includes two parts: the first explores the driving forces affecting cattle production in Costa Rica in general and in Guanacaste in particular. It is based on von Thünnen's theory of land rent. Additionally, it includes two models, the first explaining the factors influencing the type of cattle production in Costa Rica, and the second the factors that affect cattle intensification. The second part studies the macroeconomic forces driving land cover change in the study area from the 1960's to the 1990's.

Chapter 5 explores the main endogenous factors affecting the decision-making process on cattle farms. The first part elicits rancher preferences of tree arrangements on pasturelands, defining their demand for compensation for services provided by trees. This study was done using a choice experiment. The second part includes the analysis of cattle farmer livelihoods and its implication for forest and tree resource management.

Chapter 6 mentions the current and potential strategies for introducing forest and tree resource management on cattle farms. The first part analyzes the current strategies of forest and tree resource management and the second defines possible alternatives for including trees in cattle production systems. Finally, Chapter 7 includes the conclusions and recommendations.

1.2 PROBLEM STATEMENT

Even though recent research has highlighted the rapid degradation of tropical dry forest zones, which are considered the most inhabited and endangered ecosystem in Central America, rain forest ecosystems have received more attention (Charpentier *et al.*, 2002; Fonseca and Meza, 2002; Gonzales, 2002; Gonzales Iturbe *et al.*, 2002; Ceccon *et al.*, 2003; Kauffman *et al.*, 2003). Dry forest zones in Central America have been converted to grassland and others agricultural uses for decades. Only 0.1 to 2% of the original dry forest zone of the Pacific coast of Central America still has forest cover (Schlönvoigt and Ibrahim, 2001). A similar picture exists for other dry areas around the world (Gillespie, 2000; Da Silva *et al.* 2002).

Even though the intensity of the deforestation is different in each country, during the 1980's Costa Rica experienced one of the world's highest deforestation rates. More than half of the deforestation has occurred since 1950; the trend prompted forecasters to issue a warning that by 1995 no forest would remain outside national parks, with devastating consequences to biodiversity conservation in light of ecosystem fragmentation (Gottfried *et al.*, 1994; Didia, 1997; Abler *et al.*, 1998; Bouman and Nieuwenhuyse, 1999; Chomitz *et al.*, 1999; Pagiola, 2002; Sanchez, 2002; Armenteras, *et al.*, 2003).

Since the late 1980's reduction in subsidies and changes in the demographic conditions of the country brought down cattle profitability and rendered cattle ranching a less attractive business. As the cattle sector contracted, areas formerly dedicated to pasture were abandoned prompting an increase in tree cover since ranchers were not able or willing to keep pasture lands clear of natural regeneration. By 1991, secondary growth covered an estimated 400,000 hectares in Costa Rica, with an estimated increase of 30,000 hectares/year. This change in the landscape was more visible in the dry areas of the Pacific Northwest of Costa Rica. More recent estimates show that more than 50% of the Guanacaste province, at the heart of the dry forest zone in the Pacific Northwest, is covered by secondary forest with young trees (Gonzales, 2002; Spittler, 2002a). This situation creates new opportunities and challenges for establishing more sustainable and profitable forest management schemes in this section of the country.

Since the early 1960's Costa Rica's economy has constantly been growing, improving the standard of living. The Costa Rican government has paid a lot of attention to improving health care and education. For this and other factors, livelihoods have changed from rural to urban based livelihoods increasing the number of absentee landlords. More and more people are moving from rural to urban areas in search of better paying jobs. The reduction of rural populations and the improvement of social conditions (education level, per capita income) have increased labour costs because opportunity costs of agricultural activities have increased. Cattle production is one of those activities with decreased profitability, but it is a low risk activity. Thus, cattle ranching is part of the livelihood strategy of absentee landlords who make their living as professionals living in urban areas.

The new tendency of environmentally sound production and the emphasis on ecotourism have created a new generation of middle-aged professionals who are concerned with environmental protection. However, the increase in forest cover could be endangered if cattle ranching were to again become a lucrative business. There is a gap in the knowledge of cattle farmer livelihoods and the implication on the management of forest and tree resources.

However, there is a gap in the knowledge regarding the appropriate management of native species populating these newly forested areas (Holl and Quiros-Nietzen, 1999; Mora and Chinchilla, 2002; Moya, 2002). Even though some researchers have studied the biophysical characteristics of forest and tree resources in dry areas, fewer studies have tackled the socio-economic, political and institutional factors underpinning natural regeneration processes on cattle ranches. However, a recent survey by Campos *et al.* (2001) showed that trees on pasturelands are the main wood source legally and illegally traded in Costa Rica. Therefore, forest and tree resources are becoming once again an important source of income for cattle producers. That is why it is important to ascertain whether and how, under this new context ranchers are interested in managing these tree resources.

As for the future, there are some expectations about a potential return of cattle production in Costa Rica. A new boost to cattle profitability may increase a new conversion wave of secondary growth into pasturelands, since the net present value of cattle production would be higher than the value of forest-linked activities. This asymmetry in return is prompted by fully valuing the benefits of clearing forested areas and introducing pasture and cattle whereas only half of what accounts for the environmental and economic benefits is linked to conservation. Therefore, as long as local ranchers and other farmers do not receive compensation for providing environmental benefits, they would not consider them as revenue sources when making land-use change decisions in the future (Pagiola *et al.*, 2002a). The challenge is to provide economically viable alternatives to endogenise environmental values in decision making processes so that the collective behaviour of private cattle producers is in line with the interests of society at large, thus enhancing our opportunities to improve forest and tree resource management on cattle farms.

This research specifically attempts to shed light on the lack of knowledge regarding the biophysical and spatial factors influencing farm characteristics and locations and the lack of knowledge of the factors underlying farmer responses to technology change. This research explores these problems, making a scientific contribution to the conservation of dry forest zone.

1.3 OBJECTIVES

1.3.1 Principal objective

To contribute to a better understanding of the cultural, economic, social, political and biophysical factors underlying land use trends in the dry tropics of Costa Rica, aiming to identify economically viable options to increase forest cover.

1.3.2 Specific objectives

1. To develop and test a predictive model of biophysical and spatial factors driving land use change as identified by census, spatial and time series data

2. To identify the economic, social, political and cultural factors that also influence land use changes

3. To understand farmer preferences about the spatial arrangement of trees on cattle farms

4. To study cattle farmer livelihoods and how the forest and tree resources can be included in their livelihood

5. To determine the potential of using spatial models, livelihoods approach and choice experiments as tools for policy analysis and definition

6. To make policy recommendations for the sustainability of forest and tree resources on cattle farms in Costa Rica

1.4 GUIDING RESEARCH QUESTIONS AND HYPOTHESES

- **Question 1.** What are the biophysical and spatial factors underlying cattle farm characteristics in Costa Rica?

- **Hypothesis 1.** Elevation and rainfall are the main biophysical forces underlying the type of cattle production, dairy or beef.

- **Question 2**: Which land use changes can be identified and quantified in Cañas over the past decade?

- **Hypothesis 2.** The main land use change up to the early 1990's was the conversion of the dry forest zone into cattle pastures; as cattle prices plummeted after 1994, areas of forest regeneration have expanded at the expense of cattle pastures.

- **Question 3**: Which exogenous farm factors have influenced decisions on land use change?

- **Hypothesis 3.** Beef prices, in addition to government subsidies and incentives are the key external factors driving land use change.

- **Question 4**: Which endogenous farm factors have influenced decisions on land use change?

- **Hypothesis 4.** Opportunity costs of forest and tree resource management, as well as socio-economic characteristics of the farmers are the main internal factors that influence land use change.

- **Question 5**: How have farmer livelihoods influenced the presence of forest and tree resources on cattle farms?

- **Hypothesis 5.** Farmers with the best incomes are more motivated to keep forest and tree resources on their farms

- **Question 6**: What is the potential for introducing new agroforestry and silvopastoral technologies on cattle farms?

- **Hypothesis 6.** Demand for new technology rises with decreasing opportunity costs of sound management of forest and tree resources on cattle farms.

1.5 CONCEPTUAL FRAMEWORK

The study adopts the livelihoods approach to analyse how the cultural, economic, social, political and biophysical factors drive land use trends in the dry tropics of Costa Rica. This approach allows the analysis of the endogenous and exogenous forces affecting forest and tree resource management on cattle farms. The livelihood framework also allows the discussion of farmer perceptions about forest and tree resources and how the endogenous and exogenous factors affect the presence and management of these resources on cattle farms, exploring some alternatives to introduce forest and tree resource management on cattle farms.

According to Ellis (2000), livelihoods are the "capabilities, assets (stores, resources, claims and access) and activities required for a means of living." The definition links assets to people's options in pursuing a means of living. Livelihood strategies comprise the range, combination and choices made and undertaken in order to achieve livelihood objectives. Livelihood strategies are influenced by environmental, cultural, social and political conditions (McKee, 1989; DFID, 2000; Ellis, 2000; Rider Smith *et al.*, 2001; Quinn *et al.*, 2003). According to the DFID definition, a livelihood strategy is influenced by the vulnerability context, the livelihood assets and the transformation of structures and processes (Figure 1.1). Vulnerability affects the incomes of farmers, which in turn help farmers to overcome the shocks caused by natural and economic agents.

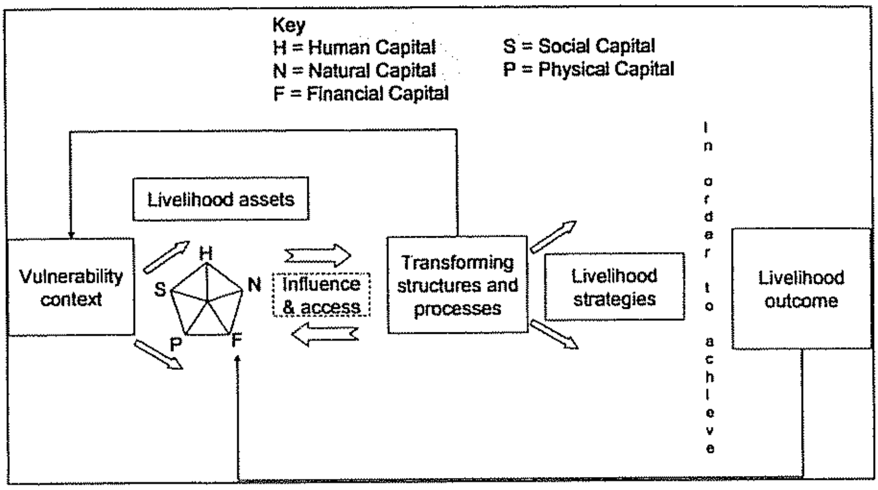

Figure 1.1 - Sustainable livelihoods framework

Source: DFID (2000)

Based on the DFID framework, our framework analyzes the five capitals (human, social, natural, physical and financial), including the environmental vulnerability context of cattle farms located in the dry forest. Furthermore, the impact of the environmental vulnerability context on farmer assets is analyzed, exploring how it affects farmer livelihoods and the forest and tree resources. Finally, the political, social and market conditions were considered in defining the strategy for introducing forest and tree resource management into cattle farmer livelihoods (Figure 2:2). The five livelihoods assets consider mainly the endogenous factors, while the environmental vulnerability context and the social, political and market conditions comprise the exogenous factors.

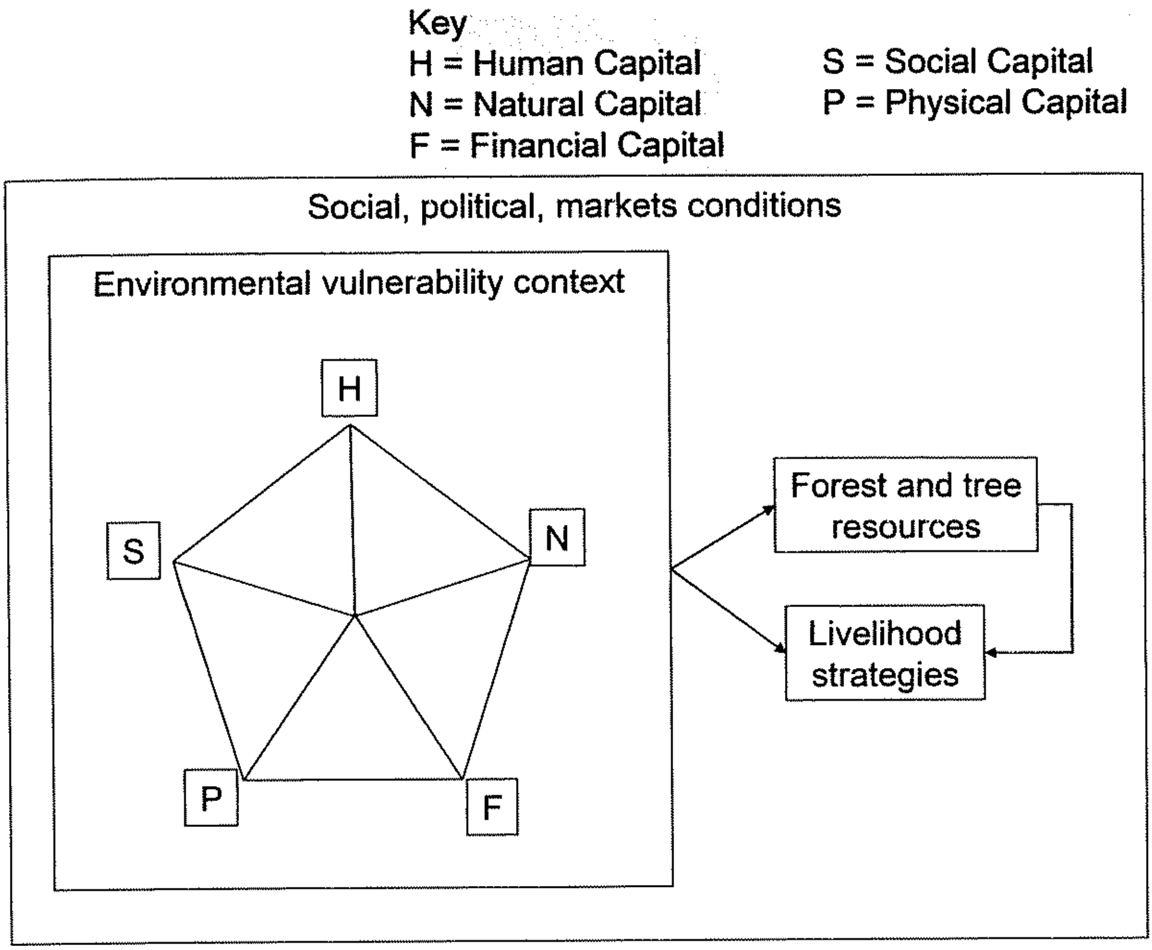

Figure 1.2 - Conceptual framework for livelihood analysis of the strategy to introduce forest and tree resource management into cattle farm livelihoods

Source: based on DFID (2000)

The analysis of exogenous factors was conducted using a spatial and geographic land use model, analysis of aerial photographs of the land cover in the study area from the 1960s to 1990, and a literature review of the main socioeconomic changes in Costa Rica. The spatial models focus on the definition of the natural capital in farmer livelihoods, land rent theory proposed by von Thünnen which suggests that the most profitable activities tend to be located closer to markets. This approach allows for an analysis of the extent to which biophysical, geographic and spatial factors affect the type of cattle production in Costa Rica. It is widely argued that some geographic factors favor dairy production. The methodology allows for measuring the effect of the factors underlying von Thünnen's theory of land rent.

Similar models were pioneered by Chomitz and Gray (1996) and Nelson and Hellerstein (1997) in modelling deforestation in tropical areas. We use the same approach to analyze spatial technology distribution in order to understand which geographic factors define the presence of beef farms in Guanacaste.

Our model includes factors such as elevation, precipitation, dry months, and water supply. The study allows one to measure the individual effect of each factor, identifying which are the main factors affecting the distribution of the cattle production in Costa Rica.

In addition, to understand the dynamics of land cover change in the dry forest zone of Costa Rica and the relationship with social and political factors, an analysis of time series aerial photographs was conducted. This study focuses on the analysis of the human and social factors affecting cattle farmer livelihoods and also includes an analysis of the social, political and market conditions. Land cover is defined as "the biophysical state of the earth's surface and immediate subsurface" (Briassoulis, 2000). The term originally referred to the vegetation covering land surface, but it now includes human structures like buildings or pavement, and other aspects of the physical environment such as soils, biodiversity, as well as surface and groundwater (Briassoulis, 2000).

Theories were elaborated to explain how the socioeconomic factors, which include technological or political forces, drive land use or land cover change. The discussion is based on the land degradation-deforestation hypothesis which states that at initial stages of development, a country needs to use the natural resource; however, as the economy grows, people reduce the use of natural resources. In Costa Rica, a rapid deforestation process was reported from the 1960s to the 1980s; nevertheless, as the standard of living improved, the government enforced more sound environmental laws. Nowadays, Costa Rica is considered by many a world leader in environmental policies, allowing the recuperation of forest cover. The evolution of land cover in Costa Rica can help to predict how land cover would change in other Central American countries as their economy and social conditions improve.

The other part of the study considers the endogenous factors affecting the presence of forest and tree resources on cattle farms. The analysis was based on the study of the five capitals comprising farmer livelihoods. Farmer preferences for forest and tree resource systems on their farms were explained and a rapid rural appraisal (RRA) of cattle farms in the study area was conducted.

As mentioned before, a livelihood framework considers the definition of five capitals: human, physical, financial, social and natural. These capitals comprise farmer assets in their livelihood strategy. We follow the capital definition provided by Ellis (2000).

- **Natural capital** refers to natural resources used by human populations. In cattle ranching assets like land, water, livestock, forest and tree resources and other natural resources can be included. This includes data from the RRA, the spatial and geographic models and the analysis of the aerial photographs.

- **Physical capital** refers to assets used for production processes, such as tools, machines, equipment and land improvement like terraces or irrigation canals, infrastructure such as access to roads, basic health and education services. It includes data from the spatial and geographic models.

- **Human capital** refers to the level of education (both formal and informal education) and health status of individuals and populations. This includes the analysis of the socioeconomic factors affecting the land cover in the study area from the 1960s to the 1990s, data from the RRA and also data from Ramos (2003) and Monterroso (2005).

- **Financial capital** refers to cash stocks accessed in order to purchase either production or consumption goods and includes credit, income and savings. In recent times, the remittances from overseas are becoming important financial capital for urban and rural livelihoods. Data was based on Ramos (2003) and Monterroso (2005).

- **Social capital** refers to social networks and associations from which people support their livelihoods. The analysis was based on Ramos (2003).

The analysis of farmer preferences of forest and tree resources on cattle farms uses the choice experiment approach. Forest owners and users have long recognized that forests provide a range of environmental services in addition to valuable commodities such as timber, fiber, fuel wood, edible and medicinal plants and game. However, not all these services directly benefit the owners, as they may be driven by national and international societies. It is argued that as long as farmers do not receive any compensation for providing these services, they are unlikely to take them into account when making decisions about land use change (Kreuter and Workman, 1994; Chomitz *et al.*, 1999; Bishop and Landell-Mills, 2002; Kerr, 2002; Pagiola, 2002; Pagiola *et al.*, 2002b; Pagiola and Ruthenberg, 2002; Unisfera, 2004).

The introduction of management of forest and tree resources requires understanding farmer willingness to invest in forest and tree management. It is hypothesized that farmers are interested in forest and tree resource management and also that they are interested in investing in it. Nevertheless, the production of externalities by forest and tree resources on cattle farms can provide financial support for the introduction on forest management. One of the first approaches to include externalities in farmer decision-making processes is the payment for environmental services (PES).

There are different approaches to define the PES. The Costa Rican government uses land opportunity cost. Under this assumption, PES considers that farmers with a low opportunity cost for their land would be motivated to dedicate their land to forest protection with a payment higher than their opportunity cost. The incentive for forest protection was defined as equal to the rental price for pasture, between 20 – 40 US$/hectare. This payment is adequate for cattle farming in marginal areas; nevertheless, payments are not enough to compensate for the cost of forgone alternatives such as dairy farming, export-oriented agriculture and urbanisation (Chomitz *et al.*, 1999; Pagiola, 2002; Ortiz *et al.*, 2003; Unisfera, 2004).

Another approach in defining the PES is to determine farmer demand for compensation by using economic valuation approaches. Traditionally, economic valuation approaches were based on contingent valuation, in which a hypothetical scenario is shown, asking the participant to give a value to the scenario. This approach allows one to know how much farmers are willingness to receive as compensation for the forgone income produced by the increase of forest cover. Considering that farmers are concerned about grass quality, mainly due to the limitation of producing enough forage in the dry season, the introduction of forest and trees result in a trade-off between trees and grasses.

Nevertheless, the increase in tree cover in paddocks increases the competition for growing factors. In the dry areas, trees compete with other species for water (McIntyre *et al.*, 1997). When the relationships between grasses and tress are competitive, normally grasses reduce their productivity, forcing farmers to reduce the competition with trees by cutting the forest cover. Only at that point farmers began to have a decrease in productivity due to tree resources, and it is here when PES can be implemented.

Forest and tree resources on cattle farms can provide different products such as forage and shade for livestock. Nevertheless, the inclusion of forest management on cattle farms demands the understanding of how farmers perceive these benefits and also how farmer livelihoods are influenced by cattle production and forest resources.

Due to the lack of time and budget, this research only considers beef farms in the livelihood analysis which limits the findings of this research to beef production areas. For a complete livelihood analysis of livestock farmers, it is necessary to include those farms. The discussion about dairy farms is based on observations of dairy areas which does not allow for an in-depth discussion about the implication of dairy or beef farms on forest and tree resources.

The land use models (Logit models) only consider the type of livestock production units, not other types of agricultural activities. Nevertheless, there is no census data for other types of agricultural production systems; the only data available is for the livestock sector. The analysis conducted only considered beef or dairy production, which in many cases is not the only alternative for farmers.

1.6 DEMOGRAPHIC CHANGES IN COSTA RICA DURING THE PERIOD 1960-2000

The Costa Rican agricultural sector has had an impressive expansion since 1961 (Bulmer-Yhomas, 1978; Schneider-Sliwa and Brown, 1986; Field, 1988). The agricultural exports grew from US$ 136 million/year in the 1960s to US$ 4,267 million/year in the period 1993 – 2001, representing an increase of 3,015% (Table 1.1). Although the annual value of beef exports increased from US$ 8 million in the period 1961–1970 to US$ 38 million in the period 1993 – 2001, its share in the overall agricultural exports decreased from 5% to 1% in the same period. Coffee, bananas and sugar also had the same trends as beef. Non-traditional products such as ornamental plants increased their share in agricultural exports from 25% in 1961–1970 to 75% in 1993 – 2001. Diversification of the agricultural sector has reduced its vulnerability towards fluctuations in international markets.

Costa Rica and other Central American countries entered the U.S. beef market after World War II. At that moment, governments and international development agencies were interested in expanding cattle production. Construction of public infrastructure, highways and beef processing plants in Puntarenas pushed the production of beef for the USA market. By the end of the 1970s, Costa Rica had become the fourth largest beef exporter to the U.S. market. In the 1980s, however, beef demand levelled off, reducing cattle production in Costa Rica (Peters, 2001).

Table 1.1 - Average agricultural export value, 1961 to 2001

Average exports	1961 – 1970		1971 – 1986		1987 – 1992		1993 – 2001	
	10^6 US$	%	10^6 US$	%	10^6 US$	%	10^6 US$	%
Coffee	52	41	208	28	305	20	304	8
Bananas	34	25	163	24	328	19	592	16
Beef	7	5	46	7	56	4	38	1
Sugar	6	5	22	4	18	1	35	1
Others	35	25	294	38	966	56	3.266	75
Total	136	100	736	100	1.675	100	4.237	100

Contrary to popular belief, national and international beef prices have constantly increased since the 1960s (Table 1.2); nevertheless, beef exportation has decreased since 1970. The same occurred with the animal stocking rate (AS), which has decreased although livestock units have increased. This implies a reduction in the intensification of cattle production. This study explores the reason for the reduction in the intensification of cattle production systems in the dry forest of Costa Rica.

Table 1.2 - Time series of some socioeconomic factors affecting land cover change in Costa Rica, 1961–1992

Variables	Units	1961 – 1970	1970 – 1986	1986 – 1992
Costa Rican beef prices	US$/kg	0.77	1.79	2.40
U.S. beef prices	US$/head	405	754	1,113
Ratio of agricultural/non-agricultural	Percentages	92	59	37
Ratio of rural/urban	Percentages	176	121	85
Animal Stocking Rate	LU/hectares	1,11	1,09	0,92
Cattle	Number of	1,226,354	2,032,772	2,147,024
Exports/production	Percentages	22	33	15

In 1960, the Costa Rican Gross Domestic Product was US$ 336 per capita, and the major economic activities were agriculture, comprising 28% of the Gross Domestic Product. Exports were comprised largely of agricultural crops like coffee, bananas, beef, sugar and cocoa. Sixty three percent of the labour force was rural in 1963, and nearly half of the total labour force was employed in the agricultural sector (Field, 1988).

From 1960 to 1970, Costa Rica's economy grew at an annual rate of 6.5% in real terms due to increased exports of coffee, bananas, sugar and beef. Concomitantly, workers moved from self-employment and non-paid family work to wage-earner status. The wage-earner labour force in Costa Rica increased from 66% in 1963 to 74% in 1973, while self-employment decreased from 21% to 17%. This is an indication that economic growth brought better jobs to Costa Rican workers (Field, 1988).

Another concomitant of economic growth is the movement of workers out of low-paying sectors, especially agriculture into higher-paying sectors. The labour force employed in agriculture fell from 49.7% in 1963 to 38.2% in 1973. Many rural workers left agriculture to move into better-paid sectors such as the service and industrial sectors. In 1963, the agricultural sector employed 49% of the labour force with an annual wage of US$ 793, while the service sector employed 17% of the labour force, with an annual wage of US$ 1,624 (Field, 1988; Gindling and Berry, 1992).

From 1963 to 1973, Costa Ricans improved their educational level. Workers without education decreased from 15 to 10%, elementary education increased from 37% to 45%, secondary education went from 9% to 16% and university education moved from 2% to 4%. At the end of 1973, the enrolment in primary schools was virtually 100% (Field, 1988).

As a comparison, in Nicaragua half of rural income came from agricultural activities and the educational level of agricultural workers was 2 years of schooling (Deininger *et al.*, 2003). These differences in education provide the Costa Rican population more non-agricultural options improving their possibilities to diversify their livelihood. As Costa Rica's population become more educated, moving to non-agricultural jobs, Nicaragua's remained in agricultural jobs. This created a migration flow from Nicaragua to Costa Rica, in which Nicaraguans are the labour base of many agricultural crops in Costa Rica.

The Costa Rican economy continued growing during the 1970s. The Gross National Product increased 7.0% annually from 1965 to 1970, 6.0% annually from 1970 to 1975 and 5.2% annually from 1975 to 1980. In 1973, Costa Rica was hit by the oil shock producing a reduction of 13% in real wages; nevertheless, the rise in coffee prices and the availability of credits allowed the economy to adjust, increasing real wages by 30% (Field, 1988). World coffee prices started to decline in 1977, producing a reduction of 45% in coffee prices from 1977 to 1981. This reduction of national incomes forced the Costa Rican government to increase the external debt 14-fold from 1970 to 1981 (Field, 1988).

Political events in Central American countries disrupted the Central American Common Market at the end of the 1970s, where Costa Rica exported 80% of its manufactured products; however, the labour force grew 4.0% annually, and unemployment fell from 7.3% in 1973 to 4.9% in 1979. From 1973 to 1980, 180,600 new jobs were created, but only 9,100 were created in the agricultural sector (Field, 1988; Abler *et al.*, 1998).

Costa Rica enjoyed favourable macroeconomic conditions during the 1960s and 1970s; however, in 1980 macroeconomic events forced a severe economy readjustment. All economic indicators declined; real Gross National Production per capita fell by 18%, inflation reached 90%, unemployment doubled, real wages plummeted by 40% and payments of foreign debts were suspended (Field, 1988).

In the 1980s, the Costa Rican economy faced a downturn that could not be avoided. The economy was hit by the combination of payment balances, larger debts, higher international rates, inability to borrow and meet payments, rising import prices, falling export prices, and world recession which reduced the demand for traditional exports. Net international monetary reserves became negative in 1980, and by September 1980 devaluation began (Field, 1988).

Average wages fell by 40% from 1979 to 1982; thus, real wages were lower in 1983 than in 1979. Costa Rican workers suffered real wage cuts of 25% as a result of the economic crisis. During the crisis, employment shifted in favour of poorer jobs, reversing the improvements that had taken place. The agricultural sector created 80% of the new jobs, although it had the lowest wages. Agricultural production increased 6% from 1980 to 1981 (Field, 1988).

As an indication of the crisis during the 1980s, from 1981 – 1987 Central America received 5.3 billion US$ as USA aid, representing 65% of all USA assistance to Latin America, and almost 9% of USA economic and military assistance in the world in 1986. However, in 1985 Central American exportation was 79% of the 1979 level, changing from US$ 4.4 billion in 1979 to US$ 3.5 billion in 1985. Only Costa Rica and Honduras showed export recoveries in 1985 of levels 95% above the 1979 levels. By 1985, Costa Rica's non-traditional export recovery was 115% of the 1979 levels and Guatemala and Honduras had recovered to 96 and 94% of the 1979 levels, respectively (Lindenberg, 1988). Nevertheless, Costa Rica started an impressible program toward tourism in the 1980s, and by 1993 ecotourism was the most important economic activity in the country (Campbell, 1999).

Costa Rica must simultaneously address several problems: a rapidly growing population combined with limited arable land, severe cash constraints in both the public and private sectors, one of the highest per capita debt burdens in the developing world, a high inflation rate, growing unemployment and widespread environmental degradation (Griffith and Zepeda, 1994; Procesos, 2002). As a general view of the demographic conditions of Costa Rica, the agricultural based livelihoods had decreased with an increase of non-agricultural based livelihoods due to the improvement on the socioeconomic conditions (Rodríguez et al., 2002).

1.7 BIOPHYSICAL CONDITION OF THE STUDY AREA

Costa Rica is bordered by Nicaragua to the north and Panama to the South (Figure 4:1). The country is highly influenced by the Inter-tropical Convergence Zone (ICZ), producing wet conditions most of the year. According to the Holdridge life zones classification (Holdridge, *et al.* 1971), Costa Rica has 23 life zones, with tropical wet forest, tropical moist forest, transition from premontane wet forest to lowlands and premontane wet forest covering 54% of the country. Only 2.7% of Costa Rica has been classified as a tropical dry forest zone. Unlike other Central American countries, precipitation in Costa Rica is rather evenly distributed throughout the year. 97% of the land surface receives more than 2000 mm/year of rain. Only 17% of the land has more than 5 dry months (Figure 3:3).

The Guanacaste province is located in the northwest part of Costa Rica. Although being the country's driest area, the transition from premontane moist forest to lowlands is predominant (41%) with tropical moist forest (23%) being the next dominant cover type. Eighty seven percent of the Guanacaste province belongs to the moist or rain forest (Holdridge *et al.*, 1971). The tropical dry forest zone covers only 10% of Guanacaste. Though 90% of Guanacaste is subjected to precipitation exceeding 2000 mm/year, irregular rainfall distribution is prominent, causing seasonal drought during more than 4 months of the year in 93% of the province.

The region studied is located in the counties of Cañas and Bagaces, Guanacaste. The farms surveyed are in the Bebedero sub-watershed which belongs to the Tempisque River watershed. This is the oldest lowland non-indigenous inhabited area of Costa Rica. It has been populated since the XVI century according to Mateo-Vega (2001) and Peters (2001). The area has been classified as a tropical dry forest zone (Holdridge *et al.*, 1971); however, some areas classified as humid forest because of the amount of rainfall (Watson *et al.*, 2002). In our case, Bagaces and Cañas were considered a dry forest zone due to the long dry season. The study area covers 570 km^2; representing 54% of the tropical dry forest zone in Costa Rica (Figure 1.3).

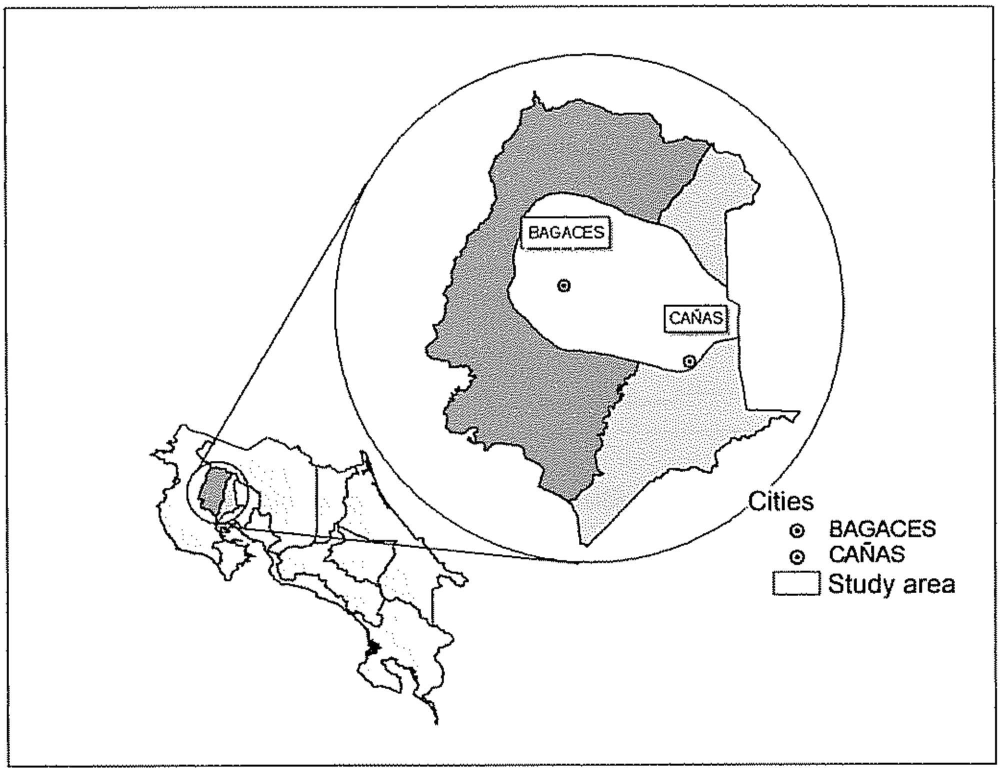

Figure 1.3 - Location of the study area in Costa Rica

Source: Based on ITCR (2000)

1.7.1 Rainfall and water supply

Bagaces and Cañas are the driest counties in Costa Rica with more than 6 dry months of no rain, an average temperature of 27.3 °C and 1,400 mm of rainfall during the year. The humidity during the dry season ranges between 60 to 65%, while during the wet season it ranges between 80 to 90%. Ground water supplies appear sufficient for cattle production needs. A large number of rivers cross the area and are fed by the upper part of the watershed which produces 2,000 mm/year of rainfall (Figure 1.4). Therefore, rainfall distribution is the main limitation for cattle production since 64% of both counties have more than five dry months with almost 95% of the total rainfall occurring from May to November, with 50% of it falling between August and October (Mateo-Vega, 2001; Cubero, 2002; Watson *et al.*, 2002).

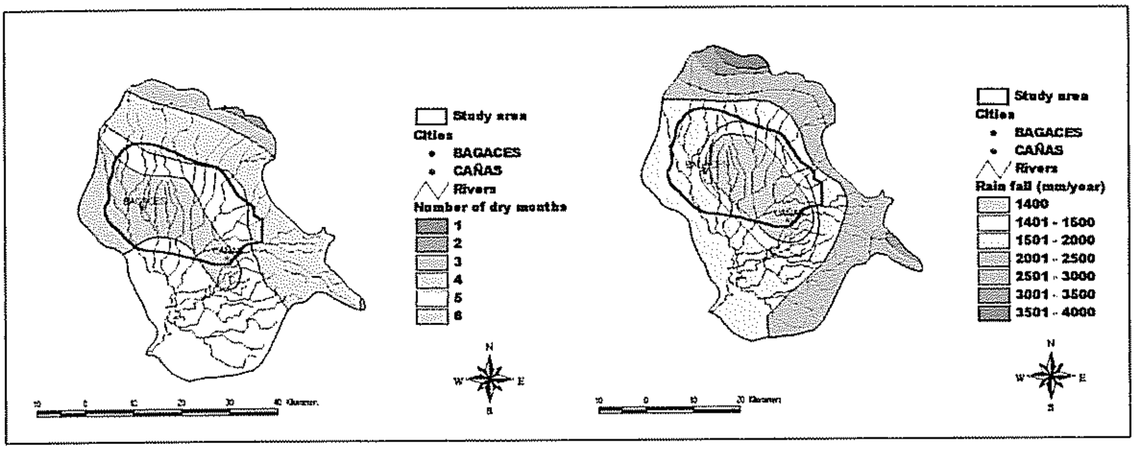

Figure 1.4 - Dry months and rainfall distribution in the Bebedero watershed, Costa Rica

Source: Based on ITCR (2000)

Although the upper part of the watershed is humid, most of the area features a "Dry Atmospheric Association", meaning it has long dry periods. As a result, other life zone classifications were found in the watershed such as tropical moist forest, premontane moist forest which has a "dry" association with it. Here, productive lands without irrigation present more restrictions for agricultural and forest production activities (Mateo-Vega, 2001).

Dry spells are part of Bagaces and Cañas' history. In the XX Century at least fifteen droughts were registered. The most important ones were reported in 1922, 1925, 1957, 1958, 1963, 1972, 1973, 1974, 1975, 1977, 1982, 1983, 1986, 1994 and 1997. The most severe droughts on record were for the years 1972 and 1975. Therefore, droughts seem to be a recurrent phenomenon in the area. The Tempisque River has been the main source of transportation and water since the XVII century. As a result, most agricultural and livestock operations have historically been located next to the Tempisque river or its tributaries, which provide a secure source of water in dry spells (Peters, 2001).

In recent decades the largest irrigation project in Costa Rica was established in Cañas and Bagaces utilizing water from the Arenal dam. The Arenal Tempisque irrigation system was constructed in the 1970s and is able to irrigate 62,000 hectares with an average water flow of 50 m^3/sec during the dry season and 85 m^3/sec in the wet season

(Coto, 2001). Thus, water supply may not be inhibiting cattle production; rather the effect of rainfall distribution on forage is the main problem.

1.7.2 Soil and topography

The topography is for the most part regular with some mountains in the northwest. In 44% of the area, the slope ranges between 2 to 15%, whereas it gets steeper (30 to 60%) in nearly 40% of the counties (Figure 1.5). Finally, the southern tip is more level which makes irrigation systems possible. Thus, the topography is not a limiting factor for cattle production.

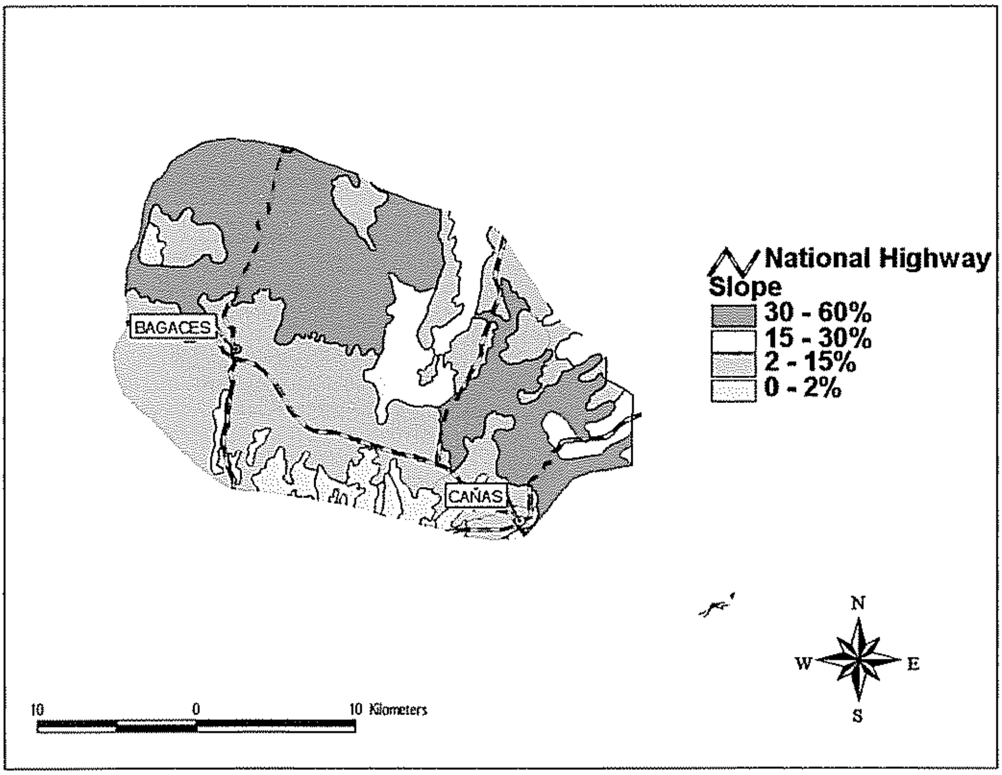

Figure 1.5 - Soil slope in the study area in the dry forest zone of Costa Rica

Source: Based on ITCR (2000)

According to United States Department of Agriculture soil classification (USDA, 1982), the area includes 5 of the 10 soil types: alfisol, entisol, inceptisol, mollisol and vertisol with an ustic humid regimen, implying that humidity is present when conditions are favourable for plant growth. Soils are of recent formation, with medium fertility, and are good for cattle production (USDA, 1982).

1.7.3 Current and potential land uses

The mollisol and alfisol types, which are the most fertile soils, cover only 10% of the area and are mainly used for agricultural production. Cattle ranches are concentrated on medium to low fertility soils. Permanent crops, including pasturelands, are recommended in 58% of the area due to potential soil use and weather conditions (Figure 1.6). Forest production and annual crops are recommended in 27% and 15% of the area, respectively.

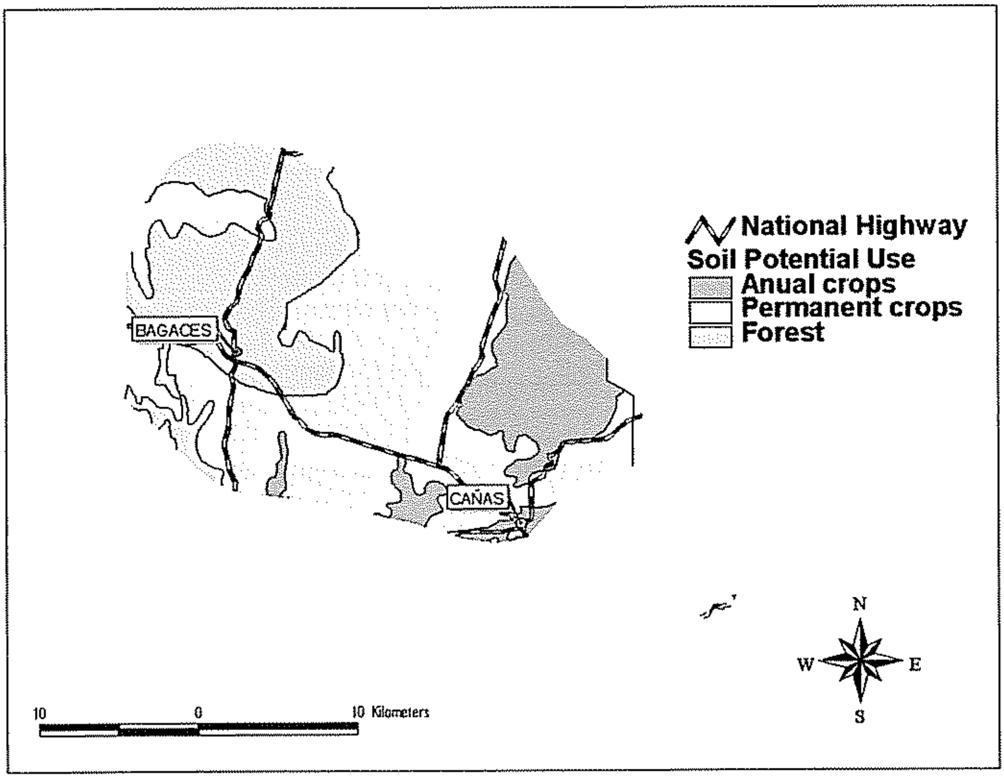

Figure 1.6 - Potential soil use in Cañas y Bagaces counties, Costa Rica

Source: Based on ITCR (2000)

Pastureland was the main land use reported in 1992, covering 56% of the area; whereas natural forest patches represented only 3% with an average of 585 hectares per patch. Dispersed trees on pasturelands were probably classified as pasture; therefore, reducing the true forest cover figure from 1992.

Prior to independence from Spain, pasturelands were considered public domain. The process of privatizing pasturelands started in the XVI century. Originally the Spanish kings gave away land for agricultural uses, but the ecological conditions favoured the development of cattle production. Then, as cattle production profitability increased, its expansion drove a massive land conversion process from forest to pastures (Mata, 2001; Peters, 2001). In 34 years, from 1950 to 1984, pasturelands increased from 39.2% to 62.32% in the Tempisque watershed, while forest cover was reduced from 45.2% to 18.1% in the same period (Table 1.3). The data in Table 1.3 depicts a strong tendency toward pastureland expansion, whereas agricultural uses remain almost unchanged. This supports the idea that ecological conditions favoured cattle production as the main economic activity.

Table 1.3 - Land cover (%) in the Tempisque watershed, Costa Rica, 1950 and 1984

Use	1950	1984
Annual crops	10.38	12.21
Permanent crops	0.90	3.50
Pasturelands	39.20	62.32
Forest	45.20	18.10
Infrastructure	3.86	3.80

Source: Peters (2001).

The Costa Rican government utilizes a heavy government interventionist approach to the management of its forest resources, and over the past 15 years the supply of wood from natural forests has diminished due to deforestation combined with the establishment of conservation areas (Gottfried *et al.*, 1994; Piotto, *et al.*, 2003). Thus, land cover has increased. FONAFIFO (2001) found that 38% of the study area is covered by forest (Figure 1.7). Nevertheless, this classification only considers the areas covered with continuous forest, and it does not consider the trees in paddocks. If pasturelands with tree cover were considered, the area covered by some kind of forest resource would increase considerably. However, 38% of the forest cover, in a traditional cattle production area, represented an important element to be considered when working with farmers. It is possible that forest and tree resources are an important input and output in livestock ranches.

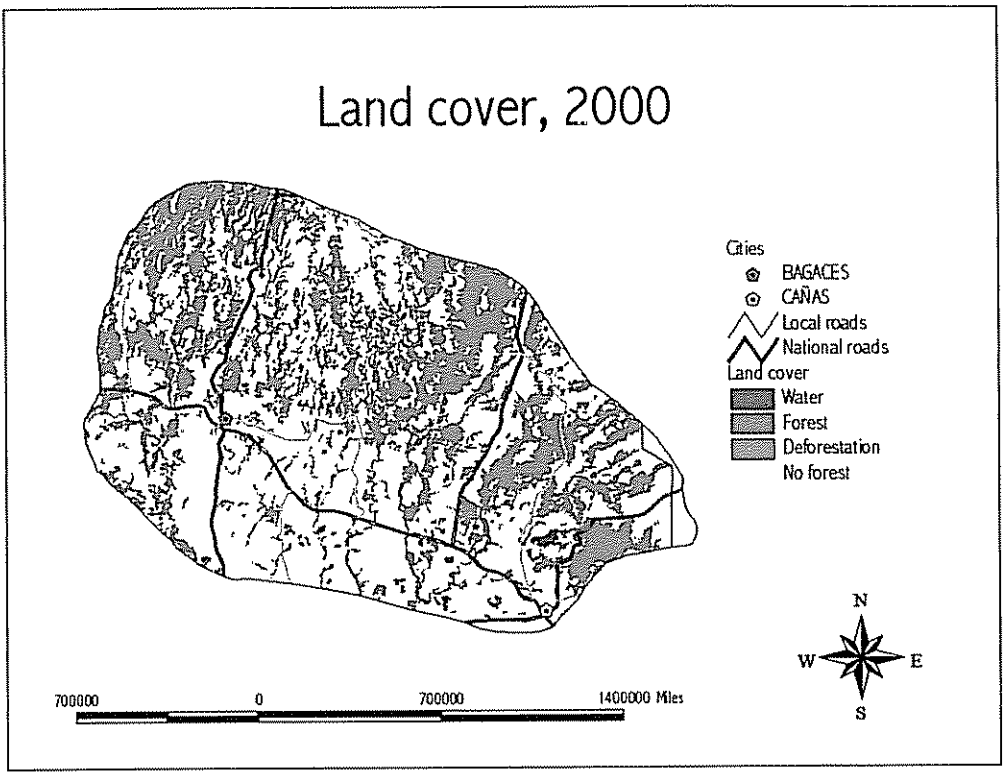

Figure 1.7 - Land cover 2000 in the study area

Source: FONAFIFO (2001)

Chapter 2

METHODOLOGY AND METHODS

2.1 GENERAL OVERVIEW

The methodology used in this research was divided into the analysis of the exogenous and endogenous driving forces. The first step of the research was the Rapid Rural Appraisal (RRA), followed by the analysis of the exogenous factors, ending with the analysis of the endogenous factors (Figure 2.1). Then, data was combined to discuss farmer livelihood strategies and how forest and tree resources can be included in farmer livelihoods.

