Fachhochschule Köln
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UNIVERSIDAD AUTÓNOMA DE SAN LUIS POTOSÍ

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FACULTADES DE CIENCIAS QUÍMICAS, INGENIERÍA Y MEDICINA

PROGRAMAS MULTIDISCIPLINARIOS DE POSGRADO EN CIENCIAS AMBIENTALES

AND

COLOGNE UNIVERSITY OF APPLIED SCIENCES

INSTITUTE FOR TECHNOLOGY AND RESOURCES MANAGEMENT IN THE TROPICS AND SUBTROPICS

NATIVE TREE SPECIES IN SILVOPASTORAL SYSTEMS: A BIOECONOMIC ASSESSMENT IN CACHOEIRAS DE MACACU, RJ - BRAZIL

THESIS TO OBTAIN THE DEGREE OF

MAESTRÍA EN CIENCIAS AMBIENTALES

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MASTER OF SCIENCE

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IN THE SPECIALIZATION: RESOURCES MANAGEMENT

DEGREE AWARDED BY COLOGNE UNIVERSITY OF APPLIED SCIENCES

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COLOGNE, GERMANY **AUGUST, 2012**

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COLOGNE, GERMANY **DATE 31.08.2012**

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LA MAESTRÍA EN CIENCIAS AMBIENTALES RECIBE APOYO A TRAVÉS DEL PROGRAMA NACIONAL DE POSGRADOS (PNPC - CONACYT)

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DEDICATED

A mi madre

A mi abuelita E.P.D

A mis hermanos Vianey y Ricardo

A Felix

A mis amigos

Porque siempre los llevo en el corazón, porque han llenado mi vida de bellos recuerdos, y porque nunca dejaré de agradecerles.

Así es -suspiró el coronel-. La vida es la cosa mejor que se ha inventado (Gabriel García Márquez).

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Each one of you is part of this research and without you would not have been possible to finish it.

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SUMMARY

Keywords: silvopastoral systems, economic analysis, native tree species, cattle production.

The objectives of this research were: to characterize the current cattle production system in Cachoeiras de Macacu, typify the uses of the native tree species in pasturelands to identify there silvopastoral potential, to select the optimal silvopastoral systems for the research area based on their characteristics and economic feasibility.

Cattle breeding in the municipality of Cachoeiras de Macacu were characterized through 21 semi-structured interviews in cattle farms; the tree species in pastureland were also characterized with the aim to select the optimal silvopastoral system for Cachoeiras de Macacu.

Thirty five native tree species and sixteen exotic tree species were found in pasturelands of Cachoeiras de Macacu. Based on their uses and their wood quality tree species were prioritized and three of them were selected to be included as the timber component of four silvopastoral models: *Anadenanthera colubrina* (Vell.) Brenan, *Tabebuia serratifolia* (Vahl.) Nichols and *Tabebuia roseoalba* (Ridley) Sandwith. The four selected silvopastoral models were: (1) timber boundaries, (2) timber boundaries and subdivision fences, (3) timber boundaries, subdivision fences and scattered trees and (4) scattered trees.

For the economic analysis an average farm was selected. Its characteristics were: 16 ha of surface and a herd of 28 animals: 1 bull, 13 cows and 14 calves, a cash flow sheet was calculated for the current cattle production system and the 4 silvopastoral models including the costs of animals and tree management in a 15 years period, the revenues were represented by the sale of calves, fuelwood and lumber wood. The net cash flow for a 15 years period for the current cattle production system was: R$ 31,835.0, for model 1: $R 73,215.0, model 2: $R 100,841.3, model 3: R$ 150, 756.1 and model 4: R$ 66, 669.2.

The economic analysis was made using the following indicators: Net Present Value (NPV), Internal Rate of Return (IRR) and Benefit / Cost Ratio using a discount rate of 8.39%; the current cattle production system showed a NPV of $R 3,415.74, IRR 37% and B/C 1.48; model 2 showed a NPV of R$ 4,110.87, IRR 20% and B/C 1.56; model 3 showed a NPV of R$ 6588.89, IRR 16% and B/C 1.81 and model 4 showed a NPV of R$ 3,460.35, IRR 24% and B/C 1.45.

All silvopastoral models evaluated according with the obtained economic indicators showed an economic feasibility to be implemented in the research area.

RESUMEN

Palabras clave: sistemas silvopastoriles, análisis económico, especies arbóreas nativas, producción ganadera

Los objetivos de esta investigación fueron caracterizar al sistema de producción ganadera en el municipio de Cachoeiras de Macacu, caracterizar los usos de las especies arbóreas nativas presentes en potreros para identificar el potencial de su implementación en sistemas silvopastoriles, seleccionar a los sistemas silvopastoriles óptimos para el municipio en base a sus características y su viabilidad económica por medio de una análisis económico.

La producción ganadera en el municipio de Cachoeiras de Macacu fue caracterizada por medio de 21 entrevistas semi-estructuradas a productores ganaderos, se caracterizaron las especies arbóreas presentes en potreros con el fin de seleccionar un sistema silvopastoril óptimo para la producción ganadera del municipio.

Treinta y cinco especies arbóreas nativas y 16 especies arbóreas exóticas fueron encontradas en potreros de Cachoeiras de Macacu, en base a los usos de las especies y la calidad de su madera fueron priorizadas y tres de ellas seleccionadas para ser incluidas como el componente maderable en 4 modelos silvopastoriles: *Anadenanthera colubrina* (Vell.) Brenan*, Tabebuia serratifolia* (Vahl.) Nichols y *Tabebuia roseoalba* (Ridley) Sandwith. Los 4 modelos silvopastoriles seleccionados fueron: (1) árboles maderables en linderos (2) arboles maderables en linderos y cercas de subdivisión, (3) árboles maderables, cercas de subdivisión y arboles dispersos, (4) arboles dispersos.

Se seleccionó un caso de estudio para una finca promedio de 16 ha de superficie y un hato ganadero de 28 animales: 13 vacas, 1 toro y 14 becerros, en base a esta finca promedio se elaboraron planillas de flujo de caja para un ciclo de 15 años, se evaluó el sistema de producción ganadera actual y los 4 modelos silvopastoriles seleccionados incluyendo los costos de manejo pecuario y forestal así como las ganancias provenientes de la venta de ganado anual y las ventas de madera para leña y madera en pie. Se estimó un flujo de caja neto en un periodo de 15 años para el sistema actual de R$ 31,835.0, Modelo 1: $R 73,215.0, modelo 2: $R 100,841.3, modelo 3: R$ 150, 756.1 y modelo 4: R$ 66, 669.2.

Se realizó un análisis económico en base a los siguientes indicadores: Valor actual neto (VAN), tasa interna de retorno (TIR) y relación beneficio/ costo (B/C), utilizando una tasa de descuento de 8.39%. El sistema de producción ganadera actual indicó un valor de VAN de R$ 587.46, TIR 12% y B/C 1.09; el modelo 1 arrojó un valor de VAN de $R 3, 415.74, TIR 37% y B/C 1.48; el modelo 2 indicó un valor de VAN de R$ 4,110.87, TIR 20% y B/C 1.56; el modelo 3 mostró valor de VAN R$ 6588.89, TIR 16% y B/C 1.81, finalmente el modelo 4 indico un valor de VAN de R$ 3,460.35, TIR 24% y B/C 1.45

Todos los modelos silvopastoriles evaluados en base a los valores de los indicadores económicos utilizados, presentaron viabilidad económica para ser implantados en el área de estudio.

ZUSAMMENFASSUNG

Stichworte: silvopastorale Systeme, ökonomische Analysen, einheimische Baumarten, Viehzucht

Die Ziele dieser Untersuchung waren die Charakterisierung der derzeitigen Viehzucht in Cachoeiras de Macacu, die Charakterisierung der Nutzung der einheimischen Baumarten, speziell auf den Viehweiden, mit dem Ziel dessen silvopastorales Potential erkennen zu können, die Auswahl des optimalen silvopastoralen Systems für das Forschungsgebiet, basierend auf dessen Charakterisierung und der ökonomischen Durchführbarkeit.

Die Charakterisierung der Viehzucht in der Gemeinde von Cachoeiras de Macacu wurde durch 21, semi-strukturierte Befragungen in den Viehfarmen durchgeführt. Mit dem Ziel ein optimales slivopastorales System für Cachoeiras de Macacu erstellen zu können wurden die einheimischen Baumarten charakterisiert.

Dabei wurden 35 einheimische und 16 exotische Baumarten in den Viehweiden von Cachoeiras de Macacu gefunden. Die Baumarten wurden auf Basis ihres Nutzens und ihrer Holzqualität priorisiert und anschließend drei Baumarten für die Baumkomponente ausgewählt: *Anadenanthera colubrina* (Vell.) Brenan, *Tabebuia serratifolia* (Vahl.) Nichols und *Tabebuia roseoalba* (Ridley) Sandwith. Die vier silvopastoralen Modelle sind (1) timber boundaries, (2) timber boundaries und subdivision fences, (3) timber boundaries, subdivision fences und scattered trees und (4) scattered trees.

Für die Durchführung der ökonomischen Analyse wurde eine durchschnittliche Farm mit der folgenden Charakteristik ausgewählt: 16 ha Fläche und einer Herde von 28 Tieren: 13 Kühe, 1 Bulle und 14 Kälber, darauf aufbauend wurde der Geldfluss über eine Periode von 15 Jahre errechnet. Dieser Geldfluss bezieht sich auf die Kosten der durchschnittlichen Viezucht, sowie die der vier silvopastoralen Modelle, inklusive der Kosten für die Verwaltung der Tiere und der Bäume. Die Einnahmen resultieren aus den jährlichen Verkäufen der Kälber, der aus den Bäumen gewonnenen Kohle und dem Bauholz. Der Netto Geldfluß auf eine Periode von 15 Jahren für die derzeitige Viehzucht, betrug hierbei R$ 31,835.0, für das erste Modell: $R 73,215.0, für das zweite Modell $R 100,841.3, für das dritte Modell: R$ 150, 756.1 und für das vierte Modell: R$ 66, 669.2.

Die ökonomische Analyse wurde mit den folgenden Indikatoren durchgeführt: Netto Gegenwartswert (NGW), Interne Zinsfuß Methode (IZF) und Benefit-Cost Ratio (BCR) mit einem Zinsatz von 8.39%; das derzeitige Vieh Produktionsystem hat einen NGW von $R 3,415.74, IZF 37% und BCR 1.48; Modell 2 hat einen NGW von R$ 4,110.87, IZF 20% und BCR 1.56; Modell 3 hat einen NGW von R$ 6588.89, IRR 16% und BCR 1.81 und Modell 4 hat einen NGW von R$ 3,460.35, IZF 24% und BCR 1.45.

Alle der evaluierten silvopastoralen Modelle bezogen auf das Forschungsgebiet zeigen eine ökonomische Durchführbarkeit.

ACRONYMS AND ABBREVIATIONS

EMATER: Instituto de Assistência Técnica e Extensão Rural do Rio de Janeiro

EMBRAPA: Empresa Brasileira de Pesquisa Agropecuaria

B/C: Benefit – Cost Ratio

c.a: circa

ha: Hectares

IRR: Internal Rate of Return

m^3: Cubic meters

masl: meters at sea level

NPV: Net Present Value

Km^2: Square kilometer

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CHAPTER 1. INTRODUCTION

Tropical deforestation, including both the permanent conversion of forests to croplands and pastureland, and the temporary or partial removal of forests for shifting cultivation and selective logging is estimated to have released on the order of 1-2 PgC/yr (15-35% of annual fossil fuel emissions) during the 1990s (Amazon Institute for Environmental Research, 2005).

According to the IPCC (2007), deforestation produces 14.3 % of the annual emissions of CO_2 in the world, South America is one of the regions with the largest rate of deforestation according with (FAO, 2010), being conversion of forest land to agriculture and urbanization the main causes of deforestation (Figure 1).

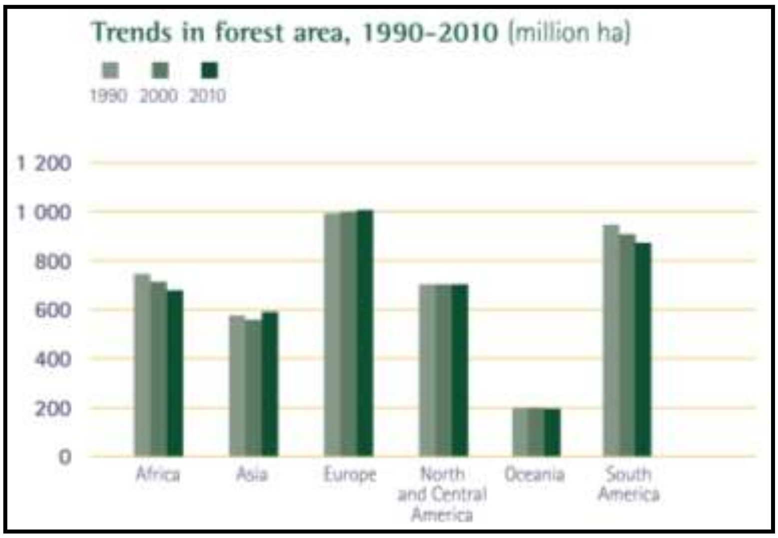

Figure 1. Trends in forest area 1990-2010, (FAO, 2010).

The situation of Brazil it is not different when compared with the Global status, the Atlantic Forest one of the largest biomes distributed in Brazil, extended originally from the northeast, in the state of Rio Grande do Norte to the southernmost border of Brazil, along its coastline, has been reduced to 11% to 16% (Ribeiro M, Martensen A, Ponzoni F, Hirota M, & Metzger J, 2009) from its original distribution.

At a landscape scale, most remaining Atlantic Forest cover is embedded within dynamic agro-mosaics including elements such as small forest fragments, early-to-late secondary forest patches and exotic tree monocultures (Tabarelli, Venceslau Aguiar, Ribeiro, Metzger, & Peres, 2010), in the state of Rio de Janeiro which once was fully covered by Atlantic Forest, the forest cover has been reduced to almost 10% of the original covered area, as a result of the urban population growth and the land-use change for agriculture to supply the demands of the growing population.

One of the answers to the drivers of pressure in the region: the land use change in cattle production are silvopastoral systems, due to the functions they play in human modified ecosystems, these systems according to (Beer, Harvey A, Ibrahim, Harmand M, Somarriba, & Jiménez, 2003) play an important role in the soil CO_2 fixation and in the woody biomass production, they also have a control in the biodiversity conservation in fragmented landscapes, because they provide habitats and resources for plants and animals, they keep the landscape connectivity and also reduce the frequency and intensity of fire, providing buffer zones for protected areas.

Silvopastoral systems as one type of a major criteria of classification (Agroforestry Systems) represent an alternative of land-management to the actual pressing issues on the Worlds' forests, which contemplate the environmental, economic and social aspects of the production and the interactive association between woody perennials (trees and shrubs) and agricultural crops and/or animals for multiple products and services.

This research assesses the bioeconomic feasibility of native tree species in silvopastoral systems in the municipality of Cachoeiras de Macacu in Rio de Janeiro, Brazil, as a sustainable land cover alternative to the current and most widespread land cover (cattle production), to reduce and mitigate the pressure on forest remnants and enhance their recovery.

1.1 Problematic

The Atlantic Forest it is a group of different vegetation types with one of the biggest biodiversity levels, this biome and its associated ecosystems (restingas and mangroves) harbor high levels of endemism and biodiversity. The Atlantic Forest (Mata Atlântica) contains an estimated of 250 species of mammals (55 endemic), 340 amphibians (90 endemic), 1,023 birds (188 endemic), and approximately 20,000 plant species (Critical Ecosystem Partnership Fund, 2011), is one of the most threatened and mega diverse biomes in the planet.

According to (Instituto de Pesquisas Jardim Botanico do Rio de Janeiro, 2009), 15,782 species of plants are recognized for the Atlantic Forest, representing the 5% of the world flora, from which 45% are endemic of this forest, 261 species of mammals, 1020 birds, 197 reptiles and 340 amphibians with their corresponding endemism of 22 percent, 18 percent, 30 percent and 26 percent (Galindo Leal & de Gusmao Camara, 2003).

The Atlantic Forest is a biome that includes two mayor vegetation types: Atlantic Rain Forest and Atlantic Semi-Deciduous Forest; the Atlantic Rainforest covers mostly the low to the medium elevations of the eastern slopes of the mountain chain along the coastline from southern to northern Brazil; the Atlantic Semi-Deciduous Forest extends across the plateau in the center and the southeastern interior of the country (Morellato C & Haddad B, 2000).

The original vegetative cover area of this biome has been reduced to only 7-8 percent (Figure 2) of the original distribution (Galindo Leal & de Gusmao Camara, 2003).

This biome is one of the 25 biodiversity hotspots (Figure 3) according with (Myers, Russell A, Mittermeier G, Mittermeier A, da Fonseca A, & Kent, 2000).

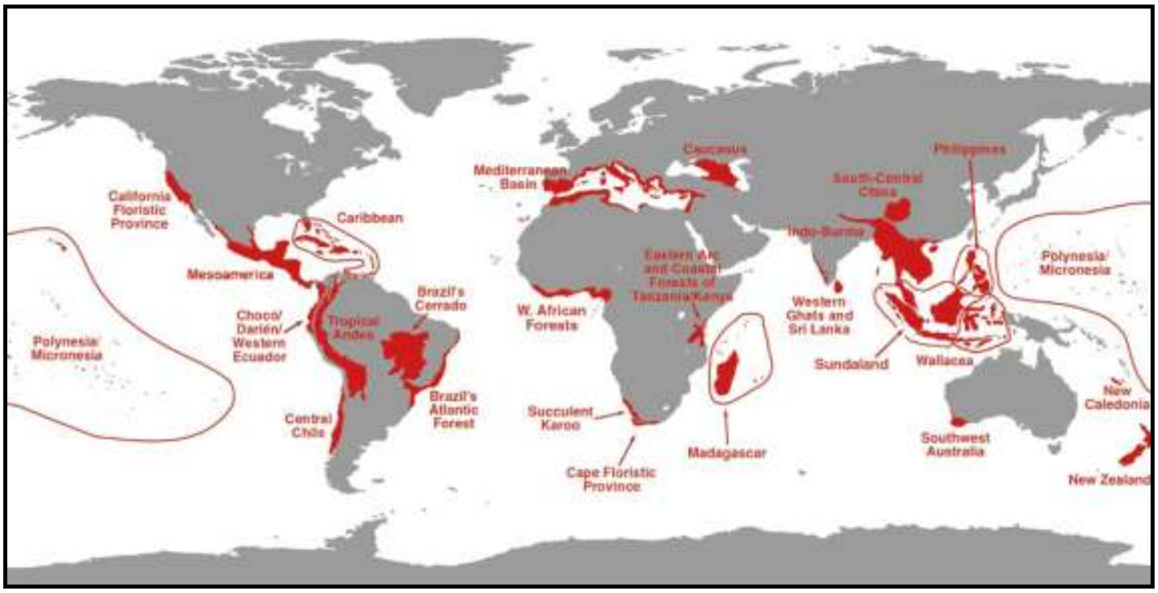

Figure 2. The 25 hotspots of the world, (Myers, Russell A, Mittermeier G, Mittermeier A, da Fonseca A, & Kent, 2000).

The domains of the Atlantic Forest branched approximately 70 percent of Brazil's surface, 169 million people and about 80 percent of the Brazilian gross domestic product is generated there (Critical Ecosystem Partnership Fund, 2011), this together with the high levels of biodiversity and endemism show the important role of this ecosystem in the World.

This forest originally covered an area c.a 1.1 million km^2, now it has been reduced to less than 11%-16% (Tabarelli, Venceslau Aguiar, Ribeiro, Metzger, & Peres, 2010) of and it remains in a landscape of fragmented patches ((Oliveira-Filho & Fontes L, 2000), (Critical Ecosystem Partnership Fund, 2011), (Instituto de Pesquisas Jardim Botanico do Rio de Janeiro, 2009).

The intense devastation of the biome started since the arrival or the Portuguese Conquers to Brazil, since their arrival vast areas were burned and cleared for pastureland (activity that still continues this nowadays), the devastation of the Atlantic Forest evolved together with the economic growth of the country; (Galindo Leal & de Gusmao Camara, 2003) mention that the population growth in the 1900s, the development of the Brazilian timber industry in the 20th century, the oil crisis of 1970 that brought the substitution of oil for alcohol therefore the extension of the sugar cane plantations were the most important causes of deforestation in the area.

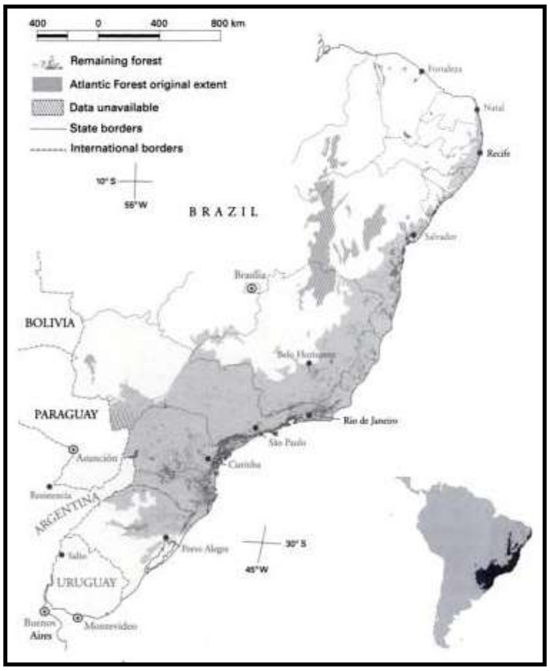

Figure 3. Original and remaining extent of Atlantic Forest in Brazil, (Galindo Leal & de Gusmao Camara, 2003).

Due to these actual conditions the Atlantic Forest needs answers that contemplate the complex relations occurring into its territory, looking for the preservation and restoration of the biome.

The remnants of the original distribution of the biome are located in its majority in isolated and dispersed fragments, through a landscape dominated by the agricultural land cover. The deforestation it is most severe in the North-East Brazil, where only the 1-2 % remains; in Rio de Janeiro state it is estimated that only 21.6 % of the original distribution remains (Critical Ecosystem Partnership Fund, 2011).