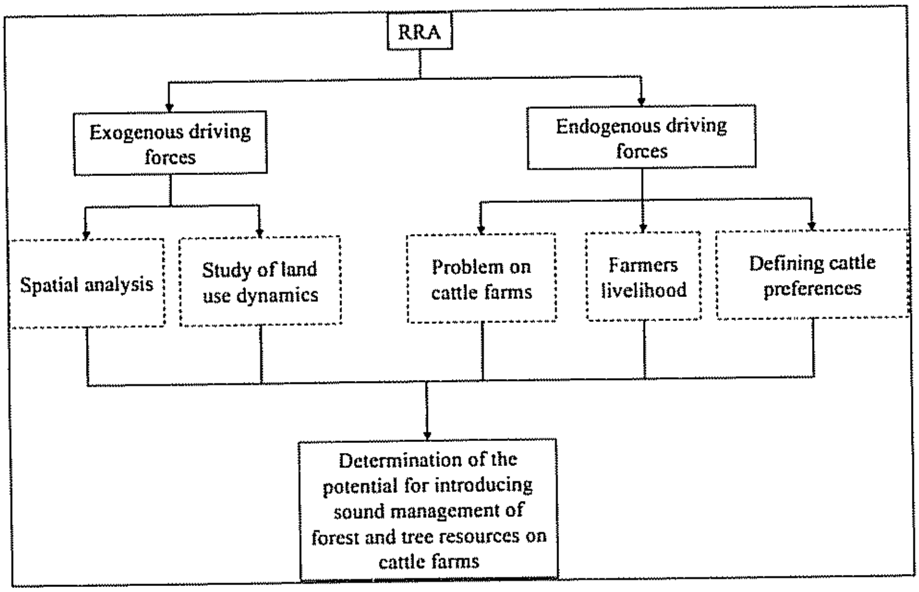

Figure 2.1 - Scheme for the methodology used in this research

This section is a general overview of the methodology; further discussion is presented in the following chapters.

2.2 RAPID RURAL APPRAISAL

The first step in the research was a Rapid Rural Appraisal (RRA), which aimed to gather general information about the study area. The RRA included information about forest and tree resources and the water supply for cattle. Data was collected using a semi-structured interview. Cattle census data was used in the definition of the sample, using a cluster analysis to define the different types of cattle farms in the area. Also, socioeconomic information about farmer households was collected.

RRA also included the analysis of cattle census data and geographic information from the Atlas of Costa Rica. The geographic information contained layers such as soils, rivers, land use, protected areas, topography, life zones and forest cover. The analysis of geographic factors described the main biophysical characteristics of the study area.

The data from cattle census contain geographic information with the geographic location of every cattle farm in Costa Rica; this allowed the linkage of data from the cattle census to data from the Atlas of Costa Rica. With the data linked, census data were analyzed at the Costa Rica level analysing the characteristics of dairy and beef farms in Costa Rica.

The analysis of the geographic information was included in the environmental vulnerability context and also as exogenous factors. More details of the methodology used in the RRA are presented in Chapter 3.

2.3 EXOGENOUS FACTORS

The analysis of the exogenous factors included the study of the spatial and geographic factors driving the type of cattle production in Costa Rica and the analysis of the main socioeconomic and political factors underlying the land cover change in the dry forest of Costa Rica. More details about the methodology are presented in Chapter 4.

2.3.1 Geographic and spatial factors affecting the type of cattle production in Costa Rica

This part was based on the von Thünen hypothesis of land rent which states that the location of farms influences the rent through transport costs. Therefore, farms located closer to markets have a higher land rent due to lower transport costs. The analysis used data from the cattle census and the atlas of Costa Rica and identified which geographic and spatial factors define the type of cattle production system (dairy or beef) in Costa Rica.

The analysis used a Logit model in defining the geographic and spatial factors influencing the type of cattle production in Costa Rica and a Tobit model to analyze how the geographic and cattle management factors impact the technology level of dairy and beef farms.

The first stage on the analysis was the definition of the transport cost which was calculated using the road layer. Roads were classified according to the average speed that a truck can drive on it. Roads were classified as first-order with an average speed of 70 km/hr, second-order roads with 40 km/hr, and beyond these 20 km/hr. This allowed for the estimation of the friction map surface, which indicated the time that is required to reach dairy or beef markets from each farm.

The main beef auctions and dairy production plants were identified as a basis for the market access cost layer. The auctions in Cañas, Ciudad Quesada, Guapiles, Limonal, Liberia, Pital, San Isidro del General, Santa Ana and Upala were identified as beef markets. Dairy markets were identified as Ciudad Quesada, El Coyol, Monteverde, San Isidro del General and Coronado where the main dairy plant companies are located.

Later, information about geographic conditions of cattle farms were added to the model. The information included was: the distance from rivers, water supply from rivers, water supply from wells, water supply from irrigation systems, and rainfall.

To complete the analysis, data of farm management practices were added. This variable was based upon the cattle management system: pasture, semi-intensive, or intensive according to the cattle census classification. Indexes of the use of health and feed management were also created and added to the model.

The Logit model was estimated with data from transport costs and geographic characteristics and used the classification of cattle farms as the left hand side of the equation. The classification considered dairy and beef farms, numbering beef farms as 0 and dairy as 1. On the right hand side, the transport costs and the geographic factors were included.

The Tobit model explored which geographic and management livestock factors influence the technology level on cattle farms in Costa Rica. The model used the Animal Stocking rate as a proxy for the level of technology. Both models, Logit and Tobit were estimated using the Limdep program, which is the Tobit model with a sample selection option. The analyses of the effects of the factors were done using the marginal substitution rate, which are the first derivate of the Logit model.

2.3.2 Land cover dynamics in the dry forest of Costa Rica

A study of time series of socioeconomic factors and aerial photographs was conducted to complete the analysis of the spatial and geographic factors affecting the type of cattle production. The study was conducted using aerial photograph classification in the Arc View program. The photograph classification considered three land cover types, such as forest, paddock with tree cover and paddocks without tree cover. Forest areas comprise those areas with more than 20% forest cover; paddocks with tree cover include paddocks with less than 20% tree cover but more than 5% and finally, pasture without tree cover was consider as those with less than 5% tree cover.

The time series data for the socioeconomic factors was obtained from different studies conducted in Costa Rica, making an abstract table. This data is presented in Chapter I and describes the socioeconomic conditions of Costa Rica.

The first analysis conducted with the aerial photograph was the estimation of the Markov transition matrix, estimating the probability of change from a state in time t to another state in time $t + 1$. According to the information of the aerial photographs from 1960, 1970, 1980 and 1992, three transitional matrixes were estimated: 1960/1970, 1970/1980 and 1980/1990.

The discussion was conducted linking the main change in the socioeconomic and political conditions to the transitional matrix. This analysis allowed for the study of the socioeconomic, political and market environment that influence the land cover change and their implications on farmer livelihoods.

2.4 ENDOGENOUS FACTORS

The analysis of endogenous factors included the definition of main cattle farm problems, eliciting farmer preferences on spatial arrangements of silvopastoral systems and the definition of farmer livelihoods. The results and details of the methodology are presented in Chapter 5.

2.4.1 Definition of cattle farm problems

The definition of cattle farm problems was conducted using a workshop with farmers from the study area. Participants were selected using the information from the RRA; 25 farmers were invited to the workshop; nevertheless, only 7 farmers came to the workshop. The methods used in the workshop were problem census and problem ranking (Geilfus, 2000):

1) **Problem census**: this started with a brainstorm. The first step was the explanation to the participants of the reason and the necessity of obtaining this data. Each problem mentioned was written down on a sheet of paper and then clipped on the board.

2) **Problem ranking:** the problems identified were ranked by farmers using a pair wise comparison. Problems were compared in pairs. Farmers mentioned which of the two problems was more important. The results were introduced in a double entrance matrix as described in (Geilfus, 2000). One point was assigned to the most important problem. When no consensus was reached, half a point was assigned to each problem compared. Then, points were added, and problems were ranked according to the points obtained.

2.4.2 Definition of farmer preferences of tree arrangements on cattle farms in the dry forest of Costa Rica

The study explored farmer perception about the spatial arrangement of tree resources on cattle farms and identified their willingness to invest and their demand for compensation for the increase in forest cover. The study used the choice experiment approach to elucidate farmer preferences.

The study began with the definition of the objective and the scenario for the choice experiment. The scenario considered a paddock where trees would be established in different spatial arrangements and with different tree occupations. This scenario was defined using the focus group method. Two focus groups were conducted; the first one was conducted in CATIE with CATIE technicians and the second one in Cañas with local farmers.

In these focus groups, the attributes and levels to be used in the choice experiment were also defined. The attributes were based on data from the RRA. The attributes and levels were defined as; the arrangement of trees, tree occupation of the pasture, the time for receiving the payment and the amount of the payment.

A second experiment was conducted to consider the possibility of combining different tree arrangements on a cattle farm. The attributes and levels were also defined in the focus groups. The attributes consider the presence of trees in border fences, the presence of trees in internal fences, the presence of dispersed trees and the amount of investment for tree management.

Once the attributes and levels were defined, the experiment was designed using the SAS program. A cyclical method was used considering 6 choice sets for three alternatives in each set.

The questionnaire for the application of the experiment first considered general questions about the farms and tree products. Farmers ranked their willingness to invest in their farms and also described the tree products that they want to obtain from their trees. Investment considered four different options: improving grasses, improving cattle breeds, improving tree management or buying new machinery. Five tree products were compared: wood, posts, forage, shade and wind protection. The second part of the questionnaire considered the knowledge and opinions of farmers about environmental service payments. At the end of this part, the four services (mitigation of greenhouse gas emissions, 2) hydrological services, 3) biodiversity conservation and 4) provision of scenic beauty for recreation and tourism) recognised by the Costa Rican Forest Law were compared.

The next part consisted of the choice experiments, starting with the explanation of the experiment. The scenario considered a 5 hectare pasture, where only one possible system can be selected. The final part of the questionnaire considered socio-economic questions about farmers.

The survey was carried out in the main beef auctions in the area: The auctions in Cañas, Liberia, Limonal and Upala, all which were visited in September of 2003. Only owners or managers of cattle farms were interviewed.

The econometric model was done in Limdep 7.0 using the NLogit Model. The prediction power and the significance of the coefficients were considered in the model definition. Furthermore, the marginal substitution rates (MSR) were calculated by dividing the beta coefficient of the technology attributes by the coefficient of the payment.

2.4.3 Cattle farmers livelihood analysis in the dry forest of Costa Rica

The final part of the analysis of the endogenous factors was the study of livelihoods for cattle farmers. The analysis considered data obtained in previous chapters of the research and also data from Ramos (2003) and Monterroso (2005) who conducted their research supported by the CERBASTAN project.

First, the main results of Ramos (2003) are presented. Later a discussion of the strategies of cattle farmers and the influences on the forest and tree resources is presented. As support to the discussion, an economic analysis of cattle farming was conducted. Data came from Monterroso (2005).

As a way to combine the information presented by Ramos (2003) using data from Monterroso (2005) and the author's own data, a SWOT analysis was done (strengths, weaknesses, opportunities and threats). This analysis was conducted using the key informant interviews and discussions in the focus groups. Key informants included Cerbastan students and other CATIE professionals who have conducted research in the area.

Chapter 3

DESCRIPTION OF THE CURRENT CATTLE PRODUCTION SITUATION IN COSTA RICA AND THE CURRENT USES OF FOREST AND TREE RESOURCES ON CATTLE FARMS LOCATED IN THE DRY FOREST OF COSTA RICA

3.1 THE CATTLE PRODUCTION IN COSTA RICA IN 2001

3.1.1 Introduction

Cattle production is a controversial issue in any discussion related to land-use conversion processes in Latin America. Basically, there are two groups, one defending the cattle industry arguing that it is necessary to support cattle production because ranching is an important source of income in rural livelihoods (Montenegro and Abarca, 1998). On the other hand, opponents of cattle production state that livestock has been responsible for the deforestation process, and new support to the sector could increase deforestation (Vaughan and Mo, 1994; Kaimowitz, 1996).

As mentioned in Chapter 1, cattle ranching has been conducted in the dry forest zone; however, in Costa Rica the new trend of forest recovery is a product of the recuperation of secondary forest in abandoned pasturelands. The province of Guanacaste has been the most important in beef production due to its geographic conditions (Montenegro and Abarca, 1998); nevertheless, no studies were found for identifying and quantifying the influence of geographic conditions on cattle production. This chapter describes the current situation of cattle production in Costa Rica defining how geographic and spatial characteristics have influenced cattle production in Costa Rica.

3.1.2 Methodology and methods

The methodology considered the analysis of the cattle Census 2001 (MAG, 2001; Corfoga, 2002) and the Atlas of Costa Rica (a cartographic data collection of Costa Rica) (ITCR, 2000). The cattle census data was collected between July 2000 and January 2001 (Corfoga, 2002).

The first phase was the linkage of the Census data with the geographic information in the program ArcView 3.2a. This merge was possible because the census data was georeferenced. The data used were elevation, rainfall, dry months and life zone. A buffer map was generated to establish the distance from the farms to the rivers. Once this information was generated, the results were exported to Microsoft Access.

In Microsoft Access, the first step was to calculate the Livestock Units (LU) per farm, since the cattle census only had animal by age information. The LU was calculated using the coefficient presented in Table 3.1.

Table 3.1 - Conversion factors used to calculate the Livestock Units in cattle farms of Costa Rica

Age range	Conversion factor
0 – 1 year	0.25
1 – 2 year	0.50
2 – 3 year	0.75
> 3 year	1.00

Source: Ibrahim (2001)

Once LU was estimated, the Animal Stocking Rate (AS) was calculated by dividing the LU by the farm size. Then, farms were classified according to their main production: beef, dual purpose and dairy farms. Following Corfoga (2002) cattle breed was used as the main criteria for this classification. Farms with only beef breeds were grouped as beef farms, the same with dairy farms. Farms with both types of breeds, beef and dairy, were catalogued as dual-purpose farms. With the updated database, the statistical analysis was conducted to calculate the means and t-tests. A significance level of 0.1 was used.

3.1.3 Results and discussion

According to the Census, by 2001 Costa Rica had 43,494 cattle farms, 26,296 beef farms, 15,065 dairy farms and 2,133 dual-purpose farms, covering 39% of the Costa Rican territory. Puntarenas (26%), Alajuela (23%), Guanacaste (19%) and Limón (17%) contained most of the beef farms. Dairy farms were highly concentrated in Cartago (41%) and Alajuela (33%). Dual-purpose farms were concentrated in Puntarenas (22%) and San José (20%) (Table 2:2). Overall, Alajuela had one quarter of the cattle farms in Costa Rica.

For the 43,494 cattle farms, 1,101,717 Livestock Units (LU) were found, divided into 690,062 LU for beef, 353,932 LU for dairy and 57,932 LU for dual-purpose farms. Barquero (2001) reported the existence of 1,369,715 head of cattle, whereas Vargas *et al.* (2002) reported 200,000 head on dairy farms, but the difference in units did not make a comparison possible.

Barquero (2001) and Corfoga, (2002) argued that during the period 1988 – 2000, dairy herds were reduced by 126,403 head (3% annually). However, dairy production increased by 293 million litres while the Animal Stocking Rate (AS) increased from 0.7 to 0.77 LU/hectare, implying an intensification. Additionally, Montenegro and Abarca (1998) ascertained that dairy production increased by 6.2% annually from 1982 to 1998. Beef production has not observed this productivity increment; a reduction in herd size will reduce the amount of beef produced. Finally, Barquero argued that most of the reduction in beef herds has occurred in animals of reproductive age, making beef production unsustainable (Muchagata and Brown, 2002).

Fifty percent of the cattle herds were in Alajuela and Guanacaste (Table 3.2); whereas, Cartago presented a high concentration of dairy herds (47% of the dairy herds). Alajuela had more than 28% of the national herd.

Table 3.2 - Distribution (%) of cattle farm types and cattle herds by provinces in Costa Rica (N = 43,494)

	Province													
Production	Alajuela		Cartago		Guanacaste		Heredia		Limón		Puntarenas		San José	
	F*	H**	F	H	F	H	F	H	F	H	F	H	F	H
Beef	23	25	2	1	19	25	4	4	17	16	26	24	11	6
Dairy	33	36	41	47	6	7	2	2	4	2	5	4	9	3
Dual	18	23	12	5	8	18	12	10	9	9	22	23	20	11
Average	26	28	16	16	14	19	4	4	12	11	18	17	10	5

* Percentages of the total number of farms
** Percentages of the total number of cattle

3.1.3.1 Productive characteristics of cattle farms in Costa Rica

Guanacaste had larger cattle production units than the rest of the country. For all systems (beef, dairy and dual purpose) Guanacaste's farms were larger than the average of the rest of the country, having more area and more livestock units (Table 3.3). However, when looking at the Animal Stocking Rate, an important indication of technology level, beef and dual purpose farms in Guanacaste had higher rates than the rest of the country. On the contrary, the rate was better for dairy production in the other provinces. This data showed that Guanacaste appears to be an adequate place to have beef farms, but not good for dairy production. Most of these differences can be explained by the geographic and climatic conditions which will be presented later in this paper.

Table 3.3 - Average herd size, farm size and Animal Stocking Rate in Guanacaste and the rest of Costa Rica (N = 43,494)

Production	Herd size (LU)		Farm size (ha)		Animal Stocking (LU/hectare)	
	Guanacaste	Country	Guanacaste	Country	Guanacaste	Country
Beef	35.9	24.0	87	52	0.93	0.82
Dairy	28.5	23.1	41	25	1.44	1.93
Dual	65.4	23.8	114	46	1.09	1.04
Average	35.6	23.7	81	41	1.01	1.25

The importance of beef production in Guanacaste is highlighted by beef farm area. Beef farms account for 42% of the province which is higher than in the rest of the country, around 27%. On the other hand, dairy production accounts for only 3% of the Guanacaste area which is lower than the average for the rest of the country (9%). This data show that Guanacaste has good conditions for beef but not for dairy production. Geographic conditions will be further discussed in Chapter 4.

According to Brockett (1988), in Costa Rica the land tenancy has followed a process of consolidation with an increase in farms with more than 100 hectares at the expense of small farms. This is especially true for Guanacaste, where 28% of the area is owned by 1% of the farms, whereas 45% of the farms own 5% of the area (Figure 3.1). Contrary to the rest of the country, medium farms (20 < 100 ha) in Guanacaste owned 21% of the land, while the national average was 35% of the land owned by medium farms.

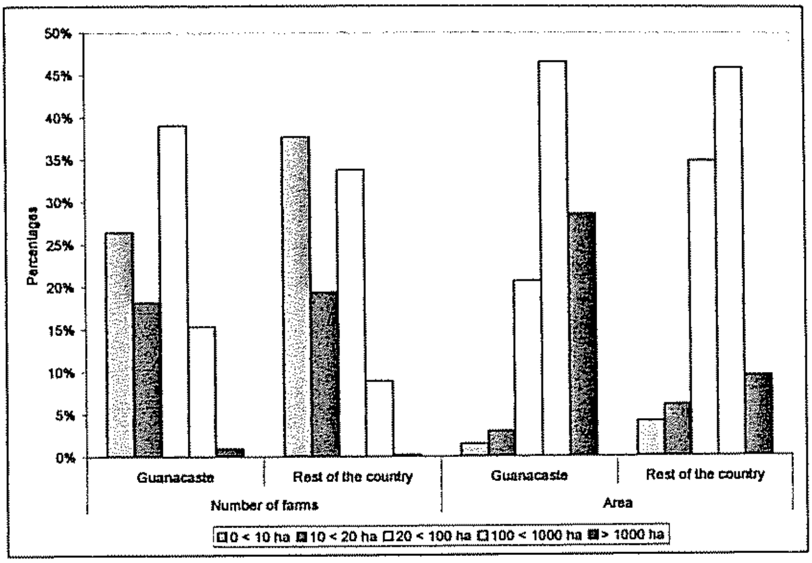

Figure 3.1 - Number of cattle farms and area distribution in Guanacaste and the rest of Costa Rica (N = 43,494)

Although Guanacaste with 75% of the farms (< 10 hectares) owned 20% of the land had lower land accumulation per farmer than in other Central American countries, the agrarian reform in Costa Rica started in the Guanacaste province at the beginning of the twenty century due to the higher land consolidation than in the rest of the country (Brockett, 1988; Peters, 2001). However, land markets tend to re-consolidate land instead of transferring land to small producers. The net accumulation of land has been principally by large coffee and livestock producers (Deininger *et al.*, 2003).

3.1.3.2 Geographic characteristics of cattle production

Although Costa Rica is a small country (52,000 km^2), it presents a large variation in geographic conditions. Elevation has been mentioned as one of the main driving forces defining cattle production (Montenegro y Abarca, 1998). As an example, Guanacaste is highly focused on beef production and not on dairy production mainly due to the difference in elevation (Table 3.4). On average Guanacaste's dairy farms were located 617 meters above level sea, while dairy farms in the rest of the country were located at 1,217 m. Specialized dairy farms in the highlands were responsible for the production of a significant proportion of the processed milk (Vargas *et al.*, 2002). The main influence of elevation is temperature, which defines the cattle breed and the technology that can be used.

Table 3.4 - Mean elevation, rainfall and number of dry months in Costa Rican cattle farming (N = 43,494)

Production	Elevation (meters)		Rainfall (mm/year)		Dry months (number of)	
	Guanacaste	Country	Guanacaste	Country	Guanacaste	Country
Beef	236	393	2,383	3,629	4.6	2.4
Dairy	617	1,217	2,747	3,217	4.1	2.4
Dual	363	683	2,564	3,476	4.4	2.6
Average	296	719	2,442	3,465	4.5	2.4

According to the Atlas of Costa Rica, the lowest rainfall in the country is 1400 mm/year; however, less than 1% of the country has less than 1,400 mm/year but more than 1,300 mm/year. The majority of the country (97.6%) has an annual average rainfall of higher than 2,000 mm/year (Figure 3.2), implying that water supply could be enough to support cattle production.

Contrary to elevation, differences in rainfall across cattle production systems were not so evident. For example, in Guanacaste beef farms were located in places at 236 meters with 2,383 mm/year of rainfall, while Guanacaste dairy farms were located in areas at 617 meters and 2,747 mm/year of rainfall which is equal to the rest of the country (Table 3.4). The difference in elevation is more than 100%, while rainfall is lower than 25%. Thus, elevation is a major force defining the type of cattle production.

Another factor affecting water availability is rainfall distribution, measured through the number of dry months. According to the Atlas of Costa Rica, rainfall is well distributed across the years; 17% of Costa Rica has less than 5 dry months while 68% has less than 3 dry months (Figure 3.3).

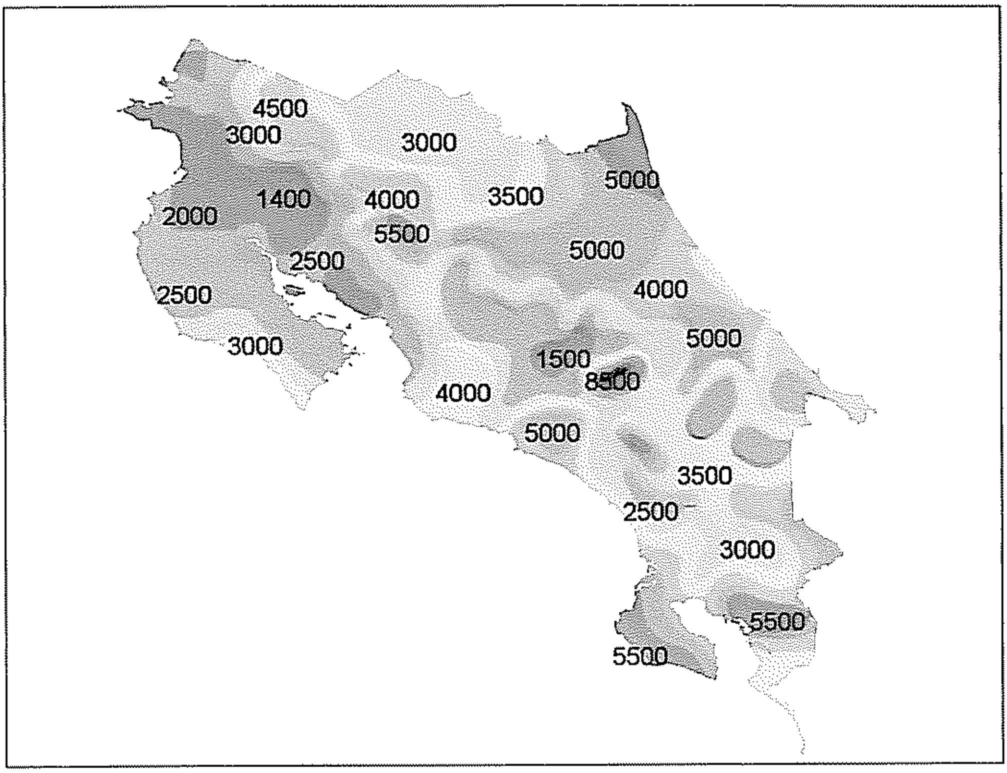

Figure 3.2 - Rainfall distribution (mm/year) in Costa Rica

Source: Based on ITCR (2000).

Like rainfall, the number of dry months did not present differences across systems. For all systems, Guanacaste presented more dry months than the rest of the country, but the differences across systems were the same for Guanacaste and the rest of Costa Rica. Therefore, from the three geographic factors discussed, elevation is the most important factor in defining the type of cattle production system. Thus, Guanacaste is a beef production province due to the elevation, and not because of the rainfall or the number of dry months.

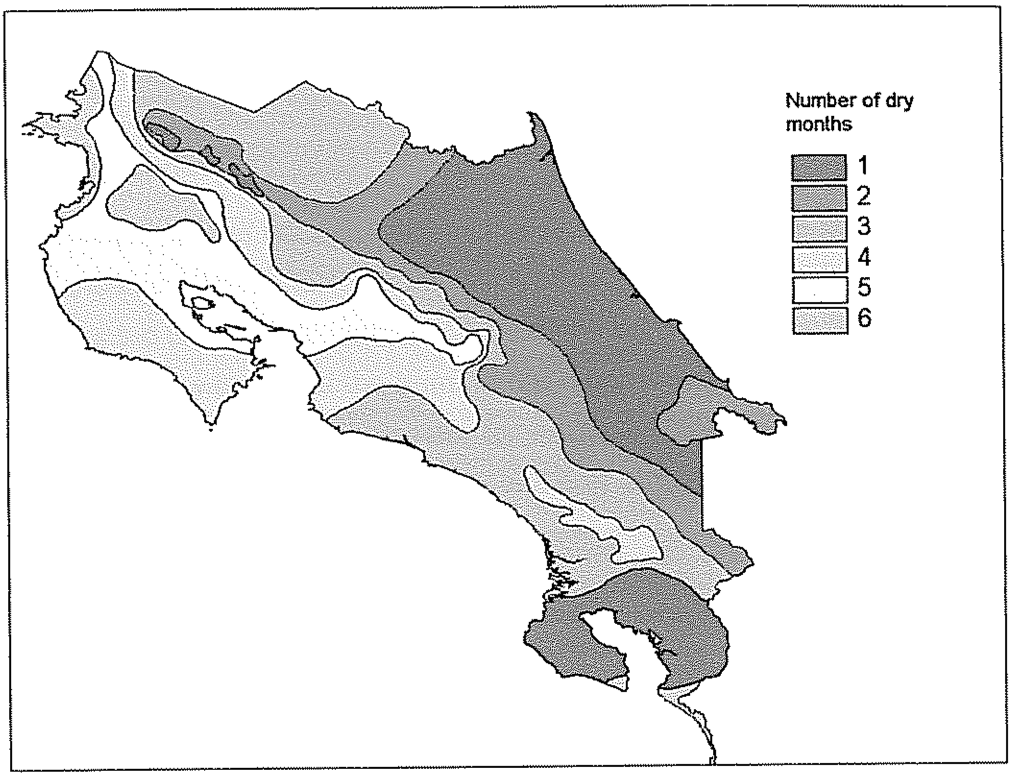

Figure 3.3 - Distribution of dry months in Costa Rica (number of dry months)

Source: Based on ITCR (2000).

According to the life zone classification census Holdridge *et al.* (1971), 97% of the country is classified as moist forest to rain forest, and only 2.7% as tropical dry forest. However, tropical dry forest zones are important for cattle production, and according to Kaimowitz (1996) the first grasslands in Central America were established here. Although the tropical dry forest zone covers only 2.7% of the country, this area was highly occupied by cattle farms. Tropical dry forest zones together with the transitional zones from tropical moist forest to lowland, tropical moist forest to perhumid and tropical moist forest to dry were the most used life zones in the cattle industry.

3.1.3.3 Beef cattle production

According to Montenegro and Abarca (1998), beef production started in 1586 when the first herds were imported from Honduras and Nicaragua. The introduction of *Hyparrhenea rufa* (Jaragua) helped to increase production, especially in Guanacaste because both cebu breeds and *H. rufa* adapted well to local conditions. The following section will describe the productivity factors that influence the beef production in Costa Rica

Productivity variables

Cross sectional data of herd size shows that Guanacaste had the largest herds in 2000. The province had the highest accumulation of cattle herds, since farms larger than 500 LU represented 0.5% of the farms but 13% of the herd. Farms smaller than 10 LU were 37% of the farms with 5% of the herd. In the other provinces, the presence of medium farms was larger than in Guanacaste; for example, farmers with 10 to 50 LU owned 40% of the herd in the rest of the country and only 30% in Guanacaste (Figure 3.4).

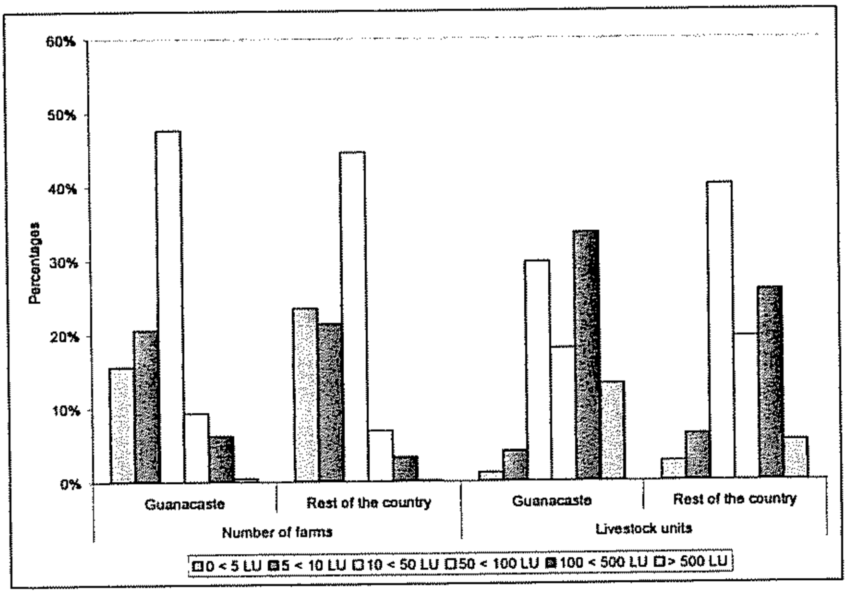

Figure 3.4 - Number of beef cattle farms and Livestock Units (LU) in Guanacaste and the rest of Costa Rica (N = 26,296)

Similar to the distribution of Livestock Units, Guanacaste presented marked land consolidation patterns which are different from the rest of the country (Figure 3.5). The largest Guanacaste farms, larger than 1000 hectares, represented 1% of the farms but 30% of the area; while farms smaller than 20 hectares were 43% of the farms but represented only 4% of the area. The main difference across Guanacaste and the rest of the country is the medium farms (20 < 100 hectares). The importance of this type of farm is lower in Guanacaste. This type of land tenancy was produced by climatic condition of the area since beef cattle farms need a minimum area to be profitable. It was mentioned that beef cattle farms need at least 60 hectares to be profitable (Ramos, 2003).

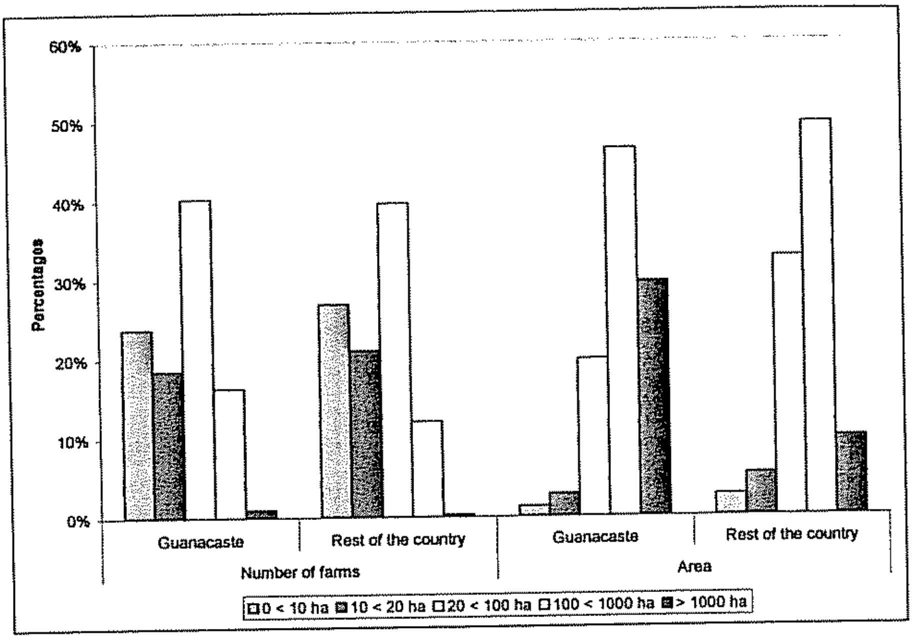

Figure 3.5 - Number of beef cattle farms and area distribution in Guanacaste and the rest of Costa Rica (N = 26,296)

Factors influencing the Animal Stocking Rate on beef cattle farms

It is argued that beef cattle production is a low technology production system with a high use of natural resource. In this section some factors that affect the Animal Stocking Rate (AS), a proxy for technology level, will be discussed. Cattle breeds cannot explain differences in AS among Guanacaste farms and the rest of the country because the *Bos indicus* breed dominated all of the country. More than 80% of the beef farms have Brahman, followed by Indubrasil (9% of beef farms), and Nelore. On average, Brahman cattle had an AS of 0.85 LU/hectare, Indubrasil 0.84 LU/hectare and Nelore 0.90 LU/hectare.

Another possible factor influencing the AS is production technology. In this case, management systems include grazing, semi-intensive and feed lots. More than 80% of the beef farms use only paddocks to feed the animals, with an average of 0.83

LU/hectare. Whereas, beef farms with semi-intensive or feed lots were less than 1.5%. Semi-intensive systems had an AS of 2.72 LU/hectare, and feed lots systems of 2.91 LU/hectare. Thus, AS is not a function of technology.

A key factor in the intensification of cattle production is pasture management. Pasture management is important for enhancing the sustainability and the intensification of livestock production (Muchagata and Brown, 2002). Most farms used grazing systems; therefore, the factor that could explain the differences in AS was the type of grasses used. Even though data regarding grasses used is not available in the census, the pasture fertilisation regimens are available. More than 95% of beef farmers did not fertilise their pastures. However, farms that fertilise had 1.14 LU/hectare, while farms that did not fertilise had 0.83 LU/hectare. This shows the positive effect of pasture fertilisation on pasture productivity. However, due to the lack of cost data, the economic benefits can be demonstrated in this research.

Pasture management has been reported as the main difference among the beef and dairy industries. Dairy farms make intensive use of pasturelands while beef cattle ranching is typically extensive, with low levels of external inputs including fertilizer application. Therefore, beef stocking rates needs to be adapted to the environmental capacity in order to be sustainable and maintain income generation (Bouman and Nieuwenhuyse, 1999; Bouman *et al.*, 1999).

Research shows that natural grasses are more profitable than other systems in beef production. Hence, although the use of nitrogen fertilization in grazing systems with *Brachiaria spp* is positive, it was not economically viable in breeding systems due to the high costs of establishment and fertilisers. It is ascertained that the profitability of beef fattening is two times higher for breeding than grazing. Returns were 106 US$/hectare/year in breeding systems and 232 US$/hectare/year in fattening systems. However, soil-mining rates indicate that production levels and economic returns would decline (Bouman *et al.*, 1999; Bouman and Nieuwenhuyse, 1999).

Regarding water supply, it can affect technology levels. It was found that 73% of beef farms used rivers as main water sources. Rivers had the lowest AS, with 0.84 LU/hectare, wells with 1.14 LU/hectare, and irrigation systems 1.38 LU/hectare.

Nevertheless, irrigation systems were not important in beef production, representing less than 10% of the farms.

Data presented did not explain the difference in AS. Neither cattle management nor cattle breed explain the difference in AS. However, soil type could explain the differences. Soils with the highest AS were Vertisol (1.26 LU/hectare), Mollisol (1.13 LU/hectare), Inceptisol/ultisol (1.10 LU/hectare), Inceptisol (1.00 LU/hectare and Alfisol (0.78 LU/hectare). The lowest AS was reported in Ultisol/histosol (0.41 LU/hectare), Entisol/inceptisol (0.58 LU/hectare), Ultisol (0.66 LU/hectare) and Histosol (0.69 LU/hectare). Guanacaste presented a high percentage of Alfisol (41% of the farms), Vertisol (9%) and Mollisol (7%), which is larger than in the rest of the country. Contrarily, percentages of Ultisol (4%) were lower than in the rest of the country. Thus, some of the AS differences can be explained by soil type. The data show that beef production is influenced mainly by the use of natural resources and not by the technology being used as shown by the soil data.

3.1.3.4 Dairy cattle production

Dairy cattle production was introduced in Costa Rica in 1920, with the introduction of the kikuyo grass. The activity began in the high lands of the Central Volcanic Corridor. During the 1980s, the activities grew fast due to the capital investment by the private sector and market protection. Nowadays, this is a stable market linked to production (Montenegro and Abarca, 1998).

Milk production in Costa Rica is an activity with increasing economic and social importance. Costa Rica is the only Central American country that is self-sufficient in milk production, with an annual per capita consumption of 152 kg. In fact, Costa Rica is one of the three Latin American countries that meet FAO's recommendations for milk consumption. Dairy farms produced 600,000 tons of milk per year, with an estimate of 60% of this milk being processed. However, dairy farms have also been responsible for some of the nation's extensive deforestation, particularly in the San Carlos lowlands (Griffith and Zepeda, 1994; Vargas *et al.*, 2002).

Productivity variables

Like beef production, dairy farms in Guanacaste are the largest farms. For dairy production, medium farms are more important than in the beef industry (Figure 3.6). This is consistent with Kaimowitz (1996), who ascertained the importance of small and medium farms in dairy production in Costa Rica. This could be due to the intensive management of dairy farms, demanding more labour and managerial skills; therefore, farmers tend to concentrate their production in small areas. Although, Guanacaste presented higher land consolidation than the rest of the country, it follows the same pattern presented for beef farms.

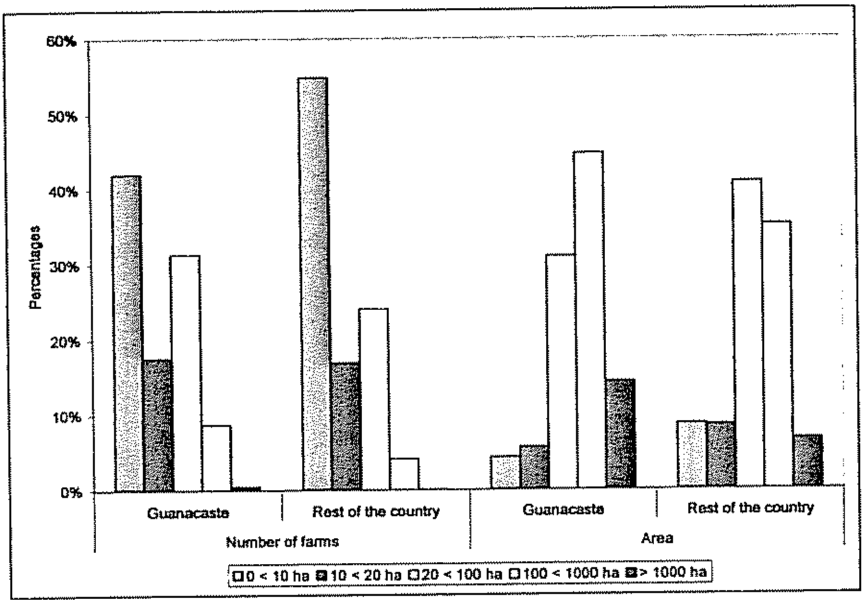

Figure 3.6 - Number of dairy cattle farms and distribution in Guanacaste and the rest of Costa Rica (N = 15,065)

Factors influencing the Animal Stocking Rate on dairy cattle farms

Contrary to beef cattle farms, the livestock breed used on dairy farms influences the AS. Farmers were able to keep 2.29 LU/hectare with Holstein, 1.98 LU/hectare with Jersey, 2.27 LU/hectare with Guernsey and 1.01 LU/hectare with Brown Swiss. Although Guanacaste has a higher percentage of Holstein cattle, 48% in Guanacaste versus 38% in the rest of the country, the presence of Jersey and Guernsey was lower. Additionally, the presence of Brown Swiss is higher in Guanacaste than in the rest of the country (36% of the Guanacaste farms versus 9% in the rest of the country). Therefore, Guanacaste has a large number of farms with lower AS, reducing the Animal Rate in the province. Contrary to this finding, Vargas *et al.* (2002) states that more than 80% of the dairy herds were Holstein. Vargas *et al.* (2002) concentrated their study in the dairy production areas with highly specialized farms that principally use Holstein.

The differences in the use of dairy cattle breeds may be influenced by climatic conditions, Brown Swiss are more tolerant to hot and dry conditions. Dairy farms with Holstein are located in the highest areas of Guanacaste, especially in the Tilaran, Tenorio and Miravalles cordilleras. Further discussion will be done in Chapter 4.

Another factor influencing the AS on dairy cattle farms is the level of technology, especially in pasture management. Ninety three percent of the dairy farms use grazing systems for production; however, the AS is lower in the grazing systems (1.86 LU/hectare) than in feed lots (4.90 LU/hectare). Nevertheless, the fertilisation regimens contribute to the improvement of the AS in the grazing systems. Without fertilisation, the AS was 1.41 LU/hectare while with fertilisation it was 2.47 LU/hectare. In Guanacaste, 26% of the dairy farms fertilised while 39% of the farms did in the rest of the country. Therefore, the Animal Stocking Rate in Guanacaste is lower than the rest of the country due to the low use of fertilisation.

Contrary to beef farms, water sources are an important factor underlying the AS on dairy cattle farms. The highest AS was found with irrigation systems that have 2.66 LU/hectare, wells with 1.71 LU/hectare, and finally rivers with 1.36 LU/hectare. In Guanacaste, 67% of farms have rivers as their main water source, and 19% had water from irrigation systems. The rest of the country, 56% had rivers and 41% depend on irrigation systems. Therefore, the lowest AS in Guanacaste dairy farms can be influenced by the low use of irrigation systems.

Dairy farms tend to be more intensive than beef farms. The principal resource used in dairy farms is labour. Labour accounts for more than 60% of total costs in a dual-purpose production system. This percentage should be higher in specialised dairy farms (Muchagata and Brown, 2002). Therefore, labour can be a constraint for some farmers. For example, during the dry season the purchase of external concentrate or hay can be more favourable than the use of silage or cut grass which requires more labour. Intensification implies higher cash requirements, greater needs for labour and sophisticated management skills. Nevertheless, extensive production practices reduce costs from half to a third of those incurred by intensive production (Griffith and Zepeda, 1994).

3.1.4 Conclusions

Cattle farms were the main land use in 2003, covering more than 39% of the Costa Rican territory. Three different types of cattle production systems can be identified: beef, dual-purpose and dairy farms; the beef farms are the most common in the country and highly concentrated in the provinces of Guanacaste and Alajuela.

A spatial pattern of the cattle industry can be identified, especially for dairy farms which are located in specific areas. Dairy farms were highly concentrated in Cartago and beef farms in Guanacaste. Beef production tends to be viable in non-suitable areas for dairy production, since dairy farms depend on the presence of specific biophysical conditions, especially elevation. Therefore, beef production can be catalogued as a basic cattle production system. Where conditions are suitable for dairy farms, farmers lean toward this production system. The biophysical conditions of Guanacaste, especially the elevation, lead toward beef production.

The beef industry tends to concentrate its production on large production units, producing land and herd accumulation; while the dairy industry is based on smaller farms, implying lower land and herd accumulations. Beef cattle farms require larger areas, producing lower land use intensity; thus, beef farms allow a higher presence of forest and tree resources on beef farms.

Regarding geographic and spatial factors, dairy farms depends more on geographic characteristics; dairy farms have better soil and climatic conditions than beef farms. Nevertheless, the level of technology on beef farms was highly affected by the geographic condition. The stocking rates for beef farms cannot be directly associated factors like cattle breeds, production systems or pasture management but can be explained by geographic factors, particularly soil type. On the other hand, the technology level on dairy farms is highly correlated with cattle breed, pasture management and animal management.

According to the analysis of the census, the dry forest of Costa Rica presents good condition for beef production, especially for the biophysical conditions. As beef farms are larger and less intensive than dairy farms, the presence of forest and tree resources could be an important asset of cattle farms located in the dry forest. Further chapters and sections will analyze the current situation of forest and tree resources on beef cattle farms and how these resources are included on farmer livelihoods.

3.2 SOCIO-ECONOMIC CHARACTERISATION AND FARM TYPOLOGIES OF CATTLE FARMERS IN CAÑAS AND BAGACES

Cattle farming is one of the most important land uses in Costa Rica, covering more than 39% of the country with more than 40,000 cattle production units. Cattle production is not only an important land use but also an important economic activity. As presented previously, cattle production, especially the beef industry, is an important activity in Guanacaste.

Since the late 1970s, agricultural transfer-of-technology views have changed (Scoones and Thompson, 1994). Agricultural technology development moved from on-station research to on-farm research. Researchers have used different frameworks to study the socio-economic forces and biophysical processes and how these interacted in agricultural production. These changes in paradigms have improved the understanding of the research about farmer realities (Chambers *et al.*, 1989; Dufumier, 1990; Spencer, 1993; Rhoades and Bebbington, 1995; Friesen *et al.*, 1999; Hoskins, 1999; Prins *et al.*, 1999).

Guanacaste represents 20% of Costa Rica's territory, and 7% of the population. According to the Instituto Nacional de Estadísticas y Censos, by the year 2000, Bagaces had a population of 15,972 inhabitants, with a density of 13 inhab/km^2, while Cañas had 24,076 inhabitants and a density of 35 inhab/km^2. Both counties had a lower density than the national average (75 inhab/km^2) and Guanacaste's average (26 inhab/km^2). The exception is the city of Cañas, with a density of 97 inhab/km^2. Populations tend to be concentrated around the main cities of Cañas and Bagaces, where more than 80% of the population lived.

Around 30% of Guanacaste's population was classified as poor in 1989, and similar data was obtained in 2000. However, in 1984 Bagaces was classified as a county with medium income levels and Cañas as an urban county. Thus, Cañas and Bagaces were not classified as poor counties.

Land use change in Cañas and Bagaces was driven by the conversion of forest areas into pasturelands, especially before the 1970s. Nevertheless, the tendency changed in the 1980s when grasslands started changing into permanent and annual crops. The main reason for this transition was the construction of the Arenal Tempisque irrigation project. Nowadays, Cañas has 14,227 hectares and Bagaces 5,567 hectares under irrigation; whereas, pasturelands in Bagaces changed from 67% of the area in 1973 to 64% in 2001, and in Cañas from 47% in 1973 to 44% in 2001. Pasturelands were reduced by 35,000 hectares from 1973 to 2001, affecting, Guanacaste's herd which was reduced from 850,000 to 350,000 animals from 1980 to 1999 (Mateo-Vega, 2001; Peters, 2001).

Traditionally, investments in cattle farms were low due the use of natural stock. Improved grasses were only introduced in the middle nineteenth century. Improved grasses increased in Guanacaste from 26,000 hectares in 1909 to 595,000 hectares in 1973 (Peters, 2001).

On the other hand, the main agricultural activities in Cañas were: cotton, sugar cane and rice production. Tilapia production has become an important commodity in recent years. However, agricultural production has suffered from unstable markets, not allowing for production diversification. The crops were incentives in different times, depending on market variations and government policies (Proambiente, 2000; Peters, 2001). Therefore, the agricultural landscape for Cañas and Bagaces continued to be based on livestock production.

3.2.1 Methodology and methods

New approaches demanded a better understanding of farmer needs because technology should consider farmer preferences and needs, and also the differences across farms and regions (Berdegué and Escobar, 1990; Dufumier, 1990). There are two main groups of methodologies; one uses quantitative data and other uses qualitative data. Quantitative methods are good in providing statistical data which can be used for regional and national extrapolation. However, they do not necessarily consider the social and cultural characteristics of the farmers. While qualitative methods are adequate to describe how social and cultural factors affect farmer characteristics, they are difficult to present statistically.

One qualitative method is the cluster analysis. This is based on the assumption that statistical analysis can define farmer groups, reducing the variation inside the groups and maximizing the variation across groups (Berdegué and Escobar, 1990). This methodology is normally used to: 1) understand the dynamics of one region by studying relationships among different groups of farms, 2) support the design of agricultural policies including studies at the farm level, 3) support the design of agricultural research policies and to define research priorities, research limitations, research beneficiaries and the baseline and 4) define research and development projects focusing on the selection of target groups (Escobar and Berdegué, 1990; Hart, 1990).

The cluster analysis methods are divided into uni-variable and multi-variable methods, depending on the number of variables used in the analysis. The uni-variable method classifies the use of one variable like farm size and herd size. The Multi-variable approach uses more than one variable, having different processes to obtain the final groups. Uni-variable methods are good in classifying specialized production systems; however, they present some problems when classifying multiple systems (Escobar and Berdegué, 1990; Martínez *et al.*, 1990). The final product of a cluster analysis is the definition of recommendation domains, which are groups of farmers with similar characteristics. The recommendation domains allow for joining or segregating groups into identifying target groups (Douglas, 1990; Escobar and Berdegué, 1990; Espinosa, *et al.*, 1990).

The first step in the cluster analysis is to define the variables that determine the types of farms while taking into consideration that a farm system is influenced by the biophysical and socioeconomic environment. The literature lists some descriptors that help to identify the farm groups, including: 1) farm size, 2) level of investment, 3) labour used on- and off-farms, 4) production systems, 5) technology level, 6) land tenancy, 7) soil quality, 8) family income, 9) product markets, 10) geographic conditions, and 12) skill management (Vincent, 1970; Fonseca, 1976; Sánchez, 1980; Berdegué *et al.*, 1990; Douglas, 1990; Duarte, 1990; Dufumier, 1990; Escobar and Berdegué, 1990; Hart, 1990; Landín, 1990a; Landín, 1990b; Miranda, 1990; Suárez and Escobar, 1990; Drösler, 1991).

The study is based on the use of the Cattle Census 2000 (MAG, 2001), that contains geographically located information for almost all Costa Rican farms (MAG, 2001; Corfoga, 2002). This allowed for the selection of farmers inside the study area and by using the SAS program using the command described in Annex I, a cluster analysis was conducted using data presented in Table 3.5.

Table 3.5 - Variables used in a cluster analysis of cattle farms located in the dry forest zone of Costa Rica

Variable name	Description	Type of data
CA	Animal Stocking Rate per farm	Continuous
AREA_FINCA	Farm size	Continuous
AREA_POTRE	Pastureland size	Continuous
BOVINO_TOT	Livestock Unit per farm	Continuous
TOTAL_CARN	Livestock Unit for beef production	Continuous
TOTAL_LECH	Livestock Unit for dairy production	Continuous
TOTAL_DPRO	Livestock Unit for beef and dairy production	Continuous
RÍO	Water supply from rivers	Binary
POZO	Water supply from wells	Binary
ACUEDUCTO	Water supply from irrigation systems	Binary
FORRAJE_HA	Forage crop area	Continuous
MANEPOTRE	Extensive animal management	Binary
ESTABULADO	Intensive animal management	Binary
SEMIESTABU	Semi-intensive animal management	Binary
IN_SAN	Health index	Ordinal
MAN_SAN	Management index	Ordinal
MAN_ALI	Feed index	Ordinal
FERTILIZA	Pasture fertilisation	Binary
ASISTENCIA	Technical assistance	Binary

Source: MAG (2001).

However, it was necessary to correct some variables before conducting the cluster analysis. First, Livestock Units (LU) were calculated using information in Bovino_total and the herd age composition. Conversion factors used are presented in Table 3.6. Once the LU were estimated, the Animal Stocking Rate (AS) was calculated dividing the LU by pasture plus forage area.

Table 3.6 - Conversion factors used to estimate livestock units

Age range	Conversion factors
0 – 1 year	0.25
1 – 2 years	0.50
2 – 3 years	0.75
> 3 years	1.00

Source: Ibrahim (2001)

The variables IN_SAN, MAN_SAN y MAN_ALI were constructed based on the health and feed variables from the Cattle Census and are presented in Table 3.7. The values range from 0 to 3, with 0 being the worst and 3 the best.

Table 3.7 - Health and feed index composition

Variable	Name	Composition
IN_SAN	Health index	IN_SAN=GUSA_BOV + VAMP_BOV + VESIC_BOV
MAN_SAN	Health management	MAN_SAN=VACUNAS + ANTIBIÓTICOS + DESPARASI
MAN_ALI	Feed index	MAN_ALI=HORMONAS + VITAMINAS + MINERALES

Neither the principal compounds nor the canonical variables are used because they do not reduce the number of variables in the analysis. Instead, individual variables are used.

In Addition to the Cattle Census 2000, other cattle censuses were consulted in order to describe the historical conditions of cattle production in the counties of Cañas and Bagaces.

3.2.2 Results and discussion

3.2.2.1 Cattle farm typologies

The cluster analysis identified six groups (Table 3.8). Groups are artificial, implying that they are not a local classification of farms. Information presented here should be considered as an explanation and interpretation of the reality. The main constraint of the analysis is that only ranch characteristics were considered and not the farmer's livelihood. It is possible that a farmer owns more than one ranch, and farms could be grouped into different groups. However, this allows some differential among types of cattle.

Group 1: Represented 33% of the cattle farms, with 175 hectares, 81 LU and 1.1 LU/hectare on average. This group included the largest number of dual-purpose farms (21%); however, 76% of the farms were beef farms. The Brahman breed was the most used, in 83% of the farms. On the other hand, dairy breeds were 10% of the total herd due to the high number of dual-purpose farms. Eighty percent of the farms implement one or two health practices, although 22% of them have two illnesses. Whereas, 99% of the farms gave one or two feed supplements, and 38% of the farms have agricultural production: rice, beans, watermelon, sorghum, and sugar cane. Fifteen percent of the farms have forest plantations, representing 254 hectares. These farms can compete and stay in the national beef market. Forest plantations could be an indication of farmer investment availability.

Group 2: Represented 42% of the farms, with 67 hectares, 24 LU and 1.2 LU/hectare on average. They had a low technology level with 100% of the farms managing the animals in pastures without fertilisation, 68% implemented one health practice and 87% gave one feed supplement. Beef was the main production; however, 7% were dual-purpose farms. Eighty two percent of the farms were dedicated to calving production and 9% to calf fattening. Brahman was in 100% of the farms; whereas, 7% had a dairy breed. Similar to group 1, 32% of the farms had agricultural production: rice, sugar cane, beans, fruits, corn and watermelon. Forest plantations were less important with only 9 hectares of plantation identified. Finally, this group presented the largest number of farms without investment, 41%. These farms have a low technology level and serious problems staying in the national beef market; many farms are being abandoned.

Group 3. Represented 14% of the total population, with 84 hectares, 52 LU and 2.3 LU/hectare on average. Ninety six percent were beef farms and 4% dual-purpose farms; 83% were dedicated to calving production (66% beef and 17% dual purpose). This is the most heterogeneous group, presenting a wide range of technology levels: 3% had an intensive or semi-intensive system, 13% received public technical assistance, 80% implemented one or two health practices, 96% gave one or two feed supplements, 21% had improved pastures and 4% used electrical fences. Twenty five percent were in agricultural activities such as: rice, sugar cane, beans, corn or watermelon. Forest plantations were not important in this group and represented only 0.4% of the area. Like group 2, 36% of farms had low investments. This group includes small cattle farms with low competitive capability. The farms that cannot remain in the national beef market are being abandoned. In some cases, farmers moved to agricultural production; however, irrigation is a limitation.

Group 4: Represented 9% of the farms, with 900 hectares and an average of 360 LU which were dedicated to calf fattening. Conversely, these farms presented a high use of inputs; 53% fertilise pastures, 95% implemented at least one health practice and 100% gave at least one feed supplement. No agricultural crops were reported. Forest plantations represented 13% of the area, with 1000 hectares. Farms in this group had high investment levels making them more competitive and able to stay in the market. Some farms produce beef for international markets.

Group 5: was formed by just one farm with the Brangus breed. Thus, characteristics are similar to group four and are included in group 4.

Group 6: was the only dairy farm in the area, with 208 hectares. Cheese was the principal product. An important characteristic of this farm was the presence of an irrigation system used as the main water supply source.

Table 3.8 - Cattle farm classification in the tropical dry forest zone of Costa Rica (N = 205)

	Unit	Groups				
		1	2	3	4 and 5	6
Farms (total 205)	Number	30	87	68	19	1
Farm size	Ha	175	67	84	936	208
Pasture area	Ha	126	36	66	574	208
Animal stocking rate	LU/ha	1.1	1.2	2.3	0.8	0.5
Livestock Units	Number	81	24	52	368	106
Beef production	%	76	93	96	100	0
Beef and milk production	%	21	7	4	0	0
Milk production	%	0	0	0	0	100
Brahman	%	83	100	100	70	0
Other beef breeds	%	6	0	0	30	0
Dairy breeds	%	10	7	4	0	100
Water supply from rivers	%	100	100	33	95	100
Water supply from wells	%	0	0	73	26	100
Water supply from irrigation systems	%	1	1	20	0	0
Extensive management	%	100	100	97	100	100
Semi-intensive management	%	0	0	3	0	0
Intensive management	%	0	0	3	0	0
Fertilisation	%	0	0	3	53	100
Technical assistance	%	3	3	13	0	0
Health index						
Number of illness %	0	76	84	100	58	100
	1	22	16	0	37	0
	2	1	0	0	5	0
Health index management						
Number of health practice %	0	0	9	13	0	0
	1	25	68	57	5	0
	2	56	18	23	37	100
	3	19	5	7	58	0
Feed index						
Number of feeding practices %	0	0	13	3	0	0
	1	6	87	53	0	100
	2	93	0	43	84	0
	3	1	0	0	16	0

Source: based on the Cattle Census (2001)

According to Villanueva *et al.* (2003a) in the area of Cañas, 64% of the farmers are dedicated to beef production, and 15% are dual-purpose farms. Comparing this typology with our finding, it is clear that the study area is predominantly for beef cattle farms. Our indeed analysis of the characteristics of cattle farms in Cañas and Bagaces made it possible to define the main types of beef cattle farms in the area, allowing for the analysis of their interaction with the forest and tree resources on cattle farms.

Finally, a large percentage of the area was not under agricultural use, 41% of the farms in group 2 and 36% of group 3 were abandoned. Thus, 60% of the area was under agricultural or cattle production, which highlights the importance of forest and tree resources in the area (Table 3.9).

Table 3.9 - Percentage of the cattle farm area under natural regeneration areas in the study area

	1	2	3	4 and 5	Total
Total area	3,009	2,494.0	2,441	7,668	15,820
Pasture area	1,679	840.0	864	4,583	7,991
Agricultural crops	60	42.0	230	11	343
Forest plantation	254	9.0	17	1,000	1,280
Inactive areas	1,016	1,603.0	1,330	2,074	6,206
Inactive/total area (%)	33.8	64.3	54.5	27.0	39.2

It is argued that the intensification has an inverse relationship with the presence of forest and tree resources on cattle farms (Betancourt *et al.*, 2003; Villacís *et al.*, 2003). This argument is discussed on the next section, and then used to define the cattle farmer livelihood strategies.

3.3 DESCRIPTION OF CURRENT TREE USES ON CATTLE FARMS

3.3.1 Introduction

The reduction in cattle activity has created new opportunities for natural regeneration on cattle farms. In Guanacaste, the long dry season and the large extension of rangelands make forest fires a common practice in grassland management. Additionally, low stocking rates are partially responsible for poor grass cover since animals do not consume enough to stimulate grass sprouting. The low intensity of grazing results in an accumulation of dry matter, making the use of fire necessary to stimulate grass germination. When fire resistant weeds dominate pasture, pasture recuperation or natural forest recovery becomes difficult. The control of fires together with animal grazing induces the natural regeneration process (Barboza, 2002; Muchagata and Brown, 2002; Vega, 2002).

Forest recovery after pasture abandonment is not a difficult process. Natural succession processes can be classified into two types: primary and secondary succession. Primary succession occurred in areas without human intervention while secondary succession occurred in areas that suffer various human interventions. Therefore, secondary succession has been induced in studies in the area (Hernández *et al.*, 2002; Muchagata and Brown, 2002).

The natural regeneration process is divided into five stages in the dry forest zone the main characteristics are: 1) open bush or abandoned pasturelands: including four-year old or younger pastures which are being abandoned and dominated by bushes like *Acacia collinsii* and *A. farnesiana*, and tree species like *Guazuma ulmifolia* and *Cochlospermum vitifolium*; 2) closed bush: abandoned pastures that are from four to ten years old, with a dominance of bush species and pioneer trees like *G. ulmifolia*; 3) young forest: from 10 to 15 years old, with the presence of two strata dominated by tree species. 4) Medium age forest: between 15 to 35 years old. This stage is dominated by long life heliophytes species, with an increment in esciophytes species. 5) late secondary forest: older than 35 years old, with an overstory up to 25 m, dominated by long life heliophytes species but a high number of esciophytes (Gonzales, 2002).

Natural regeneration patches are economically viable at 13 years old, with the maximum commercial volume obtained at 50 years. A 225 year old dry forest zone presents zero growth, implying that forest is a climax ecosystem; this point is reached in a rain forest at 190 years (Gonzales, 2002; Monge *et al.*, 2002).

Regarding the management of these forested areas, silvicultural systems consider the species strategy, even- or uneven-aged species (Pinard *et al.*, 1999). Spittler (2002a) compared three different management practices. The first two were monocyclic management systems in the short and long-run, and the third was a polycyclic management system; all systems were studied in three different farm sizes. Additionally, Spittler (2002a) compared the systems with and without incentives. He found that for small farms, incentives are required within three management alternatives. Monocyclic systems with a short–term horizon were the most profitable for large farms; whereas, the monocyclic in the long-run was the most profitable for medium and small farms (Figure 3.7). This suggests that incentives are important for motivating farmers to manage their forest patches.

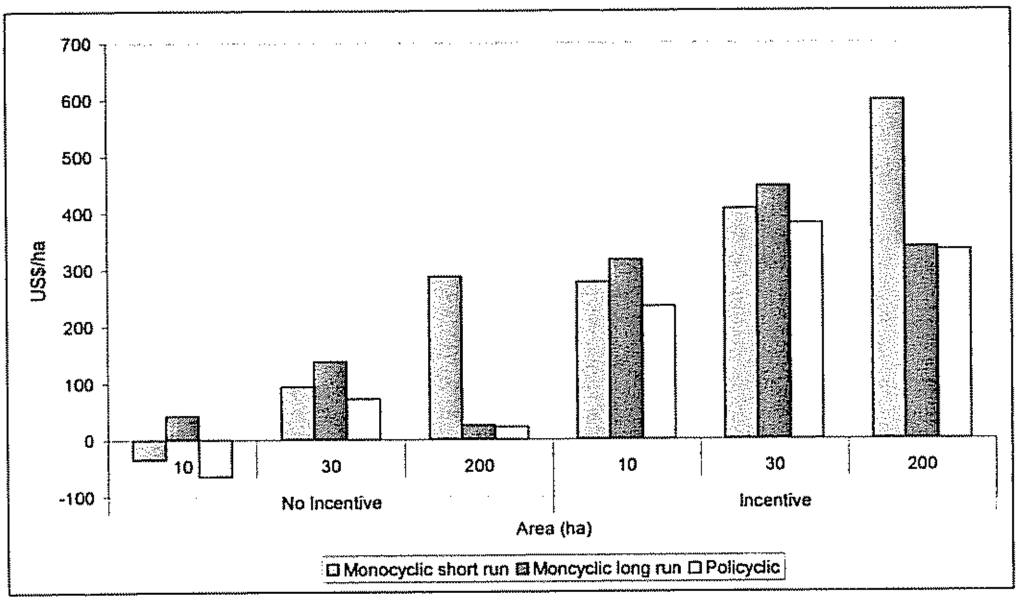

Figure 3.7 - Net Present Value for three alternatives evaluated for management of forest patches in the dry forest zone of Costa Rica

Source: Spittler (2002a)

Another form of forest management on farms is reforestation; however, this is not a common practice on cattle farms. Reforestation programs in Costa Rica have focused on non-native species. Up until 1987, one native species (*Cordia alliodora*) and three exotics (*Gmelina arborea*, *Pinus spp*, and *Eucalyptus spp*) represented 94% of forest plantations in the Atlantic lowlands of Costa Rica. In Costa Rica, commercial plantations have been encouraged by government incentive programs, reaching 14,900 hectares by the end of 1997 (Morera, 2002a; Piotto et al., 2003; Perez et al., 2003).

The other type of the presence of trees on cattle farms is live fences. Some research has been conducted to characterise the use and management of live fences; nevertheless, there is little knowledge about the functional role of live fences within the agricultural landscape (Harvey *et al.*, 2005). Live fences are not only used as farm boundaries, but also to provide forrage to feed livestock, especially in dry areas (Sanchez and Payne, 1987; Flores, 1994; Hernandez and Benavides, 1994; Medina *et al.*, 1994; Petit, 1994; Esquivel *et al.*, 2003; Harvey *et al.*, 2003; Holguin *et al.*, 2003; Muñoz *et al.*, 2003; Harvey *et al.*, 2005).

It is clear that forest and tree resources are becoming an important aspect on cattle farms, and some research has been conducted on the management of natural regeneration areas. However, few studies have been done to define the importance and uses of forest and tree resources on cattle farms. This chapter describes the current situation of forest and tree resources on cattle farms located in the dry forest zone of Costa Rica with a focus on use and management.

3.3.2 Methodology

The methodology considers the sample definition, the survey definition and elaboration, and finally data analysis.

3.3.2.1 Sample definition

A stratified sample was used based on the Cattle Census data. The stratification was conducted in the SAS program using a cluster analysis (Annex I) and the methodology presented for the socio-economic characterisation of cattle farmers in Cañas and

Bagaces. This produced 6 groups which were used to define the sample using Equation 4.

1) $$n = \frac{t^2 s^2}{d^2}$$

Where:

t = Student t value (80% probability)

s = standard deviation of the sample variable

d = error permitted in relation to the average (25%)

The Animal Stocking Rate was used in Equation 1, producing a sample size of 79 farms, distributed according to Table 3.10.

Table 3.10 - Sample size for each group

	Group					
	1	2	3	4	5	6
Population	68	87	30	18	1	1
Sample size	14	23	30	9	1	1
Percentage	21	27	100	51	100	100

After defining the sample, farms were selected using random numbers. Finally, support maps were elaborated with farm locations.

3.3.2.2 Survey definition

A semi-structured interview was used to collect information (Geilfus, 2000). Three thematic topics were defined as: 1) cattle management, 2) tree management and 3) water supply. For each line, a set of basic questions was elaborated and served to guide the interview (Table 3.11). The information was collected from October 29th to November 10th, 2001 using the questionnaire presented in Annex II.

Table 3.11 - Key questions for the semi-structured interview

Farm data	Water supply data	Forest and tree resources
➢ **Farm activities**	➢ **Water supply and use**	➢ **Tree presence**
• Activity type (agriculture, forest, etc),	• Distance from the water source	• Uses and reasons
• Farm size	• Quantity used	• Species
• Irrigation area	• Infrastructure and machinery	• Area
• Annual production	• Water sources	• Environmental service payments
• Cattle production system	• Water prices	➢ **Commercialisation**
➢ **Farm history, future plans**	• Pollution	• How many
➢ **Problems**	➢ **Problems**	• Where
• Credit	• Pollution	• When
• Insurance	• Instability	• Species
• Commercialisation	• Access (property rights)	• Prices
➢ **If you had money, in what would you invest?**	➢ **Strategies during the dry seasons**	• Problems
• Reforestation	➢ **Organisation of water management**	➢ **Silvopastoral systems**
• Others		• Knowledge
		• Management
		• Opinions
		• Pasture

3.3.2.3 Data analysis

The database was created in Microsoft Access 2000 and Microsoft Excel 2000. The dynamic table option was used to estimate percentages and averages according to the sample groups.

ANOVAS were carried out to analyze the continuous variables. This was done in the Program Systat 5.04 for Windows. A 0.1 significance level was used.

Then, four empirical models were run, two Linear and two Logit models. For the linear model, the R^2 and p-values were used to define the functional models. For the Logit model, the prediction power and p-values were observed when defining the functional model.

3.3.3 Result and discussion

The discussion is divided into six parts: first the discussion of natural regeneration areas followed by the trees outside natural regeneration areas. Third the use of silvopastoral systems is explained followed by tree uses on cattle farms. Fifth, the wood market and wood commercialisation is explored, and finally a discussion about tree management.

3.3.3.1 Natural regeneration areas on cattle farms

Throughout the wet tropics, virtually all forests managed for timber rely on natural regeneration as an indirect way to ensure long-term productivity (Guariguata and Saenz, 2002). In the area of study, second growth forest has increased. Seventy eight percent of the cattle farms have less than 25% of the area under regeneration. Group 5 had the highest percentages, followed by group 2 (Table 3.12). This data did not consider dispersed trees in pasturelands which would increase the area under forest cover. The results show that group 4 presented the lowest percentage of area under regeneration. As described earlier, this group had the most active farms including the highest investments. On the other hand, groups 2 and 3 had higher values, and were the groups with the highest rate of inactive farms. The percent of regeneration areas in cattle farms could be an indication of activities.

The increment of forest area occurred at the expense of pasturelands due to the reduction in cattle activity. Pastures have degraded, losing the pasture productivity due to the increase in the forest cover. If beef market tendencies continue, forest areas will increase.

Table 3.12 - Regeneration areas/farm area ratio by farm groups in the dry forest zone of Costa Rica (n = 77)

Regeneration area/farm size (%)	Group (%) 1	2	3	4	5	6	Average
0 – 25	92	60	80	100	0	100	78
26 – 50	8	30	20	0	0	0	18
51 – 75	0	10	0	0	100	0	4

The majority of the farms (82%) have less than 25 hectares in regeneration. Group 5 presents the largest area under regeneration (Table 3.13) due to more intensive cattle management. In this case, intensification leaves areas for natural regeneration. Group 4 presents the largest number of farms with more than 50 hectares in regeneration (38%); however, this represents less than 25% of the farm areas. Exploring the differences across groups, a statistical difference was found between groups 3 and 4, but not between groups 1, 2 and 4 (Table 3.14). The main difference between these groups is due to the high number of inactive farms in the group 3.

Table 3.13 - Regeneration areas on cattle farms by farm groups in the dry forest zone of Costa Rica (n = 77)

Regeneration area (ha)	Group (%)						Average
	1	2	3	4	5	6	
0	38	19	46	25	0	0	33
1 – 25	38	62	50	38	0	0	49
26 – 50	15	10	4	0	0	100	8
51 – 100	0	5	0	25	0	0	4
> 100	8	5	0	13	100	0	6

Table 3.14 - t-test for the natural regeneration area of farm groups in the dry forest zone of Costa Rica (n = 72)

Group	Average*	Standard error	N
1	32[a]	19.94	13
2	24[a]	15.68	21
3	6[ab]	13.58	28
4	91[ac]	25.41	8
5	1,000[d]	71.89	1
6	40[a]	71.89	1

* Different letters, difference at 0.1

For regeneration area/farm size ratio, no statistical differences were found. Nevertheless, groups 2 and 3 present the largest proportion of area in regeneration (Table 3.15). Group 4 presents the lowest proportion of area under regeneration; thus, in traditional cattle production, forest cover and pasturelands are inversely correlated, meaning that an increment in one implies a reduction in the other.

Table 3.15 - t-test for the natural regeneration area/farm size ratio according farms groups in the dry forest zone of Costa Rica (n = 72)

Group	Average* (%)	Error standard	N
1	9[a]	0.06	13
2	25[a]	0.05	21
3	14[a]	0.04	28
4	7[a]	0.08	8
5	50[a]	0.21	1
6	19[a]	0.21	1

* Different letters, difference at 0.1

One reason for the presence of regeneration areas on cattle farms is the low investment level. Groups 2 and 3 present the highest percentages of regeneration areas and the lowest investment level. In group 2, 38% of the farms did not have any investment and 36% for group 3 (Figure 3.8).

Fifty four percent of the farms surveyed were engaged in cattle production; whereas 25% of the farms did not have important economic activities. This could be an indication of a cattle production crisis because owners are not interested in production as they are reducing the investment level and leaving pasturelands for natural regeneration.

It was found that regeneration areas were largest on the active farms although natural regeneration areas and natural regeneration/farm size ratios did not present any statistical difference. However, when considering the ratio, there was a higher rate of regeneration areas in the inactive farms (Table 3.16). This is produced by the intensification in groups 4 and 5 which had the highest percentages of active farms. These large farms used natural regeneration as a fallow to improve soil and grassland quality.

Twenty two percent of the area with inactive farms was in forest regeneration. The minimal forest and tree resource cover in these farms is due to the methodology used because the regeneration area was quantified by farmers and could be underestimated. In the case of the abandoned farms, there were a lot of degraded pastures which could increase the area under regeneration up to 75% of the ranch.

Table 3.16 - Average regeneration area and regeneration area/farm size rate according to economic activity on cattle farms in the dry forest zone of Costa Rica (n = 77)

Variable	Category	Average	Standard error	N
Regeneration area (ha)	Inactive	16	31.11	18
	Cattle	41	22.80	34
	Agriculture	33	34.21	15
	Both	132	60.07	5
Regeneration area/farm size rate (%)	Inactive	22	0.05	18
	Cattle	13	0.04	34
	Agriculture	20	0.06	15
	Both	6	0.10	5

The model estimated an explanation of the cattle farm sizes in the dry forest zone as a function of pastureland areas, natural regeneration areas, forest plantation and areas under environmental service payments and a significance of 0.00 (Table 3.17). The technical marginal substitution rate (TMSR) is $TMSR(KforL)=\partial K/\partial L|q=q_0$ (Nicholson, 1997); therefore, TMRS (regeneration areas for pasture) was 0.61, implying that from each hectare of pastureland, 0.61 hectares came from natural regeneration areas, the other came from degraded pasture. For forest plantations the TMRS (regeneration for plantations) was 0.77 and the TMSR (pasture for plantation) was 1.26, implying that it is better to use the natural regeneration areas for forest plantation. However, the combination of areas in cattle ranching depends on the revenues obtained for the different land uses (Monterroso, 2005). The TMRS gave a measure of how farmers would tend to change the land use on their farms when one factor changed.

Table 3.17 - Linear model estimated explanation of cattle farm sizes in the dry forest zone of Costa Rica (R^2 = 0.79; n = 77)

Variable	Coefficient	Standard error	P values
Pasture areas	1.25	0.13	0.00
Natural regeneration areas	0.77	0.27	0.01
Forest plantations	0.99	0.28	0.00
Environmental service areas	-2.25	0.40	0.00

Farmer dependency on cattle production would probably be related to farm size. Normally farms were owned by non-resident farmers, who demand low labour costs (Peters, 2001). To evaluate this hypothesis, a Logit model was run (Table 3.18). The model presented a Log likelihood ratio of - 40.75, a chi square value of 9.9 and a significance level of 0.04. It was found that the livestock units, forest plantation and rainfall had a direct relationship to farmer dependency on cattle activities. Whereas, pasture areas and land tenure had an inverse relation. These findings show a high variation in the conditions of cattle production in the area. It is not possible to argue that the largest farms did not depend on cattle production because an increase in livestock units increased the probability of finding a dependent farmer. Whereas, area had a contrary effect; an increase in area reduced the possibility of finding a dependent farmer. Therefore, the adoption of new technology would probably increase with dependent farms because they tend to have more intensive systems.

Table 3.18 - Marginal effects of the Logit model estimated explanation for farmer dependency on cattle farms in the dry forest zone of Costa Rica (n = 63)

Variable	Coefficient	Standard error	P value
Livestock units	0.0037	0.002	0.11
Pasture areas	-0.0019	0.001	0.09
Forest plantation areas	0.0019	0.001	0.05
Land tenure	-0.1475	0.071	0.04
Rainfall	0.0002	0.000	0.20

Some farmers own farms to ensure their capital through land investment. So, they are not interested in cattle production, but in land markets. Some farmers mentioned that they can earn up to 25% in interest just trading land. This rate is higher than the passive bank rate, which is around 12%. Therefore, these farmers were not really interested in investing in cattle production since this activity was only a way to ensure their land tenancy. Their goal is to obtain enough profit to pay the manager.

It was found that the main activity in natural regeneration areas was livestock grazing, especially during the dry season (39%). However, 28% of farmers did not feed their animals in the natural regeneration areas (Table 3.19). As mentioned, forage production in natural regeneration areas was one of the main strategies for feeding animals during the dry season.

Table 3.19 - Percentages of farmers that use natural regeneration areas to feed their cattle, of cattle farms located in the dry forest zone of Costa Rica (n = 77)

Pasture season	Group						Total
	1	2	3	4	5	6	
Both seasons	31	43	32	63	0	100	39
No pasture	23	29	32	13	100	0	28
Dry season	31	24	14	13	0	0	19
Wet season	15	5	21	13	0	0	14

A direct relationship was observed between the natural regeneration areas and livestock units (LU) on cattle farms (Table 3.20). Two production functions were tested in explaining the Livestock Units on cattle farms, the Cobb-Douglas and a linear production function. The linear model was more accurate. The Cobb-Douglas presented an $R^2 = 0.65$, while the linear model an $R^2 = 0.81$. According to the model, one hectare of a forest patch can support 0.10 LU. Therefore, the TMSR (pasture for regeneration) is 3.5, implying that a hectare of pasture can support 3.5 LU for one of the regeneration areas.

Table 3.20 - Linear model estimated explanation of the livestock units in cattle farms located in the dry forest zone of Costa Rica ($R^2 = 0.81$; n = 77)

Variable	Coefficient	Standard error	P value
Pasturelands	0.35	0.02	0.00
Natural regeneration areas	0.10	0.04	0.01
Forest plantation areas	-0.14	0.04	0.00

Although the study did not include a forest survey, other researchers have conducted studies in natural regeneration areas. It was found that regeneration areas contain from 2,438 to 5,921 trees/hectare and an average of 39 species/hectare. On average, these forest patches have 96.81 m^3/hectare, a basal area of 18.57 m^2/hectare with an increment of 0.99 cm/hectare/year and a Diameter at Breast Height (DBH) of 11.9 cm, whereas grasslands can support up to 25 trees/hectare from 190 species. In pasturelands, 5,583 trees from 190 species were found with a density of 25 trees/hectare. The most common species were *Cochlospermum vitifolium*, *Quercus oleoides*, *Luehea speciosa* with more than 50 trees/hectare. The most abundant commercial species were: *Cordia alliodora*, *Lysiloma divaricatum*, *Lysiloma* *demostachys*, *Manilkara chicle*, *Simarouba glauca*, *Astronium graveolens*, *Hymenaea courbaril* and *Manilkara zapota* with more than 10 trees/hectare. Whereas, *Swietenia macrophylla*, *Genipa americana*, *Dalbergia retusa*, *Bombacopsis quinata*, *Anacardium excelsum*, *Tabebuia impetiginosa*, *Tabebuia ochracea*, *Minquartia guianensis*, *Tabebuia rosea*, *Ceiba pentandra*, *Brosimum alicastrum* presented less than 10 trees/hectare. Other important species in the dry forest zone are *Guazuma ulmifolia*, *Caltcophyllum candidissimum*, *Licania arborea*, *Luehea candida*, *Brosimum alicastrum*, *Bombacopsis quinata*, *Tabebuia rosea*, *Sapium glandulosum*, *Spondias mombim* and *Bursera simaruba* (Fonseca and Meza, 2002; Hernández *et al.*, 2002; Molina, 2002; Monge *et al.*, 2002; Morera, 2002b; Pandey, 2002).

The importance of species changes with successional stages (Table 3.21). For example *G. ulmifolia* maintains its importance throughout the succession process; however, the maximum occupation occurred between the 15 and 22 year-old trees (Gonzales, 2002). Other species like *Cordia alliodora*, *Bursera simaruba* and *Cedrela odorata* enter later into the succession, only in the second stage. Therefore, for correct management of forest patches, it is important to have a tree species survey, and if it is possible, a dynamic study.

Table 3.21 - Importance position index (IPI) of trees species according to the natural successional stage in the dry forest zone of Costa Rica

Scientific name	Stage				
	Open bush	Closed bush	Young forest	Medium forest	Late secondary forest
Guazuma ulmifolia	2	1	1	2	7
Cohlospermum vitifolium		2	2	1	11
Cordia alliodora		7	3	3	26
Lonchocarpus minimiflora	14	10	13	10	
Bursera simaruba		9	30	16	2
Spondias mombin		36	15	10	5
Bauhinia ungulate		27	7	11	33
Bauhinia manca		26	24	17	17
Acacia collinsii	1		11	28	47
Cordia bicolour	4	9	20	58	
Tabebuia ochracea		37	34	5	20
Hymenea courbaril		23	12	41	32
Tabebuia impetiginosa		21	26	18	52
Diphysa Americana	4	19	27	36	40
Enterolobium cyclocarpum	6		22	64	49
Cederla odorata		13	47	44	56
Brosimum alicastrum					1
Acacia farnesiana	3		58		
Total number of species	8	39	63	68	64

Source: Spittler (2002b).

Most of the natural regeneration areas were younger than 20 years old. It is expected that biodiversity in the area would increase because it was found that the number of species increases with forest age. In the initial stage, only 8 species were found, whereas the primary forest can have more than 65 species (Gonzales, 2002; Spittler, 2002b). The young age of natural regeneration areas implies that tree diameters are smaller than 10 cm (Table 3.22). To obtain trees with a Diameter at Breast Height larger than 30 cm, the minimum accepted by sawmills, more than 100 years are required. In most cases, more than 50 years are required to obtain wood for sawmills (Spittler, 2002b). Nevertheless, the optimal rotation in natural forest is a function of the technology used (Marozzi, 2002).

Table 3.22 - Time required to change the diameter classes of tree species in the dry forest zone of Costa Rica, Palo Verde, 1999

Diameter class	Annual diameter increase (mm/year)	Change time (years)	Total age (years)
0 – 10	3.22	31.06	31.06
10 – 20	2.36	42.38	73.44
20 – 30	2.80	35.70	109.14
30 – 40	3.16	31.62	140.76
40 – 50	2.74	36.46	177.22
50 – 60	5.85	17.09	194.31
60 – 70	4.17	23.98	218.29
70 – 80	4.45	22.45	240.74
80 – 90	6.03	15.58	256.32
> 90	6.03	Na	Na
Average	4.13	-	-

Source: Monge *et al.* (2002).

Finally, researches found that the natural regeneration process in the area is good, presenting the typical inverse J-shape (Figure 3.8). Only Monge *et al.* (2002) reported a lack of individuals in the smallest diameter class. This type of behaviour makes it possible to use polycyclic systems; the final product of these systems could be hardwood obtained in approximately 50 years; however, poles and firewood can be obtained as intermediate products.

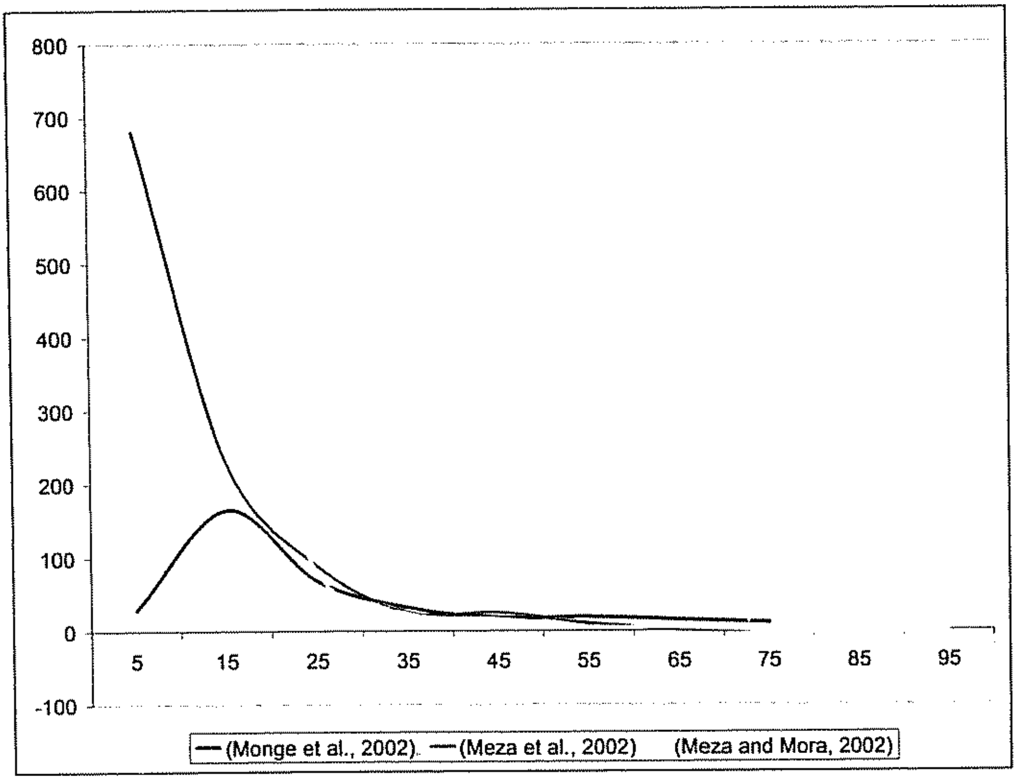

Figure 3.8 - DBH distribution of tree species in natural regeneration areas in the dry forest zone of Costa Rica

Source: based on Monge *et al.* (2002), Meza *et al.* (2002) and Meza and Mora (2002)

3.3.3.2 Trees outside natural regeneration areas

Trees outside natural regeneration areas were presented as dispersed trees in grasslands or forest plantations. However, the presence of forest plantations was low. Only 15% of the farms had forest plantations of less than 10 ha with the largest in groups 1 and 4 with more than 250 hectares (Table 3.23). In most cases the plantation was a product of government incentives like "Certificados de Abono Forestal (CAF)" or recently the environmental service payments (PES) (Sanchez, 2002).

The initial even-aged forest plantation in Costa Rica was created in the 1930s with the plantation of *Cupresus spp* in Heredia. In the 1940s, *Tectona grandis* plantations started in the central and south pacific. However, forest research began in 1942 with the creation of IICA, and since 1943 IICA and CATIE have introduced more than 250 tree species (Mora, 2002).

Table 3.23 - Area under forest plantation on cattle farms in the dry forest zone of Costa Rica (n = 77)

Forest plantation area (ha)	Groups (%)						Total
	1	2	3	4	5	6	
0	83	86	82	88	100	100	85
1 – 10	8	14	18	0	0	0	12
> 250	8	0	0	12	0	0	3

It was reported that planting trees is usually not the most rational way to respond to wood scarcities. Thus, the lower reforestation rates in recent years can be attributed to the low price of wood products, lack of knowledge about wood markets, the reduction of payments, bad experience with forest plantations in previous years and finally the importation of low priced wood. However, trees grow faster in forest plantations than in the natural forest (Dewees, 1989; Mora and Meza, 2002; Sanchez, 2002).

The main distribution of trees outside natural regeneration patches was dispersed in pasturelands. Survival and growth of woody species in tropical pastures may be limited by a number of factors, including competition with grasses, seasonal drought, herbivores and leaf cutter ants (Holl and Quiros-Nietzen, 1999). However, this kind of distribution was dominant in all groups with group 3 having the lowest percentage of dispersed trees. The second spatial arrangement was live fences (Table 3.24).

Table 3.24 - Spatial distribution (%) of trees outside natural regeneration patches in cattle farms in the dry forest zone of Costa Rica (n= 77)

Spatial arrangement	Group (%)						Total
	1	2	3	4	5	6	
Dispersed	91	90	76	100	100	100	86
Dispersed and live fences	9	5	4	0	0	0	5
Live fences	0	5	4	0	0	0	3
Plantations	0	0	8	0	0	0	3
Patches	0	0	4	0	0	0	2
Dispersed and plantations	0	0	4	0	0	0	2

Trees and forest resources on cattle farms are a product of natural regeneration or remnants from the original forest. In both cases, farmers did not make any investment in order to obtain trees. Nevertheless, farmers did not plant trees in pasturelands, since natural regeneration in the area is good (Villanueva *et al*, 2003b).

3.3.3.3 Silvopastoral systems

When farmers were asked about the presence of silvopastoral systems, most of them (70%) did not recognise any silvopastoral system on their farm. The silvopastoral systems identified in the area were live fences and windbreaks. However, according to the literature, dispersed trees and grazing in natural regeneration areas can be classified as silvopastoral systems (Pezo and Ibrahim, 1998). Since farmers did not consider these systems as silvopastoral, in this section only those systems identified by farmers are discussed (Table 3.25). The most important system was live fences which were reported by 12% of the farmers. The importance of fences within groups varies, group 4 having the highest presence of live fences.

Table 3.25 - Presence of silvopastoral systems (%) from the farmers' point of view on cattle farms in the dry forest zone of Costa Rica (n = 77)

Silvopastoral system	Group (%)						Total
	1	2	3	4	5	6	
None	62	81	68	75	100	100	70
Live fences	15	10	7	25	0	0	12
Border fences	8	10	7	0	0	0	8
Border fences and interior fences	8	0	14	0	0	0	7
Live fences and windbreaks	8	0	0	0	0	0	1
Windbreaks	0	0	4	0	0	0	1

Although windstorms are common in the area, the use of windbreaks was low. Perhaps one reason is the type of production. It is possible that wind did not affect beef production as much as dairy production. Since beef production was the main activity in the area, farmers were not as interested in establishing windbreaks as they were in dairy production areas like Monteverde. Winds are strongest during the dry season, when grasses are dry and are not growing. Therefore, wind did not affect pasture production because the limitation is not wind but rainfall. Furthermore, beef breeds are tolerant of windy conditions. So, when winds affect dairy livestock, the effect could be observed the day after the windstorm. However, beef production is different because the effect cannot be observed immediately. Finally, natural regeneration areas can function as windbreaks, reducing wind speed. Then, this could be another service provided by natural regeneration areas to ranching. Therefore, farmers did not have any incentive to establish windbreaks. Although this argument is not discussed in silvopastoral literature, it is clear that farmers in the study area are not concerned about windstorms.

Additionally, farmers were not aware of silvopastoral systems because most farmers (78%) did not plan to establish them. Farmers were more interested in establishing forest plantations than silvopastoral systems (Table 3.26). The reason could be the lack of knowledge about silvopastoral systems and the expectation of receiving incentives for establishing the forest plantation.

Table 3.26 - Farmer interest for investment in their farms in the dry forest zone of Costa Rica (n = 77)

Investment	Group (%)						Total
	1	2	3	4	5	6	
None	62	86	82	75	100	100	79
Forest plantation	31	14	18	25	0	0	19
Silvopastoral systems	8	0	0	0	0	0	1

Gobbi and Casasola (2003) argued that silvopastoral systems can increase farm profitability by 20%. However, silvopastoral systems increase labour costs by 42%, which can be the main constraint for their adoption. On the other hand, these systems reduce the cost of feeding animals. Nevertheless, the impact of the silvopastoral systems on the production demand at least 10 years to be reached thus limiting the adoption by farmers.

3.3.3.4 Tree uses on cattle farms

Trees on cattle farms are common in the area as farmers reported that they have trees on their farms. Trees provide a wide range of benefits for livestock production. Farmers reported 56 species from 19 families, with the *Anacardiaceas* and *Fabaceas* being the most common. Spittler (2002b) found that farmers in dry areas used 87 species for non-wood products and 50 for wood products (Annex III).

Wood species can be grouped into different forms. One classification considers the growth rate; where trees are grouped into fast, medium and slow growing species. Woodchips and plywood typically come from fast growing species or including *Schizolobium parahyba*, *Ceiba pentandra*, *Pseudobombax septenatum*, *Vochysia* *ferruginia*, *Vochysia guatemalensis* and *Virola koschnyi*. The rotation period of these species is from 15 to 20 years (Chinchilla and Mora, 2002).

The second group, medium growing species, is good for building furniture and it includes: *Bombacopsis quinata*, *Terminalia oblonga*, *Cedrela odorata*, *Sweitenia macrophylla*, *Cordia alliodora*, *Hyeronima alchorneoides*, *Terminalia amazonia*, *Tabebuia rosea*, *Enterolobium cyclocarpum*, *Phitecelobium saman*, *Albizzia guachepele*, *Carapa guianensis*, *Calophyllum brasiliense* and *Sterculia apetala*. Their rotation period is from 25 to 40 years (Chinchilla and Mora, 2002).

Finally, the slow growing species are more durable and harder than the others. They are good for construction and furniture. They include: *Guayacan sanctum*, *Dalbergia retusa*, *Hymenea courbaril*, *Astronium graveolens*, *Vatairea lundelli*, *Minquartia guianensis*, *Dipteryx panamensis*, *Lecythis ampla*, *Peltogyne purpurea* and *Platysmicium pinnatum*. The rotation period is from 45 to 60 years (Chinchilla and Mora, 2002).

Another classification is based on wood characteristics. These include: 1) high value wood species, 2) less valuable wood species, 3) wood species for general uses and 4) economic potential wood species (Table 3.27).

Farmers classified four species in the group of high value wood species. The wood from these species is well known and traded in national and international markets. The wood can be used to make furniture. Some species, like *Swietenia humillis*, have pest problems which reduce the possibility of commercial plantations. This species is catalogued as endangered; planting in commercial plots could be one alternative for producing this excellent wood.

On the other hand, *Cordia alliodora* is an abundant species with good regeneration in pasturelands. *C. alliodora* is a *Boraginaceae*, a native in tropical America; it is 40 meters tall and has a diameter larger than one meter. The annual increment in diameter is 1.5 cm/year. In the dry forest zone, this species grows smaller and in less valuable shapes than in wet areas. Soil characteristics greatly influence the establishment and development of trees. Grasses with aggressive growing strategies are difficult to overcome; however, weed control can resolve the problem (CATIE, 1994; Calvo and von Platen, 1996; Luján *et al.*, 1996).

Table 3.27 - Wood species mentioned by farmers in the dry forest zone of Costa Rica (n = 77)

High value wood species	Less valuable wood species	Wood species for general uses	Potentially economic wood species
Cedrela odorata	*Bombacopsis quinata*	*Andira inermis*	*Calycophyllum candidissimum*
Cordia alliodora	*Enterolobium cyclocarpum*	*Astronium graveolens*	*Cochlospermum vitifolium*
Dalbergia retusa	*Hymeneae courbaril*	*Brosimum alicastrum*	*Spondias purpúrea*
Swietenia humillis	*Tabebuia rosea*	*Bursera simaruba*	
		Byrsonima crassifolia	
		Samanea saman	
		Spondias mombin	

Fuentes: Holdridge and Poveda (1975), Pérez *at al.* (1980), Wellwood (1988)

The less valuable wood species are generally traded locally. Four species were included in this group; two of them are commonly planted, *Bombacopsis quinata* and *Tabebuia rosea*.

Wood species for general uses were the seven most mentioned species included in this category. These species are traded locally, and not in international markets. Uses ranged from furniture to railway poles. Their texture is fine with a few imperfections. Nevertheless, only *Samanea saman* was mentioned as a woody species, implying poor farmer knowledge about non-traditional wood species. The majority of the species are abundant or highly abundant, only *Samanea saman* was catalogued as scarce. This group contains species with high potential for further research.

The last group, the potentially economic wood category has 3 species. The use of the wood from these species is more restricted and recommended more for construction and plywood elaboration. The physical characteristics ranged from softwood (*Cochlospermum vitufolium*) to hardwoods (*Calycophyllum candidissimum*).

The main use of trees on cattle farms is related to cattle production since 48% of the uses mentioned by farmers include forage production or shade. This was a result of the rainfall distribution, which is very concentrated during the year and constrains the growing of grasses in the dry season. Trees are a good forage source for livestock as well as a source of shade and firewood.

The use of trees in live fences or posts represented 25% of the response. It was found that farmers use more dead wood posts than live posts. The reason could be weather conditions because in dry areas dead wood posts last longer than in wet areas. Thus, the cost of maintaining a fence with dead wood posts is lower than in the dry tropical forest. Additionally, the costs of maintaining live fences are higher than the costs of maintaining a fence with dead wood posts. These conditions can be observed in the Aguan Valley in Honduras where the CATIE/NORUEGA project is working. In the wet areas, it is common to use live fences but it is not common in the dry areas of the valley.

Eighteen species were mentioned for feeding cattle, with *G. ulmifolia* being the most common (57%). All farms reported the use *G. ulmifolia* as a source of forage, using their leaves and fruits. The fruits are especially used during the dry season, providing alternative forage to livestock (Araya *et al.*, 1994; Hernandez and Benavides, 1994; Medina *et al.*, 1994; Petit, 1994). The nutritional characteristics of *G. ulmifolia* were well documented, having from 15 to 23% protein, depending on the part of the plant consumed. The fruits can provide from 7 to 12% protein (Brewbaker *et al.*, 1989; Araya *et al.*, 1994; Flores, 1994; Medina *et al.*, 1994; Petit, 1994). Another species generally used for feeding animals is *G. sepium*, which contains around 20% protein in the leaves (Sanchez and Payne, 1987; Petit, 1994). This quantity of protein can be compared to those in concentrates; however, they are cheaper.

For wood production, 19 species were mentioned as wood species: *Cordia alliodora* (18%), *Bombacopsis quinata* (17%), *Tectona grandis* (13%), *Cedrela odorata* (7%) and *Hymenaea courbaril* (7%) are the most important species. *C. alliodora* was the most cited species due to its highly valuable wood and abundance. Therefore, *C. alliodora* has high research potential for dry tropical forest grassland management.

As mentioned early, the principle distribution of trees in grasslands is dispersed. Twenty six species of trees that provide shade to cattle were reported. The most common is

Enterolubium cyclocarpum (21%), then *C. alliodora, B. quinata* and finally *Sideroxylum capiri*.