A massive forest conversion into croplands, abandoned pastureland, real estate properties and urban areas has occurred primarily across low to intermediate elevations of the Atlantic Forest. Lowland and lower-montane forests spanning 200–800 masl have been reduced to <10% of their original extent, with remaining forest patches sizing <30 ha on average (Tabarelli, Venceslau Aguiar, Ribeiro, Metzger, & Peres, 2010).

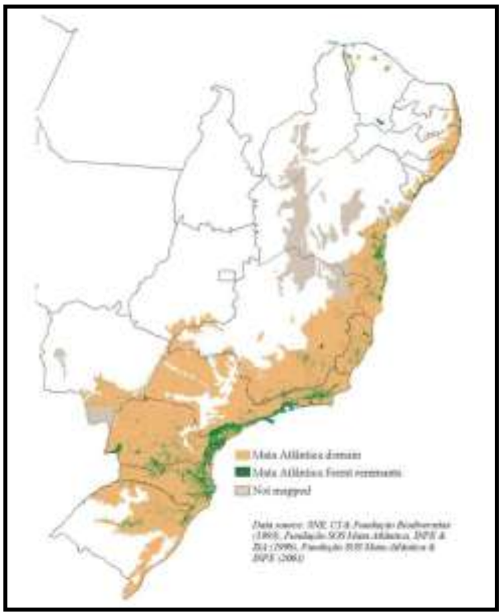

Figure 4. Original distribution of Atlantic Forest and the current remaining, (Critical Ecosystem Partnership Fund, 2011)

Cattle production is one of the most intensive land covers in Rio de Janeiro, together with the induced fire used to clean land and introduce pastureland. More than 1.8 million of animal units occupy the region, 44.5% of Rio de Janeiro surface it is occupied by pastureland and it represents 30% of the rural production. (Critical Ecosystem Partnership Fund, 2011).

In this sense and with the objective to search for solutions to the problematic of the Atlantic Forest, the DINARIO project (Climate change, landscape dynamics, land use and natural resources in the Atlantic Forest of Rio de Janeiro) emerged, this cooperation project Germany-Brazil intends the provision of methodological and scientific tools for the decision making in the Atlantic Forest. The research area of the project is located in the state of Rio de Janeiro in the municipalities of Petrópolis, Teresópolis, Nova Friburgo, Bom Jardim, Guapimirin and Cachoeiras de Macacú, this last one the research area for the purposes of this study (Figure 5).

The gradual transformation of forest into pasture and agricultural land has had profound ecological impacts in the region, changing the species composition of communities, disrupting ecosystem functions (including nutrient cycling and succession), altering habitat structure, aiding the spread of exotic species, isolating and fragmenting natural habitats, and changing the physical characteristics of both terrestrial and hydrological systems (Torrico Albino, 2006).

Cattle production usually is the last productive activity in the agricultural land cycle, after the land has being degraded and it does not produce a feasible yield of crops or agricultural products the producers choose to turn into cattle production, which does not requires so much hand labor and inputs, this land can be productive for a few years until the soil reaches it maximum capacity and starts to decay in degradation.

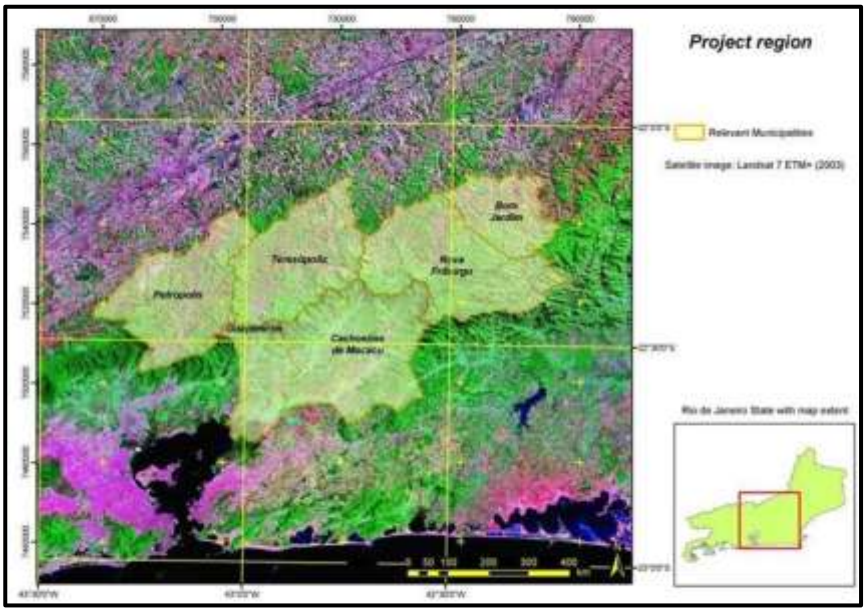

Figure 5.Municipalities of DINARIO Project, (DINARIO, 2011).

Cattle are mostly located in marginal areas like steep slopes and floodable plains covered with pastureland (Barreiro, 2009).

The productivity of land in beef meat production is very low, potentially generating revenues of about 100 – 150 R$/ha per year not even considering production costs (Schlüter & Pedroso, 2009) in a study in the region; most traditional cattle production systems are resource-driven in that they make use of locally available resources with limited alternative uses or, expressed in economic terms, low opportunity costs and low requirements of hand labor and inputs (FAO, 2009), which leads to a lack of technological improvement ending in pastureland degradation.

Figure 6. View of pastureland location in Cachoeiras de Macacu, Rio de Janeiro, photo: S. Berenice Quintana.

The average stocking rate in Teresópolis, located in the mountainous region of Rio de Janeiro, it is 11 cows per 10 ha. This was found in a range from 2 to 67 cows per 10 ha. In the humid season the average milk production is 7.5 l day -1, and in the dry season of 4.5 l day -1. After 40 months of fattening, livestock production is approximately 165 kg of clean meat/head that are marketed through agents and sold in local markets (Torrico & Janssens, 2012).

The identification of land cover alternatives to counteract the negative effects of the actual cattle production and pastureland management it is urgent, one of this alternatives is the implementation of silvopastoral systems.

Silvopastoral systems provide structures, habitats and resources that may enable the persistence of some plant and animal species within the fragmented landscape, thereby partially mitigating the negative impacts of deforestation and habitat fragmentation (Torrico Albino, 2006).

These systems are the combination of production of woody trees or shrubs with pastureland and cattle production, where all the components are interrelated, several social, economic and environmental benefits have being reported about silvopastoral systems (Chapter 3), the main barriers on implementing these systems are the lack of knowledge about them between the cattle producers, the lost of pastureland area, the shadowing of pastureland and reduction of its productivity, the implementation costs and the low revenues in the first stages of these systems.

1.1 Objetives

1.1.1 General objective

- To characterize the current cattle production systems with the goal of determining the bioeconomic potential of native tree species in the Atlantic Forest of Cachoeiras de Macacú, Rio de Janeiro, Brazil, for their establishment in silvopastoral systems

1.1.2 Specific objectives

- To characterize the current cattle production systems in terms of their socioeconomic and production patterns through a survey in the research area.

- To characterize the native tree species present in pastureland, identify their uses and select the optimal for their implementation in silvopastoral systems.

- To determine the most appropriate silvopastoral systems for the research area based on the actual production system characteristics.

- To determine the economic feasibility of the implementation of the most adequate silvopastoral systems through an analysis of economic indicators.

1.2 Research questions

- Which are the native trees species present in pasturelands of Cachoeiras de Macacú?
- Which are the uses of these native tree species?
- Which of these could be adopted in silvopastoral systems?
- What is the economical feasibility of their implementation in silvopastoral systems?
- What is the level of sensitivity of cattle producers to adopt silvopastoral systems?

1.3 State of the art

During the literature review of this research, non similar study was found in the research area, tough agroforestry systems including silvopastoral systems have being widely studied in the country and a big amount of scientific information related to the bio-economic analysis of silvopastoral systems has being developed.

The National Centre for Research in Cattle Production (EMBRAPA Gado de Corte) of Brazil, have developed several studies of economic assessment of silvopastoral systems, in a study carried out in the States of Paraná Santa Catarina and Rio Grande do Sul (Roque Rodigheri, 2003), a economic analysis in silvopastoral systems with *Eucalyptus sp., Pinus sp.* and *Ilex paraguensis* was made, the calculation of the financial indicators: NPV (Net Present Value) and the ANPV (Annual Net Present Value) showed that an agroforestry system combining *Eucalyptus* sp. or *Pinus sp.* with *Ilex paraguensis* represents a bigger revenue for the farmers when produced with a traditional system of corn + beans, concluding also that the implementation of agroforestry systems represents an option to reduce the soil erosion, a productive alternative for the degraded areas of the properties and a economically feasible production system.

The use of native species, even tough has not being widely studied, starts to take the interest of research in Brazil, the determination of the economic feasibility of a silvopastoral system using paricá (*Schizolobium amazonicum)* in Pará, Brazil (Quaresma Maneschy, Cordeiro de Santana, Bastos daVeiga, & Carvalho Filgueiras, 2008), compared a silvopastoral system with a monoculture forest plantation and found that even though the hand labor costs are bigger in the implementation of the silvopastoral system (758,44 US $/ha), when compared with a monoculture of the same specie (682,41 US $/ ha), in a period of 15 years, the silvopastoral system shows bigger values of NPV and IRR (Internal Rate of Return), which means its more viable in economic terms.

A study was conducted on a silvopastoral system at EMBRAPA Caprinos in Sobral, Ceara, Brazil, where a silvopastoral system was implemented using the specie *Mimosa caesalpiniifolia,* for wood production, in where under the management: preservation of two stems with sprout control, the revenue for a seven years cycle was $ R 267, 73 / ha

(Cavalcante de Carvalho, Garcia, de Araújo Filho, Couto, Lima Neves, & Pinheiro Rogerio, 2004).

Concerning to the use of native species, a study carried out in Southeast Brazil by (Souchie, Carneiro Campello, Ribeiro da Silva, & Saggin-Júnior, 2006), evaluated N_2-fixing tree species for their establishment in silvopastoral systems, the conclusion of this research showed that N_2-fixing tree species present better performance in the creation of silvopastoral systems when compared with non-fixers, also they recommend *Enterolobium contortisiliquum, Mimosa Caesalpiniaefolia* and *Eucalyptus spp* as the optimal species recommended for silvopastoral systems in terms of rapid growth and establishment.

In this sense EMBRAPA developed an assessment in the same region where a silvopastoral system was implemented (Franceschi Nicodemo, Porfirio da Silva, Menezes Santos, de Melo Brandao, Ribeiro de Freitas, & Caputti, 2009) combining *Brachiaria decumbens* with *Guazuma ulmifolia*, *Anadenanthera colubrina, Peltophorum dubium, Zeyheria tuberculosa, Cariniana estrellensis* and *Piptadenia gonoacantha* in a design of tree strips, where the best performance was attributed to *Guazuma ulmifolia, Peltophorum dubium* and *Piptadenia gonoacantha,* after 334 days in terms of height, diameter, and resistance to the attack of insects and diseases.

Another research carried out by (Melotto, Seleme Elidiene, Neves Marques, Valdemir Antonio, & Darlan Alba, 2009), were, considering the highest values of height, diameter of steam and survival, can be inferred that *Anadenathera colubrina, Guazuma ulmifolia* and *Calophyllum brasilienses* have potential to be establish in silvopastoral systems in the Central Region of Brazil.

To evaluate growth of Amazon native trees in silvopastoral systems in Acre, (Kamel de Oliveira, Almeida da Luz, Bezerra dos Santos, Carvalho de Oliveira, & Saraiva Lessa, 2009) implemented a silvopastoral system using the row design, the native tree species used were: (*Schizolobium amazonicum*, *Samanea tubulosa*, *Swietenia macrophyla*, *Cedrela odorata* and *Chloroleucon mangense* var. mathewsii, rice was implemented as intercrop, the result of this study showed that after 52 months *Samanea tubulosa* obtained the highest rate of growth, reaching almost 7 meters of height for this period of time.

In an analysis of agrobiodiversity carried out in the mountain region of Rio de Janeiro (Teresópolis), (Torrico Albino, 2006) found that even though silvopastoral systems are not wide spread in the region (2% of the total agricultural surface) they present highest values of species richness when compared with traditional cattle production, the most important silvopastoral species found for grasses were: *Melinis minutiflor* and *Brachiaria decumbens* and for timber: *Lonchocarpus* sp, *Tibuchina* sp, *Piptadenia gonoacantha*, *Croton floribundus*, and *Machaerium* sp, in this research the author found 34 different native tree species in pastureland, that with an adequate management could be implemented in this area in silvopastoral systems.

In a characterization of the agricultural systems in the research area of the DINARIO project (Posdena, Jansens, & Torrico, 2011), specifically for the Municipality of Cachoeiras de Macacu, was found that annual crops like manioc, maize, taro, gilo and okra, represent one of the main economic strategies of family farming in the municipality; alternative land covers systems like agroforestry are almost inexistent, 40.76% of the municipality was cover by natural and planted pastureland, 32.13 % by natural and planted forests and only 1.30 % by agroforestry systems, a totally different situation was shown when the analysis was made on a farm-basis, where 38.66 % of the total farms surface was covered by annual crops, 38.24 % of perennial crops and 18.48% covered by pastureland.

In the mountainous region of Rio de Janeiro (Teresópolis), the density of trees in pastureland varies from zero, to approximately 30 or more per hectare. Few farmers permit greater than 25% canopy cover in their pastureland fearing that greater tree cover will diminish the amount of pastureland produced (Torrico & Janssens, 2012).

In an extensive literature review for the DINARIO Project (Mallea, Torrico, Janssens M, & Gaese, 2011), systematized all the information found referent to native tree species and silvopastoral systems in the Atlantic Region, Southeast Brazil, the authors defined 4 categories of classification of the native species according with the silvopastoral potential i) forest species with high adaptation to special soil and radiation conditions, ii) forest species with positive physiological characteristics; iii) forest species with secondary production; iv) forest species with aptitude for ornamentation; v) forest species and their wood quality, the authors constructed a ranking including the native tree species with the highest potential for their establishment in silvopastoral systems, 29 species were ranked, where *Phytolacca dioica L*, *Caesalpinia ferrea* mart. Ex. Tul. Var. Ferrea, *Xilopia sericea* A. St. Hill; *Peschiera fuchsiaefolia* (A.D.C) Miers; Bauhinia forficate Link, were the highest ranked according with 18 categories of use (wood density, shelter, ornamental, human consumption, landscape restoration etc); these species fulfill the desired characteristics to be implemented in silvopastoral systems.

The identification of the potential native tree species to be established in silvopastoral systems linked with the cattle production characteristics in the research area could be important and useful for further development of policies, programs and research for the implementation of silvopastoral systems as a sustainable alternative of land cover.

CHAPTER 3. LITERATURE REVIEW

3.1 Agroforestry: An overview

The practice of cultivating crops and trees in the same unit is an ancient practice worldwide dispersed.

Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals (Figure 7), in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between the different components (Lundgren and Raintree, 1982) *cited by* (Nair Rachamandran, An introduction to agroforestry, 1993).

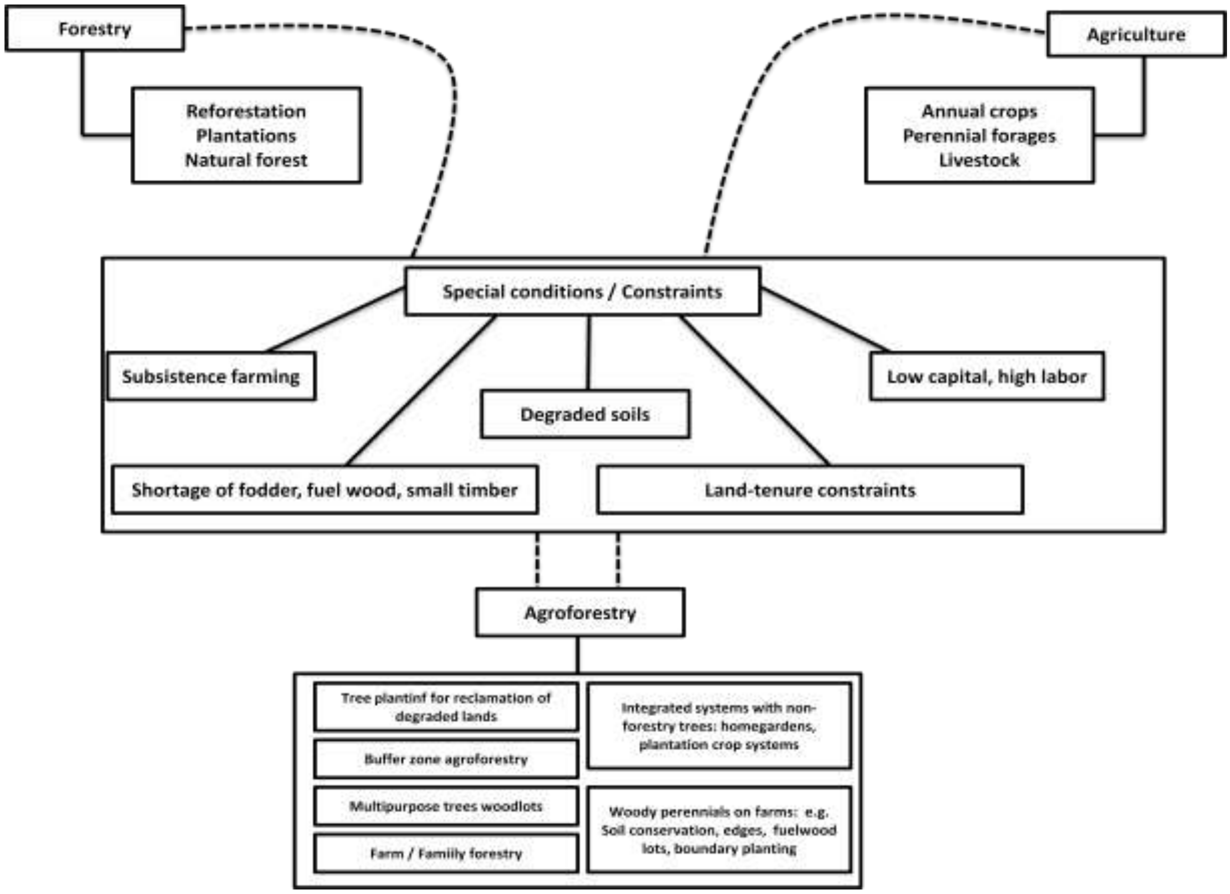

Figure 7. Interface between agriculture and forestry in response to the special needs and conditions of tropical developing countries, (Nair Rachamandran, An introduction to agroforestry, 1993).

Agroforestry systems are designed to produce a range of benefits including food, feed, fuels, often fibers, and usually renewed soil fertility (Franklin W & Sherman, 1992). According with the same author, there are three basic components of agroforestry: the land, the woody perennials and the non-tree crops/ animals.

3.2 Agroforestry classification

The classification of the agroforestry systems it is varied and it depends on the used criteria, (Nair Rachamandran, 1985) classifies agroforestry systems according with their structure, (composition and arrangement of components), its function, its socio-economic scale and level of management, and its ecological spread.

Structural basis

“Refers to the composition of the components, including spatial admixture of the woody component, vertical stratification of the component mix and temporal arrangement of the different components”.

Functional basis

”Refers to the major function or role of the system, mainly of the woody components (these can be productive, production of food, fodder, fuel wood or protective like shelterbelt, soil conservation, and etcetera”.

Socio-economic basis

“Refers to the level of inputs of management (low input, high-input) or intensity or scale of management and commercial goals (subsistence, commercial, intermediate).

Ecological basis

“Refers to the environmental condition and ecological suitability of systems, on the assumption that certain types of systems can be more appropriate for certain ecological conditions: thus there can be a set of agroforestry systems for arid and semi-arid lands, tropical high-lands, low-land humid tropics, and so on”.

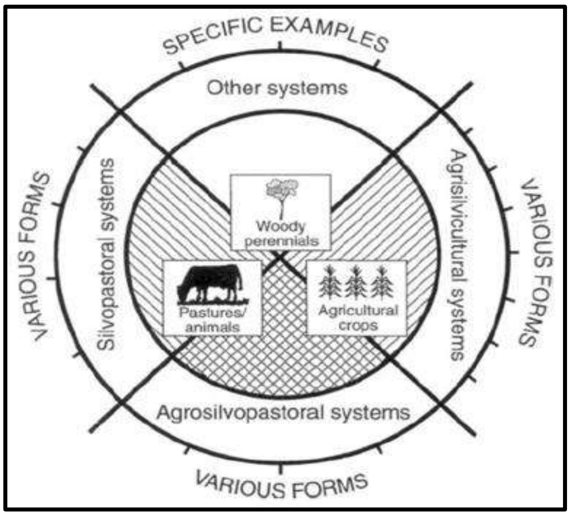

Figure 8. Classification of agroforestry systems based on the type of components, (Nair Rachamandran, 1993).

Nevertheless and according with the same author, as the three basic components are always present in al the agroforestry systems, as a first step it is necessary to classify them based on the component composition: agrisilvicultural, silvopastoral and agrosilvopastoral.

3.2.1 Agrisilvicultural systems

Agrisilviculture include hedgerow intercropping (alley cropping), use of improved 'fallow' species in shifting cultivation, multistorey combinations of multispecies plant communities, multipurpose trees and shrubs on farm lands, shade trees for commercial plantation crops, agroforestry fuel wood production, shelterbelts and windbreaks on crop production fields, and so on (Nair Rachamandran, Classification of agroforestry systems, 1985); another agrisilvicultural technique is the “Taungya system”, which tend to implement woody species with a rotation of annual crops (rice, corn, beans and manioc) until the woody component its established, the main purpose of this system is obtaining the woody material (cellulose, fuel wood) (Gazel Yared, Brienza Junior, & Tavares Marques, 1998).

3.2.2 Agrosilvopastoral systems

Agrosilvopastoral systems include the use of woody hedgerows for browse, mulch and green manure as well as for soil conservation, the crop/tree/livestock mix around homestead (home gardens), and so on (Nair Rachamandran, Classification of agroforestry systems, 1985).

3.2.3 Silvopastoral systems

Silvopastoral systems are characterized by the incorporation of trees and/or bushes in the animal production systems, it is a system that combines the woody perennial production with animals and pastureland in the same period of time or in a temporal sequence (Figure 9); the woody perennials provide the fodder (protein bank) or function as living fences around grazing land or are retained as commercial shade/ browse/fruit trees in pasturelands (Nair Rachamandran, Classification of agroforestry systems, 1985), (Franke & Casas Furtado, 2001). This systems provide economic returns from three sources (trees, forage and livestock) at different times, diversifying the market and labor possibilities (Blanco & Rattan, 2008).

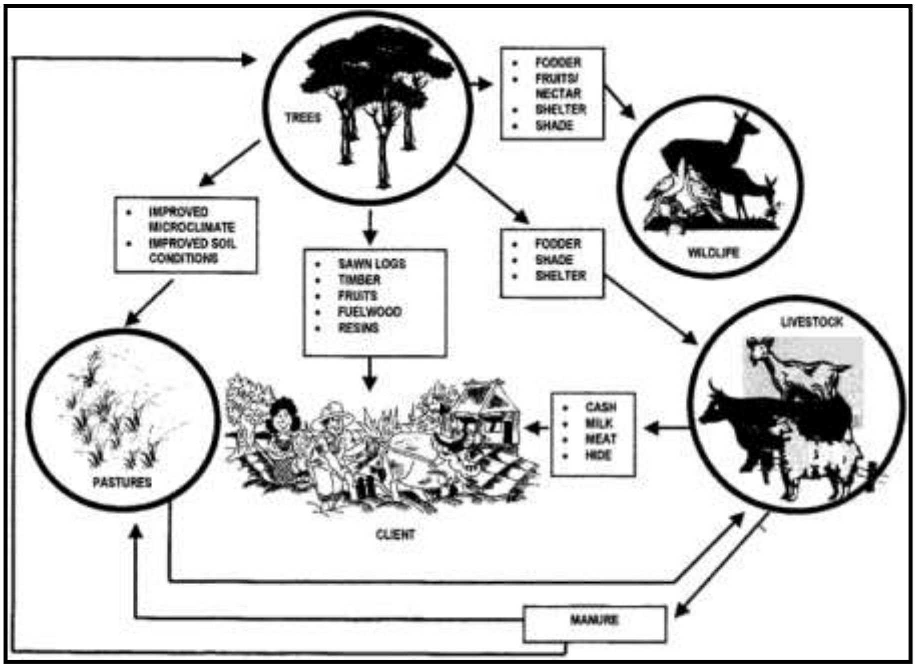

Figure 9. Model of a silvopastoral system, (FAO, 2003).

Some of the interactions in this systems according with (Musálem Santiago, 2002) are:

1) The presence of the animal component changes and it can increase some aspects of the nutrient cycling.
2) If the animal charge is high, the soil compaction can affect the tree and other associated plants growth.
3) The feeding preferences of the animals can affect the forest species composition.
4) Trees provide a propitious microclimate for the animals (shadow).
5) Animals participate in the dispersion of seeds, which favors the germination.

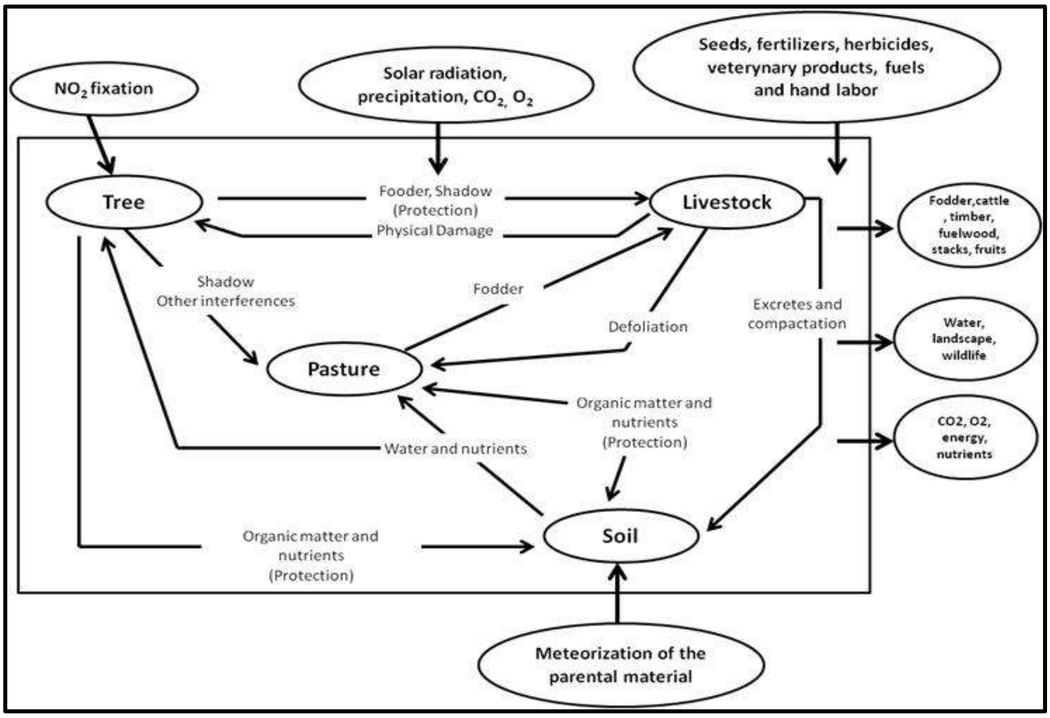

Figure 10. Simplified diagram of a silvopastoral system and the relations between components, (Ibrahim & Pezo, 1998).

Grazing is integrated into agricultural production and is carried out in grazing units with a tree gradient ranging from extensive pastureland (without trees) to pastureland with live fences, shrubs and/ or fallows, dispersed trees and forested areas used in an alternating manner through the annual cycle (Nahed-Toral, et al., 2010).

The principal inputs of the silvopastoral system are: solar radiation, precipitation, seeds, labor and veterinary products, the main outputs are: animals and tree products and services (Paap F, 1993).

Grazing livestock on silvopasture eliminates some of the costs of tree maintenance. With good grazing management, for example, herbicides and mowing may become, unnecessary), Grazing also enhances nutrient cycling and reduces commercial fertilizer costs; the animals remove few nutrients, and their waste is a valuable input for the trees. Well-managed grazing will increase organic matter and improve soil conditions. However, controlling the number of animals per acre, limiting the number of days those animals remain on each site, and avoiding compaction are critical for a successful silvopasture system (Umrani & Jain K, 2010).

3.2.3.1 Living fences

The presence of trees inside the pastureland with a specific or aleatory arrangement can be an alternative of land cover in the pastureland dedicated to cattle production, using multipurpose trees or specifically with fodder value.

The living fences are fence rows that are almost always established vegetative by planting 2- to 3-m–tall cuttings (stakes), that easily produce roots and on which several strings of wire are attached with the obvious purpose of keeping livestock in or out, (Zahawi, 2005) and (Harvey A, et al., 2005).

There are two types of living fences:

- Living fence posts
- Living fences/ hedges.

The first one are permanent, widely spaced, single lines of woody plants that are regularly pruned, they are used to support wire or other inanimate material, such as sticks of dead branches. Living fences / hedges are permanent, densely spaced, single or multiple lines of woody plants, they may comprise more than one specie and usually don't count with an inanimate element (Westley, 1992) *cited by* (Paap F, 1993).

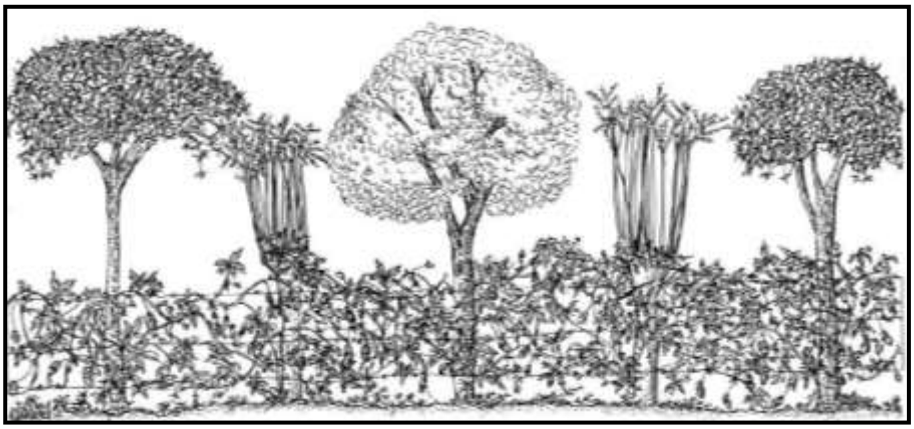

Figure 11. Diagram of a living fence, (MDA, 2008).

3.2.3.2 Scattered trees

Scattered trees also known as tree paddocks, trees in pastureland or isolated trees, are arboreal structures among agricultural landscapes, which were deliberately dropped in this landscapes after the clearing of the natural vegetation or planted with the purpose of providing benefits for the farmers like: shelter provision, fodder provision, timber / firewood provision. According with Paap (1993) scattered trees can be classified in three categories according with their function:

- Commercial trees on pasture/ rangelands
- Fruit trees and fodder .producing trees in pastureland
- Shade trees in pastures
- Pioner trees (soil improvement, nitrogen fixation)

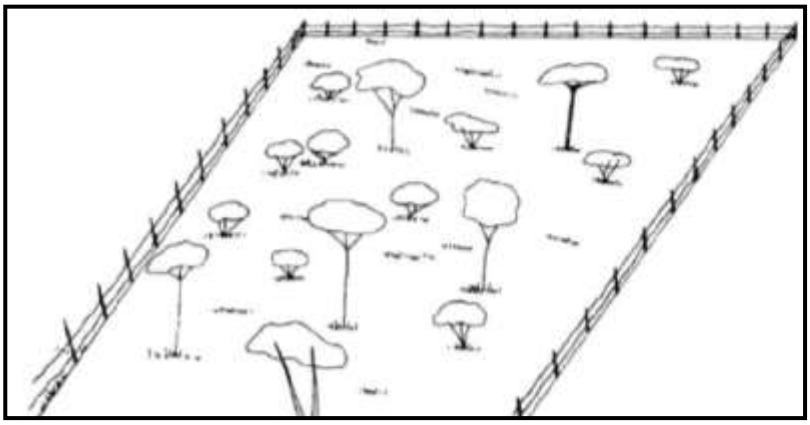

Figure 12. Diagram of scattered trees silvopastoral system, (MDA, 2008).

The disadvantages of this systems involve the additional costs related to the protection of the trees to avoid possible damages caused by the cattle, and when the canopy it to dense the trees can affect the productivity of the grass in the pastureland (Ibrahim & Pezo, 1998).

3.2.3.3 Timber boundaries

Another variation of trees in pastureland are the timber boundaries which are lines of trees planted in the limits of the farms, and/or the paddocks, their main objective it is to produce timber of stacks (Méndez, Beer, Faustino, & Otárola, 2000).

This system allows a clear delimitation of the farm area, is an alternative to produce timber in unutilized areas of the farms without competing with the crops or the pastureland, increments the value of the property, the thinning and pruning can provide fuel wood and stack for the use of the farm, the growing rate of the trees is higher when compared with block plantations, in cases of low availability of are for the agricultural production the farmers can incorporate to reforestation programs (Beer, 2000).

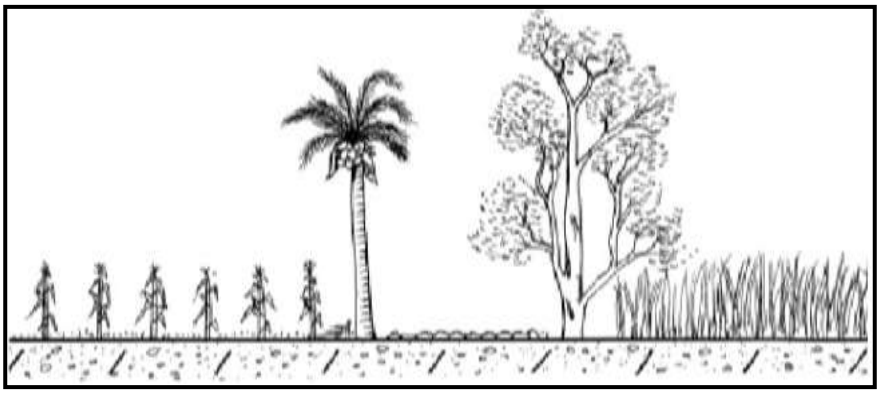

Figure 13. Diagram of timber boundaries, (Ospina Ante, 2003).

According with Beer (2000), the optimal tree species has to fulfill the following characteristics:

- High commercial value
- Fast apical growth
- Self-pruning in open-field conditions
- Successful previous trials
- Availability of certified seed (high quality of genetic material)
- Low susceptibility to plagues and diseases.
- Open canopy and
- low management needs

The disadvantages are related to the high implementation and management costs, relationships of competence are established between the tree and the pastureland, that can affect the productivity of the pastureland and the quality of the timber can be affected by factors related to the damage made by the animals (Beer, Linderos Maderables, 2000).

3.2.3.4 Protein Banks

The protein banks in silvopastoral systems are tree species which are grown in block configurations or along plot boundaries or other designated places in high densities (10 000 plants/ha); the foliage is lopped periodically and fed to animals that are kept in stalls, the main objective it is to provide the proteins missing from the grazing and usually are intercropped with grasses, fodder cane or other similar crops (Nair Rachamandran, 1993) and (Ramirez, Montoya Lerma, & Armbrecht, 2009), they complement the feedstuff of livestock, in a qualitative sense (the protein of the foliage complements low nutritive fodder/pasture) or in a quantitative sense (the foliage is used to bridge times in which pastureland production is insufficient for maintaining livestock), the most common species used for this purposes are: *Gliricidia sepium*, *Erythrina* spp and *Leucaena lecocephla* (Paap F, 1993).

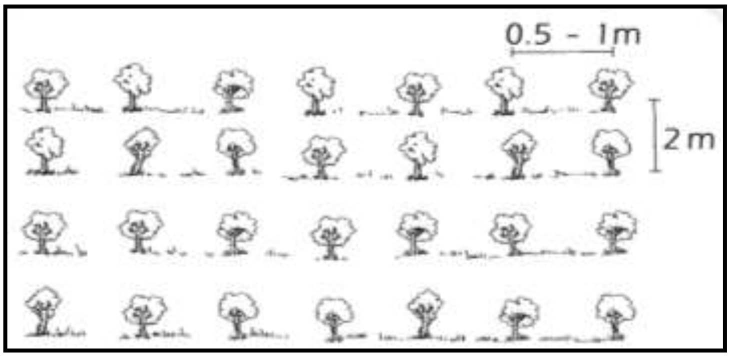

Figure 14. Diagram of a protein bank as silvopastoral system, (Ojeda P, Restrepo M, Villada Z, & Gallego, 2003).

The fodder banks must be located close to the feeders, to reduce the costs of "carry and cut" and to facilitate the organic fertilization with animal manure; the advantages of this systems are that they can be establish in small areas due to the high density of plantation, they can provide fodder the whole year and depending on the used species they can provide a higher quality of fodder, the disadvantages of this system are the high costs of implementation, and is necessary to have fertilization in the fodder bank to assure their productivity (Ojeda P, Restrepo M, Villada Z, & Gallego, 2003).

3.2.3.5 Grazing within tree plantations

In the systems where tree plantations are managed under grazing, the derived product from the trees is the main source of income, or at least the primary objective of this system, while the animal production is complementary, whether the animal are regulators of the exerted competence by the weeds or by the cover crops, or because they constitute an additional income source in these systems, before the productive stage of the trees (Ibrahim & Pezo, 1998).

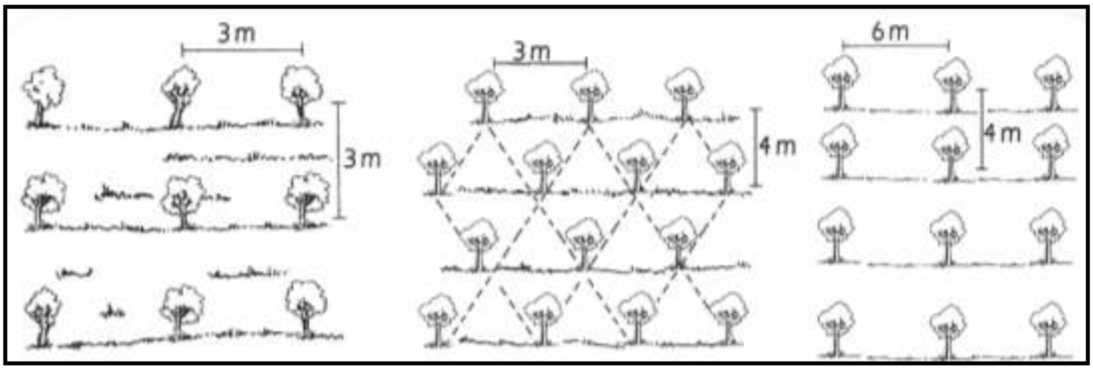

Figure 15. Diagram of different arrangements of grazing in tree plantations, (Ojeda P, Restrepo M, Villada Z, & Gallego, 2003).

3.3 Silvopastoral systems benefits

Silvopastoral systems represent a form of a close cycle of benefits, where the farmers and the environment reach a win-win situation.

The incorporation of woody species in the cattle production systems reduces the negative environmental impacts of the traditional cattle production, favors the ecological restoration of degraded pastureland, is a mechanism to diversify the cattle production enterprises generating additional products and revenues, helps to reduce the dependence on external inputs and they allow the intensification of the land cover without affecting the future productive potential (Ibrahim & Pezo, 1998).

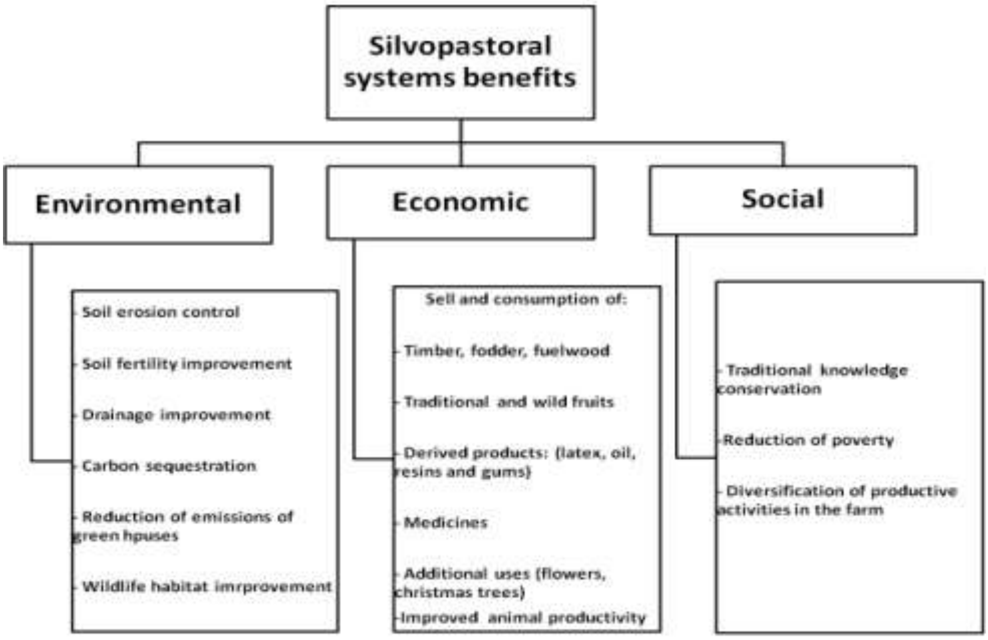

Figure 16. Silvopastoral systems benefits modified from: (Blanco & Rattan, 2008).

The benefits that silvopastoral systems provide are several and will be always determined by the type of silvopastoral design used, the own biophysical characteristics of the region, the chosen species and the management of the systems.

3.3.1 Environmental benefits of silvopastoral systems

Silvopastoral systems such as live fences, scattered trees and windbreaks[1] have an important role on the maintenance of the continuity of plant and animal populations (Harvey A, Tucker J, & Estrada, 2004); in Costa Rica, more than 100 species were found used as live fences, in Colombia also a total of 247 species were found, most of them were bird-dispersed species. (Harvey A, Tucker J, & Estrada, 2004). In Veracruz, México, isolated trees represented 33% of the total rainforest tree flora, this gives us a short approach on the importance of conservation of the agroforestry elements (Harvey A, Tucker J, & Estrada, 2004).

A study in Nicaragua, obtained a high diversity in silvopastoral systems, (91 species in 4.2 hectare), in comparison with regular grassland, but also a high diversity was found in

[1] Live fences: Narrow lines of trees or shrub species planted on farm boundaries. Isolated trees: those that are scattered in farms, occurring in varying densities and spatial arrangements. Wind breaks: linear plantings of remnant vegetation whose function is protection against wind damage.

fauna: birds (180 species) and mollusks (56 spp.), (Pérez M, Sotelo, Ramírez, Ramírez, López, & Siria, 2006).

The ways in what silvopastoral systems can enhance the biodiversity conservation can be several: it goes from conservation *in situ* of native species, provision of habitat for forest-dependent species, seed dispersal, banks of germoplasm etc.

The variation in the habitat quality, structure, and natural dynamics of different silvopastoral systems affect the wildlife in the area. For example, a windbreak in pastureland may provide habitat for edge and generalist species such as insects and rodents, whereas riparian corridors may contain remnant vegetation and be more beneficial for forest-interior species (Laurance W, 2004).

Another contribution from silvopastoral systems is landscape connectivity[2] through biological corridors in fragmented landscapes.

Silvopastoral systems increase the connectivity of populations, communities, and ecological processes, only when native species are used and the original canopy composition is maintained (Laurance W, 2004).

A study carried out in Costa Rica and Nicaragua, analyzed the role of live fences as a landscape connection element, and the results were that 167 animal species (including birds, bats, dung beetles and butterflies) were observed using them for feeding on fruits, flowers and nectar; birds were perching, on the live fences, 10% were using the live fences as display posts, and 30% were observed traveling along them (Harvey A, et al., 2005).