In pole production, there is a high preference for *Gliricida sepium* (55%), follow by *G. ulmifolia* and *Lysiloma divaricatum*. In general, the species used in pole production do not have highly valuable wood. Most of the posts were obtained from tree pruning or harvest. This product improved the cash flow of cattle farms and could be a viable alternative for forest management on cattle farms.

The use of live fences was not common in the area; thus, only 9 species were reported: *Bursera simaruba* (22%), *G. sepium* (23%) and *Spondias purpurea* (19%) were the most common. The use of highly valuable wood species in fences is not recommended because of the damage caused by nails and cables.

The last use mentioned was the production of firewood. Although firewood was not an important energy source in Costa Rica, some farmers mentioned it. Eleven species were reported as good for firewood production. The most cited were: *Calycophillum candidissima* (17%), *Byrsonima crassifolia* (17%), *G. sepium* (12%) and *L. divaricatum* (12%).

3.3.3.5 Wood market and commercialisation

Although farmers used trees to obtain wood for self-utilization, commercial harvest was not common. None of the farmers have commercially harvested, either for wood or for posts; these findings are similar to Villanueva *et al.* (2003). The reasons could be:

- The age of the natural regeneration patches: most of them are younger than 10 years old; therefore, the diameters are not large enough for sawmills.
- Farmer criteria: according to most farmers, they leave natural regeneration patches as protected areas and they appear not to be interested in commercial harvest.
- Farms are self-sufficient: apparently farms are self-sufficient in wood supply. They harvest wood for their own consumption, but they are not interested in commercial trade.

- It appears that most of the wood in the area came from Upala and Los Chiles which are areas with some forests. These areas are now harvested for wood. Wood supply in the area seems sustainable.

Most farmers are self-sufficient in wood supply. Trading wood and posts is not common and only 7% of the farmers bought wood or posts. However, group 4 presented a different trend; farmers from this group bought more wood or posts than other groups. These farmers are the most active in cattle production and have a high investment. Additionally, this group had the highest percentage of farmers that did not depend on their farms, making it possible to have the natural regeneration areas as protected areas and not for forest products. Thus, farmers prefer to buy forest products rather than harvest from their own property.

According to 54% of the interviewees, there was no problem harvesting wood on cattle farms. Twenty seven percent of the farmers said the main problem in forest activity was obtaining permission from the Ministry of Energy and the Environment (MINAE) (Table 3.28). They cited the bureaucracy of MINAE and the cost of the Forest Management Plan as reasons for the reduction in farmer willingness to manage and trade forest products. It was mentioned that the cost of a forest management plan can be higher than the revenue provided by forest activity. Evidence indicates that small farmers find it difficult to meet the additional costs associated with sustainable forest management (CIFOR, 2001). However, when farmers wanted to harvest wood or posts for their own consumption, generally they did it without permission from MINAE. This is possible because of the lack of enforcement by MINAE in transporting wood products.

Table 3.28 - Main forest harvest problems mentioned by farmers in the dry forest zone of Costa Rica

Forest problems	Group (%)						Total
	1	2	3	4	5	6	
No problems	60	69	38	50	100	100	54
MINAE permission	20	13	29	13	0	0	20
Forest fires	0	13	19	0	0	0	11
Lack of knowledge	10	6	10	0	0	0	7
MINAE permission and fires	10	0	5	25	0	0	7
Land tenancy	0	0	0	13	0	0	2

3.3.3.6 Tree management on cattle farms

As mentioned before, forest and tree resources on cattle farms were a function of cattle production. Management of these resources is based on cattle activity demand and not on the trees themselves. It was found that 45% of farmers did not knowingly manage trees. Normally, trees are left to grow naturally without intervention. The same was reported by Holguin *et al.* (2003), Villanueva *et al.* (2003a), and Villanueva *et al.* (2003b).

The most common practice in forest management was pruning which was done by 36% of the farmer interviewed (Table 3.29). However, for cattle production, trees were mainly pruned when they interfere with grass growth. Similar observations were found for weed control.

Table 3.29 - Main forest practices conducted on cattle farms in the dry forest zone of Costa Rica (n = 77)

Activities	Group (%)						Total
	1	2	3	4	5	6	
None	25	40	57	50	100	0	45
Pruning	42	15	9	25	0	0	18
Weed control	8	20	13	13	0	0	14
Pruning and weed control	8	15	13	0	0	100	12
Pruning and other activities	0	5	9	13	0	0	6
Other activities	17	5	0	0	0	0	5

3.3.4 Conclusions

The reduction of cattle production in the dry forest of Costa Rica has increased the forest and tree resources on cattle farms. The presence of tree resources complements livestock production because forest and tree resources provide forage during the dry season. However, an inverse relationship between forest patches and grasslands was found, implying that expansion of grasslands demands the reduction of forest patches.

The main reason to tolerate forest and tree resources on cattle farms is cattle production, especially forage production. It was found that forest patches can support one third of the stocking rate supported by pasturelands, possibly with lower costs than grasslands. Therefore, the main spatial tree distribution on cattle farms is dispersed in pasturelands, contributing to the production of forage and shade for livestock in paddocks. For this reason tree management is a function of cattle management.

Fifty six tree species were reported, and 18 of them were used for forage production. *G. ulmifolia* was the most common species used for forage production, mainly for the production of fruits during the dry season. Due to the dry condition of the area, the use of forest areas for browsing the animals during the dry season is a rational strategy. The main reason is the low opportunity cost of forest areas and the high cost of maintaining paddocks clear of forest regeneration.

The presence of forest and tree resources increases in those farms with more extensive production systems. As farmers use the land more intensively, forest and tree resources tend to decrease due to the trade-off between forest resources and the productivity of the grasses. This represents the relationship between forest areas and paddock, which are inversely related. The new tendency of the reduction in cattle production results in the increase of forest areas, and possibly an increase in cattle production could decrease forest areas. However, there are other socioeconomic factors that affect this relationship and they will be discussed later in the dissertation.

Chapter 4

EXOGENOUS DRIVING FORCES OF FOREST AND TREE RESOURCE MANAGEMENT ON CATTLE FARMS IN THE DRY FOREST ZONE OF COSTA RICA

4.1 GEOGRAPHIC AND SPATIAL FACTORS GOVERNING THE DISTRIBUTION OF DAIRY AND BEEF FARM DISTRIBUTIONS IN COSTA RICA

4.1.1 Introduction

Economic activity is influenced by spatial phenomenon. A necessary step toward a better understanding of the phenomenon is to map spatial patterns (Sutton and Constanza, 2002). Recent improvements in geographic information systems (GIS) have allowed for the development of spatial models that combine cartographic and geo-referenced census data. In agricultural economics, these models aim to identify spatial relationships between agricultural activities and a set of driving forces that may explain their location. The literature shows some important examples of Anselin and Hudak (1992); Chomitz and Gray (1996); Nelson and Hellerstein (1997); Mertens and Lambin (1999); Schaffer (1999); Nelson *et al.* (1999); Baritto (2000); Mertens *et al.* (2001); Rodríguez (2001); Méndez (2001); Vance and Geoghegan (2002); Mertens *et. al.* (2002); Bell and Irwin (2002); Haustsch and Klotz (2002); Nelson and Geoghegan (2002); Michel *et al.* (2002); and Muller and Zeller (2002).

Chomitz and Gray (1996) and Nelson and Hellerstein (1997) pioneered modelling land use changes by focusing on deforestation of tropical areas as a function of specific site characteristics as conceptualized by von Thunen as land rent (measured through access cost). The main land use change in Latin America has been the conversion of forest into pasturelands, especially from the 1950s to the 1980s (Vaughan and Mo, 1994; Kaimowitz, 1996; Campos *et al*, 2001; FAO, 2001).

Land rent reflects the profit gain due to the proximity of the production unit to its market. The closer one is to the market, the higher the land rent (Polèse, 1998; Nelson, 2002). The theory implies that economic activities are influenced by the distance from markets; therefore, more intensive and profitable production would by located near markets. As we move away from markets, less profitable and intensive economic activities would take place. Additionally, geographic characteristics presented a spatial distribution which also affects the production units. The combination of both, spatial (distances) and geographic (soil characteristics, weather, topography, etc) allow for an analysis of the underlying factors for the spatial distribution of the economic activities.

This chapter is based on the von Thunen theory of land rent for assessing how location and productivity of dairy and beef cattle production systems, rather than land uses, are influenced by site characteristics and the cost of access to cattle and dairy markets. In agricultural areas with stable land uses, one can analyze variation within a land use in terms of differences in technology, modelling spatial relationships based on land rent theory. Based on this rationale, the paper aims to develop a land model that assesses the effect that a set of biophysical and spatial variables have on the location and productivity of beef and dairy units in Guanacaste and Costa Rica. Modelling combines national cartographic data with geo-referenced data from the Cattle Census 2000 (MAG, 2001). This paper tested the following hypotheses:

- The most input intensive cattle production systems have higher land rent
- The most input intensive cattle production systems are more sensitive to spatial and geographic factors than less intensive systems
- Geographic and spatial factors affect the technology level more for the low intensive production system
- Dairy farms are more input intensive than beef cattle farms

A discussion of the economic theory upon which the paper is based is presented, including a section on Tobit modelling. It describes Cost Rica with its current cattle production systems. Later, methodology dealing with the geographic and spatial analysis is introduced, and the paper finishes with a presentation of the results and discussion of the findings.

4.1.1.1 Spatial economy and land rent

According to Nelson and Hellerstein (1997), the choice of a specific type of production system is defined by the comparison between the different net present values of all possible production systems present (Equation 5).

$$2) \qquad R_{hLT} = \int_{t=0}^{\infty} (P_{hLT+t} Q_{hLT+t} - C_{hLT+t} X_{hlT+t}) e^{-it} dt$$

Where R_{hLT} is the net present value, P is the product price, Q is the amount produced, C is the input cost vector, X is the input vector, *i* is the discount rate, h is the type of production system defined by a production technology, L is location, and T is time.

We assume Q_h is a Cobb-Douglass production function with an index of parcel-specific geophysical factors (G_L), such as soil type and elevation that affect productivity. Therefore, Equation 6 states that each farmer has a production function that is multiplied by a productivity factor from site conditions, where Q_h is the amount of production for a given technology h, G_L is an index of site factors affecting productivity, L refers to each plot, X_i are the production inputs.

$$3) \qquad Q_h = G_L \prod_j X_j^{\alpha_{nj}}$$

The production technology has the following restrictions:

$0 < \alpha_{nj} < 1 \Rightarrow$ Production factors are inelastic

$0 < \Sigma_j \alpha_{nj} < 1 \Rightarrow$ Productivity is scale decreasing

$G_L = \prod_{r=1}^{R} G_R^{\eta_r}$ is a multiplicative combination of site factors (Factors such as soil fertility, rainfall, dry months, etc) affecting production technology.

In most cases when dealing with remotely sensed data, only cross-sectional information is available. This translates into the lack of data on temporal changes in prices. However, changes in land use or production systems across space, a snapshot in time, are observable. In order to carry out an econometric analysis under this limited time-series information, an assumption of constant prices at central market places has been incorporated (Chomitz and Gray, 1996; Nelson and Hellerstein, 1997). Furthermore, to adjust prices, Chomitz and Gray (1996) constructed proxies for location-specific P and C, (as in equation 5) based on cost-of-access measures. These proxies are:

$$4) \qquad P_{hl} = \exp(\gamma_{oh} + \gamma_{1hl} D_{hl})$$

$$5) \qquad C_{hl} = \exp(\delta_{oh} + \delta_{1hl} D_{hl})$$

Where D is access time from plot h to markets, with technology l. Equations 7 and 8 have two assumptions:

$\gamma_{1hl} < 0 \Rightarrow$ Output price P decreases when market access costs increase

$\delta_{1hl} > 0 \Rightarrow$ Input costs increase when access costs increase

By combining Equations 5, 6, 7 and 8 Nelson and Hellerstein (1997) developed an econometric model for rent:

$$\ln(R_{hlT}) = \eta_{0h} + \eta_{1i}D_i + \eta_{2h}\ln G_h + \eta_{3h}\ln i_l + \mu_{hl}$$

$$\text{6)} \quad \ln(R_{hlT}) = v_h N_l + \mu_{hl}$$

Parcel h will be devoted to technology k if $R_{hkT} > R_{hlT}$, for all $l \neq k$

Equation 6 has two components: $v_h \mathbf{N}_l$ which is a systematic component, and μ_{hl}, an error term. If it is assumed that μ has a Weibull distribution and is not correlated to production technology, Equation 9 could be expressed as a Multinomial Logit Model (MNL model):

$$\text{7)} \quad \mathrm{Pr}ob_{hl} = \frac{e^{X_l\beta}}{\sum_j e^{X_l\beta}}$$

Where X_l is an explanatory matrix with 3 groups of variables: 1) cost of access (γ), 2) site specific geophysical variables (βi), and 3) spatial effects variables (βi). Thus biophysical and geographic site characteristics, as hypothesized, explain the productivity and profit variation of cattle production technology. For a MNL model, the marginal substitution rate is the ratio of the coefficients:

$$\text{8)} \quad MSR = \frac{\beta_i}{\gamma}$$

4.1.1.2 Tobit model

The Tobit model was originally proposed by Tobin in 1958 (Amemiya, 1984). He analysed household expenditures on durable goods using a regression model which assumes that expenditures cannot be negative. The model is called "limited dependent variables". In 1964, Goldberger coined the term Tobit, due to the similarities with probit models. The model is also known as a truncated or censored regression model. It is truncated if observations outside a specific range are totally lost and censored if at least one exogenous variable can be observed.

Considering the linear model:

$$9) \qquad y^* = x_i'\beta + u_i, \quad i = 1,\dots,N$$

Where y* is a scalar latent variable, x_i is a (K x 1) vector of exogenous variables and u_i the error term drawn from a N $(0,\sigma^2)$ distribution. Nelson (1977), Huang (1999), Skeels and Vella (1999), and Bolkesjo and Baardsen (2002) showed that a latent variable is only observed according to the censoring rules.

$$10) \qquad y = \begin{cases} y^* \leftrightarrow y^* > 0 \\ 0 \rightarrow otherwise \end{cases}$$

Equation 10 might be estimated using ordinary least squares (OLS); though, some authors argue this method is not the best in estimating a truncated or censored model (Nelson, 1977; Amemiya, 1984; Bousquet and Ivaldi, 1998). Bousquet and Ivaldi (1998) mentioned that deleting the non-observed values is not the solution, because it produces a biased sample.

Instead of OLS, Chou (1999), and Lee (1999) recommended the use of maximum likelihood estimators (MLE). Chou (1999) used a Monte Carlo test in a comparison of the performance of five different estimators for the Tobit model, and found that MLE is more consistent than OLS. Maximum likelihood estimators involve the maximization of a logarithm by an interaction scheme. The convergence is assured by the global concavity of the logarithmic likelihood function (Nelson,1977; Lillard, 1993; Honore, 1993; Honore *et al.*, 1997; Chen, 1997; Levy, 2002).

Since 1958, when Tobin proposed the model, and especially since the 1970s, a lot of applications of the model have been published. Examples range from measuring the performance of secondary education (Kirjavainen and Laokkanen, 1998) to estimating the production frontier (Greene, 1982; Shao and Lin, 2002). In most cases, the main reason for using the Tobit model was the presence of non-observed values in the sample; see, for example, Onwujekwe *et al.* (2002).

In economics, Tobit models have been used in estimating willingness to pay (Piper and Martin, 2001; Onwujekwe and Nwagbo, 2002), incorporation of firms in the global economy (Kumar and Saqib, 1996; Nassimbeni, 2001), energy utilization (Bousquet and Ivaldi, 1998), price regulation (Chou, 1999; Lee, 1999), land valuation (McMillen and McDonald, 1991), production supply (Bolkesjo and Baardsen, 2002), farmer perception of new technology (Adesina and Baidu-Forson, 1995), labour use (Skeels and Vella, 1999) and land rent or purchasing (Deininger *et al.*, 2003). However, the authors are not aware of any studies that have been conducted using a Logit/tobit model in explaining the spatial, geographic and production characteristics of cattle farms. This paper suggests a Logit model for explaining cattle production in Guancaste and Costa Rica by seeking to identify the specific factors underlying the spatial distribution and intensification of cattle farms.

4.1.1.3 Cattle production systems in Costa Rica

Cattle production has been an important economic activity in Costa Rica since 1586 when cattle were imported from Honduras and Nicaragua (Abarca, 1998) (Figure 4.1). In 2000, Costa Rica had 43,494 cattle farms, with 60% being beef farms, 34% dairy farms and 6% dual purpose farms. These farms occupied 20,294 km^2 (2.0 million ha) which is equivalent to 39% of the land surface (Chapter 3).

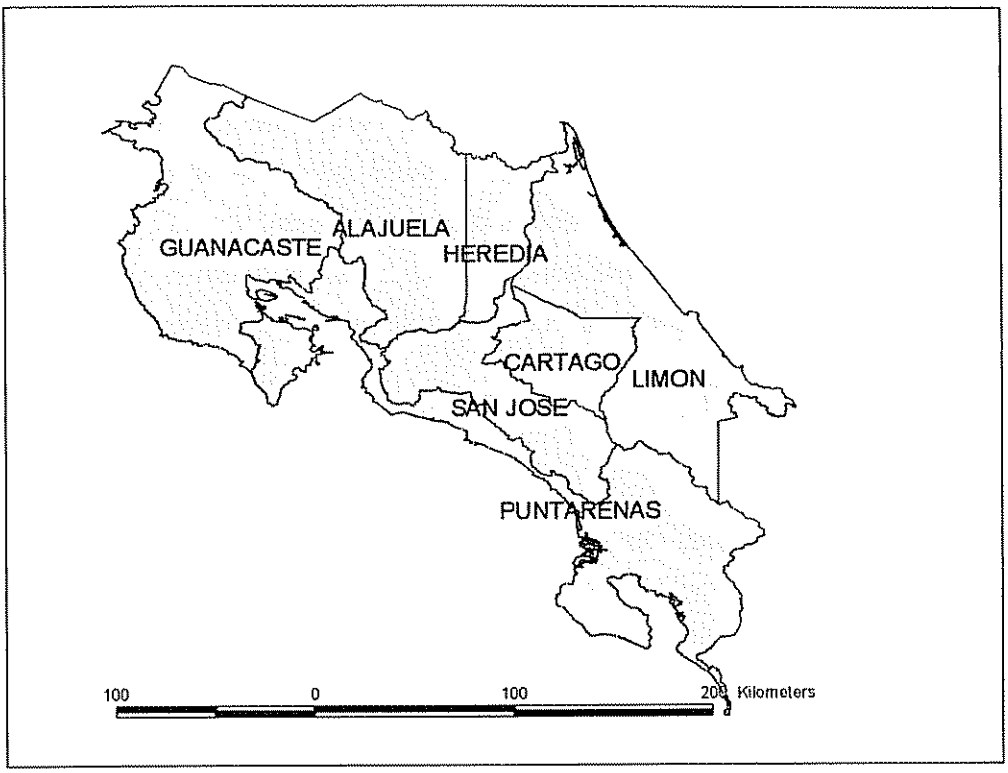

Figure 4.1 - Cattle farm locations in Costa Rica

Source: Based on MAG (2001) and ITCR (2000).

Cattle ranching has declined in Costa Rica over the past two decades (Barquero, 2001). The national herd declined from 1.7 million livestock units (LU) in 1988 to 1.1 million LU in 2001, representing a reduction of 37% (Barquero, 2001). The reduction in livestock produced an increase in forest and tree resource areas, especially in Guanacaste (Chapter 3).

Guanacaste is still dominated by medium and large farms with low intensification. This path has yielded land and herd consolidation. For example, 26% of the land is held by farms larger than 1,000 hectares with 11% of the regional herd owned by 26 farmers (Chapter 3). Land and herd consolidation is a result of the regional biophysical characteristics, especially irregular rainfall distribution, due to the requirement of keeping large areas in pasturelands to maintain livestock during the dry season. Beef production systems are influenced by farm size and have based their economic profitability on economies of scale and the use of the natural resource base (Chapter 3). In an area with a pronounced dry season and without irrigation available for forage production, medium and large farms are more viable given the steady relationship between beginning and ending of the rainy season with the supply of green forage. The forage-rain cycle prompted larger farms which are able to ensure better forage supplies for feeding cattle all year long. Flores *et al.* (2002) reported the use of forest remnants as forage areas during the dry season, but these are essentially available only on larger farms. Finally, in those areas of the province with better rainfall distribution or with irrigation, more diversified production systems have been established and include crops like sugar cane, rice and melon.

4.1.2 Methodology

The methodology was split into two parts. First, the geographic and spatial variables were generated from cartographic data and linked with census data. Second, the econometric analysis was carried out by incorporating geographic, spatial and census data into a logit/tobit model.

4.1.2.1 Geographic and spatial analysis

Data for the geographic and spatial analysis was obtained from the Costa Rican Atlas (ITCR, 2000) and the Cattle Census 2000 (MAG, 2001). The analysis was carried out in Arc View 3.2a using different layers for road systems, rainfall, rivers, soil types, towns and topography.

Market access cost definition

The starting point for assigning the transportation costs was the GIS layer for road systems. Roads were classified into three groups: first-order, second-order and third-order roads. For first-order roads, it was considered that trucks could travel at 70 km/hr, second-order roads at 40 km/hr, and beyond these, at 20 km/hr. Speed information was translated into minutes/meters which results in 0.000857min/m for first-order roads, 0.0015min/m for second-order roads, and 0.003min/m for third-order roads. This information was combined with the location of the dairy and beef markets for generating a friction map surface.

The main beef auctions and dairy processing plants were identified as a basis for the market access costs layer. The auctions in Cañas, Ciudad Quesada, Guapiles, Limonal, Liberia, Pital, San Isidro del General, Santa Ana and Upala were identified as beef markets. Dairy markets were identified as Ciudad Quesada, El Coyol, Monteverde, San Isidro del General and Coronado where the main dairy plant companies are located. The location of each town was taken from the town layer. However, in the Guanacaste study only the beef auctions in Cañas and Limonal were considered.

Combining speed information with market location (Annex IV), and using Arc View, it was possible to derive the beef and diary market access costs. These layers were then linked to the farm location layer.

Site factor variables

Site factor variables were divided into two groups, namely water supply factors and soil characteristics. Water supply factors included the distance from rivers, water supply from rivers, water supply from wells, water supply from irrigation systems, and rainfall. The distance from rivers was calculated using the river layer with buffer zones.

The soil characteristics included soil type and topography. These, and the layer described before, were linked to the farm location layer. Finally, all the information was exported as a dbf table to Microsoft Access.

Intensification variables

Two proxy variables were estimated. The first proxy refers to the technological level of cattle production. This variable was based upon the cattle management system: pasture, semi-intensive, or intensive according to the cattle census classification. Values were assigned according to Table 4.1.

Table 4.1 - Values used for the technology level variable used in the Logit/tobit model

Value	Management*
0	Pasture
1	Pasture + semi-intensive
2	Semi-intensive
3	Pasture + semi-intensive + intensive
4	Pasture + intensive
5	Semi-intensive + intensive
6	Intensive

Source: MAG (2001)

* Refers to varying intensity of production system plots within the same farms. However data is at the farm level; there is no data at the paddock level.

The second proxy was a food index based on the use of hormones, vitamins and/or mineral supplements in cattle feed. Each of these variables was given a value of 1 or 0. The food index was the addition of the three variables.

Dependent variable

In a Microsoft Access database, it was possible to join the data layers from Arc View 3.2a with the geo-referenced census data. The results were exported to Microsoft Excel. The data was purged, deleting all incomplete entries. Finally, farms were grouped into dairy and beef cattle farms based on the livestock breeds reported in the census. Dual-purpose farms were not considered because they represented less than 5% of the total farms. Values of 0 and 1 were assigned to beef and dairy farms, respectively.

Intensification of cattle farming can be evaluated using animal stocking rates, the use of specialized breeds, veterinary status, animal husbandry or quantity and quality of fences and other equipment. These reflect the amount of capital and labor available for investment in production (Muchagata and Brown, 2002). This study used the animal stocking rate as a proxy for intensification because it was the only variable that can be calculated from the census. As the census data did not include animal stocking rates, it was necessary to rely on livestock units (LU) as a basic step for estimating the animal stocking. Livestock units were calculated using the factors in Table 4.2.

Table 4.2 - Conversion factors used to estimate the livestock units in defining the animal stocking for tobit model

Age range	Conversion factor
0 – 1 year	0.25
1 – 2 year	0.50
2 – 3 year	0.75
> 3 year	1.00

Source: Ibrahim (2001)

Once LUs were determined, stocking rates were estimated by dividing the LU by the farm area.

4.1.2.2 Econometric analysis of Equation 9 and estimation of land rent

Using the cattle activity classification (0 = beef, 1 = diary) as endogenous variables, the Logit model was applied. The exogenous variables were grouped for the Logit model as: 1) market access costs, 2) water supply factors, and 3) soil characteristics.

The Tobit model used as an endogenous variable animal stocking rates (AS). On the right hand side variables were grouped into: 1) farm characteristics, 2) cattle breed, 3) technology level and 4) geographic characteristics.

Models were run in Limdep 7.0, using the Tobit model with sample selection (ANNEX V). This mode runs a Logit and a Tobit model as a whole. In addition, marginal effects were calculated for the Logit Model, being the first derivative of the model.

The functional model was defined using the Lagrangian test (Equation 14), with a level of significance of 0.05 in the Chi square distribution. Variables were only included if the Lagrangian value was higher than the Chi value. Likewise, the prediction power and the significance of the coefficients were considered in the model definition.

$$11)\qquad \lambda = -2(\text{likelihood}_{before} - \text{likelihood}_{after})$$

Furthermore, the marginal substitution rate (MSR) was calculated dividing the beta coefficient of the cost of market access by the beta coefficient of each of the other variables.

4.1.3 Results and discussion

The results revealed a difference in market access. As shown in Figures 4.2 and 4.3; beef markets are more evenly distributed in the country; however, this does not reflect lower access time for beef than for dairy farms. It was found that beef producers spend, on average, 60 minutes (± 40 minutes) travelling to the nearest beef market. In contrast, dairy farmers spend 45 minutes (± 28 minutes) travelling to dairy markets. This shows that dairy farms are concentrated around the markets. In Costa Rica, the main urban centres are located on the Central Valley, in areas with better conditions for dairy production. As milk is a bulk product, it was important to transport the product to markets as fast as possible. Beef farmers do not have the same demand thus making it possible to be located further from the markets.

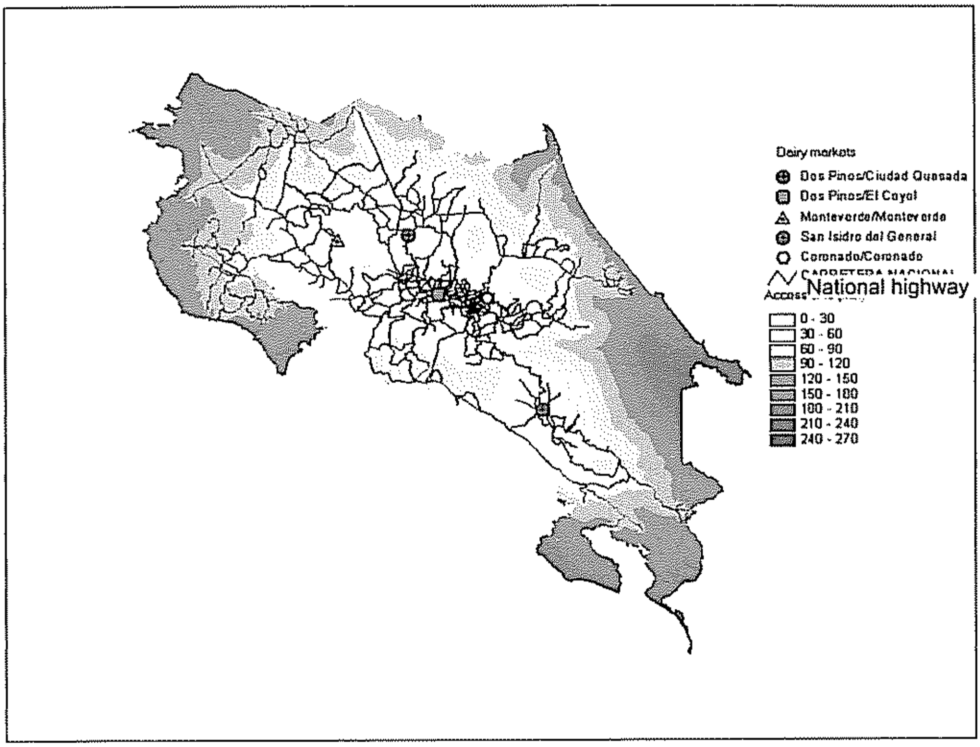

Figure 4.2 - Access to main milk markets in Costa Rica

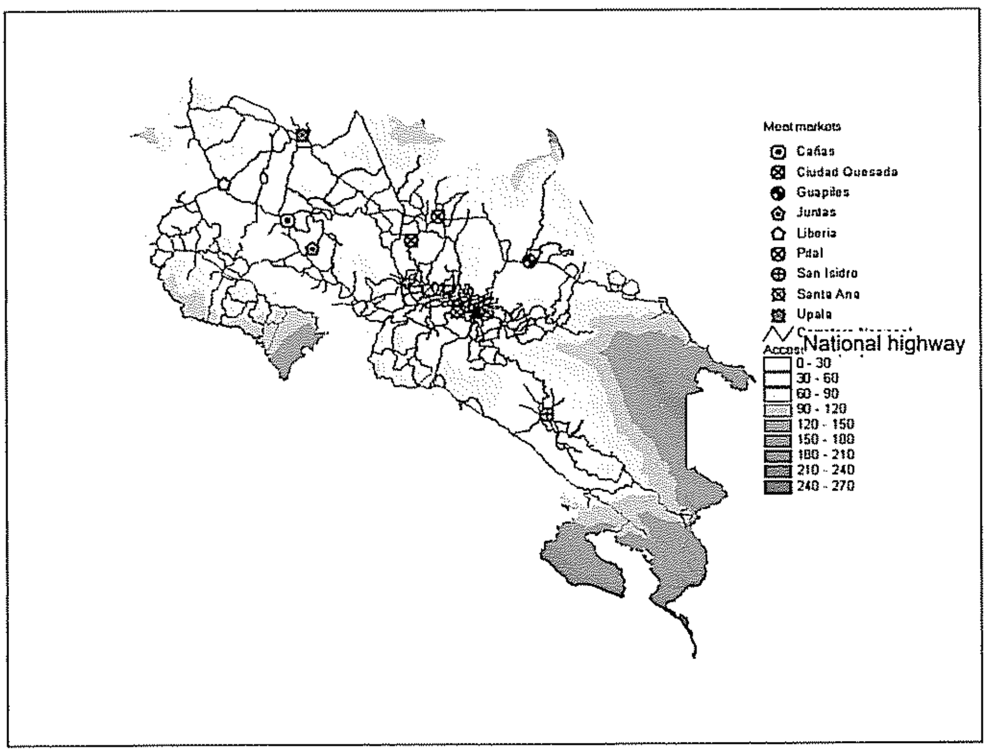

Figure 4.3 - Access to main beef markets in Costa Rica

In Guanacaste the average access time from the farms to auctions centres was 50 minutes (± 26 minutes), with a maximum value of 121 minutes. This may show that the auctions are readily available in the vicinity of cattle farms. Nevertheless, Guanacaste did not have any milk processors, which shows the importance of beef production in the province.

As shown in Table 4.3, the main geographic forces affecting dairy farming activities were: dairy market proximity, access to a river, irrigation availability, presence of a well, distance to rivers, number of dry months, elevation, and slope all of which are significant at 0.05 according to the Lagrangian test. The model was significant at 0.001. The main forces identified in other studies are access cost, elevation, slope and rainfall (Bockstael, 1996; Berry *et al.*, 1999; Mertens and Lambim, 1999; Nelson and Hellerstein, 1997; Veldkamp and Fresco, 1997; Kaimowitz *et al.*, 2000; Bhattarai and Hammig, 2001; Méndez, 2001; Nichlos *et al.*, 2001). As the Logit model is non-linear, the coefficients are not the individual effects on the probability; hence, the marginal effects were calculated.

Table 4.3 - Marginal effects of geographic factors affecting dairy farms in Costa Rica (N = 41,359)

Variables	Coefficient	Unit	Standard error	P-value
Access to dairy market	-0.00338	Minutes	0.000	0.000
Availability of river	-0.03619	Dummy	0.009	0.000
Availability of irrigation	0.30169	Dummy	0.010	0.000
Availability of well	0.11079	Dummy	0.014	0.000
Distance from rivers	-0.00002	Meters	0.000	0.000
Number of dry months	-0.05327	Number	0.002	0.000
Elevation	0.00050	Metres	0.000	0.000
Slope	-0.00365	Percentage	0.000	0.000

Likewise, for Guanacaste, factors like market access cost, river, rainfall, elevation, and slope were the main factors underlying the type of production system (Tables 4.4 and 4.5). All marginal effects were lower for beef than for dairy farms. This means that beef production is the basic cattle production system in Guanacaste, leaving dairy production as an alternative activity when certain conditions render it possible.

Table 4.4 - Marginal effects for the Guanacaste dairy farm model (N = 5,737)

Variables	Units	Coefficients	Standard error	P-value
Market access	Minutes	-0.0181	0.002	0.000
River	Dummy	-1.1254	0.099	0.000
Irrigation	Dummy	0.0111	0.136	0.935
Rainfall	mm/year	-0.0005	0.000	0.000
Elevation	Meters	0.0042	0.000	0.000
Slope	%	-0.0099	0.002	0.000

Table 4.5 - Marginal effects for the Guanacaste beef cattle farm model (N = 5,737)

Variables	Unit	Coefficients	Standard error	P-value
Market access	Minutes	0.002	0.000	0.000
River	Dummy	0.108	0.010	0.000
Dry months	Number of	0.033	0.003	0.000
Rainfall	mm/year	-0.00002	0.000	0.016
Elevation	Meters	-0.0003	0.000	0.000
Slope	%	0.001	0.000	0.000

Marginal effects are the individual effects of the factors on the probability of finding a dairy cattle farm. For example, if a river was the main water source of a given farm, the probability that this was a dairy cattle farm was reduced by 3.6%. It was found that either water supply from wells had a higher positive effect than rivers. Rivers were the main water source on beef farms, with 88% of the farms using river water as a main source of water supply.

4.1.3.1 Water supply

The first group of factors influencing the type of cattle production includes water supply options: rivers, irrigation systems and wells. As cited above, water supply from irrigation systems and wells increases the probability of finding a dairy cattle farm. Conversely, rivers increase the probability of finding a beef cattle farm. The reason for this is the higher demand for water on dairy farms. Activities like milking require a constant water supply which is provided by irrigation systems or wells, whereas river and stream flow decreases during the dry season, reducing the water supply.

The increased probability of finding beef production close to rivers is also due to the fact that beef production systems are less intensive in the use of capital resources. Kaimowitz (1996) and Vaughan and Mo (1994) for example, argue that beef farms tend to base their production on the use of natural resources rather than investing in infrastructure and technology.

The vast majority of beef (80%) and dairy (93%) farmers manage cattle in paddocks. Since the distances between rivers was 1.8 km (± 1.2 km), it suggests that animals have access to surface water sources. Similarly, Flores and Monterroso (2002) reported that almost all the farmers in Cañas and Bagaces had access to stream water sources. It was found however, that beef production farms were further from rivers, at 1.9 km (± 1.4 km), whereas dairy farms were located on average 1.6 km (± 1.0 km) from rivers.

Connected to water supply, the number of dry months constitutes another of the main geographic factors underlying the type of livestock production. This factor had an inverse relationship with dairy activity. Beef farms are located in places with 2.8 dry months (± 1.4 dry months), whereas dairy farms are in areas with 2.6 dry months (± 1.0 dry months). This is not a significant difference, but it is statistically significant ($p < 0.1$). According to Table 4.6, 84% of the dairy farms have 3 dry months or less, while on the other hand, 33% of the beef farms are located in areas with more than 3 dry months.

It was found that an increase in the number of dry months reduces the probability of finding a dairy cattle farm by 5%. The number of dry months ranges from 1 to 6, meaning that the greatest effect of dry months reduces the probability by 32%.

Table 4.6 - Number of dry months (%) by cattle production in Costa Rica (N = 41,361)

Production type	Dry months (%)					
	1	2	3	4	5	6
Beef	28	10	30	18	13	1
Milk	11	42	31	11	5	0
Average	22	21	30	16	10	1

Source: Based on MAG (2001)

For Guanacaste, the variable number of dry months was significant only for the beef model. A positive effect was found for dry months on the possibility of finding a beef cattle farm. As shown in Table 4.7, 75% of the dairy farms were located in the area with less than 4 dry months; but 55% of the beef farms were located in areas with more than 5 dry months. This shows that dairy farms need a better water supply to profit from the steady relationship between rain and availability of green forage.

Table 4.7 - Number of farms according to the number of dry months in Guanacaste, Costa Rica (N = 5,737)

Production type	Dry months (%)				
	2	3	4	5	6
Beef	0.2	5.7	38.9	47.5	7.5
Dairy	0.2	12.2	63.1	18.5	5.8
Average	0.2	6.9	43.1	42.4	7.2

Source: Based on MAG (2001)

4.1.3.2 Elevation and slope

Elevation showed a direct relationship with dairy production; an increase in elevation increases the probability of finding dairy ranches. The reason is that the better growth of dairy cattle in higher zones is due to lower temperatures. Almost 100% of the dairy herds are *Bos taurus*, whereas more than 95% of the beef cattle are *Bos indicus*. *Bos taurus* come from temperate areas and do not tolerate hot climates; they prefer higher areas with lower temperatures. For beef cattle, the opposite occurred.

Elevation in Costa Rica ranges from 0 to 3,800 m.a.s.l., and it was found that an increase by 100 m in elevation increased the probability of finding a dairy cattle farm by 5%. Comparing the elevation and irrigation effects, it was found that at an elevation of 600 m.a.s.l., the effect of elevation was equal to the effect of irrigation systems. Also, at an elevation of 600 m, the effect of dry months is equal to elevation. The effect of elevation and the probability of finding dairy farms were not related to the availability of water at higher levels. The correlation of rainfall and elevation was low (R^2 = 0.07). Although the R^2 was not significant, the trend is a reduction in rainfall with an increase in elevation (r = -0.26). Therefore, below 600 m.a.s.l., ranchers value more an increase in altitude than farmers beyond this point.

4.1.3.3 Market access cost

The last factor studied is market access cost. It was found that the further the farm is located from the market, the lower the probability of finding a dairy cattle farm, and the higher the probability of beef production. The reason is the difference in transportation costs. Dairy farmers have higher transportation costs as they transport milk, a bulk product, to market at least twice a week if they have a refrigerator. In most cases, processors transport the milk, but farmers pay through a milk price reduction which increases with the access cost. In the case of beef production, farmers tend to transport cattle to market only once or twice a year.

4.1.3.4 Marginal Substitution Rate

In analysing the Marginal Substitution Rate (MSR) for dairy farmers, it was found that for farmers it would be worth increasing their access time to markets for an increase in irrigation, well, or elevation. In contrast, it would not be worth increasing their access time for an increase in rivers, river distances, dry months or slope (Table 4.8).

Table 4.8 - Marginal substitution rate for dairy cattle in Costa Rica (N = 41,359)

Factor	LR	Units
Rivers	0.09	Minute if present
Irrigation	-0.000001	Minute if present
Well	-0.03	Minute if present
River distances	155.0	min/metres
Dry months	0.06	min/month
Elevation	-6.73	min/metres
Slope	0.92	min/%

Table 4.9 - Marginal substitution rate for dairy farms in Guanacaste, Costa Rica (N = 5,737)

Factor	MSR
Rivers	0.02 min/presence
Irrigation	- 0.02 min/presence
Rainfall	-22.22 min/mm
Elevation	- 3.92 min/m
Slope	2.38 min/%

Table 4.10 - Marginal substitution rate for beef cattle in Guanacaste, Costa Rica (N = 5,737)

Factor	MSR
Rivers	0.000002 min/presence
Dry months	0.06 min/each month
Rainfall	- 96.50 min/mm
Elevation	- 6.23 min/metres
Slope	2.24 min/%

Although this is not an economic valuation of land use attributes, it highlights some land characteristics and their value for dairy cattle farms. Hence, land near rivers, with irrigation systems or wells, on the upper lands, and with level topography seems to be most favourable for dairy production. Additionally, dairy cattle farms are concentrated in the upper parts of Cartago and Alajuela which probably present most of the characteristics mentioned.

Regarding beef farms, most are located on the worst land conditions. Beef production seems to be a more marginal activity than dairy production. Beef farms based their production on the use of natural resources since most of the farmers keep cattle in paddocks which they do not fertilise. Most beef farms have a river as the main water source and according to Flores and Monterroso (2002), they have no additional infrastructure for water storage. Additionally, most regeneration areas were used as forage areas (Current, 1995; Camargo, 1999; Alonzo, 2000; Flores and Monterroso, 2002).

In Guanacaste, Flores and Monterroso (2002) stated that some beef farmers preferred dry conditions because beef cattle had higher productivity under these conditions. Combining this assumption with the MSR for rainfall from dairy and beef farmers, it is possible to conclude that water supply is not a problem for the development of beef production. Farmers did not want wetter sites than they have now, showing that they did not need more water. Maybe the limiting condition for cattle activity was not only climatic, but also market conditions.

The other factor considered was slope. In this case, it was found that an increase in slope decreases the probability of finding a dairy farm. Dairy farms are located in plateau areas, leaving the most irregular areas for beef production.

The model performed well with a prediction accuracy of 84%. The best prediction power was with beef cattle with 92% of the classifications correct. For dairy cattle farms, the predictive power was 69%. As mentioned before, natural characteristics, which are represented here by the geographic and spatial factors, influenced beef farms more than dairy farms. Therefore, to improve the prediction accuracy of dairy farms, technical and farmer characteristics are required. However, the model used in this paper did not allow for the introduction of these variables due to the lack of georeferenced data about the socioeconomic conditions at the farm level. Nevertheless, an accuracy of 84% for the model allows for conclusions about the factors governing beef and dairy production.

For Guanacaste, the beef and dairy models each presented an accuracy of 86%. Again, the best prediction power was for beef farms with 95% accuracy. For dairy cattle farms, the prediction power was 37%. This was produced by the sample inertia since 82% of the farms were beef production. Also, dairy farms are more influenced by socioeconomic conditions which were not included in the model.

4.1.3.5 Technology factors

The Tobit model was run using the Animal Stocking Rate (AS) as a proxy for intensification, based on sample selection. Dairy AS were estimated jointly with the Logit Model. In order to complete the discussion for beef production, a simple Tobit model was run for beef AS.

Compared with the Logit model, the Tobit has less accuracy for explaining the AS; however, both Tobit models were significant at 0.001. However, the R^2 values for both models were low, 0.1 and 0.17 for diary and beef farms, respectively. For dairy farms, it was found that access to dairy markets, technology level, food index, river distance and elevation had a direct relationship with AS, while farm size and pasture area have an inverse relationship.

For beef production, distance from the market, technology, rainfall, and dry months had a direct relationship with AS, while farm size, food index, and elevation had an inverse effect. Beef and dairy farm distances from market and technology have a direct relationship to AS in both systems, while farm size has a negative relationship.

However, food index and elevation had positive effects on stocking rates in dairy farms; the effect was negative for beef farms.

Evidence presented by Vaughan and Mo (1994) and Kaimowitz (1996) suggested that beef production is based on the extensive use of natural resources. As reported by Flores and Monterroso (2002) and Flores *et al.* (2002) and according to the models presented, most beef farms in Costa Rica have the following characteristics: 1) are larger than dairy farms, 2) are located in drier areas, 3) are located on lower lands, 4) use rivers as main water sources, 5) use the *Bos indicus* breed, 6) use only pastures, 7) do not fertilise paddocks, 8) are located in more abruptly sloped lands, 9) have a lower AS than dairy farms, 10) use regeneration areas as a food source, 11) have a lower technology level and 12) are located further from market. These characteristics highlight the importance of natural resources in the activity.

On the other hand, dairy farmers invest more in technology, with more intensive systems, including irrigation. Generally, dairy farms had artificial insemination programs, which are not normally used in beef production, for improving breed characteristics. Therefore, land value in milk production areas is higher than in beef production areas because milk production requires specific biophysical conditions which are not present in all areas. Suitable areas for dairy production are normally completely used by dairy farms, limiting the availability of suitable land for expanding production. Therefore, the land value is higher because the demand for suitable land can increase but not the supply. Increase in suitable land increases the price up to the point where it is better to intensify their production. Thus, there is no incentive to deforest (Griffith and Zepeda, 1994).

Another possible reason why beef production is less intensive than dairy production could be due to the land tenure ratification (Brockett, 1988). Mertens *et al.* (2002) reported that pasture land is the cheapest form of land occupation in the Brazilian Amazon. In Costa Rica, most of the land is under private tenancy; nevertheless, beef production could be used as a way to maintain a permanent land use.

Since 39% of the Costa Rican land surface is under cattle production (Chapter 3) and considering that Alonzo (2000) reported a direct relationship between farm size and the area of forest and tree resource areas on cattle farms, beef and dairy farms count for a high percentage of forest and tree resources in Costa Rica. Similarly Van Leeuwen and Hofstede (1995) ascertained that in the Atlantic zone of Costa Rica, forest cover on cattle farms ranges from 8% to 40% of the farm size; therefore, beef and dairy farms count for at least 159,120 hectares of forest and tree resources in Costa Rica. As a result, cattle farms are the main source of wood (Campo *et al.*, 2001).

As discussed in Chapter 1, natural regeneration areas are becoming an important land cover in Guanacaste, accounting for 30,000 hectares; however, government policies poorly addressed this problem. There is a lack of knowledge about farmer perception of forest and tree resources, especially how forest and tree resources are included in farmer livelihoods. This topic will be discussed in Chapters 5 and 6.

4.1.4 Conclusions

According to the Logit model, spatial and geographic factors have important effects on the type of cattle production. The main factor is elevation, followed by the availability of irrigation systems; both factors have a direct relationship with dairy farms. Dairy farms are more sensitive to changes in spatial and geographic characteristics. If conditions were favourable for dairy production, farmers would choose dairy rather than beef production.

Beef production is less intensive than dairy production. The former occurs in unsuitable places for dairy production. Thus, beef farms are spread across the country while dairy farms are concentrated around suitable places. Consequently, transport costs for dairy production are lower affecting the rate of land rent for beef farms.

The Tobit models were not statistically significant, implying that more factors than the geographic and spatial ones are influencing the intensification in both types of cattle production systems. Maybe farmer livelihoods are more important in defining the intensification level.

The approach outlined in this study helps to better understand the main geographic and spatial factors underlying cattle activity in Costa Rica. The methodology proves to be capable of exploring the geographic and spatial factors influencing cattle production and should be applicable to the study of other types of land use. However, this was a static analysis in time, so additional studies need to be carried out to determine the main driving forces influencing land cover change over time.

4.2 POLITICAL AND MACROECONOMIC FACTORS GOVERNING LAND USE CHANGE IN THE DRY FOREST ZONE OF COSTA RICA, 1960 – 2000

4.2.1 Introduction

The tropical dry forest zone is the most populated and degraded ecosystem in Latin America (Kauffman *et al.*, 2003). Despite this fact, little is known about tropical dry forests because research has been focusing on tropical rain forests (Gonzales Iturbe *et al.*, 2002; Ceccon *et al.*, 2003). It is important to understand the former particularity for livestock as livestock production started in the dry forest zone and later moved to more humid areas (Brockett, 1988). In Latin America, pastures in the dry forest zone have been abandoned since 1980 due to reduction in beef prices (Kaimowitz, 1996).

On a worldwide scale, deforestation was responsible for 20 to 25% of the global anthropogenic green house gas (GHG) emissions during the 1990s, with the majority of deforestation occurring in tropical regions (Pandey, 2002). The conversion from forest to pastures was one of the main land use changes in Latin America over the last decades (Kaimowitz, 1996; Didia, 1997; Kaimowitz and Angelsen, 1998; Pezo *et al.*, 1999; FAO, 2001 and Kaimowitz and Angelsen, 2002). For example, in Ecuador 87% of the cleared area was used for ranching (Sierra, 2000).

Even though the intensity of this process is different in each country, during the 1980's Costa Rica experienced one of the world's highest deforestation rates, losing about 7.6% of its forests annually. More than half of the deforestation has occurred since 1950; this trend prompted forecasters to issue a warning that by 1995 no forest would remain outside national parks which would have devastating consequences to biodiversity due to ecosystem fragmentation (Gottfried *et al.*, 1994; Didia, 1997; Abler *et al.*, 1998; Bouman and Nieuwenhuyse, 1999; Chomitz *et al.*, 1999; Pagiola, 2002; Sanchez, 2002; Armenteras, *et al.*, 2003).

At the end of the 1980's and during the 1990's, reductions in subsidies and changes in demographic conditions brought down cattle profitability making cattle farming a less attractive industry. As the industry contracted, more areas formerly dedicated to pasture were abandoned prompting greater tree cover because ranchers were not able to or interested in keeping pasture lands clean of natural regeneration. By 1991, secondary growth covered an estimated 400,000 hectares in Costa Rica, with estimated increments of 30,000 hectares/year. This change in the landscape was more visible in the dry areas of the dry Pacific Northwest of Costa Rica. New estimates today show that more than 50% of the Guanacaste province, at the heart of the dry forest zone areas in the Pacific Northwest, is covered by secondary forest with young trees (Gonzales, 2002; Spittler, 2002). This situation creates new opportunities and challenges for establishing more sustainable and profitable forest management schemes in this section of the country.