In terms of soil erosion control silvopastoral systems prevent water and wind erosion. The dense root network under trees, shrubs, and grasses improves water infiltration, reduces runoff volume, and ameliorates transport of non-point source pollutants to downstream waters. Integrated systems of trees and/or shrubs with pastureland can reduce runoff by 50 to 80%, sediment transport by 80%, and about 50% of total N and total P (Daniels and Gilliam, 1996) *cited by* (Blanco & Rattan, 2008).

[2] Landscape connectivity is related to the functional connection between habitat patches and occurs when habitat patches are structurally connected or when species are able to move between discrete habitat patches (D´Eon et al., 2002 *cited by* **Fuente especificada no válida.**.

The trees influence the water cycle by increasing rain and cloud interception (with possible negative and positive effects), transpiration and retention of water in the soil, reducing runoff and increasing infiltration, silvopastoral systems can reduce ground water contamination by nitrate and other substances that are harmful to the environment and human health. As a result of less runoff and leaching, micro watersheds with forest cover or silvopastoral systems that cover a high percentage of the soil surface produce high quality water. (Umrani & Jain K, 2010).

3.3.2 Economic benefits of silvopastoral system

The adoption of alternatives of land use is mainly based on the economic benefits these alternatives will provide when compared with the current systems. The main economic costs and benefits of silvopastoral systems are resumed in the following table:

Table 1. Economic costs and benefits of silvopastoral systems

Benefits and opportunities	Costs and constraints
Maintains or increases site productivity through nutrient recycling and soil protection, at low capital and labor costs	Incompatibility of trees with free grazing, burning, common fields activities which make it difficult to protect trees
Increases the value of output on a given area of land through spatial or intertemporal production of cattle and trees.	
Spreads the needs for labor inputs more evenly seasonally so reducing the effects of sharp peaks and troughs in activity characteristic of tropical agriculture	The relatively long production period of trees delays returns beyond what may be tenable for poor farmers, and increase the risks to them associated with insecurity of tenure
Provides productive applications for underutilized land, labor or capital	
Creates capital stocks available to meet intermittent costs or unforeseen contingencies	High implementation costs of the silvopastoral systems.
Diversifies the range of outputs from a given area, in order to: (a) increase self-sufficiency, or/ and (b) reduce the risk to income from adverse climatic, biological or market impact	

Source: Modified from: (Arnold M, 1987).

The economics of silvopastoral systems is characterized obtaining revenues in the short term (sales of animals) and in the long term (timber, fuel wood, fruits etc), with an increase in the revenues when the timber component is included (Musálem Santiago, 2002).

The implementation of silvopastoral systems (fodder banks and live fences) can increment in a 49% the revenues of a dairy farm and can be financially viable in a period of four years (Gobbi A & Casasola, 2003).

3.3.3 Social benefits of silvopastoral systems

Silvopastoral systems as a sustainable alternative for cattle production, bring together several social benefits, in a firsthand the increment of income for the rural livelihood due to the diversification of production and specially for the highly valued products from the timber component, generates local requirements of hand labor for the management of the systems and enhances the traditional knowledge of tree uses when native tree species are included in the system.

According with Umrani & Jain (2010), in some areas, forests and silvopastoral systems as a type of agroforestry practice provide a large proportion of rural households food needs. These contributions come in two major forms:

a) The environmental protection role of trees and forests that enhance water and soil conservation to maintain high levels of productivity;
b) The direct food commodity contributions which can supplement normal farm yields or serve as substitute products in the event of crop failures due to floods, droughts or insect infestation.

When implemented, silvopastoral systems have the social function of fixing the men to the rural properties, mainly for the increase of the hand labor demand over the annual cycle of production; also these systems enhance the life conditions promoted by the diversification of the production (Constantin, 2010).

CHAPTER 4. METHODOLOGY

4.1 Localization

The study area is located in the municipality of Cachoeiras de Macacú (Figure 17)in the state of Rio de Janeiro; the geographic coordinates are 22º27'45" south latitude and 42º39'11" west longitude, with a surface of 953.8 km^2 (Instituto Brasileiro de Geografía e Estatística-IBGE, 2011). The altitude varies from 0 to 300 meters over the sea level.

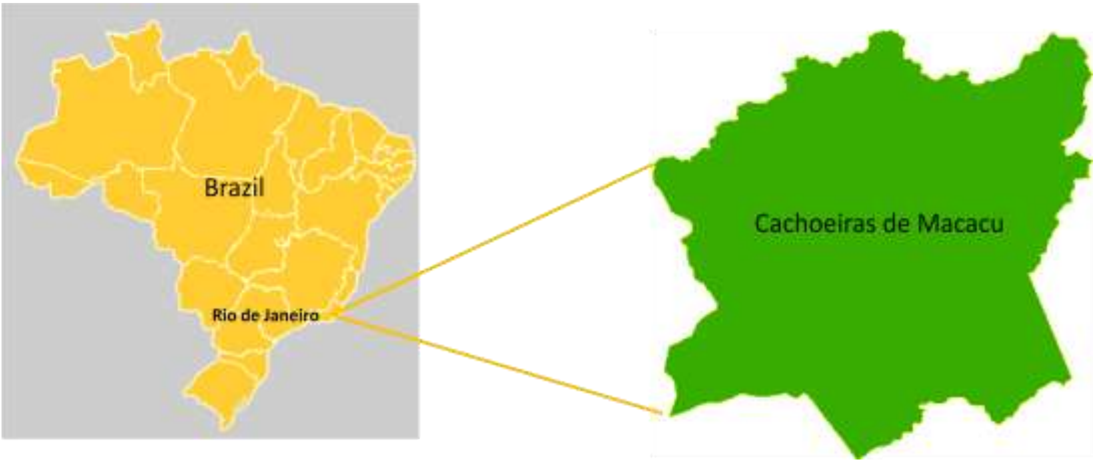

Figure 17. Location of Cachoeiras de Macacú.

The Municipality it is located in the region of the coastal lowlands of Rio de Janeiro, it limits with the Municipalities of Nova Friburgo, Rio Bonito, Guapimirim, Silva Jardim and Teresópolis (MMA, SEA, PETROBRAS, 2011).

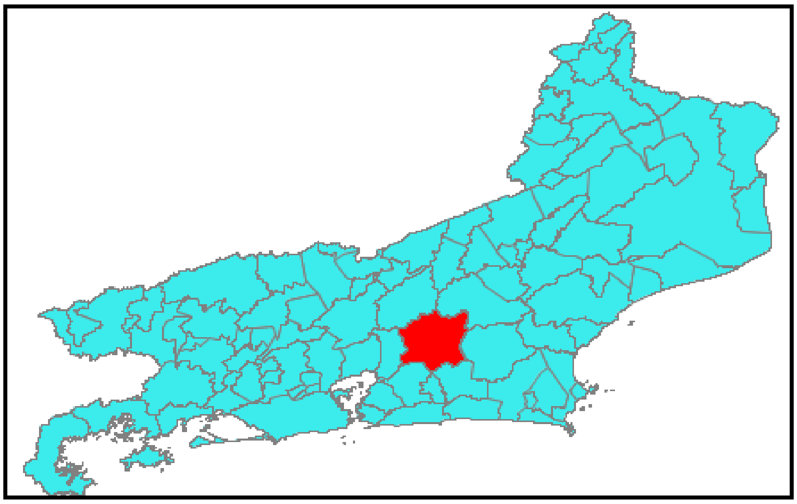

Figure 18. Location of Cachoeiras de Macacu into Rio de Janeiro State.

4.2 Biophysical characteristics

4.2.1 Climate

The climate of the region its of the type Aw[3], with an average precipitation of 175 to 198 millimeters per month and an average temperature of 23.3 °C to 22.8 °C in April and November respectively (Souchie, Carneiro Campello, Ribeiro da Silva, & Saggin-Júnior, 2006).

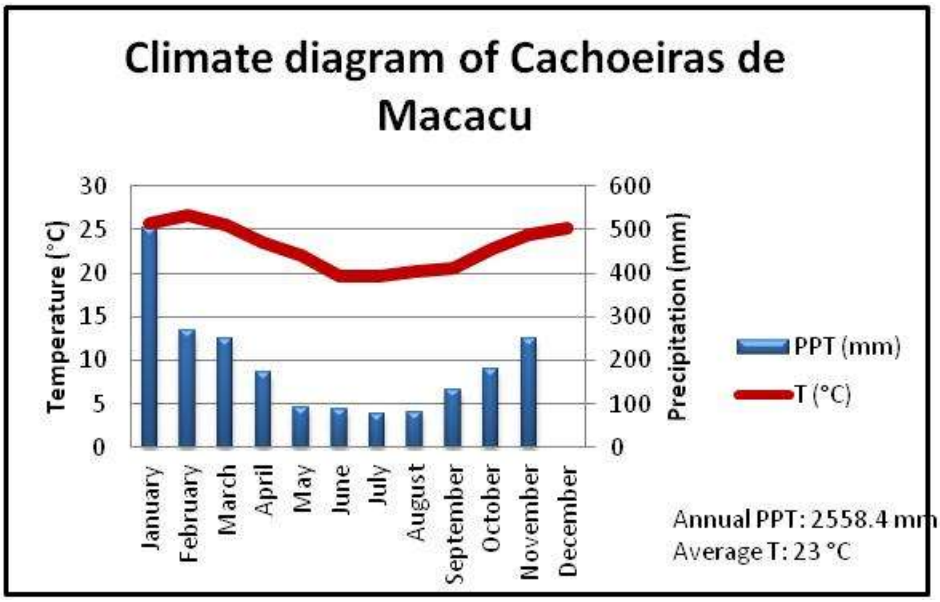

Figure 19. Climadiagram Cachoeiras de Macacu, primary data from (Kurz & Aráujo D, 2000).

In summer the rain is caused by the orographic effect and are associated to cold front, eventually intense precipitation events can occur reaching 150 mm in a period of 24 hours, in winter the days without rain can be counted as 20 (Vallejo, de Melo Campos, & Dos Santos Júnior, 2009).

4.2.2 Soils

The research area presents an association of Cambisols, rocky outcrops and Litosols, medium texture and low deepness. The soils are generally acids, with a quantity of organic matter of 58% (Coutinho Kurtz & Sue Dunn de Araújo, 2000). Gleissoils and

---

[3] Tropical humid climate, the average temperature it's over 18 °C. The rainy season it's abundant and there is a dry season in winter (Inzunza, 2005).

alluvial soils can be found in the low lands and litosoils in the hilly areas (Leal Paixão, 2000 *cited by* (Posdena, Jansens, & Torrico, 2011).

The parent material in the region is primarily granite and gneiss and the main clay mineral is Kaolinite. Granite is composed by feldspar, quartz and mica (Naegeli, 2010).

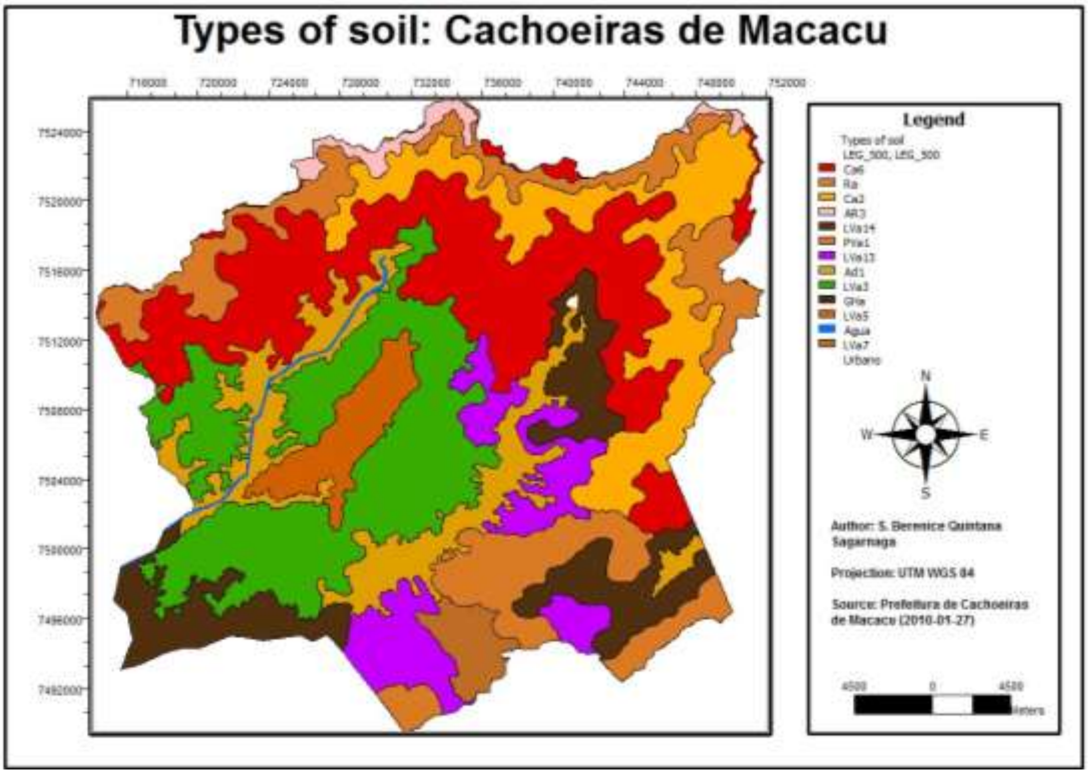

Figure 20. Types of Soil: Cachoeiras de Macacu. Author: S. Berenice Quintana Sagarnaga.

The descriptions of the present soils in the research area are described below:

- Latosols: Located in the low land and associated mainly to Submontane forest and Montane forest, the predominant Latosol is the red variation (LV).
- Cambisols: Associated also to Submontane and Montane forest, essentially mineral, barely evolved, in general shallow soils occur in transition areas.
- Gleysols: A wetland soil that, unless drained, is saturated with groundwater for long enough periods to develop a characteristic color pattern. This pattern is essentially made up of reddish, brownish or yellowish colors at surfaces of soil particles (*peds*) and/or in the upper soil horizons mixed with grayish/bluish colors inside the peds and/or deeper in the soil (FAO, 2006).

4.2.3 Hydrology

The region it is located in two hydrographic basins: Rio São João and the one of the rivers Guapi-Macacú. The hydrographic basin of Rio São João it is inserted in the Coastal Lowlands Region, and includes a drainage area circa 2160 km^2.

The hydrographic basin of Guapi-Macacú it is inserted in the hydrographic system of Guanabara Bay. With a drainage area circa of 1640 km^2, it corresponds to the 31% of the contributed continental area of this system which supplies 2.5 million habitants of the municipalities (MMA, SEA, PETROBRAS, 2011).

The Macacú River begins in the Serra dos Órgãos, and it goes along 74 km until it joins the Guapirim River (MMA, SEA, PETROBRAS, 2011).

4.2.4 Vegetation

The municipality of Cachoeiras de Macacu is located into the mountainous formation of Serra dos Orgãos, an original distribution area of Atlantic forest with its associated ecosystems, the remnants are represented mainly by: lowland forest (up to 50 m), submontane forest (50-500 m), montane forest (500- 1,500 m) and high-montane forest (1,500-1,900 m) (Mallet-Rodrigues, Parrini, Pimentel M, & Bessa, 2010).

Figure 21. Mature forest in the research area.

Representative flora species of this ecosystems are: jequitibá-rosa (*Cariniana legalis),*j equitibá-branco (*Cariniana estrellensis),* pinheiro-do-paraná *(Araucaria angustifolia)* ,imbiú *(Guatteria dusenii),* peroba (*Aspidosperma discolor*), palmito jussara *(Euterpe edulis),* ipê-amarelo (*Tabebuia alba),* ipê-roxo (*Tabebuia heptalhylla),* maçaranduba *(Manilkara elata),* sapucaia (*Lecythis lanceolata),* jatobá (*Hymenaea courbaril),* ingá(*Inga barbata),* jacarandá (*Dalbergia foliolosa),* quaresmeira (*Tibouchina granulosa) and* cedro-vermelho (*Cedrela odorata)* (Vallejo, de Melo Campos, & Dos Santos Júnior, 2009).

4.2.5 Land cover

Originally the total surface of the research area was covered by Atlantic Forest due to the actual and historic processes of land use change, now we find in the area a mosaic of land use mixed patches: remnants of the Atlantic forest surrounded by agricultural and cattle production systems.

The land uses in the research area are: Tropical forest, pastureland, agriculture, urban area, wetlands, secondary vegetation, secondary vegetation, mangrove, submontane shrubs, and rocky outcrops (Table 2).

Table 2. Land cover in Cachoeiras de Macacú.

Type	Area (ha)	%
Tropical forest	40441.12	42.4
Pastureland	41585.68	43.6
Agriculture	4578.24	4.8
Urban area	2766.02	2.9
Wetland	1430.7	1.5
Secondary vegetation	1239.94	1.3
Semideciduos tropical forest	2193.74	2.3
Mangroove	476.9	0.5
Submontane shrubs	286.14	0.3
Rocky outcrops	190.76	0.2
Exposed soil	190.76	0.2

Source: (Cardoso Fidalgo, Gomes Pedreira, Bueno de Abreu, Barroso de Moura, & Pinto Godoy, 2008).

Figure 22. Land uses in the municipality, pastureland (degraded) and agriculture, photo: S. Berenice Quintana.

As it is shown in (Figure 23) the main land uses in the research area planted pastureland for cattle production and the remnants of tropical forest, which together represent more than the 80% of the total area of the Municipality.

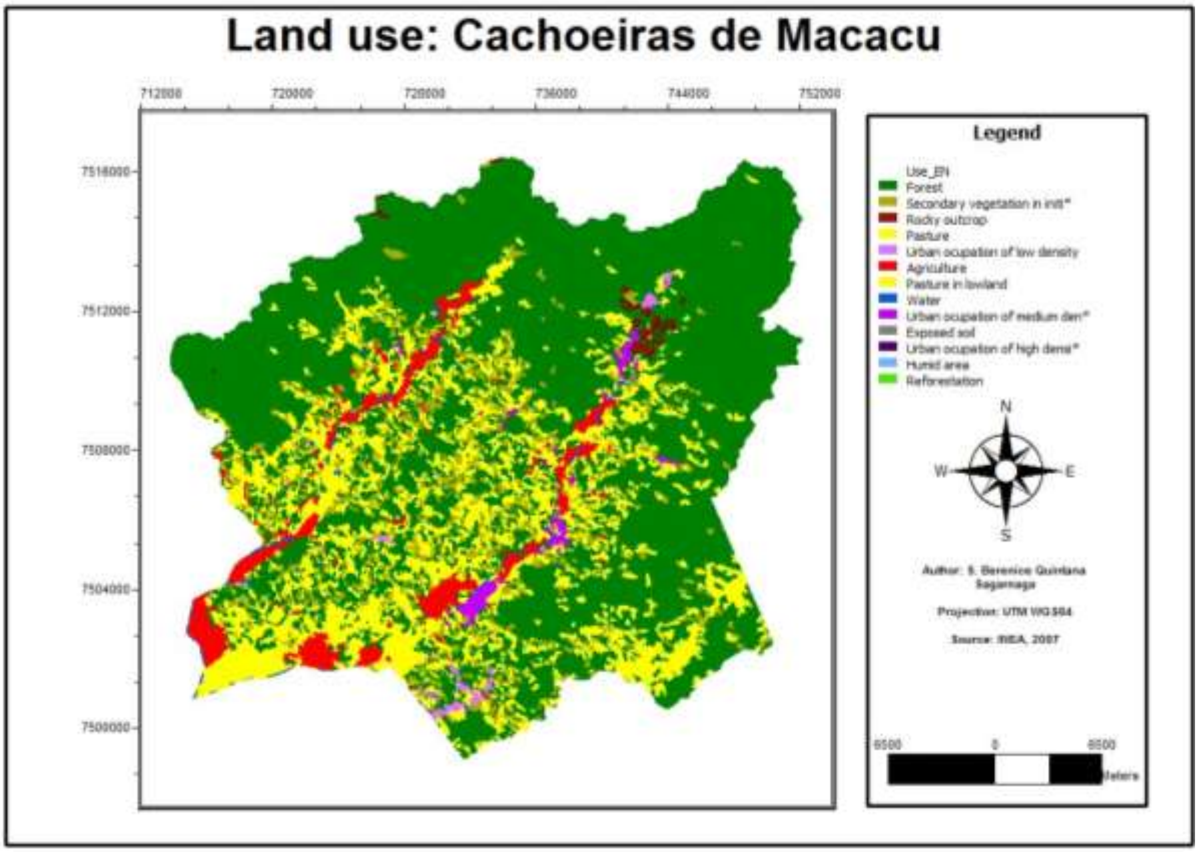

Figure 23. Land uses in Cachoeiras de Macacu, author: S. Berenice Quintana.

4.3 Socioeconomic characteristics

4.3.1 Demography

Cachoeiras de Macacu it is a municipality where the rural and the urban populations converge, representing the 86% y 14% of the total population in the municipality respectively, with 53, 370 inhabitants and demographic density of 59.3 (inhabitants/ km^2) the Gross Domestic Product (GDP) per Cápita its 13781. 91 Reales[4].

Table 3. Demography Cachoeiras de Macacu.

Total population (2000)	Total Man	Total Women	Urban Population	Rural population	Total population (2010)
48 543	27 127	27 243	47 015	7 355	54 370

Source: (Instituto Brasileiro de Geografía e Estatística-IBGE, 2011).

4.3.2 Economy

The economy of Cachoeiras de Macacú, in the period of 2002-2007, corresponded to the 5.06 % of the coastal lowlands GDP; the services sector represents the highest contributor to the economy of the municipality (Figure 24).

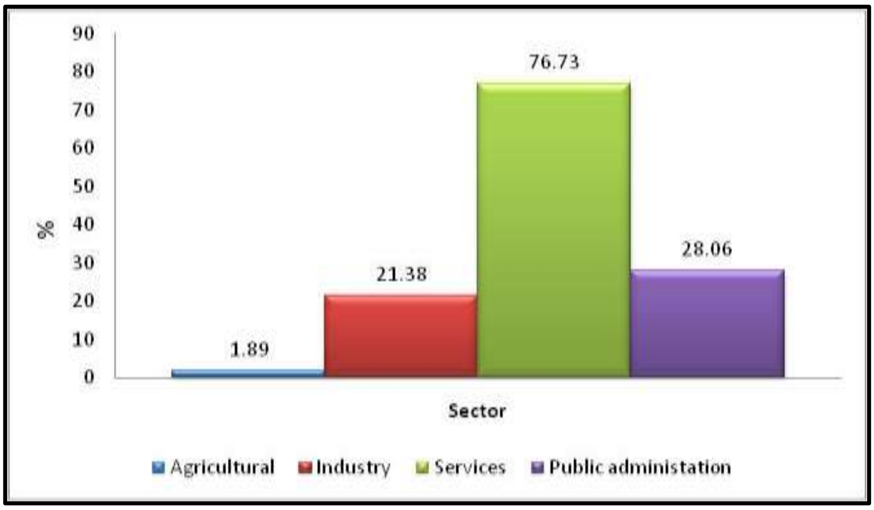

Figure 24. Participation of sector on the GDP of Cachoeiras de Macacu in 2007, (MMA, SEA, PETROBRAS, 2011).

Agriculture is the main source of income in the rural population, characterized by family units; the main agricultural products in the municipality are: guava, manioc, banana and

[4] Real: Currency of Brazil, 1 Real = 0.632 Dollars.

green corn, the cattle production is mainly dedicated to the fattening and in a lower level the milk production (REDES, 2011).

4.3.3 Education and health

The literacy rate in the municipality it is c.a 82.6 % and 86.68 according with (MMA, SEA, PETROBRAS, 2011), there are 81 primary schools and only 10 with secondary education.

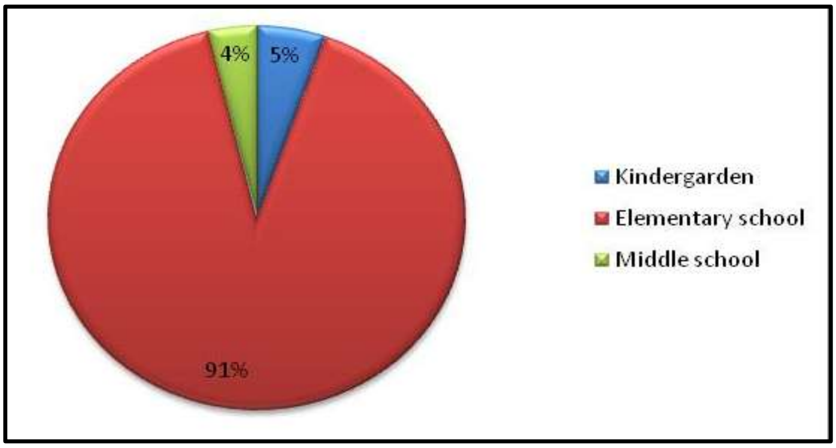

Figure 25. Access to education in Cachoeiras de Macacu by category, (IBGE, 2011).

The municipality provides the service of a hospital, an ambulatory module, community center, and a psychosocial centre, there is no state owned health centers in the municipality.

4.4 Methods

4.4.1 Secondary data acquisition

In this preparatory phase consultation to key local actors was made, based on open interviews, this secondary information was obtained from government representatives, EMBRAPA (Empresa Brasileira de Pesquisa Agropecuaria), the municipality (Prefeitura de Cachoeiras de Macacú) and EMATER (Empresa de Asistência Técnica e Extensão Rural); for the selection of the silvopastoral models and the selection of the native tree species consultation to experts from the Universidad Federal Rural de Rio de Janeiro (UFRRJ) was made, information about processes of plant production and implementation of silvopastoral systems were collected too, based on the information provided by local nurseries and literature review; visits to inputs shops of the municipality were made to construct the costs and revenues structures of the cattle production units in the municipality.

The main topics of these open interviews were the general overview about the cattle production in the municipality, as well, the most important characteristics of these productive units, the presence of silvopastoral systems in the area and the discussion about the optimal silvopastoral systems for this specific region.

4.4.2 Cattle systems characterization

During a previous literature review a questionnaire to characterize the cattle productive systems of the research area was prepared (Annex I), in order to obtain the costs and revenues structure of the systems, the general attributes of the cattle production, presence and uses of native trees in pastureland and the perception of the farmers about silvopastoral systems were the main topics of the questionnaires, the full results of the questionnaires are presented in (Bejarano, 2012, unpublished results) the questionnaire was divided in 4 sections:

1. General information of cattle farmers
2. Soil management and preparation.
3. Animal production.
4. Silvopastoral systems.

The criteria used to select cattle producers to characterize the systems was based on the concentration points of cattle production in the municipality (regions of San José de Boa Morte and Seirra Queimada), their wiliness to participate in this research, availability of time and access to the farms, the selection was made randomly and extracted from the cattle producers database provided by the Secretary of Agriculture from the City Hall.

21 cattle producers (12%) were interviewed from a total of 174; using the program Microsoft Excel © computer spreadsheet software, the information collected during the

questionnaires was systematized to be analyzed; tables for each section were constructed.

4.4.3 Trees in pastureland characterization

The identification of the trees present in the pastureland of farms was made simultaneously to the questionnaires applied to cattle producers using Table 4, this table was constructed based on the tool “local use of trees” (Agroforestry inventory) proposed by (Frans, 1997), which aims to obtain the information about the local knowledge of agroforestry: use and management of trees and also recognition walks into the farms.

This methodology consists on the elaboration of a questionnaire, the design of this questionnaire was based under the criteria of uses of trees made in a previous literature research for the DINARIO project by (Mallea, Torrico, Janssens M, & Gaese, 2011), where in an extensive literature research the author’s defined thirteen categories or variables of tree uses, this form was filled during the application if questionnaires. Every category was explained to the cattle producers, according with the characteristics and uses of the trees.

Table 4. Local uses of native trees.

Tree / Criteria	Common name of the specie
Timber	
Ornamental	
Shadow	
Meliferous	
Human consumption (medicinal, food and others)	
Present in agroforestry systems	
Helophytes	
Hygrophytes	
Grow in narrow rows	
Xerophytes	
Fast grow	
Nitrifies	
To recover degraded land	
Incidence in the farms	
Tree conditions good or bad	
Others	

4.4.4 Data analysis

With the information obtained in the questionnaires, an EXCEL sheet was developed, tables including the general information of the farmers were made, also inputs and outputs tables were constructed based on the four sections of the questionnaire, the information was homogenized with the purpose to obtain average values and infer the characteristics of a representative farm and the money fluxes of cattle production, information that was used furthermore for the economic analysis.

In relation to the information obtained from the silvopastoral systems, an EXCEL sheet was constructed as well, through an extensive literature research and using as reference the common names given by the farmers, the scientific names of the tree species present in pastureland were identified, the information given by the farmers about the traditional uses of the species were enriched also with a literature review, a table with the obtained uses in the questionnaires and the literature review was constructed.

After the analysis of the information provided by the cattle producers, joint with the literature review of the native species a new table of uses was constructed to facilitate the prioritization and choosing of the optimal species as timber components of the proposed silvopastoral models, the table of uses it is shown in Table 5.

Table 5. Categories of native species uses.

Use	Abbreviation
Timber	**T**
Fuel wood	**FW**
Medicinal	**M**
Food	**F**
Wildlife feeding	**W**
Cellulose	**X**
Fodder	**FD**
Landscaping	**L**
Environmental restoration	**R**
Shadow	**S**
Live fences	**LF**
Civil construction	**C**
Furniture elaboration	**FU**
Handcraft	**H**
Exudates (resins, gums, dyes, tannins etc)	**E**
Present in agroforestry systems	**AF**

4.4.5 Selection of silvopastoral models

Based on the information collected in the questionnaires about silvopastoral systems, specifically the characteristics of a silvopastoral model that could be adopted by the farmers, and the collected information about the use of native trees present on pastureland four theoretical silvopastoral models were chosen using three different native tree species, the selection criteria for the species was made on the number of uses they had, combined with the quality of the wood they could produce; the species with the bigger number of uses and quality of the timber were chosen for their implementation in a silvopastoral system. The chosen silvopastoral models are shown in Table 6.

Table 6. Silvopastoral models proposed.

Model	Description
Timber boundaries	Timber trees in the perimeter of the farms
Timber boundaries and subdivision fences	Timber trees in the perimeter of the farms and fences of the paddocks.
Timber boundaries, scattered trees and subdivision fences	Timber trees in the perimeter of the farms including the fences on paddocks inside the farm in combination with scattered trees inside the paddocks.
Scattered trees	Inclusion of scattered treed in inside the paddocks of pastureland.

The chosen farm size for the proposed silvopastoral models was 16 ha of surface (average size of the total farms included in this research), the attributes of each design were obtained through an intensive literature review and analysis of the obtained information in the interview and experts consultation.

4.4.6 Economic analysis of current cattle production units and silvopastoral models proposed

The financial-economic analysis of a silvopastoral project essentially is concerned with the organization's own financial performance and cash flows; cash flow refers to the receipt of revenue or income (cash inflows) and the payments of expenses (cash outflows), the net cash flow refers to the difference between the two and calculated over a range of time frames (Nuberg, George, & Reid, 2009)& (Murgueitio, et al., 2006).

To realize the feasibility of the implantation of the selected silvopastoral models, an economical analysis was made; to achieve this was necessary to evaluate economically the current system in order to be able to compare both systems. The phases of the economic analysis were:

1. Construction of the costs and revenue structures of the current cattle system and each proposed silvopastoral model (timber boundaries, timber boundaries with scattered trees and scattered trees), based on the information obtained from the questionnaires.

2. Construction of a net cash flow for a period of fifteen years (period of the timber components harvest).

3. Determination of the economic indicators: Net Present Value (NPV), Internal Rate of Return (IRR) and Benefit / Cost Ratio, to define the economic feasibility of each model.

An average farm as study case was selected based on the averages obtained in the questionnaires, this farm has 16 ha of surface and a cattle herd composed by a total of 30 animals, with a 5% mortality, fourteen productive cows, one bull and thirteen calves, the purpose of the production considered was meat production.

4.4.6.1 Net cash flow

The first step to make a financial evaluation is the construction of a net cash flow, the data to construct the net cash flow was obtained by a literature research and available data in the research area from key informants; the projections for the current system and the silvopastoral models were made for 15 years on a 16 ha basis; the net cash flow table is shown in Table 7, the general assumptions of this net cash flow based on the proposed by (Scheelje, Ibrahim, Detlefsen, Pomareda, & Sepúlveda, 2011) are:

1. The prices of products sales, inputs costs and hand labor are known and constant over the period of fifteen years.

2. The herd remains constant, every new born is sold at the end of the year, is considered one calve for each cow of the herd, this is an annual sale of twelve calves.
3. The market is perfect, the discount rate (8.9%) remains constant over the fifteen year horizon, and the cash flows are expressed in Brazilian Real.
4. The calves for sales are considered to have 8 arrobas[5] weight, with a price of 88 $ R per arroba.

Table 7. Net cash flow model for cattle production in Cachoeiras de Macacu.

Phase / Activities	Cost (16 Ha)	15 years period				
Feeding						
Common salt (25 kg)						
Mineral salt (30 kg)						
Vaccination						
Foot-and-mouth (disease) (ml)						
Rabies (ml)						
Brucellosis (ml)						
Deworming						
Ecto-endo parasites (50 ml)						
Fence maintenance						
Wire (Roll)						
Staple (Kg)						
Stake (Dozen)						
Hand labor						
Permanent, temporary (journey)						
Technical assistance (journey)						
Total costs						
Revenues						
Sale of calves						
Total revenues						
Net cash flow						

A net cash flow for each silvopastoral model was also constructed with the information obtained in the interviews; the general assumptions for this net cash flow are:

1. The prices of the acquisition of seedlings contemplate only the production costs of these.
2. It is considered a 20% of seedlings mortality.

[5] Brazilian unit of weight, mass or volume, equivalent to 15 kilograms.

3. Four pruning are considered for the fifteen year period.
4. A thinning of 25% is considered at the eighth year of the period.
5. The market is perfect, the discount rate (8.9%) remains constant over the fifteen year horizon, and the cash flows are expressed in Brazilian Real.

Table 8. Net cash flow for silvopastoral models in Cachoeiras de Macacu.

Phase / Activities	Cost (100 m)	Cost (1600 m)	15 years period				
Soil preparation							
Hand labor and inputs							
Seedlings							
Seedlings							
Transport							
Plantation							
Plantation of seedlings							
Replantation							
Fertilization							
Opening of pits							
Internal transport							
Inputs							
Cultural treatments							
Manual mowing							
Coverage fertilization							
Phytosanitary control							
Pruning							
Thinning							
Chemical Mowing							
Inputs							
Tree management							
Subtotal							
Animal management							
Animal/ Pastureland management							
Sale of calves							
Fuelwood/Stacks							
Timber							
Subtotal							
Net cash flow							

Based on: (de Matos Bentes-Gama, Lopes da Silva, Montoya Vilcahuamán, & Locatelli, 2005) & (Guirado Cola, 2011).

The reference prices for the values of timber were taken from CI Florestas[6], prices given in m^3, with prices from April 2012 (145 \$R / m^3) mature standing timber.

4.4.6.2 Net present value

The NPV indicator allows comparisons to be made between different investment alternatives over dissimilar time periods. NPV is examined at various discount rates. The discount rate can be viewed as the opportunity cost of using money. This means that the discount rate represents the next best use of money invested in the agroforestry enterprise (Chagoya Fuentes, 2004).

The NVP was calculated with the following equation:

$$NPV = \sum_{T=0}^{T} \frac{B_{t-} C_t}{(1+d)^t}$$

Where:

T: Temporal horizon from the project

B: Benefits

C: Costs

t: Time

d: Discount rate

The decision criterion for the NPV is to accept the project when NPV ≥ 0; the NPV was calculated for five different scenarios: current cattle production system, timber boundaries, timber boundaries with scattered trees and scattered trees.

4.4.6.3 Cost / Benefit analysis

In an economic analysis of an agroforestry enterprise (for the purposes of this research, silvopastoral enterprise), the benefits represent the returns from the agroforestry project sales (wood, fuel wood, fodder, fruits, etc) and also the benefits coming from the other synergic activities like livestock production or agriculture practices, the costs on the other

[6] Brazilian Institution of market research in the forest sector.
http://www.ciflorestas.com.br/texto.php?p=missao_visao

side are the variable costs (e.g. cost of ground preparation, tree seedlings, planting, management, pruning, harvesting), overhead costs (e.g. cost of planning and compliance, additional farm labor if required), capital costs (e.g. land purchase, purchase of forestry-specific machinery, depreciation) and opportunity cost (e.g. reduced gross margin from displaced livestock or cropping enterprises on land planted to trees). (Nuberg, George, & Reid, 2009).

The cost/ benefit analysis is made through the calculation of the benefit /cost ratio which relates the present value of the benefits with the present value of the costs, in this way we are able to know the additional received or lost from each dollar used in the inversion and operation of the project. (Enríquez Andrade, 2008).

This ratio is obtained when the present worth of the benefit stream is divided by the present worth of the cost stream. The absolute value of the B/C ratio will vary depending on the interest rate chosen. The higher the interest rate, the smaller the resultant benefit-cost ratio, (Gritinger, 1982) *cited by* (Chagoya Fuentes, 2004).

The calculation of the Benefit/ Cost ratio was calculated using the following equation:

$$\frac{B}{C} = \sum_{t=0}^{T} \frac{B_t}{(1+d)^t} \div \sum_{t=0}^{T} \frac{C_t}{(1+d)^t}$$

Where:

T: Temporal horizon from the project B: Benefits

C: Costs t: Time

d: Discount rate

The decision rule is to accept the project when B/C ratio ≥ 1.

4.4.6.4 Internal rate of return

The internal rate of return (IRR) is the discount rate that forces the NPV of its inflows to equal its cost. This is equivalent to forcing the NPV to equal zero. The IRR is an estimate of the projects return rate. The IRR was calculated with the following equation:

$$0 = \sum_{t=0}^{T} \frac{B_t}{(1 + IRR)^t}$$

Where:

T: Temporal horizon from the project

B: Benefits

C: Costs

t: Time

d: Discount rate

The decision rule is to accept the project when IRR ≥ d.

CHAPTER 5. RESULTS

5.1 General cattle producers characterization

Twenty one cattle producers were interviewed from a total of 174 in the municipality, the location of their properties it is shown in Figure 26.

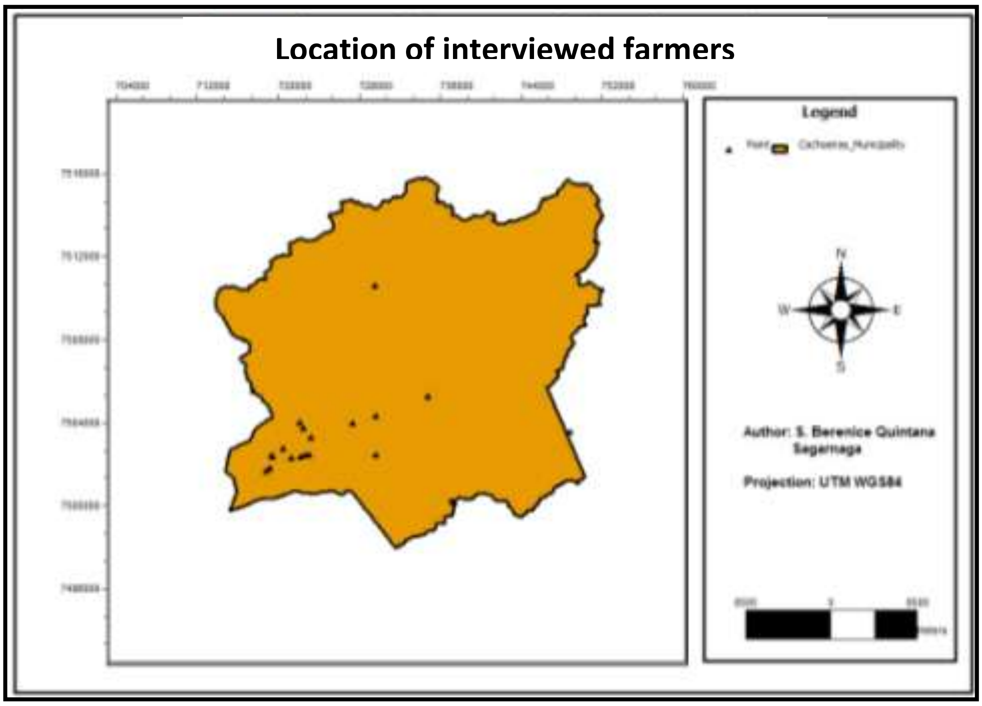

Figure 26. Location of farmers interviewed in Cachoeiras de Macacu.

According with the farm size three big producers[7] were identified with an average area of their properties of 123 ha, eleven producers can be classified as medium producers[8] with an average property area of 16 ha and seven small producers[9] were interviewed with an average of 4.29 hectares of property surface.

Three variations of farms/paddocks location were identified: top of the hill (71%) combined with hillsides and lowlands (29 %).

In general all the cattle producers were working and living in the farms, even though not all of them were the owners of the properties as it's shown in Figure 27.

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[7] A big producer can be considered when the surface of the property it is > 100hectares.
[8] Medium producer: Range of property area of 10-100 hectares.
[9] Small producer: Property area < 10 hectares according with (Posdena, Jansens, & Torrico, 2011).

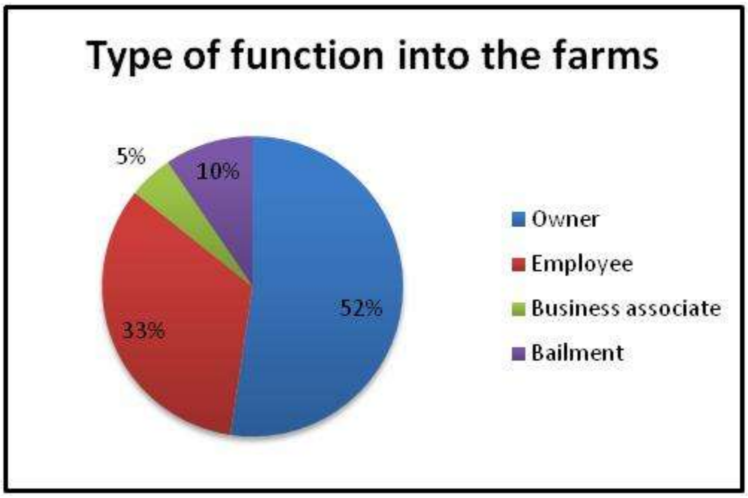

Figure 27. Type of function in the surveyed farms.

Regarding to the productive activities that generate income in the farms, 62% of the interviewed farmers combine agriculture and cattle breeding and /or milk production, the rest drives the cattle breeding or milk production as the main economic activity in the farm, the diversification of productive activities its very low, two farmers also receive income from all *Eucalyptus* plantations and pisciculture, in relation of extra incomes, nine accepted to obtain support from the government or retirement payments, the family is mainly the base of the available hand labor for medium and small productive units (62%).

In terms of technical assistance the farmers receive for the productive activities, 38% declare having no technical assistance, the 28% receives assistance from EMATER, which has no cost for the farmers, and the rest receives technical assistance from veterinarians principally for the application of vaccines for the cattle and sanity issues.

5.2 Land management

The pastureland management is very low or inexistent in the research area, 47% of the interviewed farmers declared to have realized a mechanic preparation of the soil when the pastureland was implemented, the use of herbicides is also a extended practice, 47% farmers accepted to use them to control the regrowth of primary forest combined with manual mowing, the most common grass species in pastureland are Brachiaria (*Brachiaria decumbens*) and Quicuyo (*Panicum maximum*), this grasses were established approximately 30 years ago, 57% of the interviewed farms had a portion of their surface dedicated to forest or abandoned pastureland that turned into primary forest (Figure 28).