The processes of this change are not clearly understood and few studies have been conducted to highlight the factors driving land use change in the dry forest zone. This paper is based on an economic approach to understand land use change in the tropical dry forest zone of Costa Rica. It starts with a review of the theory underpinning land use studies, followed by a description of the socio-economic factors governing land use change in Costa Rica in the period 1960 – 1990 followed by the methodology. Later, results and discussion are presented, ending with conclusions.

4.2.1.1 Land use change theory

Land cover has been defined as "the biophysical state of the Earth's surface and immediate subsurface". The term originally referred to the vegetation covering land surface, but now includes human structures like buildings or pavement, and other aspects of the physical environmental such as soils, biodiversity, and surface and groundwater (Briassoulis, 2000).

Land use involves both "the manner in which the biophysical attributes are manipulated and the intention underlying the manipulation, as well as the purpose for which land is used". Thus, land use comprises the way and purposes for which human beings use the land and its resources. Land use change or land cover change imply a quantitative change in the area occupied by a particular land use or land cover (Briassoulis, 2000).

Land cover change can be classified into two groups: conversion or modification. Conversion involves changes from one cover type to another, while modification involves alterations of structures or function without a wholesale change from one type to another. It could involve change in productivity, biomass or phenology. Land use alters land cover in three ways: 1) converting land cover or changing into a different state; 2) modifying or changing its condition without a full conversion, and 3) maintaining its condition against natural agents of change. Therefore, agricultural land use changes can be classified as: intensification, extensification, marginalization or abandonment (Briassoulis, 2000).

Many changes have been driven by technological or political forces. In economic theory, technology change is defined as an increase in total factor productivity (TFP), implying that farmers obtain the same amount of physical production with fewer inputs. Another definition is any change in the production process that increases net profit (Angelsen *et al.*, 2001). Studies about the effect of technology change on forest cover have been based on four hypotheses (Angelsen and Kaimowitz, 2001):

The Borlaug hypothesis is named after Norman Borlaug, the father of the green revolution. The hypothesis is based on the definition that total production = yield*area. Under this assumption, with the same production level, an improvement in technology implies a reduction of area. To produce enough food for the population, an increase in productivity at the same level as population growth is required. Thus, deforestation would not increase. This assumption probably holds for aggregate food production at the global level. However, the assumption does not apply to regional or local levels. Technological change at the forest frontier often has minimal impact on agricultural prices. Thus, increased profitability effects may dominate, leading to greater agricultural expansion (Rudel, 2001).

The subsistence hypothesis assumes that farmers with small farms: a) live close to the subsistence consumption level, b) are primarily concerned about meeting their subsistence target, c) only use family labour, and d) do not have any alternative uses for their family labour. Thus, technological progress reduces deforestation because higher yields allow farmers to ensure subsistence on smaller areas. The main problem with this hypothesis is that farmers do not exhibit the limited wants preference. They want to improve their social conditions, so, if a new technology gave them this opportunity, they would increase the production area in order to increase their income. With the extra profit, they can overcome land, labour or capital constraints. Thus, technology that increases farmer income can stimulate migration to the forest frontiers, increasing forest conversion (Angelsen and Kaimowitz, 2001).

The economic development hypothesis: the first hypothesis applies to the macro-level, the second to the micro-level; the hypothesis links the two. The argument is that higher agricultural productivity contributes to economic development and growth, with limited forest conversion. This chain of causation provides the underlying rationale for the Environmental Kuznets Curve (EKC), which suggests that there is an inverted U-shaped relationship between income and environmental degradation. Kuznets proposed it in 1955, and he originally considered an inverted U-shaped relationship between income growth and income inequality. The EKC links the level of environmental degradation, reflected in selected environmental indicators, to the level of economic development of a country or region. This approach implies that during the initial stages of development, some form of environmental degradation is inevitable. However, incentives to improve environmental quality increase as income increases because the Gross Domestic Product is inversely proportional to deforestation (Koop and Tole, 2001). The break-even point of the EKC in Latin America appears to be around $6600 of the GDP per capita (Bhattarai and Hammig, 2001). Thus, many Latin American countries continued to suffer from deforestation processes, as only a few of them (e.g. Costa Rica) are close to the break-even point.

The idea is similar to Scherr (1999) who presented the degradation-conservation cycle as a function of time, population and market pressures (Figure 4.4). For agroforestry, there is an initial dependency on naturally-growing and minimally managed resources. With more intensive use, tree resources may begin to degrade up to the point where farmers decide to rehabilitate resources and intensify their management (Trajectory I). Innovation may be delayed due to various constraints or market failures (III). Communities may fail to respond because of constraints or because they discover lower-cost sources that provide products or services previously obtained from trees (II). It could be possible to accelerate the response process through policy intervention (IV). As land becomes scarce or population grows, farmers tend to use more intensive systems. Therefore, the costs per unit increase as systems become more land or labour-intensive unless there are productivity improvements. Farmer choices depend on their income, the cost and reliability of alternative sources of supply, and the relative abundance of key production factors (Scherr, 1999).

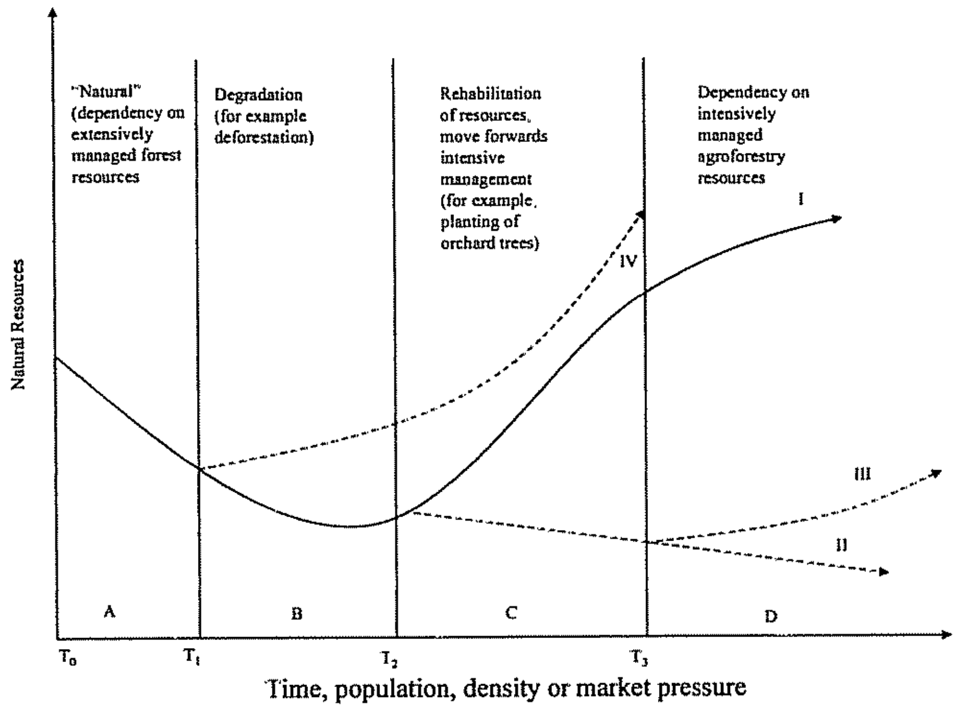

Figure 4.4 - Technology innovation cycle and its effect on natural resources

Source: Scherr (1999).

The last hypothesis is **the land degradation-deforestation hypothesis**. It is based on the idea of slash and burn techniques with fallow periods (Fujisaka *et al.*, 1998) which are no longer applied in the study area.

The impact analysis of technology change on cattle farming is divided into three schools. First, pasture technology reduces deforestation because unsuitable practices in tropical areas lead to a productivity decline, forcing farmers to abandon their pastures and clear new forest areas. It is expected that new low-cost technology could maintain productivity, thereby, reducing deforestation (White *et al.*, 2001). Second, improved pasture technology increases deforestation since improved pastures lead to higher productivity, making cattle production more profitable. Thus, farmers are motivated to clear forest. Third, technology change does not affect forest conversion, especially when the main reason for farmers to expand their pastures was to engage in land speculation (White *et al.*, 2001).

Considering the findings of Chapters 1 and 3, cattle farmers in the dry forest zone of Costa Rica based their decision on the last option. The area did not show signs of land degradation; conversely, forest cover increased during the last decades. As property rights are clearly defined in the area, there is no common or public land that farmers could use to expand their production. The only way to increase farm size is to buy land. This results in an active land market which provides farmers with real state investment incentives. More intensive and profitable farmers would force less profitable farmers out of the markets, buying the first production units of the farmers.

4.2.1.2 Factors governing land use change

The factors driving land use change can be classified into two categories, biophysical and socio-economic. Biophysical drivers include characteristics and natural environmental processes like weather and climate variations, landforms, topography, and geomorphic processes, etc. The socio-economic drivers are comprised of demographic, social, economic, political and institutional factors and processes such as demography and demographic change, industrial structure and change, etc. Biophysical drivers do not usually cause change in land cover, which in turn influences land use change decisions (Briassoulis, 2000).

Kaimowitz (1996), Angelsen and Kaimowitz (2001) and White *et al.* (2001) grouped driving forces into 7 categories: 1) type of technology: labour and capital intensity, the type of capital involved and the suitability of the technology for recently cleared forest areas, 2) farmer characteristics: income and asset levels and resource constraints, 3) output markets: farmer's market access, size, function and demand elasticity of markets, 4) labour market: wage rates, ease of hiring labour and feasibility of in- and out-migration, 5) credit markets: loan availability and conditions, 6) property regime: property security rights and how forest rights are acquired, and 7) agro-ecological conditions: land quality and accessibility.

Type of technology: Technology can be classified as labour- or capital- saving or intensive. Farmer response to new technology is influenced by several factors, and the type of technology promoted is one of them. Farmers adopt those technologies which make use of their abundant assets and are more profitable than the former ones. However, adoption of new technology is also influenced by the decisions of the farmer's neighbours and the farmer's experience (Haustsch and Klotz, 2002; Muchagata and Brown, 2002).

Economic theory suggests that farmers adopting profitable technology will expand their pastures unless one of these conditions applies: 1) the new technology reduced livestock product prices due to modification of the beef or dairy supply. Improved technology depresses prices if the aggregate supply and demand for livestock products is inelastic. 2) The new technology demands more capital, labour, or managerial skills, and farmers are limited in these resources; technologies which are capital, labour or management intensive, lead farmers to concentrate production in small areas (Kaimowitz and Angelsen, 2002). Technology that reduces the requirement of resources has the opposite effect (Kaimowitz and Angelsen, 2002). On the other hand, Cattaneo (2001) argued that in the short-run, all technology reduces deforestation even though this does not hold in the long-run.

According to Kaimowitz and Angelsen (2002), livestock researchers who argue that cattle production intensification would reduce the pressure on forest conversion did not explain how this process would occur. Empirical evidence does not support this assumption as Kaimowitz (1996) and Kaimowitz and Angelsen (2002) point out. Though cattle management indices improved from the 1950s and the 1970s, deforestation increased. Improved revenues enticed more farmers into cattle ranching, increasing the conversion of forested areas to pasturelands.

Kaimowitz and Angelsen (2002) suggested that farmers only adopt silvopastoral systems where or when land is scarce and most forest has disappeared. In a study in Costa Rica, they ascertained that owners of dual-purpose farms in Esparza adopt labour-intensive technology due to the high land value. Farmers were willing to intensify production because the opportunity cost of land is high, and they prefer hiring more labour over buying land for pastures. When new technology allows farmers to overcome constraints, technology change would increase deforestation in the long-run (Stern *et* *al.*, 1996; Kaimowitz and Angelsen, 1998; Koop and Tole, 1999; Bhattarai and Hammig, 2001).

Farmer characteristics: Howard and Valerio (1996) argue that farmers allocate capital in a rational way for the best profit alternative by striving to maximize their profit; however, beef cattle farmers are more risk adverse decision makers than profit maximizers. Thus, the decision to clear land is based on a comparison of discounted utilities from forest and non-forest land uses, including farmer risk perception (Vance and Geoghegan, 2002).

White *et al.* (2001) studied farmer livelihoods and their effect on land use decisions. They state that in Central America, technology change would not affect deforestation because demand for livestock products is not the main factor driving migration into forest areas. Thus, the introduction of intensive technology would maintain or expand forest cover only if technology were less expensive than extensive growth. However, it is found that farmers did not value trees in pasture thus reducing the probability of introducing silvopastoral systems (Van Leeuwen and Hofstede, 1995).

The livelihood framework presents the factors and issues affecting rural livelihoods by describing the relationships between factors and issues, thereby helping understand the way in which livelihoods are constructed and how they change over time (Bebbington, 1999; DFID, 2000; Abakerli, 2001; Dovie *et al.*, 2003).

Livelihood is more than the means of income generation. Ellis (2000) defined livelihoods as the "capabilities, assets (stores, resources, claims and access) and activities required for a means of living". The important issue in this definition is the linkage between assets and people's options in pursuing a livelihood. Capabilities include the options that a person or household can achieve through their income with economic, social and personal assets. "Assets refer to the access of a person or household to human, social, natural, physical and financial capitals". Pursuing a livelihood is a continuous process with a livelihood being sustainable when "it can recover from stresses and shocks, maintain or enhance the capabilities and assets without undermining the natural resource base" (Bebbington, 1999; Carter and May, 1999; DFID, 2000; Ellis, 2000; Block and Webb 2001; Morris *et al.*, 2001; Orr and

Mwale, 2001; Lindenberg, 2002; Twomlow *et al.*, 2002; Chanda *et al.*, 2003; Gheb and Crean, 2003; Pretty *et al.*, 2003). However, no single livelihood asset is sufficient to achieve a positive livelihood outcome (DFID, 2000; Betts, 2003).

Livelihood strategies comprise the range, combination and choices made and undertaken in order to achieve people's livelihood objectives. Livelihood strategies are influenced by environmental, cultural, social and political conditions. Secure livelihoods depend upon the substitutability between assets and activities; the lower the substitution, the higher vulnerability. Substitutability implies livelihood diversification, and it is defined as "the process through which rural households construct a diverse portfolio of activities and assets for improving their standard of living" (McKee, 1989; DFID, 2000; Ellis, 2000; Rider Smith *et al.*, 2001; Quinn *et al.*, 2003).

Non-agricultural activities are the main income source in rural livelihood diversification (Rider Smith *et al.*, 2001). Access to these activities is highly related to the educational level; therefore, government education policies are a key factor in defining a sustainable rural livelihood (Lipton, 1993). Most developing countries focus their development on industrialisation, moving households from a rural to an urban livelihood. This phenomenon moves people from rural to urban areas without an adequate livelihood strategy and it increases marginalisation in the main cities.

Livestock possession is a common emblem of wealth; moreover, the importance varies among regions and cultures. Livestock can improve the cash flow; improve the savings balance; reduce risk; be used as collateral for loans; produce inputs and services in crop production; be used as transport, fuel, food, and fibre; allow benefit gains from common property rights; and provide social status and identity (Barret *et al.*, 2001a; Block and Webb, 2001; Brugere and Lingard, 2003; Chanda *et al.*, 2003; Anderson, 2003). Despite these livestock benefits, improvement has not always been well received.

Livestock production does not only include the large farms, but also the medium and small ones. However, unlike large cattle farmers, small-scale farmers are severely limited in terms of income and access to livelihood assets (Dovie *et al.*, 2003). The importance of livestock in rural livelihoods varies among the original income level of the household; therefore, no single livestock strategy for cattle farmers could be found. Generally livestock production is more viable for the higher income households (Twomlow *et al.*, 2002; Brugere and Lingard, 2003; Ingram *et al.*, 2003).

Output markets: Agricultural rent in forest areas is a function of the scale of nearby urban development, soil productivity, and access to markets. Land rent diminishes as farmers are further from markets (Southgate *et al.,* 1991; Angelsen *et al.,* 2001). According to von Thünen's approach, the agricultural frontier advances up to the point where the net profit is zero (Kaimowitz and Angelsen, 1998). Numerous studies have tried to define how access to market affects land use change (Jones *et al.,* 1994; Kaimowitz, 1996; Nelson and Hellerstein, 1997; Nelson *et al.,* 1999; Baritto, 2000; Cattaneo, 2001; Méndez, 2001; Mertens *et al.*, 2001; Rodríguez, 2001; Rodríguez and Piedra, 2001; Nelson, 2002; Nelson and Geoghegan, 2002). They conclude that roads forced the expansion of the agricultural frontier.

Deforestation tends to be greater where forest lands are more accessible, agricultural and timber prices are higher, rural wages are lower, and where more opportunities exits for long distance trade. From the farmer's perspective, raising cattle extensively by converting additional forest to pasture appears perfectly rational. Moreover, a reduction in forest product prices increases deforestation (Kaimowitz, 1996; Howard and Valerio 1996; Kaimowitz and Angelsen, 1998; White *et al.*, 2001).

Pro-export policies designed to increase agricultural and forest exportation are likely to affect deforestation more than policies that promote production for domestic markets (Kaimowitz and Angelsen, 1998). Furthermore, forest certification would not necessarily increase forest conservation because of the importance of domestic markets which do not value certified wood (Merry and Carter, 1997; Sierra, 2001).

Major international markets for forest products are price sensitive and tend to favour low-priced forest products which often come from non-sustainable harvesting. This trend undermines the market share of responsible forest product suppliers who have to bear the full cost of sustainable practices yet often receive no premium price for their efforts. Other factors limiting sustainable forest management are insecure land tenure, policy and market failure, risk related to factors outside the forest sectors, lack of credit, and weak and unstable regulatory environments that encourage unsustainable or illegal practices (CIFOR, 2001).

Labour market: Labour is one of the main constraints in technology adoption, especially in agricultural frontiers. Responses to technology vary according to the availability of labour, increasing near more populated centres. Improving off-farm employment reduces deforestation because it raises the opportunity cost of the labour (Kaimowitz and Angelsen, 1998; Sierra, 2000; Bell and Irwin, 2002; Kaimowitz and Angelsen, 2002).

Credit markets: The effect of credit on land use change is ambiguous. On one hand, Kaimowitz (1996) argues that in Costa Rica cattle activity is inelastic to credit; pasture expansion in Honduras and Guatemala was produced without credit, implying that credit did not have any effect on deforestation. In contrast, Jones *et al.* (1994) and Kaimowitz and Angelsen (1998) report that in Brazil and Mexico credit and fiscal subsidies for livestock stimulated deforestation with land speculation being an important factor in Brazil. However, despite the abrogation of subsidies, cattle ranching is still expanding in the Brazilian Amazon (Muchagata and Brown, 2002).

Property regime: Property rights are an important factor underlying land cover change. In many developing countries, property rights are not clear enough to promote sustainable use of forest resources. Land speculation can thus be more profitable than cattle production (Brockett, 1988; Kaimowitz, 1996; Muchagata and Brown, 2002). This situation is aggravated when governments do not have control over national lands (Southgate *et al.*, 1991).

To overcome poor governmental control over public lands, agrarian reforms have been implemented. Agrarian reform laws encourage deforestation since governments give property titles to those farmers that clear land and grow agricultural crops (Kaimowitz, 1996). Thus, land tenancy is secured when pasture is established which provides an incentive for forest conversion. In addition, ranchers value land under pasture more than any other use (Muchagata and Brown, 2002). However, farmers in traditional livestock production areas are not forced to plant pasture as a way to secure land. In these areas, farmers have abandoned their pasture to natural regeneration (Kaimowitz and Angelsen, 2002).

Poor people in countries with a predominantly rural and agrarian structure increase their access to economic opportunities by access to land. Lack of access to land and human as well as physical capital have been identified as key determinants of poverty (Deininger *et al.*, 2003). Politically open societies, which respect property laws, private property, and market resource allocation, grew faster than societies where these freedoms were restricted. Countries with better democratic systems have a lower deforestation rate because democracy allows for the presence of more groups that are concerned with environmental protection (Didia, 1997).

Agro-ecology: Verburg *et al.* (1999) hold that human factors, like population, technology and economic conditions, as well as biophysical factors such as soil, climate and topography determine the spatial pattern of land use. Generally, the more fertile, flat, well drained and irrigated soils are more likely to be used for agricultural production. Mertens *et al.* (2002) found that farmers would deforest areas whenever the gross benefits outweigh the costs. It is expected that deforestation would take place in locations with soils, climates and topography suitable for agriculture, which provides higher revenues.

Not only land characteristics define land use trends, but also land availability. Forest conversion in Costa Rica was reduced by the exhaustion of forest areas; the fall of beef prices played a minor role (Kaimowitz and Angelsen, 2002). Forest scarcity is a prerequisite for technology intensification. If land was expensive, farmers would increase their production using more intensive technology. Therefore, more intensive technology would only maintain forest cover if this were a less expensive option than extensive growth (Angelsen and Kaimowitz, 2001; White *et al.*, 2001).

4.2.2 Methodology

The study was divided into two parts; the first was the interpretation of aerial images. In the second part, the econometric analysis was conducted.

4.2.2.1 Interpretation of aerial images

The aerial photos for the study area for the years 1962, 1970, 1986 and 1992 were imported into Arc View and interpreted using the image analysis extension. The photos were obtained from the National Institute of Geography of Costa Rica. The photos were classified into 16 categories using the non-supervised option of the extension Image Analysis in ArcView. Based on the 16 category files, the images were classified into three categories: forest cover areas, pasture with tree cover and pasture without tree cover, using the original photos as a background for a manual classification. Forest cover was defined as areas with more than 20% forest cover. Pastures with tree cover included paddocks with less than 20% tree cover but more than 5%. Finally, pastures without tree cover were considered as those with less than 5% tree cover.

4.2.2.2 Analysis

Once the images were interpreted, the Markov transition matrices were estimated using the "crosstab" command in ArcView. This command compares changes from one period to another period for each pixel. A Markov transition matrix was used to analyze the probability of change for each type of land cover (Table 4.11).

Table 4.11 - Markov Transition Matrix

T / t + 1	1	2	3	$\sum N$
1	N_{11}	n_{12}	n_{13}	$\sum n_{1i}$
2	N_{21}	n_{22}	n_{23}	$\sum n_{2i}$
3	N_{31}	n_{32}	n_{33}	$\sum n_{3i}$
$\sum n$	$\sum n_{i1}$	$\sum n_{i2}$	$\sum n_{i3}$	$\sum n_{ij}$

The matrix presented can be explained as: n_{ij} are the amount of pixels that in period t were in land use type i, and in period t + 1 were in land use type j. The probability of change will be obtained through:

$$P_{ij} = \frac{n_{ij}}{\sum_{j=1}^{N} n_{ij}} \quad (12)$$

Once the transition matrix was established, results were analysed by using as explanatory variables the ratio between beef production and exportation, U.S. beef prices, the ratio of agricultural and non-agricultural workers, Costa Rican beef prices and the ratio between rural and urban population. To explore the effect of these factors on the land cover change during the study period, each variable was calculated as the average value between the years of the aerial photo.

With this information, Poisson correlation coefficients were calculated for the probabilities of change with the socio-economic variables. Finally, cause-effect relationships were analyzed, explaining how the socio-economic variables influenced land cover change in the study area.

4.2.3 Results and discussion

The results are presented in three parts; the first is the land cover change in the area during the period 1961 to 1992. This is followed by the transition matrixes, and finally, the effect of the political, demographic and beef market change over the land cover from 1961 to 1992.

4.2.3.1 Land cover change from 1961 to 1992

As described by Flores and Monterroso (2002), the main activity in the study area is cattle production. The main land cover change in the dry forest zone of Costa Rica was the increase of tree resources in paddocks (Table 4.12 and Figure 4.5). During the 1960s, paddocks without tree resources were the main land cover which changed in 1970s when forest areas and paddocks with tree resources became the main land use. This represents an increase in forest and tree resources. Forest area increased from 23% in 1961 to 38% in 1992, presenting a stable tendency since 1970. The finding of 38% forest cover is comparable with the forest cover reported by FONAFIFO (2001), which proved that forest and tree resources have constantly been increasing since 1961.

Table 4.12 - Land cover (%) in the study area in the years 1961, 1970, 1986 and 1992

Land cover	Years (%)			
	1961	1970	1986	1992
Forest (FA)	23	39	38	38
Paddocks with tree cover (PT)	49	39	52	54
Paddocks without tree cover (PNC)	28	22	10	8
Total	100	100	100	100

In the Costa Rican Atlantic Zone, deforestation started in the late 19th century, and around 40% of the area was under rangelands by 1999. In fact, 70% of the pastures were in advanced stages of degradation. With progressive degradation of pastures, there is a point where beef cattle ranching is no longer profitable and land is abandoned to natural regeneration (Bouman and Nieuwenhuyse, 1999). The weather conditions in the dry forest zone are limiting for agricultural crops, providing better conditions for the natural regeneration process. Thus, Guanacaste has half of the secondary growth forest in Costa Rica (Gonzales, 2002; Spittler, 2002).

As presented in Figure 4.5, the dynamics of land cover change in the area focused on the 1970s in the conversion of forest areas to pastures without tree resources. Later, tree resources started to grow in the paddocks without tree resources, increasing the tree cover in the area. This course of action was brought about by the natural regeneration process which is the natural trend for recovering the original forest cover. As grasses are a non-native species, they tend to reduce their cover unless the conditions for growing them are not maintained. To keep grass cover in paddocks, it is important to manage an adequate animal stocking rate, to maintain a rotation cycle and also to control weeds. All these practices require owners to maintain a constant presence on the farm. This is not the case in the area where more than 50% of farmers are absentee landowners.

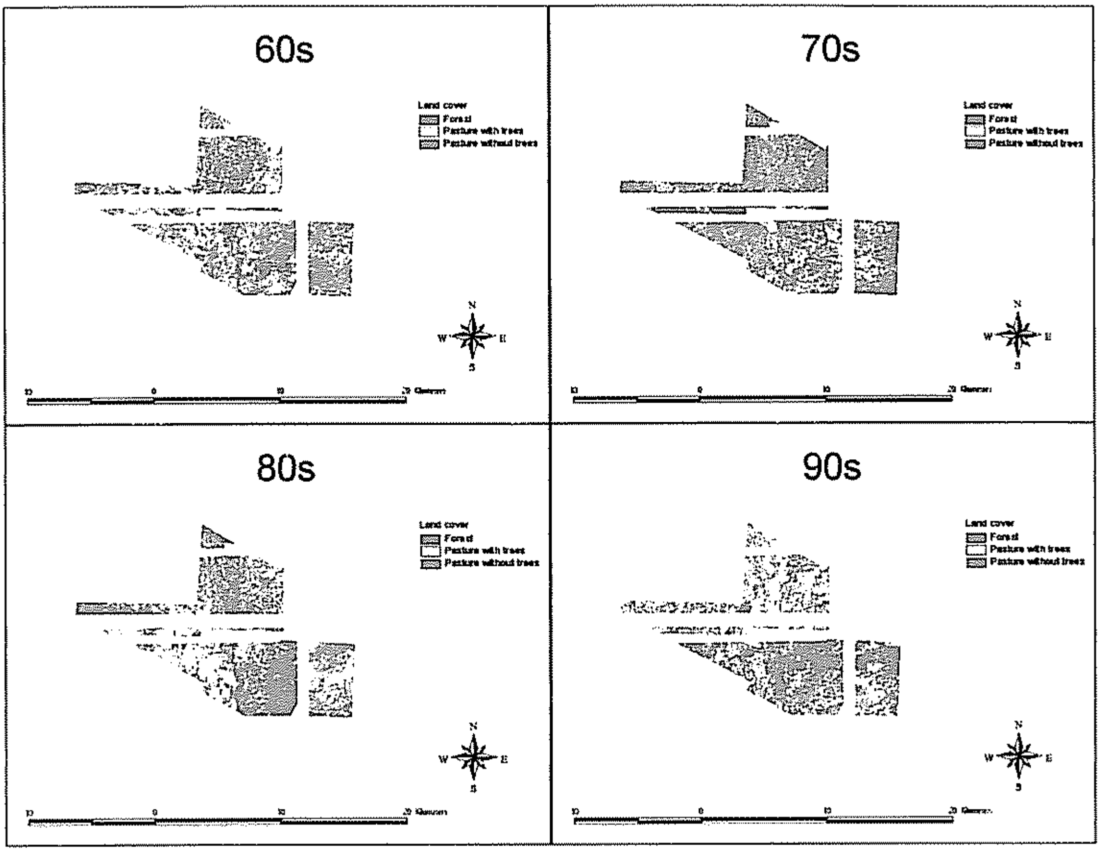

Figure 4.5 - Land cover in Cañas and Bagaces, in the years 1961, 1970, 1986 and 1992

4.2.3.2 Transition matrix

The main land cover change from 1961 to 1970 was the increase of tree resources in paddocks. Eighty four percent of paddocks without tree resources increased their tree cover with 51% passing to paddocks with tree cover and 33% to forest areas. Only 16% of the paddocks without tree cover have not changed from 1961 to 1970 (Table 4.13). From the three land covers studied, forest areas have the highest percent of areas without modification from 1961 to 1970. The increase in forest cover reported in Table 4.12 was produced by a conversion of paddocks with and without tree resources to forest areas.

Table 4.13 - Transition matrix (%) for land cover change from 1961 to 1970

61 \ 70	FA	PT	PNC	Total
FA	40	30	29	100
PT	42	36	23	100
PNC	33	51	16	100

Similar to the previous period, the main land cover change from 1970 to 1986 was the increase of forest and tree resources. However, the increment in forest and tree resources was a response to the increase of tree resources in paddocks. Sixty two percent of paddocks without tree resources and 48% of forest areas changed to paddocks with tree resources from 1970 to 1986, while 50% of the paddocks with tree resources had not changed during the same period. The increase of forest and tree resources was also motivated by the reduction of forest conversion to pasturelands. From 1961 to 1970, 59% of forest areas were converted to paddocks, while only 55% changed from 1970 to 1986. The conversion of forest areas to paddocks without tree resources was reduced from 29% forested areas from 1961 to 1970 to 7% from 1970 to 1986. Conversely, the tendency is to increase tree resources in paddocks; only 13% of the paddocks had not increased their tree cover (Table 4.14).

Table 4.14 - Transition matrix for land cover change from 1970 to 1986

70 \ 86	FA	PT	PNC	Total
FA	44	48	7	100
PT	39	50	11	100
PNC	25	62	13	100

In the period 1986–1992 the main land cover change was an increase of paddocks with tree resources at the expense of paddocks without tree resources. Contrary to previous periods, the conversion of forest areas to paddocks increased, returning to the 1961–1970 level. However, the conversion of paddocks to forest areas increased, which at the end produced a null increment in forest resource cover in the area (Table 4.15).

Table 4.15 - Transition matrix for land cover change from 1986 to 1992

86 \ 92	FA	PT	PNC	Total
FA	41	50	9	100
PT	36	56	8	100
PNC	36	56	9	100

The relationship between political, demographic and market factors and the land cover change in the dry forest zone is presented in this section and is based on the tendency of demographic and market variables. The first land cover class presented is the forest cover (FA).

Beef exportation had an important effect on the permanence of forest areas. The ratio of beef exportation/beef production has decreased since the 1960s while the conversion of forest areas to pasturelands decreased. As international beef markets require higher quality standards than local markets, an increase in beef exportation demands a higher technology level, producing an intensification of the cattle industry. To produce the quality demanded by international markets, farmers need to introduce intensified systems, which in many cases require mechanisation of production. To invest in intensified systems, farmers would have to focus their production on the most fertile soils, leaving low fertility soils for forest and tree resources. As presented in Chapter 3, beef intensification in Costa Rica is explained by the soil and breed characteristics. Considering that the paddocks in the area of Cañas and Bagaces are dominated by *Hyparhenia rufa;* to convert the *H. ruffa* pastures to improved grasses like *Brachiarias spp*, *Panicum spp* or *Pennisetum spp*, farmers would use those areas with the highest natural fertility. Furthermore, 95% of the cattle farmers did not fertilise their pastures, meaning that cattle production depends on natural soil fertility.

Regarding the conversion of forest areas to paddocks with tree resources, the urbanization process plays an important role. The rural/urban population ratio moved from 1.75 to 0.85 from 1961 to 1992, while the agricultural/non-agricultural worker ratio changed from 0.91 to 0.36. Thus, labour in rural areas has decreased, increasing the opportunity cost of agricultural labour. When labour is a limiting force, intensification of cattle production must be based on mechanisation. However, mechanisation requires higher financial investment which is no longer available for cattle farmers as it used to be during the 1970s and 1980s.

Therefore, farmers did not have enough incentive to intensify their production systems which in this case is reflected by the paddocks without tree resources. In this case, the factor underlying conversion of forest areas is the availability of labour. Citeris paribus, a reduction in labour supply increases labour cost. As paddocks without tree resources demanded more labour force; farmers prefer to convert forest areas to paddocks with tree resources, which demand less labour force. Furthermore, forest and tree resources are used as forage sources, providing an incentive to maintain trees in paddocks. Thus, the increase in the number of cattle would force farmers to convert forest areas to paddocks but farmers have enough incentives to maintain tree resources in paddocks as dispersed trees.

Contrary to the popular understanding of deforestation processes, an increase in beef prices will not increase deforestation in dry forest zone of Costa Rica. As presented in Chapter 3, beef prices have constantly increased since the 1960s, but forest cover has also increased. The limiting factors for a high rate of deforestation are the loss of government subsidies and the increase in labour costs. Farmers have market incentives to increase their production; however, they are not able to intensify cattle production (paddocks without tree cover) due to the restriction in labour markets. Therefore, farmers increase their production using less intensive production systems (paddocks with trees) which require less labour.

For the change of paddocks with tree resources, when labour is not the limiting factor, farmers tend to reduce the number of trees in paddocks, favouring the grasses. The reduction of trees in paddocks is seen as an intensification of the production systems since trees compete with grasses for nutrients and light. It was established that paddocks without trees can support a higher animal stocking rate (Chapter 3). As discussed by Kaimowitz and Angelsen (2002), livestock intensification would decrease deforestation in those areas where land is a limiting factor. In Cañas and Bagaces, there are no more public lands. An increase in labour supply will allow farmers to contract more workers in order to increase productivity, reducing tree resources in paddocks and increasing the animal stocking rate which will reduce the areas for the natural regeneration process.

Considering the discussion above, labour is a limiting factor for cattle production intensification in the area. As labour is not available and U.S. and national prices are growing, farmers focus their production on the use of paddocks with tree resources. Market incentives are not enough to promote the reduction of tree resources on cattle farms.

4.2.4 Conclusions

Based on the discussion presented above, it is possible to conclude that forest cover in the dry forest zone of Costa Rica has constantly increased since 1961. The increase in forest and tree resources was at the expense of paddocks without tree resources which were converted into paddocks with tree resources. The increase of tree resources in paddocks implies a reduction in the intensification of cattle production since paddocks without tree cover can support a higher animal stocking rate than paddocks with tree resources.

The increment of forest and tree resources was stimulated by Costa Rican socioeconomic conditions, especially the reduction in the agricultural labour supply due to the migration from rural to urban areas. The result was an increase in the labour costs for agricultural activities. The increase of labour costs has reduced the importance of the agricultural sector in the production matrix of the Costa Rican economy whereas sectors like tourism and services have increased their importance. Farmers respond to this shock by reducing the intensification of beef production; thus, the increase in forest and tree resources is especially a result of the increase in labour opportunity costs.

Regarding national and U.S. beef markets, beef prices have constantly increased since 1961; therefore, the popular belief that the beef industry crash was produced by a fall in beef prices is not supported by this finding. Beef farming has market incentives (beef prices) for increasing or at least maintaining production levels; however, labour costs and changes in government policies reduced production. The Costa Rican government has supported cattle production through cheap credit, technical assistance and by creating beef exportation plants. Most of these policies were also supported by international financial agencies, but financial support is no longer available.

If the socioeconomic conditions of Costa Rica had not changed, forest and tree resources in the dry forest zone would not be endangered. To increase forest conversion to pasturelands, it is necessary to reduce the labour costs or to find technology that increase labour productivity.

Chapter 5

MAIN ENDOGENOUS FACTORS UNDERLYING TREE AND FOREST RESOURCE MANAGEMENT ON CATTLE FARMS

5.1 ELICITING FARMER PREFERENCES FOR TREE ARRANGEMENTS ON CATTLE FARMS

5.1.1 Introduction

The dry forest zones were the first to be colonized in Central America, transforming the original forest cover to pasture lands (Cubero, 2002; Gonzales, 2002; Pagiola and Ruthenberg, 2002). From the 1970s to the 1990s, Costa Rica experienced one of the world's highest deforestation rates; the country lost about 35 – 40% of the original forest cover, driven primarily by conversion of forest areas to agriculture or pasture (Pagiola, 2002). Nevertheless, in the mid 1980s, the tendency changed due to reduction in government support for cattle farming and improvements in the Costa Rican socioeconomic conditions (Chapter 4). As a result, farmers abandoned or reduced production, leaving areas open to natural regeneration (Riviera and Mitchell Aide, 1998). By 2001 an estimated 150,000 hectares of dry forest zones were under regeneration, with most of them 15 years old or less (Gonzales, 2002; Spittler, 2002a; Spittler, 2002b; Vega Araya, 2002; Lynn Carpenter *et al.*, 2004).

The reduction in cattle activity has created new opportunities for natural regeneration on cattle farms. Forest recovery after pasture abandonment is not a difficult process. Natural succession processes can be classified into two types: primary and secondary succession. Primary succession occurred in areas without human intervention while secondary succession occurred in areas that suffer various human interventions (Hernández *et al.*, 2002; Muchagata and Brown, 2002).

Forest owners and users have long recognized that forests provide a range of environmental services in addition to valuable commodities such as timber, fibre, fuel wood, edible and medicinal plants and game. However, not all of these services directly benefit the owners as they may be driven by national and international societies. As long as farmers do not receive any compensation for providing these services, they are unlikely to consider them when making decisions about land use change (Kreuter and Workman, 1994; Chomitz *et al.*, 1999; Bishop and Landell-Mills, 2002; Kerr, 2002; Pagiola, 2002; Pagiola *et al.*, 2002b; Pagiola and Ruthenberg, 2002; Unisfera, 2004). One of the first approaches to include externalities in farmer decision-making processes is through the payment for environmental services (PES).

Costa Rica was one of the first countries to implement PES. Lately, many other countries have tried to create mechanisms for PES (Some examples are: Argentina, Bolivia, Brazil, Colombia, Costa Rica, Ecuador, El Salvador, Guyana, Honduras, Mexico, The United State of America (Brand, 2002; Echavarria, 2002; Corcuera *et al.*, 2002; Laird and ten Kate, 2002; Lascano Vaca, 2002; May *et al.*, 2002; Pagiola and Ruthenberg, 2002; Tipper, 2002; Republica de Honduras, 2003; Unisfera, 2004; Perz, 2004). On a world scale, Pagiola *et al.* (2002a) have found more than 300 projects related to the PES approach, most of them with a market-based approach.

The environmentally sound policy of the Costa Rica government is reflected by the investment in environmental aspects which have increased since 1992. By 2000, environmental issues represented 4.5% of the Costa Rican federal budget. Furthermore, in 1997, the PES program began; it is supported by the forest law (Law no. 7575 of 1996) which recognises four environmental services: 1) mitigation of greenhouse gas emissions, 2) hydrological services, 3) biodiversity conservation and 4) provision of scenic beauty for recreation and tourism (Chomitz *et al.*, 1999; CEPAL and PNUD, 2001; Bishop and Landell-Mills, 2002; CEPAL, 2002; Pagiola, 2002; Vega, 2002; Salzman, 2003). Payments are made through the Fondo Nacional para el Financiamiento Forestal (FONAFIFO).

The first challenge in developing PES is the definition, measure and quantification of environmental services, and the identification of the demand for the service. However, environmental markets are not clearly defined due to the lack of scientific evidence, cheaper substitutes, and regulatory framework as well as coordination problems, inadequate participation, cultural resistance and lack of financing (Unisfera, 2004). Since there is no market for environmental services, it is not possible to measure the value of environmental services directly by looking at market prices, thus there is a demand for economic methodologies to value these externalities (Bishop and Landell-Mills, 2002).

Alternatives for determining the value of environmental services are the choice experiments. The first use of choice experiments in valuation of environmental amenities was done by Adamowicz *et al.* (1985), who compared choice experiments and contingent valuation in measuring passive use values for a woodland caribou management program in Canada. They concluded that the choice experiments are a better method than contingent valuation. In a more theoretical study, Harless (1993) used choice experiments in testing the prospective reference theory. The use of choice experiments became more frequent in tourism studies; Morley (1994) used it in testing the behaviour of Malaysian people who selected Australia as a tourist destination. Likewise, Dellaert *et al.* (1995) used choice experiments in eliciting preferences for urban tourism packages. The use of choice experiments in environmental issues started just recently. Garrod and Willis (1998) used choice experiments in evaluating the social impacts of solid waste disposal in landfill sites, and in the same year Bullock *et al.* (1998) used the method to test the characteristics of land for red deer hunting.

More recently, Haider and Rasid (2002) defined the trade-off in water supply from a municipality in Canada; Hearne and Salinas (2002) evaluated the preferences of tourists for accommodations in a volcanic park in Costa Rica; Alvarez-Farizo and Hanley (2002) studied perceptions about the effect of wind plants on the landscape; San Miguel *et al.* (2002) studied the stability of preferences in health care with a discrete choice experiment (DCE); Morey *et al.* (2002) elicited the benefits and costs of land use policies; McIntosh and Ryan (2002) analysed the choice of patients in the Isle of Wright between waiting time for medical attention in UK hospitals; and finally, Scott *et al.* (2003) elicited the preferences of users and non-users of different models of out-of-hours care. Nevertheless, few studies have been conducted in defining farmer preferences concerning technology attributes; the only study known by the authors is Gomez (2001).

In Costa Rica, PES did not consider the quality of the services provided because the calculation of PES was based on previous forest incentive payments and land use opportunity costs, resulting in a subsidy scheme (Salzman, 2003). The incentive for forest regeneration is equal to rental price for pasture, between US$ 20 – 30/hectare. This opportunity cost is adequate for cattle farming in marginal areas. Nevertheless, payments are not enough to compensate for the cost of forgone alternatives such as dairy farming, export-oriented agriculture and urbanisation (Chomitz *et al.*, 1999; Pagiola, 2002; Ortiz *et al.*, 2003; Unisfera, 2004).

In total 314,475 hectares have been paid in the PES program from 1997 to 2002; 82% corresponded to forest protection, 10% to forest management, 7% to forest plantation (Sanchez, 2002). This trend shows that PES is a way to protect areas located in marginal areas where opportunity costs are low enough to motivate farmers to received PES.

Payments are structured as a function of complementary income for rural families but were not created to reduce rural poverty. In Costa Rica, most of the PES benefactors are farmers with medium and high incomes. Farmers with more than 70 hectares received 80% of the PES, while farmers with less than 30 hectares (37% of the total farmers) received 6% of the PES (Miranda *et al.*, 2003; Ortiz *et al.*, 2003). The concentration of medium and large farmers attempts to reduce the transaction costs which are an important compound of the cost to access PES for farmers. Transaction costs represent from 12 to 18% of the PES amount. Therefore, 80% of the farmers accessed PES through NGOs or a professional consultant (Miranda *et al.*, 2003; FAO, 2004).

From the farmers' point of view, PES is a good strategy to protect or increase forest cover because 100% of the farmers receiving PES want to maintain the area under PES (Ortiz *et al.*, 2003). However, only 33% of the PES farms were under agricultural activity before PES; the rest were under forest cover. So, the forest regeneration process had started on farms without PES, and probably the process would continue without PES (Ortiz *et. al.*, 2003).

The environmental market is not clearly defined; the Costa Rican government created the PES under the consideration of fuel taxes as well as international loans and donations (Camacho and Reyes, 2001; CEPAL and PNUD, 2001; Pagiola, 2002; Rosa and Kandel, 2002). In 2001 the amount of PES was reduced by FONAFIFO's lack of funds due to a reduction in government payments from fuel taxes (Camacho and Reyes, 2001). By 1998, demand for PES exceeded the payment capacity by 200%, and more than 70,000 hectares await incorporation into the payments. By 2000, FONAFIFO was able to pay only 34% of the demand (CEPAL and PNUD, 2001).

The PES scheme to select the PES beneficiaries has been established to include hydrological importance, the presence of significant species, the distance to protected areas and finally the ranking of the GRUAS project (Chomitz *et al.*, 1999; Vega Araya, 2002). The GRUAS study was the first national level plan to apply GIS based data to identify biological corridors and reclassify existing protected areas in order to assure representation of a minimum set of interconnected vegetation macro-types. The study took into account the local potential for land use conflict through local consultation as well as a qualitative evaluation of the potential for other environmental services. The project has been the base for the declaration of protected areas since 1996 (NIVA, 2003).

Carbon sequestration through growing trees is a comparatively cost-effective option for reducing net emissions. Agroforestry systems can be an option for carbon sequestration under Clean Development Mechanisms as they can sequestrate between 6 and 25 t C/hectare with an annual rate of 0.2 - 3.1 t C/hectare per year. As a comparison, a forest plot can store 200 t/hectare of C, 75% in living trees above ground, 16% in the form of organic soil C, and 4% in the roots. Thus, agroforestry systems can sequester 7 Gt C between 1995 and 2050 globally at a total cost of 30×10^9 US$, implying a total cost of US$ 100/tC (Fujisaka *et al.*, 1998; Pandey, 2002). However, the main limitation for the adoption of silvopastoral systems is their high initial cost (Pagiola *et al.*, 2004).

The creation of PES in Costa Rica was based on the hypotheses that opportunity costs for farms located in some areas would be lower than the payment provided by governments. The payment would motivate farmers to protect the forest covers, preventing land use change. The scheme mandates farmers to leave the area under protection, avoiding any kind of productive use different from forest plantation.

This scheme works in areas with low opportunity costs, but in areas where any agricultural production is possible, the scheme does not work. In these areas, farmers have a higher opportunity cost, but it is possible to have forest and tree resources that provide some environmental services. This type of strategy is tested by CATIE through a GEF project in Nicaragua, Costa Rica and Colombia (Pagiola *et al.*, 2004).

As mentioned in Chapters 3 and 4, the increase in forest and tree resources in Costa Rica was produced especially in abandoned pastures. Dispersed tree are found in more than 90% of the Costa Rican cattle farms (Souza de Abreu *et al.*, 2003). Tree resources in cattle farms provided services like forage and shade for livestock production (Chapter 3). However, grasses and trees compete for nutrition and light, producing a trade-off between tree resource cover and grass productivity. With a low number of trees in paddocks, grass yield increases under tree canopy due to better soil moisture and more nutrients under tree canopies (Black and Ong, 2000; Burgess *et al.*, 2000; Sakalauska *et al.*, 2001; Zugliani and Oliveira-Filho, 2004; Abule *et al.*, 2005). Furthermore, cattle use tree shade as a refuge during the hottest time of the day (Bennett *et al.*, 1984).

Farmers are concerned about grass quality principally because of the limitation of producing enough forage in the dry season. This can be resolved by introducing forest and tree resource management that could supply forage during dry season. Farmers would adopt technology that makes use of their abundant resources and responds to their problems. An alternative can be silvopastoral systems. One argument favouring silvopastoral management is that the cattle and tree interactions can be complementary or even cooperative, rather than competitive (Costanza and Neuman, 1997).

However, an increase in tree resource cover in paddocks increases the competition for growing factors. In dry areas, trees compete with other species for water (McIntyre *et al.*, 1997). When the relationship between grasses and trees are competitive, normally grasses reduce their productivity, forcing farmers to reduce the competition with trees by cutting the forest cover. Only at that point farmers began to have a decrease in productivity due to tree resources, and it is here where PES can be implemented. Some studies define that tree cover of 15 to 20% in a paddock is the maximum; however, few studies have been conducted in defining farmer perceptions of the trade-off between trees and grasses. Thus, this study explores farmer demand for compensation for introducing forest and tree resource management on cattle farms.

5.1.2 Methodology

5.1.2.1 Choice experiments

Economic valuation methods aim to measure consumer demand in monetary terms. That is, the willingness to pay for a particular non-marketed benefit, or the willingness to accept monetary compensation for the loss of benefits. A simple division includes: methods that estimate values from consumer behaviour in markets (revealed preferences), and methods that rely on consumer response to direct questions (stated preferences) (Bishop and Landell-Mills, 2002).

Revealed preference and stated preference methods, both based on conjoint analysis, are approaches that have proven to be efficient in valuing environmental services (Adamowicz *et al.*, 1994; Boxall *et al.*, 1996; Adamowicz *et al.*, 1998; Alvarez-Farizo and Hanley, 2002; Hearne and Salinas, 2002). One of the stated preference methods is the choice experiments in which people choose between different alternatives instead of only ranking them like in conjoint methods (Adamowicz *et al.*, 1985; Adamowicz *et al.*, 1994; Alpizar *et al.*, 2001; Haider and Rasid, 2002).

Traditionally, in the valuation of environmental services, contingent valuation has been used (Adamowicz *et al.*, 1994; Adamowicz *et al.*, 1998). In this method people choose between the status quo and a hypothetical better alternative, while in choice experiments people choose between alternatives described by their attributes (Heberling *et al.*, 2000; Alpizar *et al.*, 2001). Adamowicz *et al.* (1985) and Adamowicz *et al.* (1994) compared choice experiments and contingent valuation. They found that the former was a better method for valuating environmental services since it takes into account the trade-offs between the attributes that are disregarded by contingent valuation. Apart from that model, error and utility parameters were not different from contingent valuation though welfare values have a smaller variation to contingent valuation.

Moreover, choice experiments appear to overcome some of the problems related to contingent valuation such as strategic behaviour and "yeah-saying" (Adamowicz *et al.*, 1985; Heberling *et al.*, 2000; Alpizar *et al.*, 2001). Thus, choice experiments are consistent with random utility theory (proposed by Thurstone in 1927) and an alternative method to contingent valuation (Lakshmi-Ratan *et al.*, 1992; Adamowicz *et al.*, 1994; Adamowicz *et al.*, 1998; Garrod, and Willis 1998; Lindberg *et al.*, 1999).

The first step in designing choice experiments is the definition of attributes and levels associated, where it is recommended to use focal groups in this first stage (Adamowicz *et al.*, 1998; Alpizar *et al.*, 2001; Russell *et al.*, 2001). Focal groups aim to define the dimensions of the research, seek information about alternatives and attributes and begin the definition of the choice sets (Adamowicz *et al.*, 1998; Volcán, 2000). To explain the willingness to pay in choice experiments, it is required to include a monetary attribute in the choice sets (Boxall *et al.*, 1996; Heberling *et al.*, 2000; Alpizar *et al.*, 2001).

Once the attributes and associated levels have been defined, an experimental design is required. The most commonly used is the complete factorial with orthogonal design. In this design, the variation of the attributes of the alternatives is uncorrelated in all choice sets. The design is done in two stages. First, the optimal combination of attributes and levels is obtained and then combined into choice sets (Adamowicz *et al.*, 1994; Adamowicz *et al.*, 1998; Ewing and Sarigollu, 1998; Alpizar *et al.*, 2001).

In the next step the questionnaire is designed. It is important to determine the number of choice sets, or task complexity, to present to the people. The number normally ranges from 1 to 16 and up to 32 can be applied. Adamowicz *et al.* (1998) recommend the use of 8 choice sets, whereas Hensher *et al.* (2001) suggested around 16 choice sets. Task complexity can affect the decision-making process as task complexity increases, choice accuracy is reduced (Swait and Adamowicz; 1996; Adamowicz *et al.*, 1998; Bullock *et al.*, 1998; Heberling *et al.*, 2000; Alpizar *et al.*, 2001; Russell *et al.*, 2001). Thus, the use of less than 5 attributes is recommended. Beyond this point, data quality decreases because respondents can answer carelessly or use a lexicographic decision rule which is detrimental to trade-off decisions (Swait and Adamowicz, 1996; Scott, 2002; Street and Burgess, 2002).

Choice experiments were inspired by the Lancasterian microeconomic approach which assumes that individuals derive utility from the characteristics of the goods rather than from the goods themselves (Dellaert *et al.*, 1995; Adamowicz *et al.*, 1998;

Alpizar *et al.*, 2001; Hearne and Salinas, 2002). Individuals consider which goods to choose and how much to consume of the chosen goods. A specific continuous dimension is assumed as part of the framework in which the choice takes place. Based on Adamowicz *et al.* (1998) and Alpizar *et al.* (2001), the maximization equation can be described as:

$$13)\qquad Max_{c,x}U\left[c_1(A_1),...,c_N(A_N);x;s\right]$$

s.t.

$$i.\ y=\sum_{i=1}^{N}p_ic_i+x$$

$$ii.\ c_i,x\geq 0$$

iii. other *problem specific restrictions*

Where U[...] is the utility function; $c_i(A_i)$ is the alternative combination; i is a function of its generic and alternative specific attributes and price p_i; x is a composite bundle of ordinary goods with its price normalized to one, and s is income.

Alpizar *et al.* (2001) specify the maximization equation: 1) c_i's are profiles defined for all the relevant alternatives, 2) the price variable in the budget restriction must be related to the complete profile of the alternative, 3) restriction ii defines the number of alternatives that can be chosen, 4) in a purely discrete choice, the selection of a particular profile $c_j(A_j)$, which is provided in an exogenously fixed quantity, implies that, for a given income, the amount of ordinary goods z that can be purchased is also fixed; combined with the restriction that only a single profile, c_j, can be chosen, leads to: $z = y - p_jc_j$, 5) restriction iii specifies that the individual will choose a non-negative quantity of the composite good and the goods being studied. The maximization equation requires that:

$$14)\qquad \text{if } c_i=0\text{, then } \frac{\partial U}{\partial A_i}=0,\ \forall i\neq j$$

Then, if $c_i > 0$, the conditional maximization can be written as:

$$15)\qquad Max_{c,x}U_j\left[c_j(A_j);x_j;s\right]$$

$$\text{s.t.} \qquad y = p_j c_j + x_j$$

Considering the first order conditions to obtain the solution of a continuous choice, and constructing an indirect utility function, Alpizar *et al.* (2001) describe the latter as:

$$16) \qquad V[p,y,x,s,A] = \max\left|V_1^*(p_1,y,x,s,A_1),\dots,V_N^*(p_N,y,x,s,A_N)\right|$$

where V[...] is the indirect utility containing the discrete and continuous choice. According to the maximization assumption, the choice i would be selected only if:

$$17) \qquad V_j^*(p_j,y,x,s,A_j) > V_i^*(p_i,y,x,s,A_i) \;\; \forall i \neq j$$

Since not all the attributes influencing the choice decision can be modelled, the random utility approach is used to link the deterministic model with a statistical model of human behaviour. If the choice experiment consists of M choice sets, where each choice set consists of K_m alternatives, such that $S_m = \{x_{1m},\dots,x_{K\_m}\}$, where x is a vector of attributes, the probability choice will be described as:

$$18) \qquad P\{j \mid S_m\} = P\{V_j + \varepsilon_j \geq V_i + \varepsilon_i; \forall i \in S_m\} = P\{\beta x_{jn} + \varepsilon_j \geq \beta x_{in} + \varepsilon_i; \forall i \in S_m\}$$

Considering V_j is linear in the parameters, and if it is assumed that ε has a Weibull, a Multinomial Logit Model is obtained (Adamowicz *et al.*, 1994, Haaijer *et al.*, 1996; Adamowicz *et al.*, 1998; Alpizar *et al.*, 2001):

$$19) \qquad P(j \mid S_m, \beta) = \frac{\exp^{\mu V_j}}{\sum_{i \in S_m} \exp^{\mu V_i}} = \frac{\exp^{\mu \beta x_{jn}}}{\sum_{i \in S_m} \exp^{\mu \beta x_{in}}}$$

5.1.2.2 Marginal substitution rate

One of the purposes of this paper is to define the demand for compensation in different spatial arrangements of trees in pastures. Based on Alpizar, *et al.* (2003), the following utility function is assumed:

$$20) \qquad u = h(A) + \gamma(Q,z)z + \varepsilon$$

Where h(A) captures the effect of the different utility attributes, Q is a vector of personal characteristics and z is a composite bundle. Assuming a constant marginal utility of income and independence of personal characteristics, the conditional indirect utility function for a purely discrete choice is expressed as:

$$21) \quad V_j(A,z,\varepsilon)=h(A)+\bar{\gamma}(z)+\varepsilon$$

Considering that $z = y - p_i c_i$, where y is income, p_i is price and c_i is a defined profile for all the relevant alternatives. Furthermore, the probability that alternative j is preferred can be written as:

$$22) \quad \begin{aligned} P\{j\} &= P\{h_j(A_j)+\bar{\gamma}(y-p_jc_j)+\varepsilon_j > h_i(A_i)+\bar{\gamma}(y-p_ic_i)+\varepsilon_i;\forall i\neq j\} \\ P\{j\} &= P\{h_j(A_j)-\bar{\gamma}p_jc_j+\varepsilon_j > h_i(A_i)-\bar{\gamma}p_ic_i+\varepsilon_i;\forall i\neq j\} \end{aligned}$$

Equation 25 shows that income does not affect the probability of choosing a certain alternative under the current assumption. Thus, the unconditional indirect utility function can be expressed as:

$$23) \quad v(A,p_j,y,\varepsilon)=\bar{\gamma}y+\max[h_1(A_1)-p_1c_1+\varepsilon_1+...+h_N(A_N)-p_Nc_N+\varepsilon_N]$$

The Compensating Variation (CV) is obtained by solving the equality $V(A^0,p^0,y) = V(A^1,p^1,y-CV)$. Using Equation 25, and solving for CV, we have:

$$24) \quad \begin{aligned} CV = \ & \frac{1}{\bar{\gamma}}\{\max[h_1(A_1^1)-p_1^1c_1+\varepsilon_1+...+h_N(A_N^1)-p_N^1c_N+\varepsilon_N]- \\ & \max[h_1(A_1^0)-p_1^0c_1+\varepsilon_1+...+h_N(A_N^0)-p_N^0c_N+\varepsilon_N]\} \end{aligned}$$

If the error term is extreme value distributed, a MNL model is obtained as in Equation 7 and then the expected CV for a change in attributes is:

$$25) \quad E(CV)=\frac{1}{\mu\bar{\gamma}}\left\{\ln\sum_{i\in S}\exp(\mu V_{i1})-\ln\sum_{i\in S}\exp(\mu V_{i0})\right\}$$

where μV_{i1} and μV_{i0} represent the estimated indirect utility before and after the change, $\mu\gamma$ is the confounded estimate of the scale parameter and the marginal utility of money and S is the choice set. Assuming a linear utility function and only one changing attribute, the CV for a discrete choice is:

$$26) \qquad CV = \frac{1}{\gamma}\ln\left\{\frac{e^{V_{i1}}}{e^{V_{i0}}}\right\} = \frac{1}{\gamma}\ln\left(V^1 - V^0\right) = \frac{\beta_k}{\gamma}\left(A_k^1 - A_k^0\right)$$

Equation 29 shows that for a MNL model, the marginal substitution rate is the ratio of the coefficients:

$$27) \qquad MSR = \frac{\beta_i}{\gamma}$$

The methodology of the study was divided into six parts; 1) identification of principal problems faced by cattle farmers; 2) definition of attributes and levels; 3) design of the experiment; 4) elaboration of the questionnaire 5) collection of data, and 6) finally the econometric model was implemented.

5.1.2.3 Workshop

The workshop aimed to discuss with farmers the main problems faced in cattle production and how forest and tree resources are used on their farms. Optimally, a good representation of farmers located in the area would be present. Participants were selected using the rural rapid appraisal findings, selecting 25 farmers representing the 4 groups presented on Chapter 3.

In total, 24 farmers were invited, but only 3 of them responded to the invitation, having in the end 7 farmers. The methods used in the workshop were problem census and problem ranking (Geilfus, 2000):

3) **Problems census**: this started with a brainstorm. The first step was an explanation to the participants the reason and the necessity to obtain this data. Each problem mentioned was written down on a sheet of paper and then clipped to the board.

4) **Problem ranking:** the problems identified were ranked by farmers using a pair wise comparison. Problems were compared in pairs. Farmers mentioned which of the two problems was more important. The results were introduced into a double

entrance matrix as described in (Geilfus, 2000). One point was assigned to the most important problem. When no consensus was reached, 0.5 point was assigned to each problem compared. Then, points were added, and problems were ranked according to the points obtained.

5.1.2.4 Definition of attributes and levels

The basic information in defining the attributes and levels came from Flores and Monterroso (2002) and Flores *et al.* (2002). With this information, six attributes were identified and discussed in two different focus groups. The first group met in CATIE, with CATIE experts (7 participants) in silvopastoral systems, natural resource economy and participatory research. The original attributes were: products, spatial arrangement of trees, tree location, tree mix, seasonality of products and investment needed. As a result of this focus group, the attributes were modified to: product, spatial arrangement of trees, pasture occupation by trees, labour requirements and incentives. These attributes were discussed with technicians from the Minister of Agriculture (MAG) and Minister of Environment and Energy (MINAE) in San Jose. In addition to this information, it was agreed that the experiment will only consider trees in pasturelands, and only one system could be implemented in the grassland. It was defined this way because the study aims to explain the trade-off between tree cover and grass cover in paddocks.

A second focus group discussion was held with farmers and local technicians. In the discussion, the attributes were modified to: products, spatial arrangement, pasture occupation by trees, time receiving the incentive and incentive. This was followed by the elaboration of the questionnaire following the steps described in the experimental design. This questionnaire was validated in the study area. Eight interviews were carried out. From this validation, the final attributes were defined:

Table 5.1 - Attributes and levels used in the definition of the choice experiments conducted to define the preferences of tree arrangements on cattle farms located in the north part of Costa Rica

Attributes	Levels
Arrangement of trees	In fences
	In lines in pastures
	Dispersed
	In blocks
Pasture occupation by trees	4%
	10%
	20%
Time receiving the payment	5 years
	10 years
	15 years
Amount of the payment	10 US$/hectare/year
	40 US$/hectare/year
	75 US$/hectare/year
	90 US$/hectare/year
	110 US$/hectare/year

The levels of the attributes were defined using secondary information. For tree arrangements, the information came from Flores and Monterroso (2002) and Flores *et al.* (2002). Pasture occupation was based on Ibrahim (2003), and the time and amount of payment were defined according to the Costa Rican PES.

In addition to the main experiment, a second one was conducted to understand how farmers would be interested in combining the different tree arrangements on farms. Therefore, the second choice experiment considered the combination of systems and farmer interests in investing in those systems. The attributes and levels used were:

Table 5.2 - Attributes and levels used in the definition of the choice experiments conducted to define the combination of different tree arrangements on cattle farms located in the north part of Costa Rica

Attribute	Level
Trees in border fences	Yes or no (1, 0)
Trees in internal fences	Yes or no (1, 0)
Dispersed trees	Yes or no (1, 0)
Trees in blocks	Yes or no (1, 0)
Investment	10 US$/hectare/year
	50 US$/hectare/year
	100 US$/hectare/year
	150 US$/hectare/year
	200 US$/hectare/year

5.1.2.5 Experimental design

The experiment was designed in SAS v8. The fist step was the definition of the possible combination of variables in the experiments. It was considered that all levels of the attributes occurred randomly in each choice set. Therefore, a cyclical method was used when defining the experiment.

The choice experiment used in defining the preference for tree arrangements considers three experiments, with 6 choice sets, and three alternatives per set. This produces 18 different sets, divided into three different experimental sets. Considering that the complete factorial was $3^2x4^1x5^1 = 180$ and that 18 from 180 sets were selected, 10% of the alternatives were tested.

The choice experiment conducted to define the combination of different tree arrangement considered two different designs with 6 choice sets each. Then, two alternatives were considered in each choice set. Therefore, the full factorial was $2^4x5^1 = 80$, 15% of the alternatives were tested. To obtain the design in an orthogonal experiment, the D-optimal option of SAS v8 was used.

5.1.2.6 Questionnaire elaboration and data collection

The questionnaire was divided into four parts (ANNEX VI). First, some general questions were asked about the farms and about tree products. A pair wise comparison was used to rank the willingness of farmers to invest and tree products. For investment, four different options were considered: improving grasses, improving cattle breeds, improving tree management or buying new machinery. For tree products, five were compared: wood, posts, forage, shade and wind protection. The second part of the questionnaire considered the knowledge and opinions of farmers about the payment for environmental services. At the end of this part, the four services recognised in the Costa Rican Forest Law were compared using the pair wise.

The third part consisted of the choice experiment, starting with the explanation of the experiment. The scenario considered a 5 hectare pasture, where only one possible system can be selected (ANNEX VI). The final part of the questionnaire considered socio-economic questions about the farmers.

The survey was conducted at the main beef auctions in the area: the auctions in Cañas, Liberia, Limonal and Upala, all which were visited in the month of September 2003. Only owners or managers of cattle farms were interviewed.

Ninety four interviews were collected from 11 counties, three of which were located in Alajuela and 8 in Guanacaste (Figure 5.1). Eighty four percent of the interviewees were located in the counties of Abangares, Bagaces, Cañas, Tilaran and Upala. In the end, 79 choice experiments were conducted.

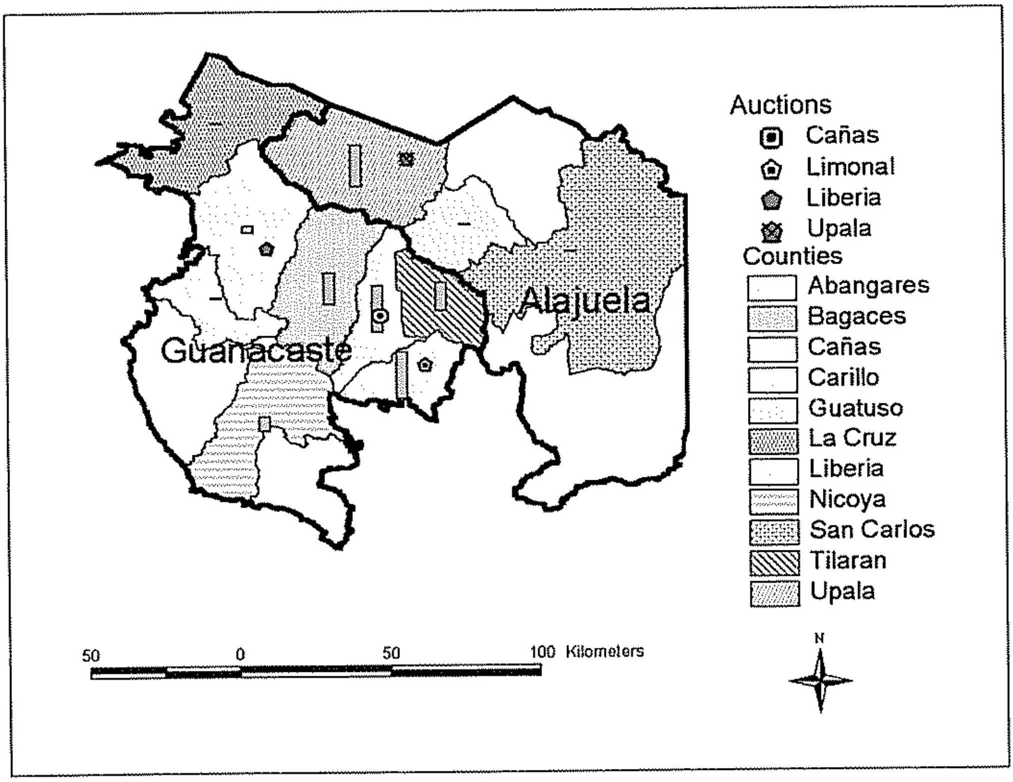

Figure 5.1 - Location of the farmers interviewed in the study

5.1.2.7 Econometric analysis

The econometric model was run in Limdep 7.0, using the NLogit Model (ANNEX VII). The prediction power and the significance of the coefficients were considered in the model definition. Furthermore, the marginal substitution rates (MSR) were calculated dividing the beta coefficient of the technology attributes by the coefficient of the payment.

5.1.3 Results and discussion

The following section presents the results of the interview starting with identification of problems related to cattle ranching, followed by the general findings of the interviews, then the choice experiment, and finally the demand for compensation.

5.1.3.1 Problems in cattle ranching

It was found that the most important problems from the farmers' point of view were climatic conditions, followed by cattle related problems (Table 5.3). Since rainfall is not subject to be modified, the main problem in cattle farms is water access which can be resolved by irrigation systems. In the area, the Costa Rican government constructed the largest irrigation system in the country. However, farmers who have access to irrigation systems do not chose cattle production as their main production. Therefore, cattle farms were located in areas where public irrigation systems are unlikely to be constructed. The solution is the construction of mini-irrigation systems which require less investment; nevertheless, farmers are not motivated enough to construct irrigation systems for cattle farming.

The second group of problems was related to cattle production. Farmers appear to be more interested in technologies that improve cattle production and not in forest or tree resource management. In contrast, beef markets were not as important as expected. They were ranked as medium important problems. Thus, farmers perceive that beef prices were not the main problem but more of improving grasses and livestock genetics. The strategy to overcome the natural conditions in the area was to use grasses and cattle breeds that are tolerant to hot and dry conditions (Chapter 3 and 4).

Farmer perception that beef prices are not the main problem in livestock farming confirms findings presented in Chapter 4. There is evidence that beef prices have constantly increased since the 1960s but cattle farming reduced in intensity. The main factors underlying cattle farming in Costa Rica are the socioeconomic conditions of the country which have improved in the last decades (Chapter 3 and 4).

Table 5.3 - List of problems cited by cattle farmers in the dry forest zone of Costa Rica (n = 7)

Rank	Category	Problems	Points	Classification
1	NC	Rainfall distribution	25	Exogenous
2	NC	Water access	25	Endogenous
3	FM	Lack of credit	23	Exogenous
4	CT	Grass quality	23	Endogenous
5	CA	Ranch administration	23	Endogenous
6	GO	Lack of training programs	20.5	Exogenous
7	CT	Bad pasture distribution	19	Endogenous
8	CT	Livestock genetics	18	Endogenous
9	CA	Farm infrastructure	18	Endogenous
10	CM	Beef prices	17	Exogenous
11	CT	Lack of technical assistance	16.5	Exogenous
12	CA	Lack of records	16	Endogenous
13	FT	Lack of technical assistance in forestry	14	Exogenous
14	CM	Beef marketing	12	Exogenous
15	FT	Forestry training	12	Exogenous
16	FP	Forest policies not adequate	9.5	Exogenous
17	FP	No adequate laws	9.5	Exogenous
18	FP	Lack of information about forest production	9.5	Exogenous
19	CT	Bats	8	Exogenous
20	FP	Application of forest policies	8	Exogenous
21	GO	Lack of training in cooperative management	7	Exogenous
22	CA	Lack of communication with the cattle auction in Cañas	6	Exogenous
23	GO	Lack of motivation to work in groups	3	Exogenous
24	FP	Attitude toward forest areas	3	Endogenous
25	FP	High cost of forest regency	2	Exogenous
26	FM	Wood supply	2	Exogenous
27	FM	Wood marketing	1.5	Exogenous

CA = cattle administration, CM = cattle markets, CT = cattle technology, FM = forest markets, FP = forest policies, FT = forest technology, GO = group organization, NC = natural conditions.

For cattle production, farmers did not mention any problem related to government policies; rather they mentioned the lack of technical assistance and credit. However, for forest production, farmers complained about government policies; 6 of 11 problems related to forest production were grouped into forest policy. Farmers cited that laws and policies were not adequate to provide incentives for forest and tree resource management.

In addition to forest policy, lack of knowledge of forest management is the most important problem in forest activity. Farmers did not have the custom or knowledge about forest management. The increment in forest areas would provide incentives to start forest management. However, few institutions are working with farmers in defining the best strategy for forest management, reflecting that forest and tree resource management is not a main concern of farmers and support institutions.

5.1.3.2 Results

The largest farms of the sample are located in the county of Abangares, and the smallest in Guatuso (Table 5.4). The farms sampled from Abanagares, Bagaces, Tilaran and Upala presented larger herd sizes than the average reported in the Cattle Census, which is 35 LU/hectare (Chapter 3). Whereas, for farm size, the counties of Abangares, Bagaces, Carrillo, La Cruz, Nicoya, Tilaran and Upala presented higher values than the average in the Census (87 hectares). Thus, it is possible to hypothesise that the smallest farms in the area did not use the auctions as a beef market. Probably, they traded cattle on farms where they obtained lower prices but did not pay the transportation cost or the cost to participate in the auctions. It is important to keep in mind that the opinions were from farmers who trade cattle in the auctions and who seem to fall into medium and large farm categories.

Table 5.4 - Salient features of number of farms, average farm size, average pastureland size, average natural regeneration area size and average herd size of the farms sampled

County	Number of farms	Farm size (ha)	Pastureland size (ha)	Natural regeneration area size (ha)	Herd size (Head)
Abangares	19	273	218	44	304
Bagaces	13	217	150	39	134
Cañas	19	87	74	12	67
Carrillo	1	60	60	1	30
Guatuso	1	28	7	21	10
La Cruz	3	152	29	123	29
Liberia	6	96	73	22	51
Nicoya	2	60	55	5	30
San Carlos	1				40
Tilaran	12	140	121	19	165
Upala	17	59	52	8	69
Average	94	147	114	27	132

Eighty seven of the 94 farmers interviewed own the farm and 7 rent the farm. Thus, results are from people that make decisions about farm management. It is important to note that almost all the farmers interviewed were male, and only 2 interviewed were female.

Farmers were more interested in improving grass and cattle breeds, followed by improving tree management and buying new machinery (Table 5.5). Sixty nine of the 94 interviewees ranked pastures as first or second priority for investment, and only 18 of them ranked tree management at the top. Tree resource management was not a priority and farmers prefer to invest in cattle technology rather than in tree resource management. However, the increase in forest cover on cattle farms and the use of trees in cattle production create opportunities to introduce tree resource management.

Table 5.5 - Rank of willingness to investment for cattle farmers located in the north part of Costa Rica (n = 87)

Order	Pastures	Cattle breed	Tree management	Machinery
1	34	11	5	2
2	35	45	13	5
3	8	23	51	9
4	10	8	18	71

Regarding tree resources, farmers were more interested in obtaining forage from trees than wood; 38 of the 94 farmers ranked forage as the main or second product while 23 of them ranked wood as the main or second product (Table 5.6). This is an important finding since most tree management projects consider wood as the main product. Shade and posts were ranked at the bottom. Thus, for introducing tree management to cattle farms, technology should focus on producing forage rather than wood.

Table 5.6 - Ranking of the tree products that farmers want to obtain from their forest and tree resources on cattle farmers located in the north part of Costa Rica (n = 88)

Order	Wood	Posts	Forage	Shade	Wind break
1	10	3	17	6	9
2	13	12	21	15	20
3	17	17	24	19	14
4	26	26	11	31	17
5	22	30	15	17	28

Knowledge of the payment for environmental services scheme in the area was low as only 48% of the farmers knew about it. They did not know the mechanism of the payments or the reason for the program. The reason is that the structure of the PES in Costa Rica is focused on large and medium sized farms. The PES was defined as a scheme to protect the environment and not as a scheme to reduce poverty. Furthermore, Guanacaste is an area with few PES (Miranda *et al.*, 2003). Although farmers that make use of auctions for trading their livestock are medium and large farmers, they did not have access to PES because the area is a low priority area for PES as defined by FONAFIFO (Miranda *et al.*, 2003).

From the people that knew the program, 91% said that PES helps to protect the environment. Most of the reasons given were related to the money received, without any relationship to the quantity or quality of the environmental services provided. This is the result of the FONAFIFO's payment mechanism which was based on the opportunity cost of land use instead of the valuation of the environmental service provided by each type of land use. This scheme reduces the motivation to quantify the services; thus farmers receive subsidies for allowing forest cover on their farms. In many cases, forest cover had been on the farms before PES, and probably would remain without PES as mentioned by Ortiz *et al.*, 2003.

The definition of the payment through the opportunity cost is not the best option when defining PES; the scheme ends in a subsidy to medium and large farms. In Costa Rica, payments were focused on large farms which do not require the payment to improve their livelihood. People that need this kind of incentive did not have access to the program. This leads one to question if Costa Rican people are making a good investment through PES. The creation of a nation wide structure such as FONAFIFO increases the transaction cost, reducing access to the small farms. The transaction cost for PES in Costa Rica is 12 to 15% of the PES (Ortiz *et al.*, 2003). A better structure to increase the participation of small farms is the community based organization as shown by the example of water service in Heredia. In the area, it is possible to use the Livestock Chamber for the PES because this institution consists of more than 1000 cattle farmers (Ramos, 2003).

When they were asked to rank the four environmental services recognised in the Costa Rican Forest Law, only 55 of the 94 know about the services. It is recognised that environmental services can be grouped into local services and global services. Services like water production and clean air (local services) were ranked at the top, while biodiversity and scenic beauty (global services) were ranked at the bottom. In the Costa Rican scheme, FONAFIFO is responsible for trading global services. However, farmers are more concerned about local services which create a gap between the country's strategy and farmer demand.

Table 5.7 - Rank of environmental services recognized by the Costa Rican forest law according to cattle farmers located in the north part of Costa Rica (n = 55)

Order	Biodiversity	Clean air	Scenic beauty	Water production
1	6	11	0	17
2	16	22	0	22
3	21	20	9	14
4	12	2	46	2

The results presented in Table 5.7 show the deficiency of the structure because the environmental service providers do not have a clear view of what the demand is for these services. Furthermore, the demand for environmental services is not clearly identified. This creates the sense that PES is a subsidy for allowing forest cover and not a payment for services provided. To improve this, a local payment structure could be implemented instead of a nation wide scheme.

An important aspect of cattle production in the area is the relatively high education level of the farmers. According to the data, the average education level was 7 years, which means they completed elementary education and one year of secondary education. In the case of farmers that received PES, the educational level is higher with many of them having university education (Miranda *et al.*, 2003). However, 7 years of education is an opportunity for any kind of project.

Contrary to the level of education which is identified as an opportunity for improving cattle farming, the age of the farmers is a constraint. Only 8% of the farmers were younger than 35 years old, and more than 50% of the farmers were older than 46 (Table 5.8) (More indeed analysis of farmers age and its implication on livelihood strategy is conducted in the next section). Furthermore, Ramos (2003) found that more than 64% of the farmers were older than 50 years and 78% of the households did not have young people dedicated to cattle production; Miranda *et al.* (2003) cited that farmers in PES are on average 54 years old. In Honduras, Nicaragua and Guatemala a RRA conducted by the CATIE/NORUEGA (CATIE/NORUEGA project is a multi-stakeholder project that aims to develop through the participatory approach sustainable land use alternatives for degraded pasture lands in Central America. Currently the author is the National Coordinator of the project in Honduras) project found that only 48% of the farmers are older than 50 years. This implies that young people are entering cattle production in Guatemala, Honduras and Nicaragua, but not in Costa Rica. This creates the possibility that cattle production will reduce or maintain its level instead of increasing since young people are basing their livelihoods in urban activities. Farmers would concentrate on more suitable soils, which are not considered by the current PES scheme.

Table 5.8 - Age and years of education for the respondents

Age	Years of education	Number	Percentage
18 – 25	3	5	5%
26 – 35	9	3	3%
36 – 45	7	22	25%
46 – 55	8	28	35%
56 – 65	8	19	22%
Older than 65	3	9	10%
General	7	86	100%

5.1.3.3 Choice experiments

79 farmers participated in the choice experiments. From this, 460 alternatives were selected out of 1422. Of the alternatives selected, the main attributes were the dispersed trees, with less than 4% pasture occupation, with a payment over 5 or 10 years and a payment ranging from 40 to 90 US$/hectare/year (Table 5.9). Farmer preferences were trees dispersed and in fences, which are the common arrangements. The other two arrangements, trees in rows in pastures or in blocks were less selected. This kind of selection is congruent with farmer objectives of beef production and not for forest products. Therefore, the lower the occupation, the higher the selection of the system. This kind of relationship identified farmer trade-offs which begin with 4% tree

cover in a paddock. Farmers feel that tree cover over 4% reduces the productivity of grasses, and the benefits of tree cover no longer exist when greater than 4% in paddocks.

There was no preference about the payment period length. Time did not influence management decisions for trees. This can be explained by the fact that some farmers think that during the time that they received the payment, they were not allowed to harvest any type of forest product. Furthermore, Miranda *et al.* (2003) stated that farmers who received PES are not interested in increasing the payment period; rather they prefer to renew the payment agreement every 5 years. Farmer mistrust of longer periods is based on the insecurity of national policies; they believe there may be future constraints for land cover change.

Finally, for the amount, payments from 40 to 90 US$/hectare/year were preferred. This range of payments shows that the opportunity cost for changing cattle production to forest protection is over FONAFIFOs PES which originally was 40 US$/hectare/year.

Table 5.9 - Characteristics selected by farmers in the model used to explain farmer preferences of tree arrangements on cattle farms located in the north part of Costa Rica

Attribute	Level	Number	%
Tree arrangement			
	In fences	137	30
	In lines in pasturelands	84	18
	In blocks	82	18
	Dispersed	157	34
Occupation of the pastures			
	4%	185	40
	10%	179	39
	20%	96	21
Time receiving the payment			
	5 years	158	34
	10 years	155	34
	15 years	147	32
Amount of payment			
	10 US$/hectare/year	64	14
	40 US$/hectare/year	105	23
	75 US$/hectare/year	107	23
	90 US$/hectare/year	108	23
	110 US$/hectare/year	76	17

The model estimates include the variables: tree arrangement, occupation of the pasture, time of payment and payment amount. The model was significant at 0.000, with a log likelihood of 481.5327 and a chi-square value of 46.9. Tree arrangement has a negative effect over the probability of choosing a system because tree arrangement was presented as a degree of occupation of pastures. As presented in Table 4:2, the level of tree coverage considers a tree occupation gradient from least to greatest for the paddocks; therefore, a living fence implies less occupation of paddocks than dispersed trees (Table 5.10).

Table 5.10 - Model estimates for explaining farmer preferences for different tree arrangements on pasturelands in the northern part of Costa Rica

Variable	Coefficient	Standard error	P value
Spatial arrangement	-0.153	0.05	0.00
Occupation	-0.048	0.01	0.00
Payment time	-0.010	0.01	0.37
Payment amount	0.004	0.00	0.01
Intercept 1	-0.008	0.12	0.95
Intercept 2	0.000	0.12	1.00

In the model used to explain the combination of tree arrangements as the number of trees (expressed in different systems) increases, the probability of choosing the alternative also increases. The preferred alternative, which was selected 81% of the time, was the one that combines the four systems: border fences, internal fences, dispersed trees and trees in blocks. The second combination considers border fences, internal fences and trees in blocks, with 62% selected. The alternatives that combine three systems were selected over 50% of the time whereas alternatives with the combination of two systems were selected in over 40% of the cases. The alternatives with only one system were selected below 40%, and the alternative without trees was selected only 16% of the time (Table 5.11).

Table 5.11 - Characteristics of the selected alternatives in the model used to explain combinations of different tree arrangements on cattle farms located in the northern part of Costa Rica

Border fences	Internal fences	Dispersed	Blocks	Total	Chosen (%)
Yes	Yes	Yes	Yes	32	81
Yes	Yes	No	Yes	65	62
No	Yes	Yes	Yes	98	58
Yes	No	Yes	Yes	98	57
Yes	Yes	No	No	32	53
Yes	Yes	Yes	No	65	52
No	No	Yes	Yes	32	47
No	Yes	No	No	98	45
Yes	No	No	No	98	44
No	No	Yes	No	65	42
No	No	No	Yes	65	34
No	No	No	No	32	16

The second NLogit model explaining the combination of different tree arrangements on farms was significance at 0.002, with a log likelihood ratio of -254.3, and a chi-square value of 20.2. Although the model was statistically significant, the value of the coefficient of dispersed trees, tree plantations (blocks) and investment were not significant at 0.1 (Table 5.12). This implies that cattle farmers are not interested in investing in tree resource management. Reducing the significance to 0.15, farmers were interested in investing in trees in fences (borders or internal fences), but not in dispersed trees or forest plantations (blocks). This is an important issue that needs to be considered when introducing any type of technology to manage forest and tree resources on cattle farms. Farmers prefer to invest in trees in fences than in forest plantations or dispersed trees.

Table 5.12 - Model estimates for explaining farmer preference for different combinations of tree arrangements on farms

Variable	Coefficient	Standard error	P value
Border fences	0.30	0.14	0.03
Internal fences	0.35	0.13	0.00
Dispersed	0.18	0.14	0.17
Blocks	0.19	0.13	0.17
Investment	0.002	0.00	0.12
Intercept	-0.11	0.13	0.41

5.1.3.4 Willingness to compensate and to pay

According to the model, the basic payment was for trees in fences with a payment of 35 US$/hectare/year, then tree in lines inside pasture (70 US$/hectare/year), followed by dispersed trees (105 US$/hectare/year) and finally trees in blocks (140 US$/hectare/year) (Table 5.13). These values are higher than the actual FONAFIFO payments which are 40 US$/hectare/year for a protected area. The reason can be the difference in the methodology to determine the payments. In FONAFIFO's approach, opportunity costs were used, while this study considers the farmer's demand for compensation. FONAFIFO considered the payment in areas where no activity other than conservation is permitted. In contrast, this study considered the management of trees in areas where cattle production systems are the main land use. Evidently, the opportunity costs of protecting these areas are higher than the FONAFIFO payments. The same findings were reported by Miranda *et al.* (2003).

Regarding the demand for compensation for tree cover in paddocks which reflect farmer trade-offs, it was found that farmers demand a compensation of 11 US$/hectare/year for every percent of tree cover in the paddock. As mentioned before, at initial stages of tree cover, an increase in tree cover improves the production conditions because trees can improve grass growing conditions. However, there is a point where the relationship between trees and grasses becomes competitive. Farmers prefer alternatives that have less than 4% tree cover, implying that this is the level where farmer trade-off between tree cover and grass productivity began. This value was comparable with FONAFIFO payments of 40 US$/hectare/year, implying that farmers with productive farms are willing to maintain 4% tree cover with FONAFIFO payments.

Table 5.13 - Demand for compensation (US$/hectare/year) for different arrangements of trees in pasture

Variable	DFC
Spatial arrangement	35 US$/hectare/year
Occupation	11 US$/hectare/year
Time of payment	2 US$/hectare/year

5.1.4 Conclusions

It is concluded that farmers are not interested in investing in managing trees on their farms because this is not their main concern. Farmers prefer to improve grasses and cattle breeds rather than improving tree management. In addition, farmers are interested in producing forage for animal feed. Technologies that improve the production of forage from trees have a higher possibility of being adopted.

The arrangement of trees in paddocks has a high influence on the adoption of silvopastoral systems. Farmers preferred dispersed trees and live fences which have a low occupation in paddocks. The increase of trees in paddocks demands payments. Farmers demand a higher payment than the FONAFIFO payments due to the higher opportunity costs of trees in paddocks. For dispersed trees, the demand for compensation is 105 US$/hectare/year and for trees in fences 35 US$/hectare/year. Therefore, for occupation, farmers demand a payment of 11 US$/hectare/year per 1% increase in forest cover in pasturelands.

According to FONAFIFO's experience, Costa Rica's PES focused on medium and large farms because these types of farms can support the transaction costs of the program. Furthermore, forest and tree resources increase as farm size increases, providing more opportunities for introducing tree resource management. Trees in fences, both border and internal, are more likely to be adopted by small and medium farms because they use less area in paddocks. Dispersed trees are more suitable for small and medium farms. Paddock size is directly related to tree cover because farmers chose a less intensive land use. Dispersed trees are not suitable for large farms which have a mechanisation process for managing the pastures. Dispersed trees do not allow for the mechanisation of paddocks. Finally, forest plantations (blocks) are more suitable for large farms because they can dedicate specific areas to forest activity which is not possible for small and in many cases for medium farms.

Regarding the nation wide scale, if the government aims to increase the forest and tree resource cover, the selection of medium and large farms presented advantages over small farms. Medium and large farms can use more area for forest and tree resources, reducing the transaction costs. However, for reducing rural poverty, small farms must be considered with a focus on trees in fences. In both cases, farmers are not willing to invest in forest management; rather they demand compensation for the increase in forest cover. Farmer trade-off starts at 4% forest cover in a paddock.

5.2 CATTLE FARM LIVELIHOOD STRATEGIES

5.2.1 Introduction

Historically, cattle production has been identified as one of the main forces driving deforestation. This tendency changed in the middle of the 1980's (Chapter 4) when forests and tree resources started to grow in the dry forest zone of Costa Rica. The area is used for cattle production mainly due to its geographic and climatic characteristics. Nowadays, it is recognised that forest and tree resources are an important asset for rural livelihoods, especially in developing countries (Hunter *et al.*, 1998; Byron and Arnold, 1999; Flores, 1999; Flores, 2000; Michaels Arnold and Ruiz Pérez, 2001; Parikesit *et al.*, 2001; Conroy *et al.*, 2002; Peroni and Hanazaki, 2002; Jagger and Pender, 2003; Gheb and Crean, 2003).

The intensity of the deforestation process is different in each country, during the 1980's, Costa Rica experienced one of the world's highest deforestation rates, losing about 7.6% of its forests annually. More than half of the deforestation has occurred since 1950; that trend prompted forecasters to issue a warning that by 1995 no forest would remain outside national parks. This in turn would have devastating consequences to biodiversity due to ecosystem fragmentation (Gottfried *et al.*, 1994; Didia, 1997; Abler *et al.*, 1998; Bouman and Nieuwenhuyse, 1999; Chomitz *et al.*, 1999; Pagiola, 2002; Sanchez, 2002; Armenteras, *et al.*, 2003).

However, at the end of the 1980's and during the 1990's, reductions in subsidies and changes in the socioeconomic conditions of the Costa Rican population brought down cattle profitability making cattle ranching less attractive. As the industry contracted, more areas formerly dedicated to pasture were abandoned prompting greater tree cover because farmers were not able to or interested in keeping paddocks clean of natural regeneration. By 1991, secondary growth forest covered an estimated 400,000 hectares in Costa Rica, with estimated increments of 30,000 hectares/year. This change in the landscape was more visible in the dry areas of the Pacific Northwest of Costa Rica. New estimates today show that more than 50% of the Guanacaste province, at the heart of the dry forest zone areas in the Pacific Northwest, is covered by secondary forest with young trees (Gonzales, 2002; Spittler, 2002). This situation creates new opportunities and challenges for establishing more sustainable and profitable forest management schemes in this section of the country.

In Cañas and Bagaces, forest and tree resources provide services for cattle ranching. These services had not been considered in the land use change decisions. Although goods and services provided by forest and tree resources are clearly identified by farmers, their participation in farmer livelihood strategies is not well understood. Basically, trees on cattle farms are used as an input for beef production.

In this quest, however, there is a gap in the knowledge regarding the appropriate management of native species populating these newly forested areas and how these resources can be used to improve rural livelihoods (Holl and Quiros-Nietzen, 1999; Mora and Chinchilla, 2002; Moya, 2002). Even though some researchers have studied the biophysical characteristics of forest and tree resources in dry areas, fewer studies have tackled the socio-economic, political and institutional driving forces underpinning natural regeneration processes on cattle ranches. However, a recent survey by Campos *et. al.* (2001) showed that trees in paddocks are the main wood source legally and illegally traded in Costa Rica. Therefore, forest and tree resources are once again becoming an important source of income for cattle producers. Thus, it is important to ascertain whether and how, under this new context, farmers are interested in managing these tree resources.

As for the future, there are some expectations about a potential come back of cattle production in Costa Rica. A new boost to cattle profitability may increase a new wave of conversion from secondary growth to pasturelands since the net present value of cattle production would be higher than the value of forest related activities. This asymmetry in return is prompted by fully valuing the benefits of clearing forested areas and introducing pasture and cattle whereas only half accounts for the environmental and economic benefits linked to conservation. As long as local farmers and other farmers do not receive compensation for providing environmental benefits, they would not consider them as revenue sources when making land use change decisions in the future (Pagiola *et al.*, 2002). The challenge is to provide economically viable alternatives to endogenise environmental values in the decision making processes so the collective behaviour of private cattle producers agrees with the interest of society at large, thus enhancing the opportunities to improve forest and tree resource management on cattle farms. Therefore, this paper aims to discuss how forest and tree resources are included in cattle farmer livelihoods, and how management can be improved.

5.2.2 Conceptual framework

5.2.2.1 Evolution of participation in agricultural research

Historically, generations of new technologies have been implemented in experimental stations, relegating farmers to the role of technology adopters. The underlying concept of extension through technology transfer has been criticised due to the prevalence of academic approaches which fail to address the ample demands of farmers (Clarke, 1991; Cornwall *et al.*, 1994; Röling, 1994; Scoones and Thompson, 1994; Rhoades and Bebbington, 1995; Slikkerveer, 1995; Amezquita, 1999; Friesen *et al.*, 1999; Gomide, 1999; Gramajo 1999; Guimaraes *et al.*, 1999; Hoskins, 1999; Muzilli, 1999; Prins *et al.*, 1999; Barrow and Hicham, 2000; Paris, 2002). Additionally, traditional agricultural research has not been efficient in explaining the biological, economic and social interactions of agroforestry systems because the focus has been on specific compounds rather than livelihood strategies based on these components. Moreover, the traditional extension model suffers from a lack of communication between researchers and farmers. New approaches imply mutual learning processes rather than unilateral technology transfer. Over the past decade, new approaches have been proposed that link on-station with on-farm research (Box, 1989; Rusten and Gold, 1991; Scherr, 1991; Spencer, 1993; Franzel *et al.*, 1995; Bustamante, 1997; Friesen *et al*, 1999; Monterrey, 1999; Wortmann *et al.*, 1999; Haggar and Reyes, 2000; Collinson, 2001).

Since the late 1970s, concepts and strategies for agricultural technology transfer have changed (Scoones and Thompson, 1994). The generation of agricultural technologies has moved from on-station research to on-farm research. Researchers have employed different conceptual and analytical frameworks to study socio-economic and biophysical processes and their interactions. Participatory methodologies, which have gained momentum during the 1990's, take into account the interest of farmers in many ways such as by improving communication between farmers and researchers (Chambers *et* *al.*, 1989; Spencer, 1993; Rhoades and Bebbington, 1995; Friesen *et al.*, 1999; Hoskins, 1999; Prins *et al.*, 1999).

The concept of participation in development is far from being new. Indeed, it was part of the New Deal rhetoric in the 1930's (Matose and Mukamuri, 1994; Eyben and Ladbury, 1995; Mosse, 1995; Francis, 2001). To better understand the historic roots of the concept of participation, it is necessary to go back to the bourgeois emancipation in Europe in the XVII and XIX centuries. In that moment, the emerging bourgeoisie claimed to share the political and economic sphere, which was in the hands of royalty. In modern times, participation in development processes was understood as the inclusion of farmers in the process of resolving rural problems (Henkel and Stirrat, 2001). Participation has become a familiar part of the language of institutions ranging from grassroots level organisations to the World Bank (Cornwall *et al.*, 1994).

Participation in agricultural research was prompted by the concern that conventional approaches preserve social inequity, and more importantly, the consideration of a gradualist learning process (Farrington and Martin, 1988; Fernández, 1994; Mosse, 2001). In this context, participation helps to understand farmer strengths and weaknesses and to account for their knowledge (Farrington, 1997; Hoskins, 1999). However, the extent to which participation is realized depends on the topics and their relevance to farmer objectives and the recognition of their knowledge (Beer, 1991; Galloway, 1997; Monterrey and Guharay, 1997; Hoskins, 1999; Prins *et. al.*, 1999).

Scientific debate of participation is strongly influenced by the new institutionalism. This theory suggests that institutions help formalize mutual expectations of cooperative behaviour which facilitates auto-control of the group thereby reducing individual transaction costs. The colloquial definition of institutions has been that of conceptualized institutions as organizations; however, the new institutional economy considers institutions as the "rules of the game". The new institutional analysis of participatory approaches requires a detailed analysis of the roles of different actors and the linkages and divisions between them. The social interfaces are critical points of interaction between different social and knowledge systems where competition for resources and conflict over social and political agendas are most likely to be found (Scoones and Thompson, 1994; Cleaver, 2001).

One of the first participatory approaches was the **Farming Systems Research and Extension** (FSRE), which emerged in the late 1970s in response to the prevailing extension model of technology transfer promoted by the green revolution. The FSRE approach was based on the assumption that the technologies developed on experimental stations, and hence off-site, are not adequate for medium or small-scale farmers. It recognized that farm level constraints limit the adoption of new technologies (Escobar and Berdegué, 1990; Cornwall *et al.*, 1994).

FSRE considers on-farm research in addition to research on experimental stations. Initially, however, research was defined by scientists with some consultation of farmers. Only since the late 1980's, FSRE has been carried out in a more participatory fashion by involving farmers in the selection of research alternatives and the evaluation of the findings. Researchers were encouraged to work with farmers to design, test and modify improved agricultural technologies that are suited to local conditions. The final product of this approach was a list of potential technologies to be used in extension programs (Escobar and Berdegué, 1990; Clarke, 1991; Cornwall *et al.*, 1994; Franzel *et al.*, 2001).

Farming Systems Research contributions are most obvious in a historical perspective as it signified an important move from a crop focus in agricultural extension to the appreciation of the complexity of agricultural systems and related decision-making (Cornwall *et al.*, 1994). Nevertheless, the main problem of the Farming Systems Research was the definition and rank of the problems. This was usually conducted by scientists and implies low participation of farmers in the research process.

Some authors argue that Farming Systems Research involves farmers in two different stages: diagnosis and adoption. Scientists consult farmers about their main production problems and then used them in designing a solution which is evaluated on-station. Validation trials are then conducted on-farm. In terms of participation, Farming Systems Research failed to adequately consider decision-making processes at the farm level because it assumed that farmer behaviour can be explained by their search for profit maximization. Nevertheless, participatory approaches have modified Farming Systems Research (Clarke, 1991; Pinney, 1991; Pinners and Balasubramanian, 1991;

Rocheleau, 1991; Cornwall *et al.*, 1994; Franzel *et al.*, 2001; Solano *et al.*, 2001; Walker *et al.*, 2001).

Addressing some of the limitations of farming systems research, **Farmer Participatory Research** was developed in the 198'0s. It involves farmers more closely in on-farm research, moving beyond contracting or consulting farmers in farmer systems research. It views the context of agricultural production as interactions between on- and off-farm resource management strategies. The recognition of what would be termed "indigenous knowledge" led to a focus on the household as an innovator and experimenter as well as an increased interest in collaborative and mutually beneficial relationships between researchers and farmers. This approach was called "farmer-first" (Cornwall *et al.*, 1994; Mundy and Compton, 1995).