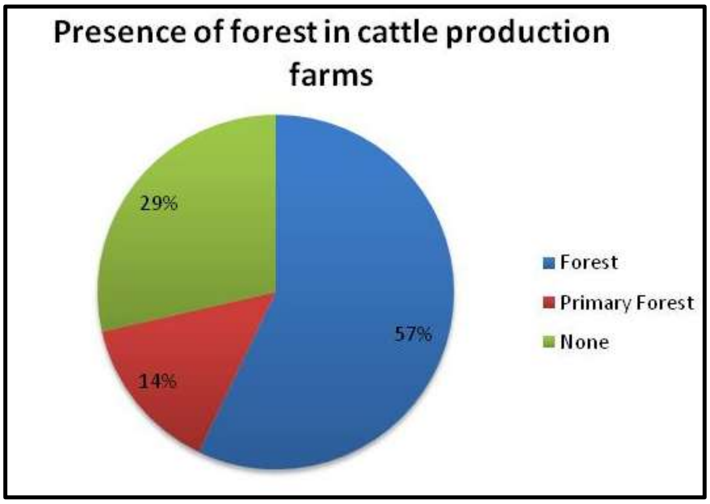

Figure 28. Presence of forest in cattle production farms of Cachoeiras de Macacu.

The grazing system is rotational with 30 day rotational period; the average number of paddocks in this system is four.

The infrastructure for the purpose of cattle production is basically composed by corrals and fences, cattle breeding activities are: fence maintenance, pastureland mowing and corrals maintenance.

5.3 Animal management

The herd is composed mainly by the race Nellore and a mixture of Zebu races (Girolanda and Mestiço), the average size of the herd is 30 animals for small producers, composed by bulls, cows and calves, the average size of the herd for a medium producer was 65 animals and for a big producer 245 animals.

Figure 29. Bovine races in cattle farms of Cachoeiras de Macacu (Left: Nellore race, right: Mestiço race), Photos: S. Berenice Quintana.

Herd feeding is based on pasture and a supplement of common salt and mineral salt , in average quantities of 57 and 77 gr.

The sanitation controls include vaccination against food and mouth disease (two applications per year), rabies (one application per year) and brucellosis (only for females in reproductive age), it is important to mention, that the Secretary of Agriculture and the Sanity Control Office of the municipality assist with the application of the vaccines along the year, a deworming (against ecto-endo parasites) is made once per year.

Cattle production income is obtained by the sale of calves at the end of the productive year, in average thirteen calves of an average size of 120 kg.

5.4 Characterization of native tree species with silvopastoral potential

The knowledge acceptance level of cattle producers to silvopastoral systems in Cachoeiras de Macacu is very low, it was found that 67% of the cattle producers had no previous knowledge about silvopastoral systems and their characteristics, even though in all the farms trees in pastureland were present, it can be inferred the empiric knowledge of the farmers about silvopastoral systems.

It is important to remark the reasons of the presence of these trees in pastureland, which is related to the benefits they provide to cattle by shadowing and the availability of fuel wood and stacks for farm's self consumption (Figure 30).

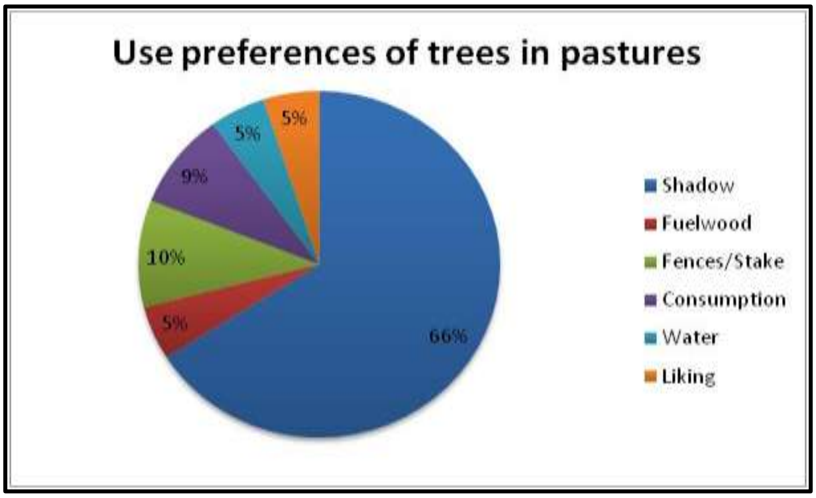

Figure 30. Use preferences of trees in pastureland.

The willingness to implement silvopastoral systems and /or more trees in their properties was characterized by a general negative answer, 67% of the farmers manifested no interest on having more trees in their pastureland, the main factors affecting a positive answer on implementing silvopastoral systems are the reduction of productivity of the pastureland due to the shadowing provided by the trees, the reduction of pastureland area that will be occupied by trees, and the lack of space to implement the systems, due to the nature of small scale farms; those who were interested on implementing silvopastoral systems pointed that the main purpose of these systems should be production of timber wood and shelter provision for the herd.

Thirty five different native species from 19 different families were found in the surveyed farms. The most representative families were Fabaceae, Myrtaceae and Mimosaceae. Sixteen exotic tree species were also found during the survey, the names and uses of these species are shown in Table 9 and Table 10.

Table 9. Native tree species and their uses in cattle production farms of Cachoeiras de Macacu.

Common name	Scientific name	Family	Uses															
			T	FW	M	F	W	X	FD	L	R	S	LF	C	FU	H	E	AF
Sapucaia	*Lecythis pisonis* Cambess.	Lecythidaceae		X			X			X		X		X				X
Carrapeta	*Guarea guidonia* L.	Meliaceae	X		X							X						
Cambará	*Gochnatia polymorpha* (Less.) Cabrera	Asteraceae		X			X	X		X	X			X			X	
Jacá	*Caesalpinia ferrea* var. Parvifolia Mart.	Fabaceae		X	X		X		X	X								
Jacatirão	*Miconia cinnamomifolia* (Dc.) Naud.	Melastomataceae		X			X	X		X	X			X			X	
Quaresma	*Tibouchina sellowiana* (Cham.) Cogn.	Melastomataceae			X	X	X	X		X		X						
Abacate	*Persea pyrifolia* Nees.	Lauraceae	X				X			X	X	X						
Ipé amarelo	*Tabebuia serratifolia (Vahl.) Nichols.*	Bignoniaceae		X	X	X	X			X	X	X		X				
Jambo	*Myrcia rostrata DC.*	Myrtaceae		X			X	X		X	X	X					X	
Garapa	*Apuleia leiocarpa* (Vogel) J.F.Macbr.	Fabaceae	X	X	X		X			X		X		X				
Amendoeira	*Pterogyne nitens* Tul.	Fabaceae		X						X	X	X			X		X	
Angico branco	*Anadenanthera colubrina* (Vell.) Brenan	Fabaceae	X	X	X		X					X					X	
Cajú	*Anacardium occidentale* L.	Anacardiaceae	X	X	X		X				X	X					X	X
Jacaré	*Piptadenia gonoacantha* (Martius) Macbride; Contrib. Gray	Mimosaceae		X			X	X		X	X						X	
Goiaba	*Psidium guajava* L.	Myrtaceae		X	X	X			X							X	X	
Brauna	*Schinopsis brasiliensis* Engl.	Anacardiaceae	X		X	X	X			X								
Caixi	*Vochysia magnifica* Warm.	*Vochysiaceae*				X	X	X		X	X							
Cajá	*Spondias mombin* L.	Anacardiaceae			X	X	X	X				X						X
Embaúba	*Cecropia hololeuca* Miq.	Urticaceae				X	X	X		X		X					X	
Grumixama	*Eugenia brasiliensis* Lam.	Myrtaceae			X	X						X						
Ipé branco	*Tabebuia roseoalba (Ridley) Sandwith.*	Bignoniaceae					X			X	X			X				
Maricá	*Mimosa bimucronata* De Candole.	Mimosaceae		X	X		X				X	X					X	X
Pitangueira	*Eugenia uniflora* L.	Myrtaceae		X	X	X												
Figueira	*Ficus spp.*	Moraceae		X	X			X		X	X	X						
Abiu	*Pouteria* spp.	Sapotaceae	X			X	X			X	X						X	
Algodão do mato	*Guazuma crinita* Mart.	Malvaceae	X									X						
Amora	*Maclura tintoria* L.	Moraceae	X	X	X		X			X	X						X	X
Biribá	*Annona muricata* L.	Annonaceae		X		X	X		X								X	
Canela amárela	*Ocotea pulchella* (Nees) Mez.	Lauraceae				X		X		X	X	X						

Copaíba	*Copaifera langsdorffii* Desf.	Fabaceae	X		X		X				X						X	
Embiriba	*Eschweilera ovata* (Cambess.) Miers	Rubiaceae	X	X	X		X			X	X							
Jenipapo	*Genipa americana* L.	Lecythidaceae	X	X	X	X		X		X	X						X	X
Mituqueiro	*Erythrina falcata* Benth.	Fabaceae			X			X		X	X							
Pinhão	*Araucaria angustifolia* (Bertol.) Kuntze.	Araucariaceae	X	X	X		X	X		X	X						X	
Sabiá	*Mimosa caesalpiniaefolia* Benth.	Mimosaceae		X					X	X				X				

T: Timber, FW: Fuelwood, M: Medicinal, F: Food, W: Wildlife feeding, X: Cellulose, FD: Fodder, L: Landscaping, R: Environmental restoration, S: Shadow, LF: Live fences, C: Construction, FU: Furniture elaboration, H: Handcraft, E: Exudates, AF: Present in agroforestry systems.

Table 10. Exotic species and their uses in cattle production farms of Cachoeiras de Macacu.

Common name	Scientific name	Family	Uses															
			T	FW	M	F	W	X	FD	L	R	S	LF	C	FU	H	E	AF
Bambu	*Bambusa* spp.	Poaceae										X						
Manga	*Manguifera indica* L.	Anacardiaceae				X												
Coco	*Cocos nucifera* L.	Arecaceae				X						X						
Jacá	*Artocarpus heterophyllus* Lam.	Moraceae				X												
Eucalipto	*Eucalyptus* spp.	Myrtaceae	X															
Laranja	*Citrus sinensis* L.	Rutaceae				X												
Ciroela	*Spondias purpurea* L.	Anacardiaceae				X												
Limão	*Citrus aurantifolia* (Christm.) Swingle	Rutaceae				X												
Acerola	*Malphigia glabra* L.	*Malpighiaceae*				X												
Bananeira	*Musa* spp.	Musaceae				X												
Framboyan	*Delonix regia* (Bojer) Raf.	Fabaceae								X								
Graviola	*Annona muricata* L.	Annonaceae			X	X												
Caqui	*Diospyros kaki* L.	Ebenaceae				X												
Carambola	*Averrhoa carambola* L.	Oxalidaceae				X												
Mandarina	*Citrus nobilis* L.	Rutaceae				X												
Maracuya	*Pasiflora edulis* L.	Passifloraceae				X												
Tamarindo	*Tamarindus indica L.*	Fabaceae				X												

T: Timber, FW: Fuelwood, M: Medicinal, F: Food, W: Wildlife feeding, X: Cellulose, FD: Fodder, L: Landscaping, R: Environmental restoration, S: Shadow, LF: Live fences, C: Construction, FU: Furniture elaboration, H: Handcraft, E: Exudates, AF: Present in agroforestry systems.

The prioritization of native tree species in pasturelands of Cachoeiras de Macacu is shown in Table 11, based on their wood density, only species with a wood density higher than 0.70 g/cm^3 are included.

Table 11. Native timber species in Cachoeiras de Macacu and their wood quality.

Common name	Scientific name	Family	Wood density g/cm^3
Sapucaia	*Lecythis pisonis* Cambess.	Lecythidaceae	0.85-1
Carrapeta	*Guarea guidonia* L.	Meliaceae	0.85-1
Ipé amarelho	*Tabebuia serratifolia (Vahl.) Nichols.*	Bignoniaceae	0.8-1.00
Angico branco	*Anadenanthera colubrina* (Vell.) Brenan	Fabaceae	0.80-1.10
Ipé branco	*Tabebuia roseoalba (Ridley) Sandwith.*	Bignoniaceae	1.19
Brauna	*Schinopsis brasiliensis* Engl.	Anacardiaceae	1.03
Biribá	*Annona muricata* L.	Annonaceae	1.03
Embiriba	*Eschweilera ovata* (Cambess.) Miers	Rubiaceae	1.03
Garapa	*Apuleia leiocarpa* (Vogel) J.F.Macbr.	Fabaceae	0.75-1
Amora	*Maclura tintoria* L.	Moraceae	0.76-0.97
Amendoeira	*Pterogyne nitens* Tul.	Fabaceae	0.70-0.87
Abiu	*Pouteria* spp.	Sapotaceae	0.63-0.87
Sabiá	*Mimosa caesalpiniaefolia* Benth.	Mimosaceae	0.87
Copaíba	*Copaifera langsdorffii* Desf.	Fabaceae	0.64-0.86
Jacaré/ Camboeteiro	*Piptadenia gonoacantha* (Martius) Macbride; Contrib. Gray	Mimosaceae	0.75-0.78
Caixi	*Vochysia magnifica* Warm.	Vochysiaceae	0.78
Pitangueira	*Eugenia uniflora* L.	Myrtaceae	0.74
Jacatirão	*Miconia cinnamomifolia* (Dc.) Naud.	Melastomataceae	0.73
Jenipapo	*Genipa americana* L.	Lecythidaceae	0.62-0.71

The three selected species to be establish in silvopastoral systems are shown in Table 12, these species are characterized by their multiple uses, they are timber species with a good wood quality, provide good shadowing and have a medium-fast growth habit. It is important to note that the rest of the species should be analyzed as well, in terms of the economic benefits they can provide in the research area.

Table 12. Native tree species proposed for their implementation in silvopastoral systems.

Common name	Scientific name	Family	Uses	Wood density g/cm^3
Angico branco	*Anadenanthera colubrina* (Vell.) Brenan	Fabaceae	T, FW, E, W, M, S	0.80-1.10
Ipé amarelho	*Tabebuia serratifolia (Vahl.) Nichols.*	Bignoniaceae	T, C, FW, F, W, M, L, R, S	0.8-1.00
Ipé branco	*Tabebuia roseoalba (Ridley) Sandwith.*	Bignoniaceae	T, C, L, R, S	1.19

5.5 Silvopastoral models

The design of the silvopastoral models was based on the farmers preferences, according with this research the production of wood and provision of shelter for cattle must be the main objectives of a proposed silvopastoral system in the research area, the evaluated models are shown in Table 13.

Table 13. Silvopastoral models evaluated.

Design	Description
Timber boundaries	Timber trees (*Anadenanthera colubrina* (Vell.) Brenan *and Tabebuia serratifolia (Vahl.) Nichols.*) In the perimeter of the farm.
Timber boundaries and trees in subdivision fences	Timber trees (*Anadenanthera colubrina* (Vell.) Brenan *and Tabebuia serratifolia (Vahl.) Nichols.*) in the perimeter of the farms including the fences on paddocks inside the farm
Timber boundaries with scattered trees	Timber trees (*Tabebuia serratifolia (Vahl.) Nichols.*) And *Tabebuia roseoalba (Ridley) Sandwith.*) In the perimeter of the farms including the fences on paddocks in combination with scattered trees inside the paddocks.
Scattered trees	Inclusion of scattered trees inside the paddocks of pastureland with *Tabebuia serratifolia (Vahl.) Nichols.*

5.5.1 Study case

An average farm was considered to evaluate the proposed silvopastoral models, based on the averages of the questionnaires, a quadrangular shape farm was considered with a 16 ha of area (400 m x 400 m), subdivided in four paddocks.

All models are considered with an established pastureland of *Brachiaria decumbens* and a carrying capacity of 1 Animal Unit[10] / ha.

[10] Animal unit: Standardized measure of animals, 250 kg.

The herd considered for this study case is composed by 30 animals considering an annual mortality of 3% (1 animal); the composition of the herd is shown in Table 14.

Table 14. Herd composition, average farm in Cachoeiras de Macacu.

Category	Weight (@)[11]	Quantity
Bull	33	1
Cow	25	14
Calve	8	13

5.5.2 Model 1: Timber boundaries

The information obtained in the general characterization of cattle production showed that the cost of fence maintenance in the farms and the conformation of the initial fences represent the largest spending on the management of the properties, this is why a design of timber boundaries was chosen.

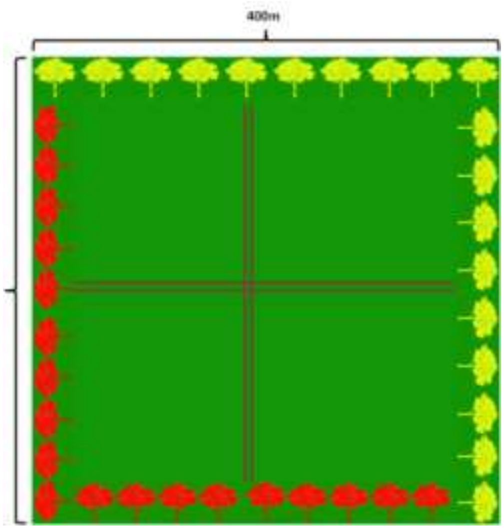

Figure 31. Timber boundaries design.

In this design trees have a separation of 3 meters, 133 trees in 400 linear meters, 533 in 1600 linear meters for a 16 ha farm, two native tree species will conform the boundaries of the farms, the cattle will be able to graze among the paddocks, trees will define farm boundaries, the chosen species for this design are: *Anadenanthera colubrina* (Vell) and *Tabebuia serratifolia (Vahl.) Nichols*, two sides of the quadrate will be formed by Angico branco and two sides by Ipê amarelo.

[11] 1 @ = 15 kg.

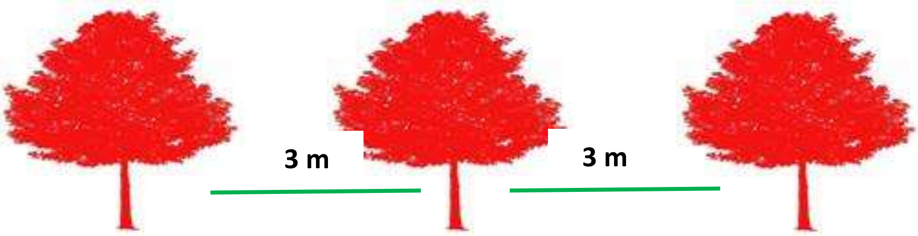

Figure 32. Separation between trees for Model 1: Timber boundaries.

It is considered a production of 242 m^3 in a 16 ha farm in a cycle of fifteen years of lumber wood of Ipê amarelo[12] and 97.75 m^3 of lumber wood Angico branco[13] in the same cycle, including a 25% thinning at the 8th year of the plantation, and continuous silvicultural activities listed in Table 17.

5.5.3 Model 2: Timber boundaries and trees in subdivision fences

This model contemplates the inclusion of trees in the boundaries and also in the subdivision paddocks of the farms, in total 790 trees, 395 from Ipê branco and 395 from Ipê amarelo, with a total production of lumber wood at the 15th year of 719 m^3 in 16 ha (592 trees).

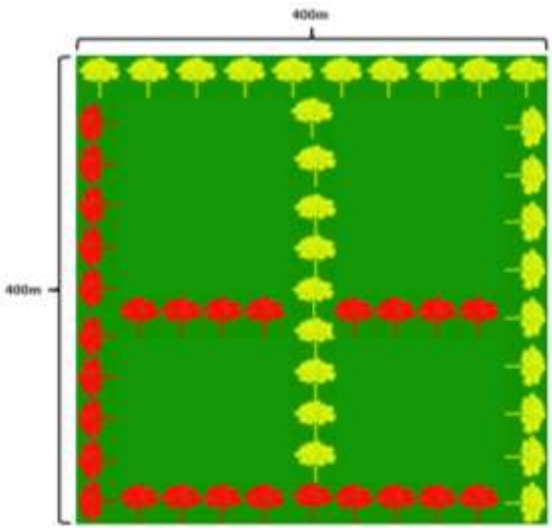

Figure 33. Timber boundaries and trees in subdivision fences design.

The separation between trees is of 3m X 3 m, and the use of wire, staples and stacks is replaced in 100% by the planted trees.

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[12] Due to the lack of specific data about the species it is considered 1.21 m^3/ tree in a fifteen years cycle from similar specie (*Tabebuia donnell-smithii*) from (Fundación Hondureña de investigación agrícola, 2007).
[13] Considering 0.49 m^3 / tree in a fifteen years cycle, reported for the same specie (Silva & Torres, 1992) *cited by* (Ramalho Carvalho, 2010).

5.5.4 Model 3: Timber boundaries, trees in subdivision fences and scattered trees

This model contemplates the inclusion of the three chosen species, the boundaries and the subdivision fences formed by Ipê amarelo (395 trees) and Angico Branco (395 trees), while the scattered trees complements contemplates the use of Ipê branco (480 trees) in a reason of 30 trees/ ha, a thinning of 25% is contemplated at the 8^{th} year of the cycle.

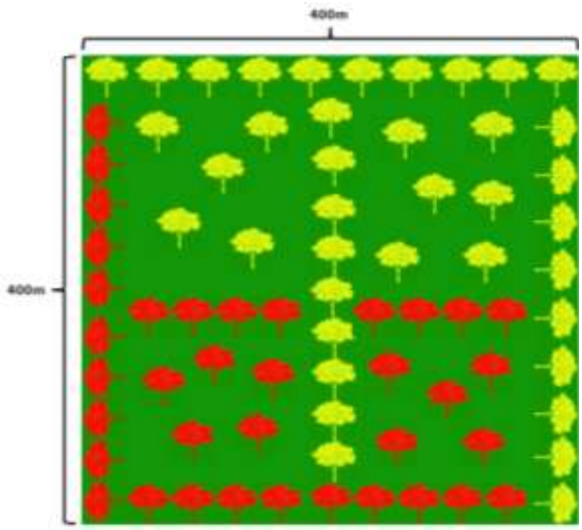

Figure 34. Timber boundaries with scattered trees design average farm.

The lumber wood estimated for this model at the 15^{th} year is 358 m^3 of Ipê amarelo, and 146 m^3 of Angico branco, the estimated production of lumber wood for the scattered trees complement using Ipê branco is 436 m^3.

5.5.5 Model 4: Scattered trees

The design of this fourth model, contemplates the inclusion of scattered trees inside the farms, in a random arrangement, for this design, is considered 30 trees/ ha, with a total of 480 trees, the specie proposed for this model is Ipê amarelo, the use of wire, staples and stack for the farm boundaries and the subdivision fences is considered.