Farmer-first consists of a mutually supportive pattern of concepts, analysis, methods and behaviour. Rather than focussing on knowledge, problems, analytical tools and priorities of the scientists, farmer-first starts with the knowledge, problems, analysis and priorities of the farmers and their households. Instead of the research station as the main action location, it put emphasis on the farmers. In lieu of the scientist as the central experimenter, it is the farmer, either a woman or a man, and other household members who matter (Drinkwater, 1994). However, this approach presented some limitations: 1) the emphasis on the farmer and his/her capability to invent and create has tended to take research agencies out of the structure; 2) the emphasis on what farmers know about technology and ecology has diverted attention from the things that they do not know about markets, politics and the mechanisms of the world beyond the farm gate, 3) the emphasis on revalidating past practices has understated the changes in the present and the implications they have had for rural people (Bebbington, 1994).

By the late 1980's, while Farming Systems Research and Extension and Farming Participatory Research remained pivotal, other approaches were developed to consider agriculture as one element in household livelihoods and not the household livelihood by itself. Users of Rapid Rural Appraisal were inspired by agro-ecosystem analysis, applied anthropology, Participatory Action Research, Farming Systems Research and Farmer Participatory Research. The focus shifted from the rapid collection of data by researchers and planners to helping farmers generate, represent, and analyse their own data. This implied a reversal of roles for the farmers and workers, and the development of new methods to change the behaviour and attitudes of outsiders. A new label emerged: Participatory Rural Appraisal (Cornwall *et al.*, 1994).

Participatory Rural Appraisal (PRA) was defined as a family of approaches and methods to enable rural people to share, enhance and analyse their knowledge of life and conditions in order to plan and act. This approach argues that the production of knowledge and the generation of potential solutions should be carried out by those whose livelihood strategies formed the subject for research. Participatory Rural Appraisal has not elaborated a formal theory of knowledge, but it embodies distinctive notions of knowledge and evidence from other approaches (Cornwall *et al.*, 1994; Bunch, 1999; Francis, 2001).

Participatory approaches and methods have common principles, such as: 1) a defined methodology and systematic learning process: the focus is on cumulative learning by all the participants, 2) multiple perspectives: a key objective is to seek diversity, rather than characterize complexity in terms of average values. Different individuals and groups make different evaluations of situations which lead to different actions, 3) group inquiry process: everyone involved recognizes that the complexity of the world will only be revealed through group inquiry, 4) context specific, 5) facilitating experts and stakeholders: the approaches are concerned with the transformation of existing activities to try to improve people's situations, 6) leading to sustained action (Pretty and Chambers, 1994). Nevertheless, the issue of quality in rural research and development methodologies is not often raised. Contextual forces appear to be more powerful than methods in determining outcomes. Participatory research and development approaches may prove as expert-driven, top-down, and extractive which are similar to the methods for the dominant paradigms (Jiggins, 1994).

There is little evidence of the long-term effectiveness of participation in materially improving the conditions of the most vulnerable people or as a strategy for social change. Critiques about participatory approaches take two main forms: those that focus on the technical limitations of the approaches, which stress the need for a re-examination of the methodological tools used such as in PRA; and those that pay closer attention to the theoretical and conceptual limitations of participation. Participation has, therefore, become an "act of faith in development". This act of faith is based on three main tenets: that participation is intrinsically a good thing (especially for the participant); that focusing on getting the techniques right is the principal way of ensuring the success of such approaches; and that considerations of power and politics on the whole should be avoided as they are divisive and obstructive (Cleaver, 2001; Kothari, 2001).

There are three main ways in which participation is used. First, it is used as a cosmetic label to make whatever is proposed appear good. Donor agencies and governments require participatory approaches. Second, it describes a co-opting practice for mobilising local labour and reducing costs. Communities contribute their time and effort to self-help projects with some outside assistance. Often this means that local people participate in the scientists' projects. Third, it is used to describe an empowering process which enables local people to do their own analysis, to take command, to gain confidence, and to make their own decisions (Chambers, 1995; Nelson and Wright, 1995; Henkel and Stirrat, 2001; Mohan, 2001; Taylor, 2001).

Finally, Borel and Romero (1991) and Etiënne (1997) argue that time gained in some agricultural research, better feedback from and to farmers, and contact with real production problems were the main advantages of PRA. On the other hand, Pinney (1991) mentioned lengthy research and the difficulty of maintaining farmer participation as the main disadvantages.

5.2.2.2 Livelihoods framework

"The livelihood framework presents the factors and issues affecting rural livelihoods, describing the relationships between factors and issues, thereby helping to understand the way in which livelihoods are constructed and how they change over time" (Bebbington, 1999; DFID, 2000; Abakerli, 2001; Dovie *et al.*, 2003).

Livelihood is more than the means of income generation. Ellis (2000) defined livelihoods as the "capabilities, assets (stores, resources, claims and access) and activities required for a means of living." The important issue in this definition is the linkage between assets and options in pursuing a livelihood. Capabilities include the options that a person or household can achieve through the economic, social and personal assets capital. "Assets refer to the access of a person or household to human, social, natural, physical and financial capitals". Pursuing a livelihood is a continuous process, with a livelihood being sustainable when "it can recover from stresses and shocks, maintain or enhance the capabilities and assets without undermining the natural resource base" (Bebbington, 1999; Carter and May, 1999; DFID, 2000; Ellis, 2000; Block and Webb 2001; Morris *et al.*, 2001; Orr and Mwale, 2001; Lindenberg, 2002; Twomlow *et al.*, 2002; Chanda *et al.*, 2003; Gheb and Crean, 2003; Pretty *et al.*, 2003). However, no single livelihood asset is sufficient for achieving a positive livelihood outcome (DFID, 2000; Betts, 2003).

Livelihood assets are classified into natural, physical, human, financial and social capital categories.

- **Natural capital** refers to natural resources used by human populations.
- **Physical capital** refers to assets used for production processes, such as tools, machines, equipment and land improvement like terraces or irrigation canals, infrastructures such as access to roads, basic health and educational services.
- **Human capital** refers to level of education and health status of individuals and populations.
- **Financial capital** refers to cash stocks accessed in order to purchase either production or consumption goods and includes credit, income and savings. In recent time the remittances from overseas are becoming important financial capital for urban and rural livelihoods.
- **Social capital** refers to social networks and associations from which people support their livelihoods.

According to Ellis (2000), livelihood incomes are classified into three categories: 1) Farm incomes: refer to income generated from own-account farming, whether on owner-occupied land or land accessed through cash or share tenancy; 2) Off-farm incomes: refer to wages or exchange labour on other farms and 3) Non-farm incomes: principally refers to non-agricultural income sources, including non-farm rural wage or salaried employment; non-farm rural self-employment is sometimes called business incomes; rental income obtained from leasing land or property; urban-to-rural or rural-to-rural remittances arising from within national boundaries, other urban transfers to rural households; and international remittances arising from cross-border and overseas migration.

Livelihood strategies are comprised of the range, combination and choices made and undertaken in order to achieve livelihood objectives. Livelihood strategies are influenced by environmental, cultural, social and political conditions. Secure livelihoods depend upon the substitutability between assets and activities; the lower the substitution, the higher the vulnerability. Substitutability implies livelihood diversification which is defined as "the process through which rural households construct a diverse portfolio of activities and assets for improving their standard of living" (McKee, 1989; DFID, 2000; Ellis, 2000; Rider Smith *et al.*, 2001; Quinn *et al.*, 2003).

Vulnerability was defined by Ellis (2000) as a high degree of exposure to risk, shocks and stress. To understand vulnerability; it is important to study how farmers use the resources, which groups produce which crops, how important are the crops for the livelihood, what portion of the output is traded in the market, how crop prices vary through the year, how predictable price fluctuations are, the correlation in crop price cycles, what proportion of household food needs is met by own production and what portion is purchased, when in the year cash income is most important, and if this coincides with the time in which cash is most available (DFID, 2000).

Income diversification as a risk strategy implies trade-offs between higher income with higher probability of failure, and lower income with lower probability of failure (Ellis, 2000). Diversification is a response to external factors like shock, trends and seasonality. In economic terms, seasonality implies that "returns to labour vary during the year in on-farm and off-farm labour markets" (Ellis, 2000; DFID, 2000; Barret *et al.*, 2001b; German, 2002).

Non-agricultural activities are the main income sources in rural livelihood diversification (Rider Smith *et al.*, 2001). Access to these activities is highly related to the level of education; therefore, government education policies are a key factor in defining a sustainable rural livelihood (Lipton, 1993). Most developing countries focus their development on industrialisation, moving households from a rural to an urban livelihood. This phenomena moves people from rural to urban areas without an adequate livelihood strategy and increases marginalisation in the main cities.

Therefore, a strategy to recover the dynamics in rural areas is needed. One alternative for rangeland diversification can be agroforestry systems. These systems can reduce farm risk, diversifying the production; they can also provide an option for improvement in the use of natural and human resources (Scherr, 1995).

Livestock possession is a common emblem of wealth but the importance varies among regions and cultures. Livestock can improve cash flow; improve the savings balance; reduce risk; be used as collateral for loans; produce inputs and services in crop production; be used as transport, fuel, food, and fibre; capture benefits from common property rights; and provide social status and identity (Barret *et al.*, 2001a; Block and Webb, 2001; Brugere and Lingard, 2003; Chanda *et al.*, 2003; Anderson, 2003). Despite these benefits of livestock, improvement has not always been well promoted.

Livestock production does not only include the large farms, but also the medium and small ones. However, unlike large cattle farmers, small-scale farmers are severely constrained in terms of capital and access to livelihood assets (Dovie *et al.*, 2003). The importance of livestock in rural livelihoods varies among household income levels; therefore, no single livestock strategy for cattle farmers could be found. Generally livestock production is more viable for the high income households (Twomlow *et al.*, 2002; Brugere and Lingard, 2003; Ingram *et al.*, 2003).

5.2.3 Methodology

This chapter discusses the current situation of cattle farms in the dry forest zone of Costa Rica using the livelihood framework. Most of the information is based on Ramos (2003), whose dissertation was supported by the Cerbastan project in the framework of this research. Additional, financial data for cattle farms came from Monterroso (2005), who was also sponsored by Cerbastan.

The methodology used is mainly a review of the literature and other secondary information. The results of previous chapters were discussed, focusing on those chapters that discuss the factors that affect cattle farm livelihoods. The information was ordered in the five capitals, human, social, natural, physical and financial capitals. The information from the present study was complemented with the main results of Ramos (2003) who conducted an analysis of household livelihood strategies in the area of Cañas and Bagaces. Data was collected using a semi-structured interview in 53 households with cattle farms. Later, survey data was cross-referenced with key information interviews with the main government and non-government institutions present in the area. The semi-structured interview considered information about the household members; human and social capital; on-, off- and non-farm activities; issues about natural and physical capital; identification of the main problems and risks related to cattle production; perception about the future of the livestock industry and issues about forest and tree resources. The analysis was divided into two parts; first, descriptive statistics were used in describing the main variables. Later, a cluster analysis was conducted for defining a typology of households in the area.

Monterroso (2005), on the other hand, conducted a financial analysis of cattle farms using the Farming Systems approach. First, a cluster analysis was done to define four cattle farmer typologies. From these groups, Monterroso (2005) selected 8 farms to monitor their financial activities over one year. Monthly data about sales and costs were collected.

As a way to combine the information presented by Ramos (2003) data from Monterroso (2005) and the author's own data, a SWOT analysis was done (strengths, weaknesses, opportunities and threats). This analysis was conducted using the key informant interviews and discussions in focus groups. Key informants include Cerbastan students and other CATIE professionals who have conducted research in the area. The results of this analysis are presented in Chapter 6 as the potential role of forest and tree resources in the livelihood strategy of cattle farmers in Cañas and Bagaces.

5.2.4 Results and discussions

The results are presented in six parts: capital with livelihood assets, vulnerability context, transforming structures and processes, livelihood strategies of cattle farmers, current role of forest and tree resources in livelihood strategies and potential roles of forest and tree resource management in the livelihood strategies of cattle farmers in Cañas and Bagaces. The last two sections, the current role of forest and tree resources in livelihood strategies and the potential roles of forest and tree resource management in the livelihood strategies of cattle farmers in Cañas and Bagaces are presented in Chapter 6.

5.2.4.1 Capital with livelihood assets

The discussion in this part refers to the livelihood assets, the natural, human, social, physical and financial capital, and how the capital assets affect the forest and tree resources.

Natural capital

As mentioned in Chapters 2 and 3, cattle production in Costa Rica is highly specialised. Cattle farms focus their production on one product either beef or dairy. Contrary to other Central American countries, where most of the cattle production can be catalogued as dual-purpose (beef and dairy), in Guanacaste the geographic conditions favoured the beef industry.

According to the logit model, beef production occurs in areas where dairy production is not suitable for dairy production. Since the study area is located in the dry forest zone with 5 to 6 dry months per year, annual precipitation of 1400 mm, an average temperature of 27.3°C, and an elevation range from 100 to 300 masl, beef production is more viable than dairy production. Furthermore, the Tobit model showed that geographic conditions are more important in beef cattle production than technology levels.

The factors mentioned above show that beef production is based on natural capital; hence, the natural capital of the study area favoured the production of beef cattle. To highlight the importance of natural capital, most of the production is based on the use of pasture without fertilization, livestock tolerant to dry conditions and little use of food supplements (Chapter 3 and 4).

According to the interpretation of aerial photos (Chapter 4), the area has presented a stable forest cover of 38% since the 1970's with an increase of tree cover in cattle pastures. The area of pastures with trees increased from 39% in the 1970's to 54% in the 1990's. Based on the socioeconomic trends over the past 50 years, it is anticipated that forest area will remain stable or may increase at the expense of pasturelands.

Furthermore, national and international beef prices were not the main driving forces for the change of forest cover to pasturelands. The tendency of increases in beef prices would not affect forest cover (Chapter 4). Contrarily, the social conditions, especially the labour supply, were the main forces driving land use change. The standard of living in Costa Rica has been improving and has increased labour costs; it is expected that this trend would not change in the next years.

Considering these factors, forest and tree resources are an important natural asset in the capital of households. Forest areas are used as an input for livestock production. It was found that forest cover represented around 25% of cattle farms, and trees in pastures increased from 39% in the 1970's to 54% in the 1990's (Chapter 3). According to the RRA, the main use of forest and tree resources is the production of forage, followed by wood production. The first use of forest and tree resources is linked to livestock production, representing an important feed source for supporting cattle during the dry season. The second product is related to capital stock and it is a future capital stock that can be used by farmers.

Human capital

One of the main factors defining the human capital in the area is the education level of the members of the household. As mentioned earlier, the social status in Costa Rica has improved, particularly the level of education. Ramos (2003) found that children of farmers exhibited a high educational level with 32% having primary education, 38% high school and 30% university education. This situation is unlike their parents who reported 66% illiteracy. Improvements in the level of education brings more opportunities for receiving non-farm incomes which provide better options for obtaining a better standard of living. Normally children of farmers migrate to urban areas to pursue their studies. The change to urban areas and probably the specialisation in non-agricultural professions brings more opportunities for urban-based livelihoods. Furthermore, Miranda *et al.* (2003) found that farmers who do not depend on cattle production are those that have a higher educational level.

Improvements in education levels also improve human capital; nevertheless, it does not necessarily imply improvements in livestock production. If new skills learned are not related to rural activities, the livestock industry would not be improved by this change due to the loss of skills needed for managing cattle farms. In Costa Rica, non-rural activity incomes increase faster than agricultural jobs (Berdegué *et al.*, 2000).

An important issue supporting the idea that improvements in the level of education are moving young people to urban-based livelihoods is the fact that more than 64% of the farmers were older than 50 years old and 78% of the households did not have young people dedicated to cattle production (Ramos, 2003). Miranda *et al.* (2003) cited that farmers who received PES are on average 54 years old. In Honduras, Nicaragua and Guatemala, an RRA conducted by the CATIE/NORUEGA project found that only 48% of the farmers are older than 50 years old. This implies that young people are entering into cattle production in Guatemala, Honduras and Nicaragua, but not in Costa Rica. Therefore, human capital in the area is changing to non-farm activities at the expense of cattle production.

As human capital changes, the labour opportunity cost for livestock activities increases due to a reduction in the labour supply. In the case of beef production, the reduction in labour supply is not a problem; farmers mentioned that one of the reasons for being in cattle production is the low labour demand. Human capital demanded during the process is also low as farmers make use of their natural capital (natural resources, pasturelands, grasslands and natural regeneration areas for grazing and browsing cattle) which have a lower opportunity cost. However, farmers also mentioned labour requirements as a disadvantage for agricultural production, suggesting that labour is either scarce or too expensive in the area.

Most of seasonal workers come from Nicaragua, where labour is cheaper. The migration from Nicaragua reflects the socioeconomic situation in both countries. Nicaragua has a lower Human Development Index than Costa Rica (UNDP, 2002). Nicaraguan also has fewer opportunities to get non-agricultural jobs which paid better. According to the UNDP (2002), the adult literacy rate in Costa Rica is 95% while in Nicaragua it is 66%. This difference in social conditions produces a migration from Nicaragua to Costa Rica. However, it is not clear what would be the effect on the Costa

Rican economy if the situation in Nicaragua improves. If this happens, it might be probable that Nicaraguans return to their country, reducing the labour supply in Costa Rica. This will imply an increase in the cost of production.

Permanent labour might be a constraint in the area because most of the labourers are Costa Rican and are more expensive because they demand all the social benefits included in the Costa Rican legislation. Furthermore, labour is attracted to other areas such as to the Atlantic zone to work in agricultural activities like pineapple, banana and other services.

Another factor affecting the agricultural labour market is competition with other sectors. It was reported that the service sector was the one with the highest growth rate in Cañas (Proambiente, 2000). Therefore, a new expansion of livestock ranches would not be possible due to the competition with other sectors that have better wages and represent better options for a livelihood.

Social capital

Ramos (2003) found the presence of more than 28 civil organizations. However, it was found that less than a third of the farmers are member of any social organization. From the group interviewed, 11 were in the Chamber of Livestock (Camara de Ganaderos) and 9 in other types of social organization (Ramos, 2003). This type of behaviour denotes that cattle farmers normally work individually and do not rely on any organization. This is a common scheme in Central America. In the area, this situation is reinforced by the large number of farmers who live outside the area. Farmers that do not identify with the culture within the area were not interested in forming groups thereby weakening the formal institutions around cattle production.

Physical capital

The physical capital used for livestock production households referred to access to markets (roads), land and livestock. Land appears to be the most important asset for beef farms. The RRA showed that the size of cattle farms vary across the different types of farms; from 67 hectares to 938 hectares in 2002 (Chapter 3). Basically the cattle farms do not have irrigation systems (75%). It is important to remember that 25%

of the farms are covered by forest areas. Cattle production is based on the rest of the farm, using these forest cover areas for browsing during the dry season.

In the area, farms were obtained by purchase, inheritance or land adjudication. Fifteen percent of the households obtained the farms by the IDA (The national organisation for the agrarian reform, Instituto de Desarrollo Agricola "IDA"), 26% by inheritance and 59% by purchase (Table 6:1) (Ramos, 2003). The high percentage of purchased farms may indicate an active land market. It was found that most buyers are not from the area; many of them came from the Central Valley, especially Heredia, Alajuela and San Jose.

Table 5.14 - Origin of land property according to farm size, based on a survey of 53 cattle farms in Guanacaste, Costa Rica

Farm area (ha)	Way obtained the farm			Total
	IDA	Inheritance	Purchase	
2 to 25	3 (18%)	4 (24%)	10 (59%)	17 (100%)
26 to 50	5 (29%)	5 (29%)	7 (41%)	17 (100%)
51 to 150	0 (0%)	2 (20%)	8 (80%)	10 (100%)
151 to 800	0 (0%)	3 (33%)	6 (67%)	9 (100%)
Total	8 (15%)	14 (26%)	31 (58%)	53 (100%)

Source: Ramos (2003)

Ramos (2003) ascertained that most farms larger than 50 hectares were purchased on the market (Table 6:1). A 50 hectare cattle farm could represent a good investment for an urban-based livelihood household which is looking for a secure capital investment and a place for rural vacations. Considering the large number of farms bought and sold in the area, ranches appear to be a good long-term investment, providing a means for retirement savings for absentee landlords with urban-based livelihood strategies.

Irrigation appears to be an important input in agricultural production because the area is a dry forest zone. Ramos (2003) reported that 75% of households did not have access to an irrigation system. Thirty one of the 53 households mentioned that the production obtained on the ranches was not enough to meet the livelihood needs and 22 of the 31 did not have irrigation. Non-farm or off-farm activities appear to be more important in farms without irrigation, especially during the dry season. Hence, the main income activities on cattle farms were: livestock sales, crop sales, labour sales, ranch rent and grassland rent.

The second physical capital is cattle. Like land, livestock units in the area vary across cattle farm types. Animal units (One Animal Unit represents 450 Kg of animal weight) vary from 24 to 386 AU (Chapter 3). Considering the low use of machinery and labour, cattle production is based on two main resources; land and livestock. One way to explore the efficiency of the use of these two resources is the Animal Stocking Rate which varies from 0.5 to 2.3 UA/hectare. As discussed in Chapter 3, beef production in Guanacaste is more intensive than in the rest of the country probably because of the use of natural capital in the area.

Regarding transportation facilities, the study area has good road systems with the Pan-American Highway passing through the area. The area has three asphalt roads and many secondary roads (Chapter 4). This kind of infrastructure guarantees that a household will have rapid access to the main beef market in the area. In fact an auction can be reached in less than one hour. Therefore, road systems provide a low transportation cost, and in general terms, they are equally distributed across the area.

Financial capital

It was reported that access to credit is difficult due to the lack of guarantees. Agriculture in general has decreased access to credit. In 2002, only 9.3% of the bank credit was for agricultural production while services comprised 58.8% of the portfolio. Small farms have the least access to commercial credit because they have less credit guarantees (Ramos, 2003). Therefore, most of investments on cattle farms are done using their own money.

Livestock production is not only perceived as a physical asset but as a capital asset. Although they have access to bank services, many farmers use cattle as a savings account (Ramos, 2003) appears that the return rate obtained in livestock production is higher than the bank rate. However, Monterroso (2005) found that cattle ranches are not very profitable. He found that almost all cattle farms obtain a low return rate. Considering both studies; Ramos (2003) and Monterroso (2005) it is clear that the profitability of livestock production is low, but the risk is also low.

Monterroso (2005) reported that cattle farms have a rate of return of 25%, depending on the technology level. To illustrate this finding, a simulation of two groups, low and high technology farms, was conducted. The main difference between both systems is the Animal Stocking Rate, 0.50 for the low technology farm and 1.5 for the high technology farm. In a hypothetical farm of 60 hectares with 25% of the return rate and no fixed costs (land and animals), the high technology farm appears to be the best option. However, when considering not only the variable costs but the land and livestock costs, cattle production had a low return rate. The best option reported a return of 12% (Table 6:2), which is comparable with the bank account rate.

Table 5.15 - Simulation of cattle ranch profitability according Monterroso (2005) for groups in the area of Cañas and Bagaces, Costa Rica

Group	Low technology	High technology
Area (A)	61	60
Animal stocking rate (AS)	0.5	1.5
Head (Area*AS)	29	86
Cows (C)	28	84
Bulls (B)	1	2
Pregnancy	1	1
Time between births (years) (TBB)	2.0	1.5
Annual births [(cows*pregnancy)/TBB]	8	39
Male (50% of births)	4	20
Female (50% of births) (M)	4	20
Fattening time (years) (F)	1	1
Price (US$/kg)	0.83	0.83
Annual sales (US$/year) (AN)=[(M+F)/TBB*P]	1,162	5,810
Monthly sales (US$/month) (MS)=[AN/12]	97	484
Net income/month [MS*0.25]	24	121
Land value (LV)=[A*$300]	18,417	18,116
US$/hectare/month [MS/A]	0.39	2.00
Cow and bull values (CBV)=[(C*450*P)+(B*500*P)]	11,100	32,400
Total investment (TI)=[LV+CBV]	29,517	50,516
Fixed capital rent (FR)=[AN/CBV]	10%	18%
Rent including the variable costs (RVC)=[AN/TI]	4%	12%

Source: based on Monterroso (2005)

Considering that a hectare rents for 0.39 US$/month and 2 US$/month for the low and high technology farms respectively, and that a hectare of pasture could be rented for 3.75 to 5 US$/head/month, it appears that renting paddocks is a better business. This phenomenon occurs in the area as farmers allocate some of their areas to be rented. Normally, small farmers rent their areas to large land owners. Using this strategy, land-owners did not have to know about animal management, while the livestock owners did not have the land cost.

When considering land value, intensification appears to be an option; however, few intensive systems were found in the area. Perhaps intensification is not an option for many farmers because: 1) of lack of funds, especially the lowest income ranches who depend on cattle production, 2) labour supply could by restrictive, especially permanent workers who demand better conditions, 3) many farmers did not live in the area and intensification would demand more managerial skills and time, and farmers have a high opportunity cost. Therefore, the adoption of more intensive technology required that costs and managerial time must be at least the same or lower than traditional technologies.

5.2.4.2 Vulnerability context

As presented in Chapter 1, the area is a dry forest zone with a cycle of drought occurring in the area (cycle of 5 to 6 dry months). Therefore, the main constraint in the area is rainfall, which was overcome with the construction of the Tempisque-Arenal irrigation system. However, this system did not cover all of the area, and cattle production has been concentrated in areas without irrigation systems.

The seasonality of dry months required farmers to develop complex systems for managing their farms. Some farmers use the strategy to buy animals at the beginning of the wet season and to sell them at the beginning of the dry season. However, the main strategy employed is the use of the forest cover areas as feed stock during the dry season. Farmers that use this strategy need to maintain forest areas that require a minimum farm size of both paddocks and forest areas which are important issues for cattle production in the area.

The second strategy utilised is the use of grass paddocks during the wet season when grasses can grow. In the dry season farmers use the forest areas for grazing; however, it is known that forest areas can support lower animal stocking rates than paddocks. Some farmers mentioned the use of the two strategies, buying and selling animals and the use of forest areas during the dry season.

Another possibility for feeding during the dry season is the use of external inputs like food concentrates and hay. The use of this type of strategy increases the demand for financial capital. Forest resources are an excellent supplement for beef production, providing on-farm inputs which do not demand financial capital.

5.2.4.3 Livelihood strategies of cattle farmers

Fifty six percent of the farmers believe that cattle production could be improved. However, many of them did not want to see their children dedicate their lives to livestock production. As discussed before, the improvement in the level of education of the new generation has changed the livelihood strategy from rural to urban. The urbanisation of Costa Rica has created new opportunities for non-farm activities. This change in livelihood strategies has changed the cattle farm strategies, especially in the use of labour. Ortiz *et al.* (2003) ascertained that less than 20% of the farmers receiving PES depend on on-farms activities for their livelihood.

The low demand of labour is seen by farmers as an advantage of including livestock in their household livelihood. Many of livestock advantages cited by farmers are related to labour, risk and climatic conditions (Table 6:3). Therefore, livestock production is a rational production system under the current conditions of the area. Regarding agricultural activities, farmers saw few advantages for this kind of production, showing that livestock production is the basic production in the area. The main disadvantages of livestock production are related to financial capital which means that the farmers can buy land but not have enough money to buy livestock. Therefore, the strategy of renting land to other farmers as a way to capitalise on their assets appears to be a rational decision.

Table 5.16 - Advantages and disadvantages of agricultural and livestock production from farmers' point of view in the counties of Cañas and Bagaces (n = 53).

Activity	Advantages	Disadvantages
Agriculture	Short production cycle	Higher price variations Higher risk due to pest and weather conditions Higher labour demand
Livestock	Lower price variations Lower risk Low labour demand Low pest control Better for local climatic conditions, especially low water supply Livestock can be sold at any time, when it is required	Long production cycle Higher initial capital demand

Source: Ramos (2003).

Regarding the household livelihood portfolio, 21 activities were reported by farmers: cattle production (100%), crop production sales (40%), production for self-consumption (40%) and non-agricultural jobs (25%). On average, households combine 3 different income generation activities with 81% combining 2 to 4 activities. However, only 39% of the households had some expanded investments in livestock production in the last 5 years. Therefore, 44% of the households reported cattle production was not the main income source (Ramos, 2003). Farmers who did not depend on cattle production are those who bought their farm, unlike farmers who inherited farms and depend more on cattle production like those with IDA farms. Under this scenario, forest and tree resources have a high potential to increase because farmers are not able to improve their pastures by cutting natural regeneration areas.

Ramos (2003) reported that the presence of natural regeneration areas did not give prestige to the farmers because ranchers believe that these areas appear to be abandoned and can be an indication of economic limitations. In contrast, the presence of remnant forest, secondary forest, riparian forest and live fences give prestige to the owners because farmers that have one of these areas look like people who respect the law and protect the environment (Table 6:4).

Table 5.17 - Cultural reasons for having forest and tree resources on cattle farms in Cañas and Bagaces, Costa Rica (n=53)

Forest and tree resources	Give prestige	Do not give prestige
Natural regeneration areas		Abandoned farm, indication of economic limitations of the household. Extensive browsing on natural regeneration areas to reduce production cost
Remnant forest	Indication that farm is large enough to support different land uses Indication that owners protect biodiversity Law requirement	
Secondary forest	Indication that farm is large enough to support different land uses Biodiversity valuation	
Riparian forest	Law requirement Biodiversity valuation	
Live fences	Indication of production activity and good cattle management	

Source: Ramos (2003).

Forest and tree resources have different reasons for being included in the livelihood. Farmers want to have paddocks without trees; therefore, the presence of trees in paddocks is a response to farmer limitations for keeping pastures clean basically due to the lack of labour, financial capital and managerial skills. Farmers are more interested in traditional paddocks with few trees, and they expect compensation for the increase of forest cover in paddocks (Chapter 5); they are not interested in investing in forest and tree resource management.

5.2.5 Conclusions

The livelihood approach allows the analysis of the socioeconomic factors influencing forest and tree management on cattle farms. An analysis of the five capitals showed that cattle farmers located in the dry forest of Costa Rica have good natural, physical and human capita with the financial and social capitals being the main constraints for the cattle production in the area. The natural capital is one of the main reasons why cattle production is the main economic activity in the area. Forest and tree resources can improve the natural capital, providing resources for feeding livestock.

Human capital is very important in the area. Improvement in human capital is providing new non-farm opportunities for younger generations. Cattle farmers' sons and daughters have a higher educational level than their parents, changing their livelihood to a more urban-based one. Farmers' children presented a high percentage of university studies, which are often not related to cattle production. Therefore, to pursue their livelihood, farmers' children will probably not depend on the cattle farms but will use them as a spare time activity.

The main constraint on the social capital is the high percentage of absentee farmers. It was found that most of the farmers did not live in the area. As the social conditions in Costa Rica improve, young professionals that live in the metropolitan area of the country invest their money in cattle farms in the area. The result is that a large number of cattle farm owners live in the main cities of Costa Rica and are part-time farmers. This situation weakens the social capital because it does not allow farmers to dedicate time to local organizations like the livestock chamber. It is expected that social capital will not be improved in the future.

It was found that financial capital is one of the main constraints for cattle production. As more intensive production systems often demand more financial capital, the low intensification level can be explained due to the lack of financial capital. It was reported that farmers do not have access to credit, especially farmers with small and medium farms. Additionally, cattle farm profitability is low due the low technology management index reported in the area. As cattle farms become more intensive, profitability increases. Nevertheless, change in the production systems requires investment in pasturelands and cattle breeds which demand financial capital.

Farmers based their production on the natural capital, which is also the basic capital used to overcome the dry period. Forest and tree resources are included in cattle farmer livelihoods because they improve the natural capital. This creates new opportunities for introducing forest and tree resource management on cattle farmers. Some strategies to reach this goal will be discussed on the next section.

Chapter 6

CURRENT AND POTENTIAL ROLE OF FOREST AND TREE RESOURCES IN LIVELIHOOD STRATEGIES OF CATTLE FARMERS IN GUANACASTE, COSTA RICA

6.1 CURRENT ROLE OF FOREST AND TREE RESOURCES IN LIVELIHOOD STRATEGIES

Costa Rica has created sound environmental policies since the mid 1980s. Policies like environmental education in schools, government advertising about environmental protection and protection programs have created a more sensible approach about the environment. Nevertheless, the impression that farmers saw natural regeneration areas as unwanted input to their farms gave an indication that natural regeneration areas exist due to the high cost of keeping pastures in good shape. Thus, natural regeneration areas are good for foresters, but not the best option for farmers.

Probably, with economic incentives, paddocks would be maintained without trees because natural regeneration areas can only support one quarter of the animal stocking rate that a paddock without trees can (Chapter 3). Tropical grasses are not tolerant to shade, and better growth is obtained in an open area with good penetration of sun radiation. For this reason, paddocks with trees are not demanded by farmers.

Farmers see these areas as a means for generating savings due to the future stock value of wood. Fifty two percent of the farmers believed they have enough trees, 28% have too many trees and 20% have a few trees; 75% reported a willingness to increase forest cover (Ramos, 2003). Nonetheless, the choice experiments indicated that farmers are interested in obtaining compensation when increasing forest cover (Chapter 5). However, one can expect an increase in forest cover because much of the cattle development during the past was produced by government incentives. These would not return because the national and international policies are now more interested in reducing the deforestation process.

The main factors affecting the decision to increase forest cover are: non- and off-farms jobs, labour costs for maintaining trees, the long-term cycle of forest production, forest fires, farmer age and risk. Older people felt that unless they had a successor, they would not be motivated to invest in long-term activities such as forest production. Furthermore, 80% of the farmers mentioned that the forest law did not allow them to make use of their forest and tree resources due to the high cost of obtaining harvest permission.

Fifty seven percent of the farmers believed that deforestation was not a problem in the area; rather, they believed that forest cover had grown (Ramos, 2003). In Chapter 4, it was discussed that forest cover in the area has been stable since the 1970s, and the importance of tree resources in paddocks has increased from 39% in the 1970s to 54% in the 1990s.

6.2 POTENTIAL ROLE OF FOREST AND TREE RESOURCE MANAGEMENT IN THE LIVELIHOOD STRATEGIES OF CATTLE FARMERS IN CAÑAS AND BAGACES

The analysis of the potential role of forest and tree resource management is based on a SWOT analysis. The SWOT results are presented into two different parts: first the strengths and weaknesses, which refer to on-farm conditions, and then the opportunities, which refer to external conditions.

Strengths referred to farmer livelihoods (education, knowledge and income sources and farmer interest), ranch characteristics (soil fertility, size, location, cattle breed, and pasture) and natural regeneration characteristics (size, low cost, current uses, number of valuable species). On the other hand, weaknesses refer to farmer characteristics (opportunity costs, lack of interest in investing, age, succession, lack of knowledge, expectation in receiving payment), farm characteristics (specialisation), and wood production (time, uncontrolled uses, lack of markets) (Table 6.1).

Strengths are referred to as the farm characteristics which represent natural and physical capital. On the contrary, the main weakness came from farmer characteristics which mainly included human capital. Therefore, forest and tree resources are included in household livelihoods because they improve the natural and physical capital of cattle farms. However, farmers have little knowledge about forest and tree resources, which implies a weakness in the livelihood strategies that include forest and tree resources. Another weakness is associated with the time required in producing wood products. Therefore, any strategy must include farmer knowledge about forest management and finding practices that produce forest products in a short or medium time.

Table 6.1 - Strengths and weaknesses of introducing forest and tree resources to cattle farms located in the dry forest zone of Costa Rica

Strengths	Weaknesses
➢ Educational level of the farmers. They would be able to conduct research and introduce new technologies without technical supervision ➢ Good knowledge of cattle production and management ➢ Soil fertility is enough for livestock and forest production (pasture degradation did not occur due to loss in soil fertility but to inadequate pasture management) ➢ Most ranches are large enough to maintain profitable cattle production, leaving areas to natural regeneration ➢ Most ranches have a good location, near beef and wood markets ➢ Forest regeneration on cattle farms reduces the cost of forest production ➢ Low opportunity costs of natural regeneration areas because there are few viable production options ➢ The number of wood species in forest regeneration areas which puts an economic value on these areas ➢ Farmer interest in forest management and environmental protection	➢ High opportunity costs of labour (most farmer livelihoods do not depend on cattle production) ➢ Lack of interest in investing in cattle production ➢ Farmer age could limit interest in medium- or long-term investment ➢ Lack of knowledge about forest management ➢ Farmers may be unwilling to invest in cattle or forest production as they do not expect their children to continue livestock production ➢ Expectation of payments for forest management ➢ Long period required to gain a final forest product ➢ Uncontrolled use of natural regeneration areas because browsing damages valuable species and reduces final value ➢ Lack of knowledge about the species and conditions for natural regeneration ➢ Lack of market for some wood species

As discussed in the financial capital parts, cattle farms have low profitability; land and livestock represent a large investment in cattle farms. Therefore, a possible reason for households to invest in livestock production could be land valuation. Natural and physical capital increases land prices in the area (Chapter 3 and 4). Furthermore, the area has good road systems which reduce transportation costs. Households buy farms in the area as a way to invest money in livestock which is a low risk activity.

Opportunities are related to markets (wood demand, industry, incentives for forest management, green markets, free market trades), organisations (Chamber of Livestock), availability of skilled labour, other projects near the area (national parks, other projects), land cover stability, social perception of forest and tree resources, the attraction of new investors, the benefits of the area as a connector of protected areas, the image of Costa Rica as an environmentally concerned country and local infrastructure. Threats include high labour costs, the forest law (cost of forest management plans, incentives to keep natural regeneration in its initial stage, illegal harvesting), low presence of government organisation, free market trade, low government creditability, expansion of cattle production and the urbanisation process (Table 6.2).

Table 6.2 - Opportunities and threats for introducing forest and tree resources to cattle farms located in the dry forest zone of Costa Rica

Opportunities	Threats
➢ Demand for wood products is likely to increase ➢ The new free market trade, which will open markets for environmentally sound forest products ➢ Presence of forest industry near the area, and possibility to introduce new industry ➢ The interest of the Costa Rican government in sustainable forest management ➢ Presence of the Chamber of Livestock (Camara de Ganaderos), which can help to introduce forest and tree resource management ➢ Availability of skilled labour, especially foresters, who can support farmers in silvicultural practices ➢ Experience in managing livestock in natural regeneration areas near the area ➢ Stability of natural regeneration areas and increase of forest cover in pasture ➢ Positive social perception toward the conservation of forest and tree resources ➢ Possibility of attracting foreign investment for forest and tree resource management ➢ Development of green markets, especially for certified wood and organic beef ➢ Presence of national parks around the area; converting the zone into an important connector of protected areas ➢ Costa Rica's international prestige in natural resource conservation ➢ Infrastructure present in the area which facilitates the implementation of projects ➢ Presence of project testing mechanisms for payment for environmental services regarding silvopastoral systems (GEF project in Esparza)	➢ High labour costs in Costa Rica. Labour-intensive new technologies may not be easily accepted by farmers ➢ High costs for preparing forest management plans as required by forest law (once trees reach a specific diameter a forest management plan is required if harvesting is planned) ➢ Low presence of MINAE personnel facilitates illegal harvesting. Sound forest management may not compete with illegal harvesting ➢ Low presence of MINAE and MAG hampers implementation and monitoring of a forest project ➢ The free trade agreements signed by Costa Rica allow for importation of low-cost wood products from countries like Chile and Brazil, competing fiercely with local products ➢ Decreased credibility of government programs (mismanagement, corruption, etc.) ➢ Possible expansion of cattle production (if government policies provide incentives, expansion of pasturelands would take place at the expense of forest cover) ➢ Rapid urbanization process in the country, putting more pressure on forest areas

The main opportunities for forest and tree resource management come from markets. New opportunities would be created through the new free market trade and the possibility of exporting forest products. Similarly, the forest industry presents opportunities for forest management. The area is surrounded by forest industry, especially sawmills. The industry would demand more forest products as external and internal demand for forest product grow due to the new free market trade. Besides, local organisations, like the Chamber of Livestock, provide opportunities to introduce forest management in cattle farms. However, it is important to improve farmer knowledge about forest management.

On the other hand, farmers feel that the forest laws are contrary to forest management on cattle farms. They mentioned that Costa Rica appears more concerned with forest conservation than forest production. Probably this kind of perception is a product of the lack of knowledge about the forest laws. The way to solve this problem is to teach farmers about the forest laws.

Greater government intervention might increase forest cover, but not induce better forest management. What government intervention is required depends upon the objective for increases in forest cover. If forest cover is justified for biodiversity protection without any economic activity, no intervention is required. Considering that farmers were not really interested in investing in cattle production, forest cover in the area seems under little pressure. An increase in forest cover could be expected.

If however, the government wishes to see an increase in the economic use of the forest and tree resources, then management of forest and tree resources is required in order to obtain high quality forest products. Thus, the discussion aims to explore alternatives to introduce the management of these resources.

Most strengths and opportunities are related to the natural and physical capital. Forest resources on cattle farms are used in cattle production as a strategy to reduce production costs. A strategy to introduce the management of these resources must consider this fact. Although silvopastoral systems might appear to be an option, more research to understand the relationship between pasture and trees, livestock and trees and the management of these relationships is required.

Most farmers in the area have a least 20% of their area under forest cover (Chapter 3), and most paddocks have trees. Considering that most of these forest and tree resources are younger than 20 years old, the potential to improve forest production is high. Then, considering that more than 50 years are required to obtain wood from these resources, the reason to invest in forest management is the expectation of an increase in forest product prices.

As mentioned above, the introduction of forest and tree resource management is likely to be accepted if it fits into household livelihood strategies. However, there is a lack of knowledge about the species and their management in natural regeneration sites. Furthermore, any initiative to introduce forest management to cattle ranches needs on-farm research for at least 15 or 20 years, which is the minimum time required for obtaining important results in any forestry project. Currently, data from the Palo Verde National Park are available, but they did not conduct any on-farm research.

A classification of farmers is required for focusing different strategies according to the type of farmers. Ramos (2003) found four groups based on a livelihoods approach. First she considered the importance of livestock production in farmer portfolios. This resulted in two groups, those whose livelihood depended on cattle production and those whose livelihood did not depend on cattle production. She also discussed the original assets capital, having the best and worst capital. Ramos (2003) cited that the best income groups have the most stable forest areas; therefore, they are the most interested in long-term investments. Thus, the work should be concentrated on the highest income farmers first and then continue with the lower income farmers.

Since farmers are not interested in investing in forest and tree resource management (Chapter 5), any type of forest management on cattle farms requires payment. However, it is recognised that tree resource cover in paddocks have a positive effect with low paddock occupation. According to farmer perception, tree cover over 4% requires a compensation of 11 US$ per each percent of tree cover increase (Chapter 5). Nonetheless, 25 trees/hectares or a 20% cover is normally recognised as optimal tree cover in paddocks, but it is necessary to define this break even point for different types of grasses because grasses respond differently to tree shade.

Furthermore, the different types of tree arrangements require different payment amounts. As paddock occupation increases, farmers demanded a higher payment. The cheapest arrangement is trees in fences followed by trees in rows inside paddocks. Trees in fences are more suitable for farms that are under an intensified production system and that demand the use of machinery. Dispersed trees are more suitable for medium and low intensity farms, which do not demand the use of machinery for paddock management. This arrangement required a higher payment than trees in fences. Therefore, for the purpose of starting with the introduction of tree management on cattle farms, the best option is to begin with trees in fences and then the management of dispersed trees.

Trees in fences can be used to produce forage as a main product. Species like *Acacia angustissima, Acacia farnesiana, Acacia pennatula, Anacardium excelsum, Anacardium occidentale, Brosimum alicastrum, Bursera simaruba, Caesalpinia coriaria, Cassia grandis, Ceiba pentandra, Cordia dentata, Diphysa americana, Erythrina berteroana, Erythrina fusca, Gliricidia sepium, Guazuma ulmifolia, Jatropha curcas, Pithecellobium dulce, Prosopis juliflora, Senna atomaria, Spondias mombim, Spondias purpureas* can be used. However, it is necessary to evaluate together with farmers which are the most suitable species and management.

Chapter 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

The methodology used in the study allows the study of the main exogenous and endogenous forces underlying forest and tree resource management on cattle farms in Guanacaste, Costa Rica. The use of the livelihood framework proves to be adequate to discuss how these factors influence cattle farmer decisions. The logit model, the analysis of the aerial photographs and the analysis of farmer preferences of tree arrangements add extra value to the livelihood analysis, making it possible to quantify the natural and physical capitals.

From the livelihood assets analysed, natural capital was the principal asset of cattle farmers. The Costa Rican agroecological condition allows cattle production in much of its territory, with cattle ranching being the main land use in 2003. Three types of cattle production systems are present in the country; beef, dual-purpose and dairy farms; which present a spatial distribution. Dairy farms were highly concentrated in Cartago, whereas beef farms were prevalent in Guanacaste due to the differences in the geographic conditions. Elevation and water supply are the main assets in the natural capital in cattle farmer livelihoods. Where conditions are suitable for dairy farms, farmers lean toward this production. In conclusion, the Costa Rican geographic conditions favoured cattle farming, especially when the elevation allowed for dairy production.

The spatial arrangement of cattle farms in the country is affected by the geographic condition with the beef farms being more dependent on natural capital. Beef farms tend to be larger than dairy farms, producing land and herd accumulation, while the dairy industry is based on smaller farms, implying lower land and herd accumulations. Beef cattle farms require large areas because their production is based on the use of natural stock. Thus, beef farms may be less interested in intensification than dairy farms, allowing a higher presence of forest and tree resources on farms.

Forest and tree resource cover in the dry forest zone in Costa Rica has constantly increased since the 1970s. Forest and tree resources increased at the expense of paddocks without tree resources which were converted into paddocks with tree resources. The increase of tree resources in paddocks implies a reduction in the intensification of cattle production since paddocks without tree cover can support a higher animal stocking rate than paddocks with tree resources. In conclusion, forest and tree resources are on cattle farms as a result of the reduction in the cattle production and not as a result of the introduction of forest management in cattle farmer livelihoods.

This increment of forest and tree resources was induced by changes in farmer livelihoods, especially in human capital. The main driving force was the reduction in the agricultural labour supply due to the migration from rural to urban areas and the improvement in the level of education. The result was an increase in the labour costs for agricultural activities, reducing the importance of the agricultural sector in the Costa Rican economy. On the other hand, sectors like tourism and services have increased their importance. Farmers respond to this shock by reducing the intensity of beef production; thus, the increase in forest and tree resources is especially a result of the increase in labour opportunity costs.

Livestock production is not the main income source in cattle farmer livelihoods which instead is more linked to non-farm activities. Labour costs and the education level of cattle farmers have risen in the last decades. As agricultural activities are normally the worst paying jobs, better-educated people are attracted to non-agricultural activities that have better paying jobs. The new generations are less interested in cattle farming. Therefore, an expansion of forest cover can be expected as many farms are likely to be abandoned and it will be reflected in the increasing number of trees in paddocks.

Other important exogenous factors affecting forest cover in cattle production areas are beef and forest product prices. In the domestic and U.S. beef markets, beef prices have tended to increase. Contrary to the popular belief, the collapse of the beef industry was not induced by declining beef prices but by high labour costs and changes in government policies. The Costa Rican government supported cattle production through cheap credit, technical assistance and the creation of beef exportation plants. Most of these policies were also supported by international donor agencies but this financial support is no longer available.

As the study area belongs to the dry forest zone, there are severe constraints on grass production during the dry period. The main reason to tolerate forest and tree resources on livestock farms is therefore the production of forage during the dry season. Although forest and tree resources can improve the natural capital, farmers are not interested in investing in managing their trees. Farmers prefer to improve grasses and cattle breeds rather than improving tree management. Technologies that improve the production of forage from trees have a higher possibility to be adopted.

The adoption of new technologies also depends on farmer preferences. The type of tree arrangement in paddocks has a large influence on the adoption of silvopastoral systems. Farmers preferred dispersed trees and live fences with low densities in paddocks. Dispersed trees are a common spatial distribution on cattle farms as they mostly originated from natural regeneration or remnant trees. On the other hand, live fences are not very common in the study area because they are not a natural arrangement of trees; farmers need to plant the trees in the fences. This implies that dispersed trees have a lower establishment cost in comparison with any other spatial arrangement.

Forest patches are another common spatial arrangement of forest resources on cattle farms. These are typically used for cattle browsing especially during the dry season. Forest patches only support one third of the stocking rate of pasturelands but they have low opportunity costs. Forest and tree resources thus constitute a good food supply during the dry season because of their low demand for financial capital.

Under present conditions, farmers are not interested in managing their forest resources, any increase in tree cover in the form of dispersed trees or live fences in paddocks demands incentive schemes. Farmers demand a higher payment than current FONAFIFO payments because of the higher opportunity costs of trees in paddocks. For dispersed trees and live fences the demand for compensation is 105 US$/ha/year and 35 US$/ha/year, respectively. Farmers demand a payment of 11 US$/ha/year for each 1% increase in forest cover on pasturelands.

Despite the perspectives for management of forest and tree resources in cattle farms with incentives schemes, a new deforestation process in the dry forest zone of Costa

Rica is unlikely because of the limitation in labour supply and change in farmer livelihoods. Considering that 38% of the area is cover by forest areas, for biodiversity conservation no incentive scheme is needed. The forest and tree resources on cattle farms provide wood and other forest products but to achieve the most value added, management of these resources is required. In this case, the Costa Rican government needs to create a program for introducing forest management to cattle farms; it should be a program that can focus on the impulse of ecotourism and it should include a research project to identify the best economic and ecological options for managing the forest and tree resources in cattle farms.

According to FONAFIFO's experience in Costa Rica, PES focused on medium and large farms because these types of farms can easily absorb the related transaction costs. Furthermore, forest and tree resources increase as farm size increases, providing more opportunities for introducing tree resource management. Trees in fences are more likely to be adopted by small and medium farms because they occupy less area. Dispersed trees are more suitable for small and medium farms. Paddock size is directly related to tree cover and consequently beef farms, which are larger than dairy farms, have a higher potential for introducing forest and tree resource management. Dispersed trees are not suitable for large farms which have mechanised pasture management; nevertheless, forest plantations (blocks) are more suitable for large farms because they can dedicate specific areas to forestry.

From the government's perspective, the increase of forest and tree resources and cattle farms is more feasible for medium and large farms. Farmers with medium and large farms can use more area for forest and tree resources, thus reducing the transaction costs. However, for reducing rural poverty, small farms must be considered and the focus should be on trees in fences. In both cases, farmers are not willing to invest in forest management; rather they demand compensation for an increase in forest cover. Farmer trade-off starts at 4% forest cover in a paddock.

In the area of study, the farms with higher location rent are the most intensively managed. These farms are under urbanization pressure that increases the opportunity costs to maintain cattle farms. Livestock production is likely to be concentrated on those farms with lower location rent and lower opportunity costs. Farms with the best locations will need to intensify their production if they want to compete with the demand for housing areas. Thus, projects aiming at the intensification of beef cattle production need to focus on those ranches with higher location rent. The owners of farms with lower location rent will be less motivated to intensify production unless the land value increases. But for forest and tree resources, it is better to work with farms with lower location rent because they tend to have larger areas with forest cover.

7.2 RECOMMENDATIONS

The inclusion of forest and tree resource management is possible in the study area. Forest cover has constantly increased along with the improvement on the social condition in the country. As discussed, social conditions are one of the main factors affecting the presence of forest and tree resources on cattle farms. However, the introduction of forest management needs to consider that forest and tree resources are not the main concern of cattle farmers; they prefer to improve their pasture, cattle genetics and machinery rather than manage their forest areas.

The inclusion of forest management will demand a holistic project that works with farmers in solving their main problem, forage production. Once farmers have their main problems solved, they will be willing to work on improving forest management. However, there is a lack in the knowledge regarding the management of tree species in silvopastoral systems. On-farm research will be necessary to define alternatives for introducing forest management on cattle farms, especially the management of native species that are under regeneration.

Farmers should reinforce the social organization in the area. The livestock chambers may be the linking organization between farmers and the national government. The livestock chambers around the country can be the coordinators of this project together with the Ministry of Agriculture and Livestock.

The government needs to pay attention to the forest cover in the area and give technical assistance to farmers for better management of the forest and tree resources. The government can also support the management costs through credits that farmers would pay when forest products are harvested.

As forest activity is a medium and long-term activity, the research will demand at least 15 years. It is important to consider first the management of the natural regeneration before including forest plantations. Trees from natural regeneration would have a lower cost, and they are also a resource already present on the farms. Probably the best strategy is to select some farms as demonstration farms for conducting research. A typology will be necessary for defining these case study farms in order to later have valid data for the rest of the area. A monitoring of a least four farms per farm type is recommended in order to have the opportunity to compare data across farms and across groups.

The research needs to focus on the relationship between trees and grasses, especially defining what the optimum quantity of trees in paddocks is. This combination needs to be defined for the different types of grasses used in the area. The study of the combination needs to consider the spatial arrangement of trees. Once the best combination of trees in paddocks is identified, it is necessary to explore different alternatives for managing these trees. This demands on-farm plots with different tree management alternatives. As mentioned before, the evaluation of these plots should be done for at least 15 years.

Parallel to the on-farm research, training the farmers about the different possibilities for managing their trees will be necessary. This can be conducted using the demonstration farms as training plots. Around the demonstration plots, groups of farmers can be organized to discuss the different alternatives for managing trees. In managing these groups, a participatory approach can be used. Farmers should also be trained in the forestry laws and regulations for forest management and harvesting.

As a general conclusion, forest and tree resources are not in danger; the problem is how to add value to the natural regeneration process already undergone in the area. The aerial photographs showed a stability of forest cover areas since the 1970s, and the tendency is to maintain this cover.

Chapter 8

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Chapter 9

ANNEX

ANNEX I: SAS PROGRAM FOR CLUSTER ANALYSIS

```
options ls=78 ps=60 pageno=1;
data cluster;
input AREA_FINCA AREA_POTRE BOVINO_TOT TOTAL_CARN TOTAL_LECH
    TOTAL_DPRO RIO POZO ACUEDUCTO FORRAJE_HA MANEPOTRE ESTABULADO
    SEMIESTABU IN_SAN MAN_SAN MAN_ALI FERTILIZA ASISTENCIA;
ID_FINCA=_N_;
CARDS;
[Siguen 205 observaciones con las 18 variables arriba mencionadas]

;
data cluster;set cluster;
proc standard mean=0 std=1 out=a;
var AREA_FINCA AREA_POTRE BOVINO_TOT TOTAL_CARN TOTAL_LECH
  TOTAL_DPRO RIO POZO FORRAJE_HA MAN_SAN MAN_ALI FERTILIZA;
proc cluster out=tree method=ward p=30 pseudo;
var AREA_FINCA AREA_POTRE BOVINO_TOT TOTAL_CARN TOTAL_LECH
  TOTAL_DPRO RIO POZO FORRAJE_HA MAN_SAN MAN_ALI FERTILIZA;
id ID_FINCA;
proc plot;
  PLOT _PST2_*_NCL_='T'/hectaresXIS=0 TO 30 BY 2 VPOS=15 HPOS=50;
proc tree NCL=7 OUT=OUT;
COPY ID_FINCA;
PROC SORT;BY CLUSTER ID_FINCA;
PROC PRINT;VAR CLUSTER ID_FINCA;
PROC FREQ;
  tables cluster;
data b;merge a out;keep ID_FINCA cluster
     AREA_FINCA AREA_POTRE BOVINO_TOT TOTAL_CARN TOTAL_LECH
     TOTAL_DPRO RIO POZO FORRAJE_HA MAN_SAN MAN_ALI FERTILIZA;
proc stepdisc;
  classes cluster;
    var AREA_FINCA AREA_POTRE BOVINO_TOT TOTAL_CARN TOTAL_LECH
    TOTAL_DPRO RIO POZO FORRAJE_HA MAN_SAN MAN_ALI FERTILIZA;
data out2;set out;keep ID_FINCA cluster;
proc sort;by ID_FINCA;
data total;merge cluster out2;by ID_FINCA;
PROC GLM;
  classes cluster;
    model AREA_FINCA AREA_POTRE BOVINO_TOT TOTAL_CARN TOTAL_LECH
    TOTAL_DPRO FORRAJE_HA = cluster;
         means cluster / duncan;
proc freq;
  tables cluster*(RIO POZO ACUEDUCTO MANEPOTRE ESTABULADO SEMIESTABU
       IN_SAN MAN_SAN MAN_ALI FERTILIZA ASISTENCIA)/chisq;
Run;
```

ANNEX II: QUESTIONNAIRE USED FOR COLLECTING DATA IN THE RRA

ID_Finca	Area Finca (total)	Pecuario 1	Area pecuario
	0		0

Produccion pecuario 1	Area bajo riego pecuario 1	Tipo de riego pecuario 1
0	0	

Pecuario 2	Area pecuario 2	Produccion pecuario 2	Area bajo riego pe
	0	0	0

Tipo de riego pecuario 2	Cultivo 1	Area cultivo 1	Produccion cultiv
		0	0

Area bajo riego cultivo 1	Tipo de riego cultivo 1	Cultivo 2
0		

Area cultivo 2	Produccion cultivo 2	Area bajo riego cultivo 2
0	0	0

Tipo de riego cultivo 2

Observacion produccion

Fuente de agua 1	Tipo consumo fuente 1	Distancias fuente 1
	0	0

Cantidad fuente 1

Fuente de agua 2	Tipo consumo fuente 2	Distancias fuente 2
	0	0

Cantidad fuente 2

Fuente de agua 3	Tipo consumo fuente 3	Distancias fuente 3
	0	0

Cantidad fuente 3

Fuente de agua 4	Tipo consumo fuente 4	Distancias fuente 4
	0	0

Cantidad fuente 4

Observaciones fuente de agua

Tarifa agua potable

Conflictos de acceso

Proteccion de fuentes de agua

Estrategias en tiempo de sequia

Variacion del hato en epoca seca

Organizacion en torno al agua

Area tacotales	Area plantaciones	PSA
	0	0

Distribucion de arboles fuera de tacotales

Especie 1	Uso 1	Especie 2
Uso 2	Especie 3	Uso 3
Especie 4	Uso 4	Especie 5
Uso 5	Especie 6	Uso 6
Especie 7	Uso 7	Especie 8
Uso 8	Especie 9	Uso 9
Especie 10	Uso 10	

Observaciones especies

Uso de area de tacotal

Cuanto madera	Cuanto poste	Cuanto leña	Cuando	Donde/Quien
0	0	0	0	

Especies

Observaciones consumo
Problemas forestales
Actividades de manejo de arboles
Interes en participar en la invetigacion
Inversiones en finca
Historia de la finca (pasado)
Plan de finca (futuro)
Tenencia de la tierra
Observacion de la tenencia de la tierra
Obseravaciones generales

ANNEX III: TREE SPECIES MENTIONED BY FARMER OF THE DRY FOREST OF COSTA RICA (N = 77)

Family	Scientific name	Actual condition*	Uses**
	Hyeronima alchornoides	NA	NA
Anacardiaceae	*Anacardium excelsum*	A	Ap,Comes,Cons,Fo,Or
Anacardiaceae	*Ancardium occidentale*	I	Ap,Comes,Fo,Me,Or
Anacardiaceae	*Astronium graveolens*	A	Ar,Cons,Or
Anacardiáceas	*Mangifera indica*	I	Ar,L,Comes,Fo,Me,Or
Anacardiaceae	*Spondias mombim*	HA	Ap,Ar,Comes,Fo,Me
Anacardiaceae	*Spondias pupurea*	HA	Ap,Comes,Fo,Me
Arecaceae	*Acrocomia aculeata*	HA	Ap,Cons,Fo
Arecaceae	*Attalea spp*	NA	NA
Bignoniaceae	*Cresentia alata*	HA	Ar,L,Comes,Fo,Me,Or
Bignoniaceae	*Tabebuia ochracea*	HA	Ap,L,Cons,Or
Bignoniaceae	*Tabebuia rosea*	HA	Ap,L,Cons,Me,Or
Bixaceae	*Cochlospermum vitifolium*	HA	Ap,Ar,Comes,Or,PQ
Bombacaceae	*Bombacopsis quinata*	A	Ap,Ar,Comes,Cons
Bombacaceae	*Pseudobombax septenatum*	HA	Or
Boraginaceae	*Cordia alliodora*	A	L,Cons,Fo,Me,Or
Boraginaceae	*Cordia dentata*	HA	L,Comes,Fo
Boraginaceae	*Cordia gerascanthus*	ES	L,Cons,Fo,Or
Burseraceae	*Bursera simaruba*	HA	CB,Cons,Fo,Me,Or
Burseraceae	*Bursera spp*	NA	
Euphorbiaceae	*Croton niveus*	HA	Fo,Or
Fabaceae-Caes.	*Caeasalpinia eriostachys*	A	Ap,L,Cons,Or
Fabaceae-Caes.	*Delonix regia*	I	Ar,Ap,Or
Fabaceae-Caes.	*Hymenaea courbaril*	A	Ap,Ar,L,Comes,Cons,Fo,Me,Or
Fabaceae-Caes.	*Tamarindus indica*	I	Ap,L,Comes,Fo,Me,Or
Fabaceae-Mim.	*Acacia centralis*	ES	Ap
Fabaceae-Mim.	*Enterolobium ciclocarpum*	HA	Ap,Ar,L,Cons,Fo,Or
Fabaceae-Mim.	*Leucaena spp*	NA	Ap,L,Comes,Fo,Or
Fabaceae-Mim.	*Lysiloma divaricatum*	A	Ap,Ar,Cons
Fabaceae-Mim.	*Machaerium biovulatum*	A	Cons,Fo
Fabaceae-Mim.	*Samanea saman*	ES	Ap,Const,Or
Fabaceae-Pap.	*Andira inermis*	HA	Cons,Fo,Or
Fabaceae-Pap.	*Dalbergia retusa*	E	Ar,Ap,Or
Fabaceae-Pap.	*Diphysa Americana*	HA	Ap,Ar,CB,L,Cons,Fo,Me,Ol,Or,PQ
Fabaceae-Pap.	*Gliricidia sepium*	HA	Ap,Ar,CB,L,Comes,Cons,Fo,Me,To
Fabaceae-Pap.	*Lonchocarpus costaricensis*	ES	CB
Fabaceae-Pap.	*Myrospermum frutescens*	A	L,Cons,Fo,Or
Fagaceae	*Quercus oleoides*	A	Ap,L,Cons,Fo,Ol,Or
Malpighiaceae	*Byrsonima crassifolia*	HA	Ap,L,Comes,Fo,Me,Or,Col
Meliaceae	*Azadirachta indica*	I	Ap,CB,L,Cons,Me,Or,PQ
Meliaceae	*Cedrela odorata*	A	Ar,Cons,Me,Or
Meliaceae	*Cedrela spp*	NA	Ar,Cons,Me,Or
Meliaceae	*Swietenia humilis*	E	Ar,Cons,Or
Moraceae	*Brosimum alicastrum*	A	Ap,Comes,Cons,Fo

Moraceae	*Ficus goldmanii*	HA	Or
Moraceae	*Ficus werckleana*	A	Comes,Fo,Or,PQ
Myrtaceae	*Psidium guayaba*	HA	Ap,L,Comes,Fo,Me,Or
Pinaceae	*Pinus spp*	I	NA
Rubiaceae	*Calycophyllum candidissimum*	HA	Fo
Sapotaceae	*Chrysophyllum spp*	NA	NA
Sapotaceae	*Manilkara spp*	NA	Ap,L,Comes,Cons,Fo
Sapotaceae	*Sideroxylon capiri*	A	Ap,L,Cons,Fo
Sterculiaceae	*Guazuma ulmifolia*	HA	Ar,Comes,Fo,Me,To
Verbenaceae	*Gmelina arbórea*	I	L,Cons,Fo,Or
Verbenaceae	*Tectona grandis*	I	Ap,Ar,Cons,Or,Col
Zygophyllaceae	*Guaiacum sanctum*	E	Ar,Cons,Me,Or

* A = Abundant, ES = Escase, HA = High abundant, E = Endagered

** Ap = Apícola, Ar = artesanías, CB = Control Biológico, Col = Colorante, Comes = Comestible, Cons = Construcción, Fo = Forraje, L = Leña, Me = Medicinal, Ol = Oleaginosa, Or = Ornamental, PQ = Prospección química, To = Toxica

Source: Based on Poveda and Sánchez (1999)

ANNEX IV: COST DISTANCE MODELING DISCUSSION

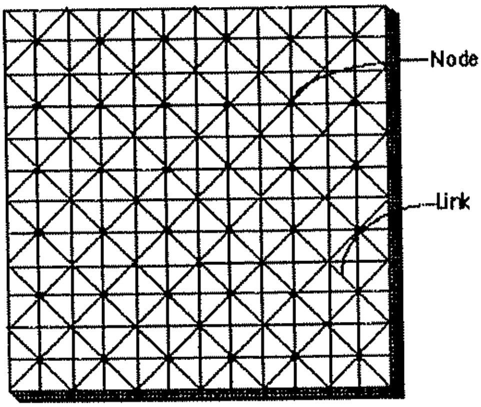
These functions are similar to Euclidean distance functions, but instead of calculating the actual distance from one point to another, they determine the shortest cost distance (or accumulated travel cost) from each cell to the nearest cell in the set of source cells. A second exception is that cost distance functions apply distance not in geographic units but in cost units.

All cost distance functions require a source Grid and a cost Grid. A source Grid can contain single or multiple zones, which may or may not be connected. All cells that have a value (including 0) are processed as source cells. All non-source cells need to be assigned No Data on the source Grid.

A cost Grid assigns an impedance in some uniform-unit measurement system that depicts the cost involved in moving through any particular cell. The value of each cell in the cost Grid is assumed to represent the cost-per-unit distance of passing through the cell, where a unit distance corresponds to the cell width. These costs may be travel time, dollars, preference and so forth.

The Cost Calculations

The aGrid.CostDistance request creates an output Grid in which each cell is assigned the accumulative cost to the closest source cell. The algorithm utilizes the node/link cell representation. In the node/link representation, each center of a cell is considered a node and each node is connected by links to its adjacent nodes.

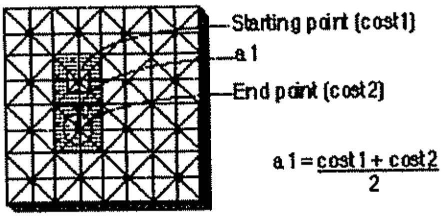


Nodes and links: a view of a grid through the graph theory

Every link has an impedance associated with it. The impedance is derived from the costs associated with the cells at each end of the link (from the cost surface) and from the direction of movement. If moving from a cell to one of its four directly connected neighbors, the cost to move across the links to the neighboring node is 1 times the cost of cell 1 plus the cost of cell 2 divided by 2.

a1 = cost1 + cost2 / 2

where cost1 is the cost of cell 1, cost2 is the cost of cell 2 and a1 is the length of the link from cell 1 to cell 2.

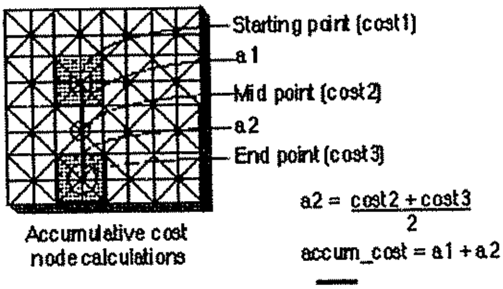


Horizontal and vertical node calculations

The accumulative cost is determined by the following formula.

accum_cost = a1 + (cost2 + cost3) / 2

where cost2 is the cost of cell 2, cost3 is the cost of cell 3 and accum_cost is the accumulative cost to move into cell 3 and cell 1.



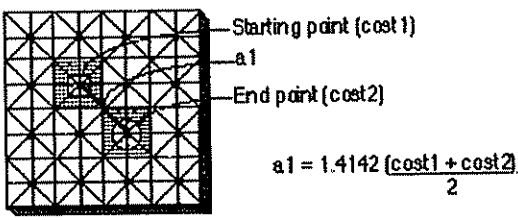
Accumulative cost node calculations

If the movement is diagonal, the cost to travel over the link is 1.414216 (or the square root of 2), times the cost of cell 1 plus the cost of cell 2 divided by 2.

a1 = 1.414216(cost1 + cost2) / 2

But when determining the accumulative cost for diagonal movement the following formula must be used.

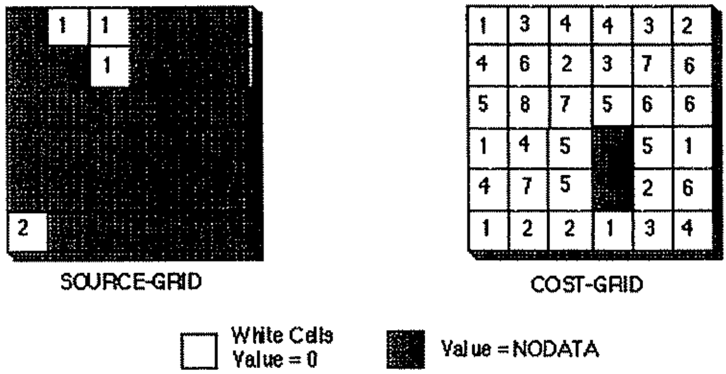
accum_cost = a1 + 1.414216(cost2 + cost3) / 2



Diagonal node calculations

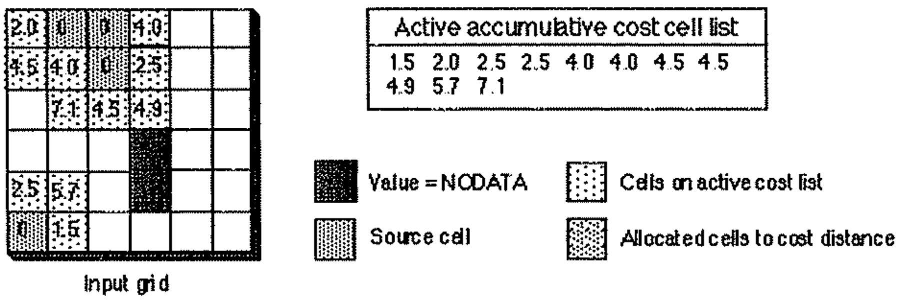
The Algorithm

Creating an accumulative cost-distance Grid using graph theory can be viewed as an attempt to identify the lowest cost cell and adding it to an output list. It is an iterative process that begins with the source cells. The goal of each cell is to be assigned quickly to the output cost-distance Grid.

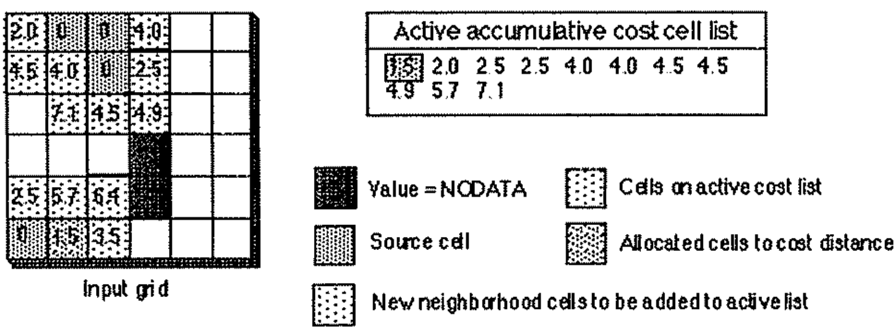


In the first iteration, the source cells are identified and assigned to zero since there is no accumulative cost to return to themselves. Next, all the source cell's neighbors are activated and a cost is assigned to the links between the source cells nodes and the neighborhood cell's nodes using the above accumulative cost formulas. Each of these neighborhood cells can now reach a source, consequently, they can be chosen or assigned to the output accumulative cost Grid. To be assigned to the output Grid, a cell must have the next least-cost path to a source.

The accumulative cost values are arranged in a list from the lowest accumulative cost to the highest.

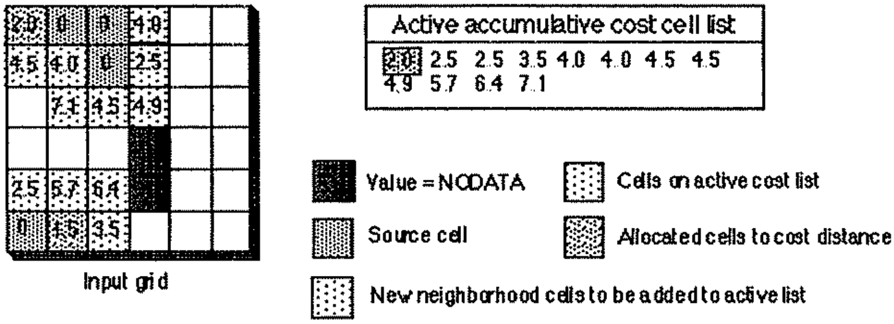


The lowest cost cell is chosen from the active cost list and the value for that cell location is assigned to the output cost-distance Grid. The list of active cells is now expanded to include the neighbors of the chosen cell, because those cells now have a way to reach a source. Only those cells that can possibly reach a source can be active in the list. The cost to move into these cells is calculated using the accumulative cost formulas.

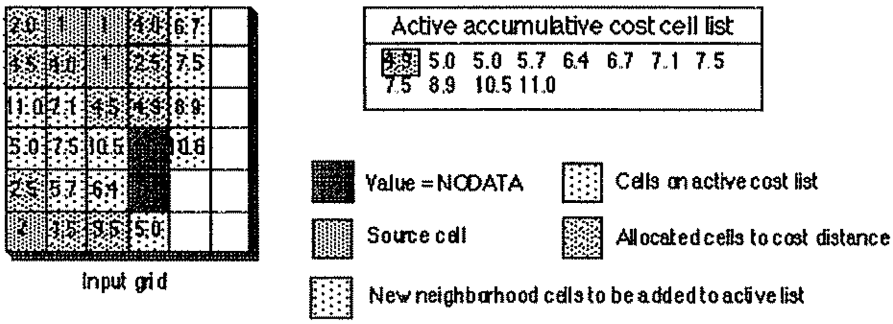


Again, the active cell on the list with the lowest cost is chosen, the neighborhood is expanded, the new costs are calculated and these new cost cells are added to the active list

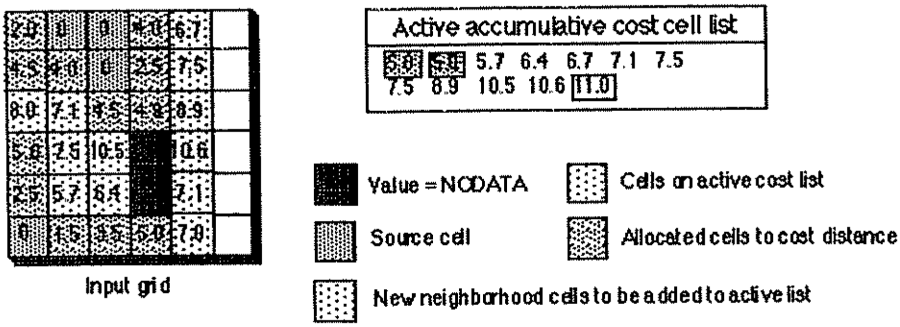
Source cells do not have to be connected. All disconnected sources contribute equally to the active list. Only the cell with the lowest accumulative cost is chosen and expanded, regardless of the source to which it will be allocated.



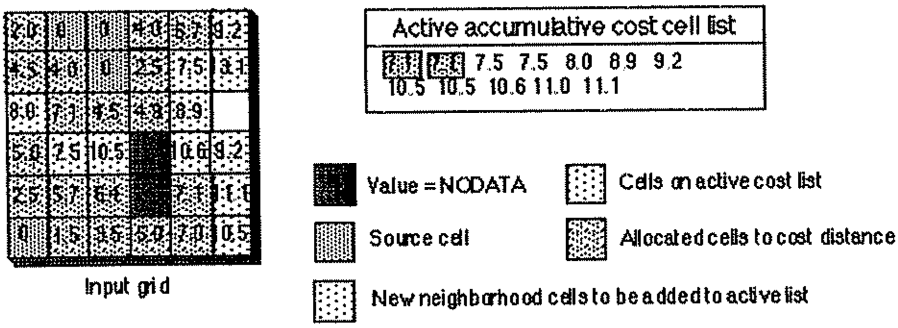
Furthermore, cells on the active list are updated if a new, cheaper route is created by the addition of new cell locations to the output Grid.

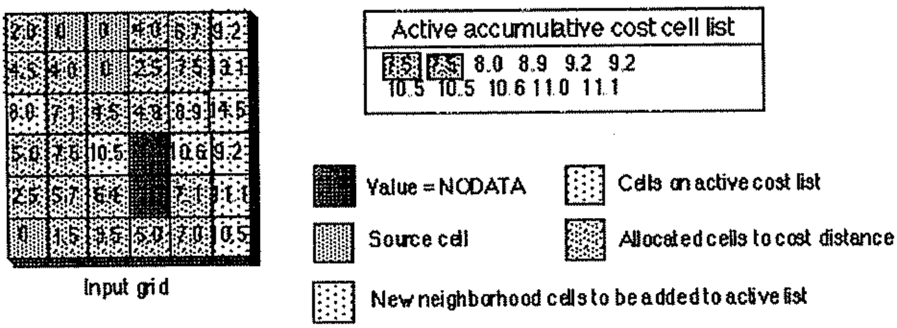


This updating can occur with the advent of new paths for cells on the active list as more cells are allocated to the output Grid. When the cell with the lowest value on the active accumulative cost list is allocated to the output Grid, all the accumulative costs are calculated. These costs are also calculated for the neighboring cells of the newly assigned output cell, even if the neighboring cells are on the active list through another cell. If the new accumulative cost for the locations on the active list is greater than the one that the cells currently has, the value is ignored. If the accumulative cost is less, then the old accumulative cost for the location is replaced on the active list with the new value. That cell, which has discovered a cheaper and more desirable path to a source, then moves up on the active chosen list. In the example below, the cell location at row 3, column 1 (highlighted by the box) had an accumulative cost of 11.0 when it was put on the active list to reach the source at the top of the Grid. But because the lower source expanded to this location, the cell had access to a cheaper accumulative cost path to reach a source. The value for the location was updated on the active list and allocated to the output earlier, because of this lower accumulative cost.

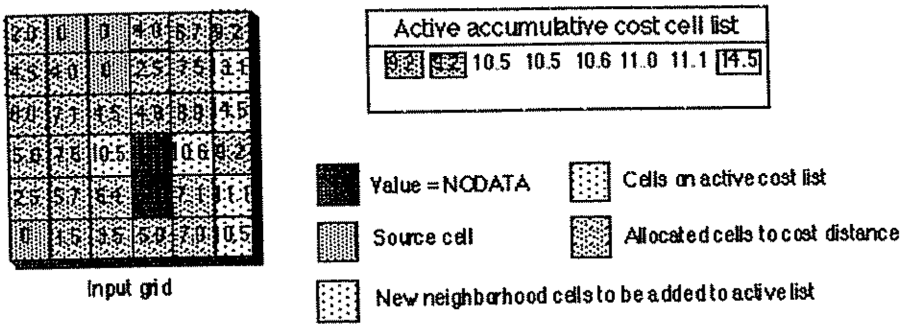


If there are multiple zones or disconnected sets of source cells on the input source Grid, the growing process continues and allocates the cheapest cost cell from the active list, regardless of which source it is from. When the growth fronts meet, the least cost path back to the source proceeds until all eligible cells have received a cost value.

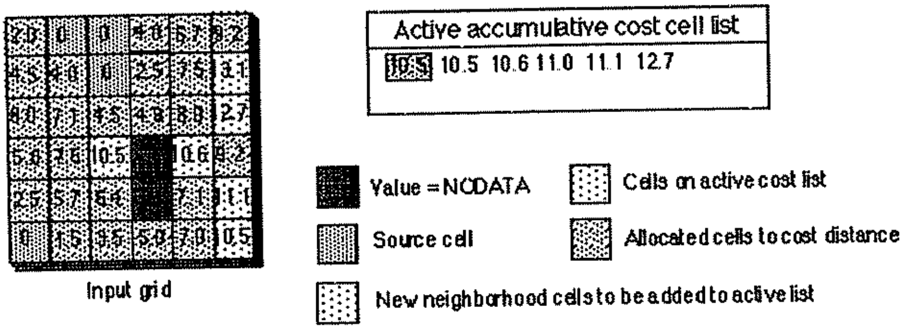




It is conceivable that when the growing patterns meet, cells from one growth pattern will discover that they can reach a source cell in another set or growth pattern more cheaply; if so, they will be reassigned to the new source. This behavior was witnessed by the cell at row 3, column 1 earlier, but is also exemplified below by the cell located at row 3, column 6.



Input grid



Input grid

When all cells have been chosen from the active list, the result is the accumulative-cost or weighted-distance Grid. The procedure used ensures that the lowest accumulative cost is guaranteed for each cell.

2.0	0.0	0.0	4.0	6.7	9.2
4.5	4.0	0.0	2.5	7.5	13.1
8.0	7.1	4.5	4.9	8.9	12.7
5.0	7.5	10.5		10.6	9.2
2.5	5.7	6.4		7.1	11.1
0.0	1.5	3.5	5.0	7.0	10.5

Cost distance output grid

Cost Back Link

The cost-distance Grid identifies the accumulative cost for each cell to return to the closest cell in the set of source cells. It does not show which source cell to return to or how to get there. The cost back link returns a Grid with a value range from 0 to 8 that can be used to reconstruct the route to the source. Each value (0 through 8) identifies which neighboring cell to move into to get back to the source. 0 is a source, 1 indicates move to the immediate right, 2 to the lower right diagonal, 3 to the cell immediately south, etc..

6	7	8
5	0	1
4	3	2

Back-link positions

If the cell is assigned 5 as part of the least cost path to a source, the path should move to the left neighboring cell. If that cell has 7, the path should move due north.

1	0	0	5	4	5
7	1	0	5	5	6
3	8	7	6	6	3
3	5	7		3	4
3	4	4		4	5
0	5	5	5	5	5

Back link output grid

Cost Allocation

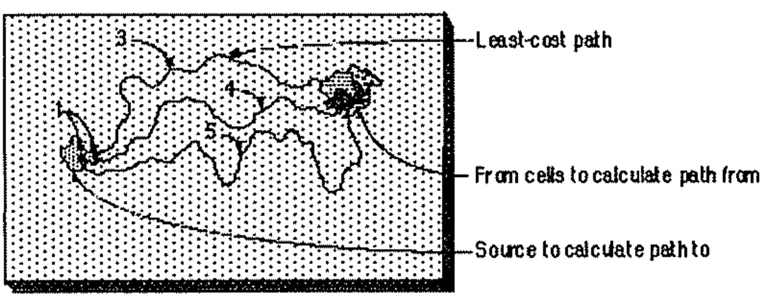
Cost allocation produces a Grid very similar to the Euclidean allocation function; like the Euclidean function, it returns a Grid identifying which cells will be allocated to which source, but unlike the Euclidean function, on the basis of the lowest accumulative cost to reach a source.

1	1	1	1	1	1
1	1	1	1	1	1
2	1	1	1	1	2
2	2	1		2	2
2	2	2		2	2
2	2	2	2	2	2

Cost allocation output grid

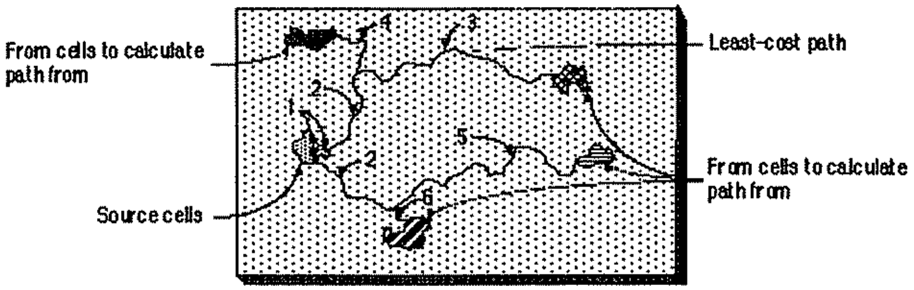
Cost Path

Once the accumulative cost and back-link Grids are created, least-cost path routes can be derived from any designated destination cell or zone(s). The cost-path request retraces the destination cells through the back-link Grid to a source. If there are multiple cells or zones as input destinations, the least cost path can be calculated from each cell (resulting in multiple paths, one path for each cell), or each zone (one path from each zone).



COSTPATH using the BYZONE keyword

When two or more cost paths from different zones converge on the way to a source and continue the remaining distance together, the joint path to the cell is assigned 2, since the owner of the segment cannot be determined. The value assigned to each path is assigned by the order in which the zone cells are encountered in the scanning process.



COSTPATH using the BYZONE keyword from multiple cell locations to a single source

The set of source cells consists of all cells in the source Grid that have valid values. Cells that have No Data values are not included in the source set. The value 0 is considered a legitimate source. Cell locations with No Data in the cost Grid act as barriers in the cost surface functions. Any cell location that is assigned No Data on the input cost surface will receive No Data on all three output Grids of the aGrid.CostDistance request. If a mask has been set in the analysis environment, any masked cells will be treated as No Data values.

ANNEX V: LIMDEP PROGRAM IN CALCUTING THE TOBIT MODEL WITH SELECTED SAMPLE

```
Logit;

Lhs = tiprod2;

    Rhs = ro,acueduct,pozo,pendient,elevacio,messec,planlech,bufferio; marginal
    effects;

hold$

SELECT;

Tobit;

MLE;

Lhs = tobit1;

Rhs = planlech,elevacio,area_fin,bufferio,area_pot,maneanim,in_alim$


TOBIT;Lhs=TOBIT3;Rhs=AREA_FIN,MANEANIM,IN_ALIM

  ,ELEVACIO,PPA,MESSEC,subasta$
```

ANNEX VI: QUESTIONARIE USED IN COLECTING THE DATA FOR THE CHOICE EXPERIMENT

El Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) conjuntamente con la Hacienda La Pacifica están desarrollando un proyecto de investigación que busca el manejo de los recursos arbóreos y forestales existentes en las fincas ganaderas. En etapas anteriores de la investigación se ha destacado la creciente importancia de los árboles en las fincas ganaderas de la región Guanacasteca. Sin embargo, no existen aun sistemas de producción que incorporen el manejo del árbol, ni tampoco se conoce en cuales condiciones los productores estarían interesados en incorporar el árbol en sus sistemas productivos. Por lo anterior, esta encuesta explorara que tipos de sistemas y cuales incentivos son necesarios para el manejo de los árboles presentes en las fincas ganaderas.

A. Preguntas generales

1. Localización de su finca: ____________________ cantón
2. Tamaño de la finca: ____________ ha
3. Área de potreros: ____________ ha
4. Área en tacotales: ____________ ha
5. La finca es:

5.0. Propia ( )
5.1. Alquilada ( )
5.2. Prestada ( )
5.3. Otros ( ) especificar: ________________

6. Tamaño del hato: ________________numero de animales

B. Preguntas sobre problemas y manejo de los árboles

7. Si usted tuviera dinero para invertir en su finca, en que invertiría (seleccione solo uno de cada pareja):

Mejora de pastos		Mejora de la raza del ganado	
Mejora de pastos		Manejo de los árboles	
Mejora de pastos		Compra de maquinaria	
Mejora de la raza del ganado		Manejo de los árboles	
Mejora de la raza del ganado		Compra de maquinaria	
Manejo de los árboles		Compra de maquinaria	

8. A continuación se le presentaran diferentes productos que podemos obtener de los árboles favor seleccione el mas importante de cada pareja

Madera		Postes	
Madera		Alimento para el ganado	
Madera		Sombra	
Madera		Protección contra el viento	
Postes		Alimento para el ganado	
Postes		Sombra	
Postes		Protección contra el viento	
Alimento para el ganado		Sombra	
Alimento para el ganado		Protección contra el viento	
Protección contra el viento		Sombra	

9. Maneja los árboles de su finca
9.0. No ( ) Pasar a 10
9.1. Si ( )
10. Si la respuesta fue si, por favor detállelos:
10.0. ___
10.1. ___
10.2. ___
10.3. ___
10.4. ___

C. Conocimiento sobre Pago por Servicios Ambientales

11. Conoce usted sobre el programa de Pago por Servicios Ambientales
11.0. No ( ) Pasar a experimento
11.1. Si ( )
12. Cree que el Pago por Servicios Ambientales es una alternativa para conservar el ambiente
12.0. No ( )
12.1. Si ( )
13. Razones del si o del no: ________________
14. Ha recibido usted pago por el servicio ambiental que brindan los árboles de su finca
14.0. No ( ) Pasar a experimento
14.1. Si ( )
15. Cuanto recibió: ____________________
16. Área incentivada: ____________________

17. Que servicio ambiental considera usted mas importante

Biodiversidad		Aire puro	
Biodiversidad		Belleza escénica	
Biodiversidad		Producción de agua	
Aire puro		Belleza escénica	
Aire puro		Producción de agua	
Belleza escénica		Producción de agua	

D. Explicación del experimento

Actualmente la legislación forestal de Costa Rica reconoce cuatro servicios ambientales: protección de la biodiversidad, captura de carbono, belleza escénica y producción de agua. Costa Rica se ha destacado como un país pionero en el pago por los servicios ambientales proveídos por el bosque, sin embargo no existe mucha experiencia en el pago de los servicios ambientales proveídos por los árboles presentes en las fincas ganaderas. Por lo anterior, con este estudio pretendemos investigar cual es el monto demandado por los productores ganaderos en compensación por los servicios ambientales proveídos por los árboles. Un aspecto importante es determinar los pagos a las diferentes formas en que se encuentran los árboles en las fincas ganaderas, por lo cual hemos desarrollado varios escenarios en los cuales usted decidirá cual es el mejor. Los escenarios están compuestos por una combinación de características:

Arreglo espacial de los árboles: esta características se refiere a la forma en la cual se pueden presentar los árboles en las fincas ganaderas. Se considera que los árboles pueden estar en:

- En línea en la cerca (Foto 1)
- En línea en el potrero
- En bloque (Foto 2)
- Dispersos (Foto 3)

Ocupación del potrero: en la región se ha encontrado una creciente importancia de las pasturas arboladas. Varios estudios muestran que los árboles cubren desde el 4% hasta mas del 25% del área de las pasturas. En este caso consideramos como ocupación del potrero por árboles la suma de las áreas que se encuentran bajo las copas de los árboles. Consideramos tres niveles de cobertura:

- 4 – 10 arboles/hectares (Foto 4)
- 10 – 20 arboles/hectares (Foto 5)
- 20 – 40 arboles/hectares (Foto 6)

Tiempo de pago del incentivo: en la experiencia de Costa Rica en el Pago por Servicios Ambientales, el periodo de pago ha sido de 5 años. Sin embargo en este estudio consideramos tres diferentes tiempo de pago del incentivo:

- 5 años
- 10 años
- 15 años

Monto del incentivo: en Costa Rica el Pago por Servicios Ambientales se ha realizado por hectárea incentivada y un pago anual. En nuestro caso, revisamos los reportes del país, y escogimos diferentes opciones de monto del pago. Los montos presentados son por hectárea y anuales

- ¢ 4,000/hectares/año
- ¢ 16,000/hectares/año
- ¢ 30,000/hectares/año

¢ 36,000/hectares/año
¢ 44,000/hectares/año

¿Tiene alguna pregunta sobre el texto anterior?

A continuación le vamos a presentar tres alternativas hipotéticas. Estas alternativas consideran el establecimiento de un sistema silvopastoril en 5 hectares. No es necesario que usted cuente actualmente con alguno de estos sistemas, por el contrario, le solicitamos que usted decida sobre que sistema establecer considerando un potrero sin árboles. Los árboles pueden provenir de regeneración natural o de plantaciones, así que no se considera como un criterio para selección. Vea el ejemplo a continuación:

En el ejemplo anterior se le presentaron tres diferentes alternativas para el establecimiento de un sistema silvopastoril. Como usted puede ver, las alternativas consideran diferentes arreglos espaciales, monto y tiempo de recibir el incentivo. En cuanto al tiempo de recibir el incentivo y el monto del incentivo, se presenta una combinación donde el mayor monto del incentivo solo se percibe por 10 año, mientras que el monto mas bajo se percibe por 15 años. Para en arreglo y la ocupación de los potreros, se presentan tres combinaciones, en línea en el potrero, en bloque y dispersos, en los tres niveles de ocupación, 4, 10 y 20%. De esta forma la alternativa 1 presenta un arreglo en línea en los potreros con una ocupación de 20%, con un incentivo de ¢ 44,000 anuales por un periodo de 10 años. La alternativa dos un arreglo en bloque, ocupando el 4% del potrero, con un incentivo de ¢ 4,000 anuales por un periodo de 10 años. Finalmente la alternativa tres presenta un arreglo de árboles dispersos ocupando el 10% del potrero, con un incentivo de ¢ 16,000 por 5 años.

¿Tiene alguna pregunta?.

Suponga ahora que el MINAE esta interesado en iniciar un proyecto Pago por Servicios Ambientales en las fincas ganaderas, si embargo no sabe cuanto los ganaderos están interesados en percibir como pago, por lo cual se le presentaran varias alternativas para que usted elija el arreglo espacial y el pago por el servicio ambiental. ¿Esta interesado en participar en el estudio?

Ahora le vamos a presentar diferentes alternativas donde usted podrá elegir cual situación es su preferida. Recuerde que las situaciones que sigue ahora son totalmente hipotéticas aunque posibles en el futuro. Asuma que las características que no mencionamos son iguales en todas las alternativas. Recuerde por favor que no hay repuestas correctas o incorrectas.

E. Experimento

Set numero: ______

Alternativa 1	1	2	3
Alternativa 2	1	2	3
Alternativa 3	1	2	3
Alternativa 4	1	2	3
Alternativa 5	1	2	3
Alternativa 6	1	2	3

F. Plan de inversión

Esta sección sirve para analizar cuales son las preferencias de los productores en cuanto a sistemas silvopastoriles, y que combinaciones estarían interesados a establecer en su finca. Como apoyo al productor, se podrá realizar un mapa de la finca, detallando los sistemas silvopastoriles elegidos por los productores, los lugares donde los establecería y el área de cada uno. Favor completar los espacios abajo:

Potre ros	Sist ema	rea	Sis tema	rea	Si stema	rea	Sis tema	rea

G. Preguntas sobre la entrevista

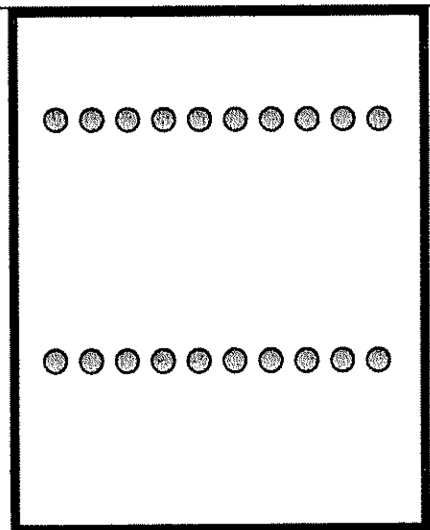
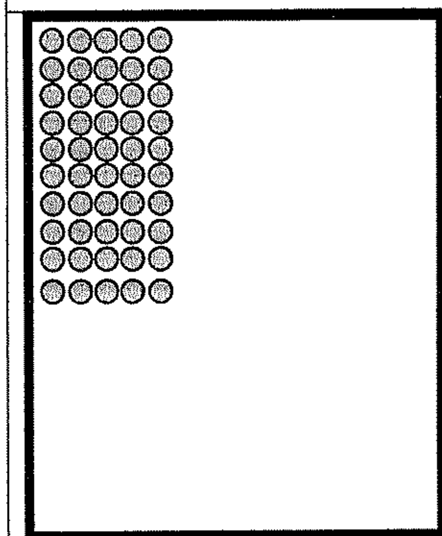
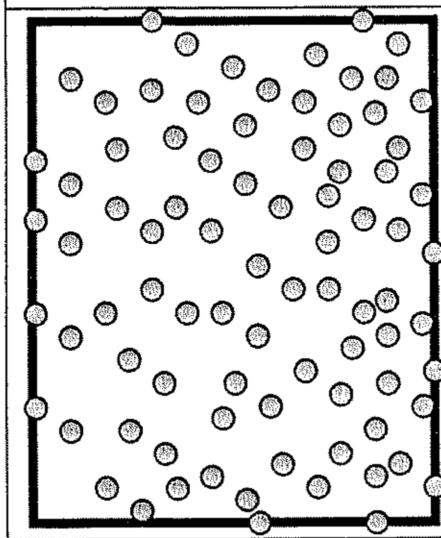
18. Cual de los aspectos incluidos en los cuadros le resultó más importante (Escoja solamente una alternativa)
18.0. Diseño ( )
18.1. Años de recibir el incentivo ( )
18.2. Monto del incentivo ( )
19. Cree usted que la entrevista era:
19.0. Muy difícil ( )
19.1. Regularmente difícil ( )
19.2. Fácil ( )
19.3. Muy fácil ( )
20. Se sintió usted seguro al escoger su situación preferida? (Escoja solamente una alternativa)
20.0. Muy seguro ( )
20.1. Seguro ( )
20.2. Regularmente seguro ( )
20.3. Inseguro ( )
20.4. Muy inseguro ( )
21. Solamente para los que no quisieron no participar en el estudio. ¿Qué motivo tiene para no participar en el estudio
21.0. No estoy interesado en el tema
21.1. No me gustaron las situaciones a elegir
21.2. No me pareció que las opciones fueran validas o creíbles
21.3. No creo en el programa de Pago por Servicios Ambientales
21.4. Otras razones: ____________________

H. Preguntas socioeconómicas

22. Sexo del entrevistado
22.0. Masculino ( )
22.1. Femenino ( )
23. Edad del encuestado
23.0. 18 a 25 años ( )
23.1. 26 a 35 años ( )
23.2. 36 a 45 años ( )
23.3. 46 a 55 años ( )
23.4. 56 a 65 años ( )
23.5. Mayor de 66 años
24. Años de estudios formales: ____________________

Muchas gracias por su colaboración!

ANNEX VII: EXEMPLO OF THE CHOICE SET USED IN THE CHOICE EXPERIMENTS

Años de recibir el incentive	5 años	10 años	15 años
Incentivo anual por hectárea	¢ 16,000	¢ 30,000	¢ 36,000
Arreglo espacial	En línea en el potrero	En bloque	Disperso
Ocupación del potrero	4 – 10 arboles/hectares	10 – 20 arboles/hectares	20 – 40 arboles/hectares
Diseño			
	1	2	3

ANNEX IX: LIMDEP PROGRAM FOR ESTIMATING THE NLOGIT MODEL

```
NLOGIT;Lhs=ELECCION;Choices=1, 2, 3;

Rhs=ONE,ARREGLO2,OCUPACIO,TIEMPOTE,DOLLAR; List$
```