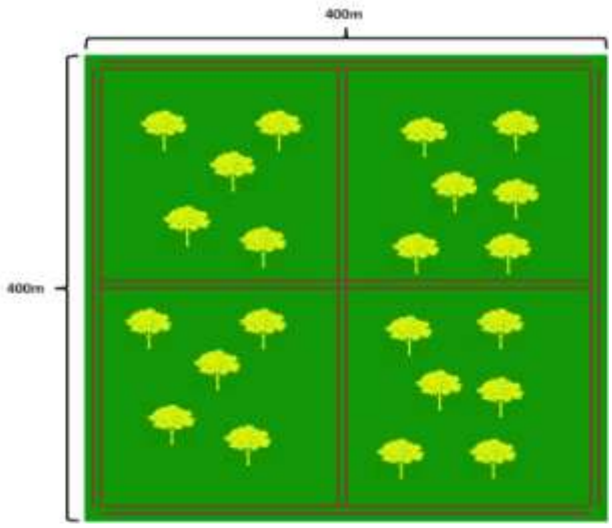

Figure 35. Scattered trees design.

The expected production of lumber wood of this model, including a thinning of 25% at the 15th year, will be of 435 m^3.

5.6 Economic analysis

5.6.1 Cash flow analysis

The technical coefficients matrix of the current cattle production system are shown in Table 15, the main activities and expenses identified for cattle production in the research area are: inputs dedicated to herd feeding, herd vaccination and deworming, fence maintenance and hand labor for pastureland and animal management.

Table 15. Technical coefficients for cattle production in Cachoeiras de Macacu.

Feeding				
Concept	**Quantity (kg/day/animal)**	**Period (days)**	**No. animals**	**Total (kg)**
Common salt	0.06	365.00	28.00	197.52
Mineral salt	0.08	365.00	28.00	302.32
Vaccination				
Vaccine	**Dosage per year**		**No. animals**	**Total doses**
Foot-and-mouth disease (5 ml)	2.00		28.00	56.00
Rabies (2 ml)	1.00		28.00	26.00
Brucellosis (2 ml)	1.00		14.00	14.00
Deworming				
Product	**Dosage per year (ml/animal)**		**No. animals**	**Total dosage (ml)**
Ecto-endo parasites	16.00		28.00	448.00

Fence maintenance			
Element	**Quantity (rolls, kg and units) / year/ha**	**Hectares**	**Total**
Wire	0.53	16.00	8.48
Staple	0.66	16.00	10.58
Stake	0.77	16.00	12.27
Hand labour			
Activity: Pastureland management, animal management, fence maintenance, vaccination, deworming			Journey/activity/year
Permanent, temporary			240
Technical assistence			0

The costs structure for cattle production is shown in Table 16, the expenses of fence maintenance (22.5%) and hand labor (65.6 %) represent the highest expenses in the cattle production.

Table 16. Average costs structure for cattle production per year in Cachoeiras de Macacu.

Costs for cattle production per year in Cachoeiras de Macacu			
Feeding			
Concept	**Quantity**	**Unit price (R $)**	**Total (R $)**
Common salt (25 kg)	8	15	120
Mineral salt (30 kg)	10	46	460
Vaccination			
Foot-and-mouth (disease) (ml)	56	1.8	100.8
Rabies (ml)	28	0.7	19.6
Brucellosis (ml)	14	2.5	35
Deworming			
Ecto-endo parasites (50 ml)	9	27	243
Fence maintenance			
Wire (Roll)	13.0	104	1352
Staple (Kg)	12.0	8.7	104.4
Stake (Dozen)	3.0	135	405
Hand labour			
Permanent, temporary (journey)	240	20	4800
Technical assistence (journey)	0	0	0
		Total	**7639.8**

1 R = 0.632 Dollars (April, 2012).

The cash flow constructed for the current cattle production system it is shown in Annex 2, for a fifteen years cycle; the establishment cost of the four proposed silvopastoral models (timber boundaries, timber boundaries and subdivision fences, timber boundaries subdivision fences and scattered trees and scattered trees) are shown in Table 17.

The total implementation and management costs are $14, 347.00 (Model 1), $16,690.3 (Model 2), $21,046.7 (Model 3) and $14,396 (Model 4); Model 3 total costs are the highest, due to the higher quantity of planted trees; the cultural treatments represent the highest expenses in the implementation of the Model, this is related to the acquisition of inputs for the phytosanitary control and tree fertilization and required hand labor for cultural treatments.

The implementation costs of the proposed silvopastoral models show an average increase of 217% compared with the current costs of cattle production in Cachoeiras de Macacu.

Table 17. Implementation costs of four different silvopastoral models in Cachoeiras de Macacu.

Phase / Activities	Costs (R $)			
	Model 1 (1600 m)[14]	**Model 2 (2400 m)**	**Model 3 (2400 m & 480 trees)**	**Model 4 (480 trees)**
Soil preparation				
Hand labor and inputs	2,400.0	2400	2400	2400
Subtotal	2,400.0	2,400.0	2,400.0	2,400.0
Seedlings				
Seedlings	399.6	649.4	937.4	288
Transport	166.5	270.6	390.6	120
Subtotal	566.1	919.9	1,328.0	408.0
Plantation				
Plantation of seedlings	173.2	281.385	406.2	124.8
Replantation	34.6	56.1925	81.2	24.96
Fertilization	532.8	865.8	1249.8	384
Opening of pits	266.4	432.9	624.9	192
Internal transport	266.4	432.9	624.9	192
Inputs	399.6	649.35	937.4	288
Subtotal	1,672.9	2,718.5	3,924.4	1,205.8
Cultural treatments				
Manual mowing	139.9	227.2725	328.1	100.8
Coverage fertilization	73.3	119.0475	171.8	52.8
Phytosanitary control	40.0	64.935	93.7	28.8
Pruning	1,040.0	1690	2730	1040
Thinning	1,040.0	1690	2730	1040
Chemical Mowing	133.2	216.45	312.5	96

[14] Linear meters for the perimeter of the farms.

Inputs	532.8	865.8	1249.8	384
Subtotal	2,999.1	4,873.5	7,615.9	2,742.4
Tree management				
Subtotal	7,638.1	10,911.9	15,268.3	6,756.2
Animal management				
Animal/ Pastureland management	6708.9	5778.4	5778.4	7639.8
Total	14,347.0	16,690.3	21,046.7	14,396.0

1 R = 0.632 Dollars (April, 2012).

The receipt coming from the sales of calves, fuel-wood and timber for the evaluated periods are shown in Table 18.

The total receipt of Model 3 is the highest when compared with the others systems, the higher income coming from the sale of timber (R $147751.35), the sale of fuel-wood (R$ 1,695.75) and the sale of calves (R$ 9,152).

Table 18. Gross income per year of the five evaluated scenarios.

Model	Concept	Income (R$)	Total income (R$)
Current system	Sale of calves	9152	9152
	Timber & Fuelwood	0	
1	Sale of calves	9152	62737.7
	Timber & Fuelwood	53585.7	
2	Sale of calves	9152	89530.55
	Timber & Fuelwood	80378.55	
3	Sale of calves	9152	156903.35
	Timber & Fuelwood	147751.35	
4	Sale of calves	9152	77964.8
	Timber & Fuelwood	68812.8	

1 R = 0.632 Dollars (April, 2012).

The cash flow for the silvopastoral models proposed and the current cattle production are shown in Table 19, Model 3 (Timber boundaries, subdivision fences and scattered trees) represent the highest net cash flow (150,756.1) for the fifteen year of cycle, the complete cash flows for the models can be consulted in the annexes.

Table 19. Cash flow for the five evaluated scenarios[15].

Phase / Activities	Current system	Model 1	Model 2	Model 3	Model 4
Costs (R $)					
Soil preparation					
Hand labor and inputs	0.0	2,400.0	2400	2400	2400
Subtotal	**0.0**	**2,400.0**	**2,400.0**	**2,400.0**	**2,400.0**
Seedlings					
Seedlings	0.0	399.6	649.4	937.4	288
Transport	0.0	166.5	270.6	390.6	120
Subtotal	**0.0**	**566.1**	**919.9**	**1,328.0**	**408.0**
Plantation					
Plantation of seedlings	0.0	266.4	281.385	406.2	124.8
Replantation	0.0	33.3	56.1925	81.2	24.96
Fertilization	0.0	219.8	2597.4	3749.4	1152
Opening of pits	0.0	266.4	432.9	624.9	192
Internal transport	0.0	166.5	432.9	624.9	192
Inputs	0.0	799.2	1948.05	2812.2	864
Subtotal	**0.0**	**1,751.5**	**5,748.8**	**8,298.8**	**2,549.8**
Cultural treatments					
Manual mowing	0.0	2,097.9	3409.0875	4921.5	1512
Coverage fertilization	0.0	219.8	357.1425	515.4	158.4
Phytosanitary control	0.0	119.9	194.805	281.1	86.4
Pruning	0.0	4,160.0	8450	13650	4160
Thinning	0.0	1,040.0	3380	5460	1040
Chemical Mowing	0.0	1,998.0	3246.75	4687.5	1440
Inputs	0.0	2,664.0	4329	6057	1920
Subtotal	**0.0**	**12,299.6**	**23,366.8**	**35,572.5**	**10,316.8**
Tree management	**0.0**				
Subtotal	**0.0**	**17,017.2**	**32,435.5**	**47,599.3**	**15,674.6**
Animal management					
Animal/ Pastureland management	114,597.0	**100633.5**	86676	86676	114597
Total costs	**114,597.0**	**117,650.7**	**119,111.5**	**134,275.3**	**130,271.6**
Receipts (R $)					
Sale of calves	146432	137280	137280	137280	128128
Fuelwood	0	1130.5	3990	1695.75	1440
Timber	0	52455.2	78682.8	146055.6	67372.8
Subtotal	146432	190865.7	219952.8	285031.35	196940.8
Net cash flow	***31,835.0***	***73,215.0***	***100,841.3***	***150,756.1***	***66,669.2***

1 R = 0.632 Dollars (April, 2012).

15 For a fifteen years period.

For Models 2 and 4, the first two years of the fifteen years cycle present negative cash flows ($R-7538.30, R$ -1325.1) and (R$ -12, 316, R$ -862.20) respectively, for Model 3 four years present negative cash flow due to the increases in inputs and required hand labor, Model 2 presents a negative cash flow on the first year of the cycle (R$ 2,647.50).

5.6.2 Economic indicators analysis

The estimated economic indicators NPV, IRR and B/C Ratio for the five evaluated scenarios are shown in Table 20.

The highest value of NPV correspond to Model 3 (Timber trees, subdivision fences and scattered trees) with a value R$ 6,588.89, this means that income benefits from the implementation of the silvopastoral model in the 15th overpass the costs of animal / tree management ,therefore the economic profitability of this system is the highest when compared with the current system and the proposed silvopastoral models; the analysis of the obtained values of NPV shows that the four proposed silvopastoral models are economically feasible because the decision rule met the criteria (NPV ≥ 0) the NPV values are higher than 0.

The investment in the proposed silvopastoral models have a capital recovery period of fifteen years.

Table 20. Economic indicators for the evaluated systems.

Economic Indicator	Current system	Model 1	Model 2	Model 3	Model 4
Initial investment ($R)	-	14,347.0	16,690.3	21,046.7	14,396.0
Lumber ($R)	0	52455.2	78682.8	146055.6	67372.8
Fuelwood ($ R)	0	1130.5	3990	1695.75	1440
Calves ($ R)	9152	9152	9152	9152	9152
Net cash flow	31,835.0	73,215.0	100,841.3	150,756.1	66,669.2
NPV ($ R)	587.46	3415.74	4110.87	6588.89	3460.35
IRR (%)[16]	12%	37%	20%	16%	24%
B/C Ratio	1.09	1.48	1.56	1.81	1.45

1 R = 0.632 Dollars (April, 2012).

[16] 8.9%

The analysis of the IRR shows that the five evaluated scenarios are economically feasible, all calculated values of IRR are higher when compared with the used discount rate (8.9%) fulfilling the rule of decision (IRR ≥ d) therefore the invested money gives an average annual profitability of 24.4% with a discount rate of 8.9%.

The cost/ benefit analysis shows that the five evaluated scenarios are economically feasible, all values are higher than 0; the return of the initial investment is on the 15th year of the cycle, which shows the profitability of every real invested on the models, in this sense the value of the benefit/cost ratio of Model 3, presents the highest value (1.81), this means that for every Real invested R$ 0.81 are obtained as profit.

This economic analysis shows the financial feasibility of the implementation of four different silvopastoral models in Cachoeiras de Macacu.

CHAPTER 6. DISCUSSION

6.1 Cattle production in Cachoeiras de Macacu

The cattle production oriented to breeding in Cachoeiras de Macacu is conducted mostly as a secondary activity (67%) and is a production system with a very low technological level, these limitations are translated in the low productivity and profitability of these systems, representing a net income of 94.5 R$ / ha/ year, with such characteristics as is necessary to improve the system.

The low management, the lack of practices to recover or restore degraded pasturelands and inadequate species are the main attributes of pasturelands in Cachoeiras de Macacu.

The low animal yield is related to the lack of genetic management and to the mestiço nature of the herd, the weight of sale of calves (120 kg) is very low when compared with other regions of Brazil like in Minas Gerais where the average weight is 210 kg, a fact that implies a lower income to the system.

The inputs of the system are mainly dedicated to sanitary control, fence maintenance and feeding of the herd.

Average cattle breeding results (28 animals in 16 ha of surface) in this research show similar results with those obtained by (Marques da Silva, Abreu de Carvalho, Alves Sousa, & Ávila Nieto, 2010) in Pará Brasil, where in a 17 hectares of pastureland area, the herd is composed by 26 animals, the profitability of cattle production in this area is also very low and has several constraints to obtain enough income to sustain the household economy and to invest in the productive activities.

Similar results were found by (Barreiro, 2009), in Teresópolis, Brazil, were 75% of the surveyed farmers carried out cattle breeding as a secondary activity, in the same study it was found that the revenues from cattle breeding were in the range of R$100 to R$ 150 per hectare per year, results not far from those obtained in this research (R$ 94.5), concluding that cattle production systems in the research area are a very low profit productive activity.

6.2 Native tree species in pasturelands of Cachoeiras de Macacu

The thirty five native tree species prioritized in this research represent just a sample of the wide variety of uses and available species in the research area.

In a similar study (Rosa Cruz, Detlefsen, Ibrahim, de Camino, & Galloway, 2010) found 63 species from 17 different families in 35 five farms, the most representative families were Fabaceae, Myrtaceae y Sapotaceae, a higher number compared with the value obtained in this research (35 species), however the most representative families were similar, Fabaceae, Myrtaceae and Mimosaceae were the most represented in this research.

A higher number of species was found by (Scheelje, Ibrahim, Detlefsen, Pomareda, & Sepúlveda, 2011) 57 sampled farms, 42 different tree species were found in pasturelands of Esparza, Costa Rica.

In a study carried out by (Plata Prada, 2012), 38 species and 22 families of trees in pasturelands of Costa Rica, most of them timber and fodder trees, similar result to the obtained in this research.

(Perez Sánchez, 2006) reported for a similar study, 153 tree species in pasturelands, the most common species: (*Quercus* sp.), (*Guazuma ulmifolia*), (*Lonchocarpus minimiflorus*), (*Pinus* sp), (*Byrsonima crassifolia*), (*Schizolobium parahyba*), (*Cedrela odorata*), (*Gliricidia sepium*), (*Leucaena trichandra*) and (*Perymenium grande*), for this research the most common species were: sapucaia (*Lecythis pisonis*), carrapeta (*Guarea guidonia*), cambará (*Gochnatia polymorpha*), quaresmeira (*Tibouchina sellowiana*), Ipê amarelo (*Tabebuia alba*) and garapa (*Apuleia leiocarpa*), the predominance of this species can be attributed to the preference of the farmers for this species due to their uses, all of them are result from natural regeneration, they provide fuelwood for farms, self consumption and shelter for cattle.

The most common uses of native tree species in pasturelands in Cachoeiras de Macacu are: provision of shelter (48%), furnishing of fuelwood (60%), supply of food (37 %) and supply of timber (37%), higher values were found in a similar study by (Perez Sánchez, 2006), where the 90% of the species were used to obtain fuelwood and 33% to obtain timber.

The results of this research showed that cattle producers are aware of the benefits that trees can provide and this is the reason of the presence of this trees in pasturelands (mostly product of the natural regeneration): provision of shelter for animal welfare and provision of fuel-wood, fruits and remedies for farm self consumption; on the other hand farmers manifested a reluctance to include larger amounts of trees in pastureland because they might reduce the productivity of the pasture, the perception about inclusion of silvopastoral systems is a negative reaction in terms of increasing the number of trees in the pasturelands; those whom in a hypothetical case of implementing more trees in their pasturelands show a positive reaction, expressed an interest on having timber species that could provide an extra income besides the cattle production.

6.3 Economic feasibility of silvopastoral systems with native tree species in Cachoeiras de Macacu

All evaluated silvopastoral models were economically feasible in a higher or lower lever, and each one of them could be recommended to be implemented in Cachoeiras de Macacu.

The most feasible system analyzing NPV and B/C is model 3, compared with the current production system and the other evaluated silvopastoral models, this is caused by the larger quantity of planted trees resulted in an increased amount of sold lumber wood.

When compared with the current cattle production system, the four evaluated models show a higher performance in terms of their economic feasibility; these results could be used as tools of decision making for the research area.

In a similar study in Costa Rica (Rosa Cruz, Detlefsen, Ibrahim, de Camino, & Galloway, 2010), the results of an economical evaluation of scattered trees in farms >25 ha of surface showed a NPV of R$ 439.02/ ha, higher value compared with the average NPV obtained in this research R$ 274.22/ ha, the values of the B/C were of 0.98 for the current cattle production system and 1.12 with a silvopastoral system implemented, in both studies the NPV and B/C ratio values showed the economic feasibility of the implementation of silvopastoral systems in cattle production farms.

(Scheelje, Ibrahim, Detlefsen, Pomareda, & Sepúlveda, 2011), reported the economic feasibility of silvopastoral systems in Costa Rica, obtaining a NPV of R$ 2, 653.50, lower value compared with the obtained in this research, even though profitable compared with the current cattle production system, is it important to notice that the capital recovery period for the mentioned study starts on at the firsts years of the silvopastoral system implementation, different situation for the proposed models, where the capital recovery starts only at the 15th year of implementation.

The negative cash flow of the silvopastoral models in the first years of the evaluated period and the capital recovery period or payback of the investment (the payback starts at the 15th year of the silvopastoral models establishment) could represent a barrier in the adoption of these systems, it is important to include the implementation of silvopastoral systems in credit programs that could diminish these negative cash flows, in this sense, there is a financing program[17] from Brazilian Government, that has a financial line destined to the implementation of agroforestry projects, could be interesting to explore the details of this program and how the silvopastoral systems could be included in its benefits.

6.3 Economic feasibility of *Eucalyptus* spp in silvopastoral systems

Is important to make a comparison of the results obtained on this research with those that evaluated economically *Eucalyptus* spp as the timber component of silvopastoral systems in Brazil, because is the most used tree species in silvopastoral systems in Brazil (Radomsky & Ribaski, 2009).

Eucalyptus is the exotic tree species with the highest commercial importance in Brazil, intended to the production of pulp and paper, charcoal, essential oils, fibers and sheets pellets, firewood, timber and furniture (Dubé, 1999), due to the intrinsic characteristics of

[17] Pronaf Floresta http://www.bcb.gov.br/?PRONAFFAQ#14

the species: exotic, fast growth, easy adaptation to different environment and high production (Obregón Sánchez & Restrepo, 2006).

The implementation and management costs of a silvopastoral system using *Eucalyptus* spp are lower when compared with the costs of the evaluated models on this research, in an economic evaluation made in Minas Gerais, Brazil (Dias Müller, et al., 2011), the implementation costs for a period of 10 years were of R$ 1079.10/ ha, the average implementation costs for the evaluated systems were R$6,267. 79.

In an economic analysis made for a silvopastoral system planted with *Eucalyptus* spp and milk production in Minas Gerais Brazil (Silva do Vale, Lopes da Silva, Garcia, de Carvaloh Almeida, & Lani, 2004), it was found a NPV value of R$ 16, 302.50 for a fifteen year period and a discount rate of 8%, a higher value when compared with the NPV values for the evaluated model in this research (R$ 3,415.74, $R4, 110.87 $R 6, 588.89 and $R 3460.35).

In relation with the IRR, previous researches also show lower values for silvopastoral systems with *Eucalyptus* spp., (de Souza Nogueira, Angelo, Joaquim Santos, de Souza Nogueira, & Belknap, 2012) determined a 24% for the IRR in a twelve year cycle.

In this sense, further research could be oriented on identifying the pros-cons of the inclusion of *Eucalyptus* spp. as the timber component in silvopastoral systems in the research area.

CHAPTER 7. CONCLUSIONS

- Cattle production in Cachoeiras de Macacu is an activity with a low level of profitability, generally carried out by the farmers as a secondary activity.

- A diverse amount of native tree species is available in the pasturelands of Cachoeiras de Macacu, 35 native species were found encompassing a wide variety of uses: timber, fuel wood, medicinal, feeding of wildlife, soil protection, fodder, provision of shelter etc.

- The most common use of native tree species in pasturelands of Cachoeiras de Macacu is to obtain fuelwood, followed by provision of shelter for the herd, obtaining of alimentary products and obtaining of timber.

- Cattle producers in Cachoeiras de Macacu show a negative disposition of implementing silvopastoral systems in their properties, because the incorporation of trees might cause a loss of pasture productivity due to the excess of shadowing and area occupied by the trees.

- Analyzed economic indicators: NPV, IRR, B/C Ratio were higher in all the silvopastoral models evaluated compared with the current cattle production system; Model 3 represents the highest financial benefits.

- According to the evaluated economic analysis made for this research, the four proposed silvopastoral models (timber boundaries + cattle breeding, timber boundaries and subdivision fences + cattle breeding, timber boundaries, subdivision fences and scattered trees + cattle breeding and scattered trees + cattle breeding) are economically feasible and represent a highly profitable alternative to the current cattle production.

- It must be considered the assessment of *Eucalyptus* spp for its inclusion in silvopastoral systems in the research area, considering not only the economic aspects but the social and environmental aspects, implementing *Eucalyptus* spp mixed with native species could be a feasible alternative for the proposed silvopastoral models on the firsts stages of the cycle, because it will generate profits earlier and the capital recovery period could be shorter, fact that could be more attractive for cattle producers.

- The four evaluated silvopastoral models are recommended for Cachoeiras de Macacu and they could represent an improvement in the economic and environmental welfare of the research area.

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ANNEXES

Annex 1. Questionnaire characterization of cattle production systems

Questionário geral para clasificação dos produtores pecuários

Localização_____________________________

Área___________________________________

Coordenadas Geográficas_________________

Altitude________________________________

Caracterização geral

1.1 Nome ____

1.2 Em relação a sua propriedade rural, o Senhor :____

Mora

Mora e trabalha

Trabalha

Outro_____________________

1.3 Como é a sua forma de trabalho?____

Meeiro

Arrendatario

Parceiro

Diarista

Assalariado

Proprietário

Outra____________________

1.4 Que atividades produtivas sào as que voçe realiça na sua propiedade?

Agricultura

Pecuaria (gado leite)

Pecuaria (gado carne)

Pecuaria (duplo proposito)

Florestal

Outras___________________

1.5 Que tipo de atividades generam renda na sua propiedade?____________________________________

1.6 Qual é a renda anual obtida na atividade pecuaría?____

1.7 Alguém da moradia recibe outros beneficios de governo?_____________________________________

Assistência governo

Bolsas (aposentadouria)

Outras_________________

1.8 Recebe assesoria tecnica____

1.8.1 Se sim de quem?____

1.8.2 Costos?____

1.9 Quantas pessoas trabalham e/ou obtém renda fora do lote?___________________________________

1.10 Número lotes na propiedade?____

1.11 Onde localiça-se sua propriedade?

Topo de morro

Encosta

Baixada

Preparo do solo e manejo

2.1 Cómo é o preparo de solo? ____

Arado manual

Arado com maquinário

Não faz

Outro____________________

2.1.1 No caso de ser mecanizado, qual é o tipo? ____

2.2 Na sua produção pratica a queima da mata no preparo de área para lavoura/ pastagem?____

2.3 Como faz o controle do mato?____

Veneno (herbicida)

Rotação do culturas

Não faz

Outro______________________

2.3.1 O controle do mato depende do tipo de mato?_____________________________________

2.3.2 Se sim qual e o tipo do mato/tipo do controle?_____________________________________

2.4 Tem cultura de capim e/ou forrageiras?____

2.4.1 Se sim quales?____

2.5 Tem pastagems melhorados na sua propiedade?____

2.5.1 Se sim quales?____

2.6 Tem mata ou capoeira na sua propiedade?____

2.6.1 Sabe quanto tempo tem a mata ou capoeira?_______________________________________

2.6.2 Se deixa o gado entrar nas áreas de mata/capoeira?_________________________________

2.7 Faz alguma das seguientes practicas?____

Plantio em nivel

Terraças

Rotação de culturas/pastagems

Recuperação de pastagem

Outra______________________

Criação de animais

3.1 Qual é o tipo de criação? ____

Gado leite

Gado carne

Criação

Outros

3.1.1 Número de animais aproximado por atividade? _____________________

3.2 Qual é a raça dos animaís?____

3.3 Insumos de atividade pecuária

Atividade	Insumos	Unidade	Quantidade	Dose	Quantidade /ha	R$ Unidade	Custo/ha	Custo Total
Manutenção de cercas	Arame							
	Grampos							
	Postes							
Vacinação	Aftosa							
	Raiva							
	Bruceloses							
	Outras							
Desparasitação	Vermifugaçao							
	Carrapaticida							
Alimentação	Sal comum							
	Sal mineral							
	Silagem capim							
	Capim picado							
	Pastagem melhorada							
Vitaminas	A							
	B2							
	D							
	E							
	Outras							
Fertilização	Adubo							
	Uréia							
Manejo Pastagem	Sementes							
	Herbicida							

3.4 Mão de obra de atividade pecuaria

Atividade	Mão de Obra		En que meses trabalha	Freqüência	Jornais/ano	R$/ano
	Permanente (Familiar)	Temporários				
Manutenção de cercas						
Manutenção de currais						
Manutenção de maquinário						
Manutenção pastagem						
Aplicação de herbicidas						
Aplicação de adubo						
Manejo de animais						
Corte de capim						
Administração						

3.5 Renda de atividade pecuária

Unidade	Quantidade de animais principio ano	Quantidade de animais comprados	Preço de compra do animai vivo	Quantidade de animais sacrificados	Quantidade de animais vendidos	Preço de venta de animai vivo
Vaca						
Touro						
Bezerro						
Bezerra						
Novilho/a						
Boi Gordo						
Total						

Sistemas Silvipastoris

4.1 Conhece os sistemas silvipastoris (SSP), ou seja, árvores plantadas juntos as pastagens?____

4.1.1 Se sim quales?

Murões vivos

Bancos de forragem

Plantacões com pastagem

Cultivos em aldeias

Outros____

4.2 Aplicam algumo na sua propriedade?____

4.2.1 Se sim qual?____

4.3 Ten árvores nas áreas de pastagem?____

4.3.1 Por que?

____
____
____

4.4 Conhece os nomes e usos das arvores?____

Árvore/Criterio	**Nome vulgar**
Madera	
Ornamental	
Sombra	
Melífera y fonte de alimento para fauna silvestre	
Consumo humano (medicinal, alimenticia e outros)	
Presente em sistemas agroflorestais	
Heliófila	
Higrófita	
Cresce em caminhos	
Xerófita	
Crescimento rápido	
Espécie nitrificadora	
Para recuperacão de zonas degradadas	
Incidência nas propriedades	
Condiões da árvore (Buena ou mala)	
TOTAL	

4.5 Gostaria de implementar SSP na sua propiedade?____

4.5.1 Se sim com que fim?

____

4.5.2 Se não porque?

____

Annex 2. Cash flow of the current cattle production system

Phase / Activities	Cost (1 Ha)	Cost (16 Ha)	Year														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Feeding																	
Common salt (25 kg)	7.5	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0
Mineral salt (30 kg)	28.8	460.0	460.0	460.0	460.0	460.0	460.0	460.0	460.0	460.0	460.0	460.0	460.0	460.0	460.0	460.0	460.0
Subtotal	36.3	580.0	580.0	580.0	580.0	580.0	580.0	580.0	580.0	580.0	580.0	580.0	580.0	580.0	580.0	580.0	580.0
Vaccination																	
Foot-and-mouth (disease) (ml)	6.3	100.8	100.8	100.8	100.8	100.8	100.8	100.8	100.8	100.8	100.8	100.8	100.8	100.8	100.8	100.8	100.8
Rabies (ml)	1.2	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6
Brucellosis (ml)	2.2	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
Subtotal	9.7	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4
Deworming																	
Ecto-endo parasites (50 ml)	15.2	243.0	243.0	243.0	243.0	243.0	243.0	243.0	243.0	243.0	243.0	243.0	243.0	243.0	243.0	243.0	243.0
Subtotal	15.2	243.0	243.0	243.0	243.0	243.0	243.0	243.0	243.0	243.0	243.0	243.0	243.0	243.0	243.0	243.0	243.0
Fence maintenance																	
Wire (Roll)	84.5	1352.0	1352.0	1352.0	1352.0	1352.0	1352.0	1352.0	1352.0	1352.0	1352.0	1352.0	1352.0	1352.0	1352.0	1352.0	1352.0
Staple (Kg)	6.5	104.4	104.4	104.4	104.4	104.4	104.4	104.4	104.4	104.4	104.4	104.4	104.4	104.4	104.4	104.4	104.4
Stake (Dozen)	25.3	405.0	405.0	405.0	405.0	405.0	405.0	405.0	405.0	405.0	405.0	405.0	405.0	405.0	405.0	405.0	405.0
Subtotal	116.3	1861.4	1861.4	1861.4	1861.4	1861.4	1861.4	1861.4	1861.4	1861.4	1861.4	1861.4	1861.4	1861.4	1861.4	1861.4	1861.4
Hand labour																	
Permanent, temporary (journey)	300.0	4800.0	4800.0	4800.0	4800.0	4800.0	4800.0	4800.0	4800.0	4800.0	4800.0	4800.0	4800.0	4800.0	4800.0	4800.0	4800.0
Technical assistence (journey)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	**300.0**	**4800.0**	**4800.0**	**4800.0**	**4800.0**	**4800.0**	**4800.0**	**4800.0**	**4800.0**	**4800.0**	**4800.0**	**4800.0**	**4800.0**	**4800.0**	**4800.0**	**4800.0**	**4800.0**
Total costs	**477.5**	**7639.8**	**7639.8**	**7639.8**	**7639.8**	**7639.8**	**7639.8**	**7639.8**	**7639.8**	**7639.8**	**7639.8**	**7639.8**	**7639.8**	**7639.8**	**7639.8**	**7639.8**	**7639.8**
Revenues																	
Sale of calves	572.0	9152	9152	9152	9152	9152	9152	9152	9152	9152	9152	9152	9152	9152	9152	9152	9152

Total revenues	**572.0**	**9152**	**9152.0**	**9152.0**	**9152.0**	**9152.0**	**9152.0**	**9152.0**	**9152.0**	**9152.0**	**9152.0**	**9152.0**	**9152.0**	**9152.0**	**9152.0**	**9152.0**	**9152.0**
Net cash flow	**94.5**	**1512.2**	**1512.2**	**1512.2**	**1512.2**	**1512.2**	**1512.2**	**1512.2**	**1512.2**	**1512.2**	**1512.2**	**1512.2**	**1512.2**	**1512.2**	**1512.2**	**1512.2**	**1512.2**

Annex 3. Cash flow implementation of timber boundaries system.

Phase / Activities	**Cost (100 m)***	**Cost (1600 m)****	**Year**														
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Soil preparation																	
Hand labor and inputs	150.0	2,400.0	2,400.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	**150.0**	**2,400.0**	**2,400.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Seedlings																	
Seedlings	25.0	399.6	399.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transport	10.4	166.5	166.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	**35.4**	**566.1**	566.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plantation																	
Plantation of seedlings	10.8	173.2	266.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Replantation	2.2	34.6	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fertilization	33.3	532.8	73.3	73.3	73.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Opening of pits	16.7	266.4	266.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Internal transport	16.7	266.4	166.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Inputs	25.0	399.6	399.6	399.6	399.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	**104.6**	**1,672.9**	**1,205.4**	**472.9**	**472.9**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Cultural treatments																	
Manual mowing	8,74	139.9	139.9	139.9	139.9	139.9	139.9	139.9	139.9	139.9	139.9	139.9	139.9	139.9	139.9	139.9	139.9
Coverage fertilization	4.6	73.3	73.3	73.3	73.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Phytosanitary control	2.5	40.0	40.0	40.0	40.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pruning	65.0	1,040.0	0.0	1,040.0	0.0	0.0	0.0	1,040.0	0.0	0.0	0.0	1,040.0	0.0		0.0	1,040.0	0.0
Thinning	65.0	1,040.0	0.0	0.0	0.0	0.0	0.0	0.0		1,040.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chemical Mowing	8.3	133.2	133.2	133.2	133.2	133.2	133.2	133.2	133.2	133.2	133.2	133.2	133.2	133.2	133.2	133.2	133.2
Inputs	33.3	532.8	532.8	532.8	532.8	532.8	0.0	266.4	0.0	266.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	**178.7**	**2,999.1**	919.1	1,959.1	919.1	805.9	273.1	1,579.5	273.1	1,579.5	273.1	1,313.1	273.1	273.1	273.1	1,313.1	273.1
Tree management																	
Subtotal	**468.6**	**7,638.1**	**5,090.6**	**2,431.9**	**1,391.9**	**805.9**	**273.1**	**1,579.5**	**273.1**	**1,579.5**	**273.1**	**1,313.1**	**273.1**	**273.1**	**273.1**	**1,313.1**	**273.1**
Animal management																	
Animal/ Pasture management	**419.3**	**6708.9**	**6708.9**	**6708.9**	**6708.9**	**6708.9**	**6708.9**	**6708.9**	**6708.9**	**6708.9**	**6708.9**	**6708.9**	**6708.9**	**6708.9**	**6708.9**	**6708.9**	**6708.9**
Subtotal	**887.9**	**14,347.0**	**11,799.5**	**9,140.8**	**8,100.8**	**7,514.8**	**6,982.0**	**8,288.4**	**6,982.0**	**8,288.4**	**6,982.0**	**8,022.0**	**6,982.0**	**6,982.0**	**6,982.0**	**8,022.0**	**6,982.0**
Revenues																	
Sale of calves	572.0	9152	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0
Fuelwood/Stacks	70.7	1,130.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,130.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Timber	3,278.5	52455.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52,455.2
Subtotal	3,921.1	62,737.7	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	10,282.5	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	61,607.2
Net cash flow	**3,033.2**	**48,390.7**	**-2,647.5**	**11.2**	**1,051.2**	**1,637.2**	**2,170.0**	**863.6**	**2,170.0**	**1,994.1**	**2,170.0**	**1,130.0**	**2,170.0**	**2,170.0**	**2,170.0**	**1,130.0**	**54,625.2**

Annex 4. Cash flow implementation of timber boundaries and subdivision fences

Phase / Activities	**Cost (2400 m)**	**Year**														
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Soil preparation																
Hand labor and inputs	2,400.0	2,400.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Subtotal	**2,400.0**	**2,400.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Seedlings																
Seedlings	649.4	649.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transport	270.6	270.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	**919.9**	919.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plantation																
Plantation of seedlings	281.4	281.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Replantation	56.2	56.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fertilization	865.8	865.8	865.8	865.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Opening of pits	432.9	432.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Internal transport	432.9	432.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Inputs	649.4	649.4	649.4	649.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	**2,718.5**	**2,718.5**	**1,515.2**	**1,515.2**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Cultural treatments																
Manual mowing	227.3	227.3	227.3	227.3	227.3	227.3	227.3	227.3	227.3	227.3	227.3	227.3	227.3	227.3	227.3	227.3
Coverage fertilization	119.0	119.0	119.0	119.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phytosanitary control	64.9	64.9	64.9	64.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pruning	1,690.0	1,690.0	1,690.0	0.0	0.0	0.0	1,690.0	0.0	0.0	0.0	1,690.0	0.0		0.0	1,690.0	0.0
Thinning	1,690.0	1,690.0	0.0	0.0	0.0	0.0	0.0		1,690.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chemical Mowing	216.5	216.5	216.5	216.5	216.5	216.5	216.5	216.5	216.5	216.5	216.5	216.5	216.5	216.5	216.5	216.5
Inputs	865.8	865.8	865.8	865.8	865.8	0.0	432.9	0.0	432.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	**4,873.5**	4,873.5	3,183.5	1,493.5	1,309.5	443.7	2,566.6	443.7	2,566.6	443.7	2,133.7	443.7	443.7	443.7	2,133.7	443.7
Tree management																
Subtotal	**10,911.9**	**10,911.9**	**4,698.7**	**3,008.7**	**1,309.5**	**443.7**	**2,566.6**	**443.7**	**2,566.6**	**443.7**	**2,133.7**	**443.7**	**443.7**	**443.7**	**2,133.7**	**443.7**
Animal management																
Animal/ Pastureland management	5,778.4	5,778.4	5,778.4	5,778.4	5,778.4	5,778.4	5,778.4	5,778.4	5,778.4	5,778.4	5,778.4	5,778.4	5,778.4	5,778.4	5,778.4	5,778.4
Subtotal	**16,690.3**	**16,690.3**	**10,477.1**	**8,787.1**	**7,087.9**	**6,222.1**	**8,345.0**	**6,222.1**	**8,345.0**	**6,222.1**	**7,912.1**	**6,222.1**	**6,222.1**	**6,222.1**	**7,912.1**	**6,222.1**

Revenues																
Sale of calves	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0
Fuelwood/Stacks	3,990.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3,990.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Timber	78,682.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	78,682.8
Sutotal	91,824.8	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	13,142.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	87,834.8
Net cash flow	**75,134.5**	**-7,538.3**	**-1,325.1**	**364.9**	**2,064.1**	**2,929.9**	**807.0**	**2,929.9**	**4,797.0**	**2,929.9**	**1,239.9**	**2,929.9**	**2,929.9**	**2,929.9**	**1,239.9**	**81,612.7**

Annex 5. Cash flow implementation of timber boundaries, subdivision fences and scattered trees.

Phase / Activities	2400 m & 480 trees	Year														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Soil preparation																
Hand labor and inputs	2,400.0	2,400.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	**2,400.0**	**2,400.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Seedlings																
Seedlings	937.4	937.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transport	390.6	390.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	**1,328.0**	1,328.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plantation																
Plantation of seedlings	406.2	406.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Replantation	81.2	81.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fertilization	1,249.8	1,249.8	1,249.8	1,249.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Opening of pits	624.9	624.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Internal transport	624.9	624.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Inputs	937.4	937.4	937.4	937.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	**3,924.4**	**3,924.4**	**2,187.2**	**2,187.2**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Cultural treatments																

Manual mowing	328.1	328.1	328.1	328.1	328.1	328.1	328.1	328.1	328.1	328.1	328.1	328.1	328.1	328.1	328.1	328.1
Coverage fertilization	171.8	171.8	171.8	171.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phytosanitary control	93.7	93.7	93.7	93.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pruning	2,730.0	2,730.0	2,730.0	0.0	0.0	0.0	2,730.0	0.0	0.0	0.0	2,730.0	0.0		0.0	2,730.0	0.0
Thinning	2,730.0	2,730.0	0.0	0.0	0.0	0.0	0.0		2,730.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chemical Mowing	312.5	312.5	312.5	312.5	312.5	312.5	312.5	312.5	312.5	312.5	312.5	312.5	312.5	312.5	312.5	312.5
Inputs	1,249.8	1,249.8	1,249.8	1,249.8	1,249.8	0.0	624.9	0.0	432.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	**7,615.9**	7,615.9	4,885.9	2,155.9	1,890.4	640.6	3,995.5	640.6	3,803.5	640.6	3,370.6	640.6	640.6	640.6	3,370.6	640.6
Tree management																
Subtotal	**15,268.3**	**15,268.3**	**7,073.1**	**4,343.1**	**1,890.4**	**640.6**	**3,995.5**	**640.6**	**3,803.5**	**640.6**	**3,370.6**	**640.6**	**640.6**	**640.6**	**3,370.6**	**640.6**
Animal management																
Animal/ Pastureland management	5,778.4	5,778.4	5,778.4	5,778.4	5,778.4	5,778.4	5,778.4	5,778.4	5,778.4	5,778.4	5,778.4	5,778.4	5,778.4	5,778.4	5,778.4	5,778.4
Subtotal	**21,046.7**	**21,046.7**	**12,851.5**	**10,121.5**	**7,668.8**	**6,419.0**	**9,773.9**	**6,419.0**	**9,581.9**	**6,419.0**	**9,149.0**	**6,419.0**	**6,419.0**	**6,419.0**	**9,149.0**	**6,419.0**
Revenues																
Sale of calves	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0
Fuelwood/Stacks	1695.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1695.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Timber	146055.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	146055.6
Sutotal	156,903.4	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	10,847.8	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	155,207.6
Net cash flow	**135,856.7**	**-11,894.7**	**-3,699.5**	**-969.5**	**1,483.2**	**2,733.0**	**-621.9**	**2,733.0**	**1,265.9**	**2,733.0**	**3.0**	**2,733.0**	**2,733.0**	**2,733.0**	**3.0**	**148,788.6**

Annex 6. Cash flow implementation of scattered trees

Phase / Activities	**Cost (480 trees)**	**Year**														
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Soil preparation																
Hand labor and inputs	2,400.0	2,400.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Subtotal	**2,400.0**	**2,400.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Seedlings																
Seedlings	288.0	288.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transport	120.0	120.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	**408.0**	408.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plantation																
Plantation of seedlings	124.8	124.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Replantation	25.0	25.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fertilization	384.0	384.0	384.0	384.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Opening of pits	192.0	192.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Internal transport	192.0	192.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Inputs	288.0	288.0	288.0	288.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	**1,205.8**	**1,205.8**	**672.0**	**672.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Cultural treatments																
Manual mowing	100.8	100.8	100.8	100.8	100.8	100.8	100.8	100.8	100.8	100.8	100.8	100.8	100.8	100.8	100.8	100.8
Coverage fertilization	52.8	52.8	52.8	52.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phytosanitary control	28.8	28.8	28.8	28.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pruning	1,040.0	0.0	1,040.0	0.0	0.0	0.0	1,040.0	0.0	0.0	0.0	1,040.0	0.0		0.0	1,040.0	0.0
Thinning	1,040.0	0.0	0.0	0.0	0.0	0.0	0.0		1,040.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chemical Mowing	96.0	96.0	96.0	96.0	96.0	96.0	96.0	96.0	96.0	96.0	96.0	96.0	96.0	96.0	96.0	96.0
Inputs	384.0	384.0	384.0	384.0	384.0	0.0	192.0	0.0	192.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	**2,742.4**	662.4	1,702.4	662.4	580.8	196.8	1,428.8	196.8	1,428.8	196.8	1,236.8	196.8	196.8	196.8	1,236.8	196.8
Tree management																
Subtotal	**6,756.2**	**4,676.2**	**2,374.4**	**1,334.4**	**580.8**	**196.8**	**1,428.8**	**196.8**	**1,428.8**	**196.8**	**1,236.8**	**196.8**	**196.8**	**196.8**	**1,236.8**	**196.8**
Animal management																
Animal/ Pastureland management	7,639.8	7,639.8	7,639.8	7,639.8	7,639.8	7,639.8	7,639.8	7,639.8	7,639.8	7,639.8	7,639.8	7,639.8	7,639.8	7,639.8	7,639.8	7,639.8

Subtotal	**14,396.0**	**12,316.0**	**10,014.2**	**8,974.2**	**8,220.6**	**7,836.6**	**9,068.6**	**7,836.6**	**9,068.6**	**7,836.6**	**8,876.6**	**7,836.6**	**7,836.6**	**7,836.6**	**8,876.6**	**7,836.6**
Revenues																
Sale of calves	9152	0.0	9152	9152	9152	9152	9152	9152	9152	9152	9152	9152	9152	9152	9152	9152
Fuelwood/Stacks	1,440.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,440.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Timber	52,635.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	67,372.8
Subtotal	63,227.0	0.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	10,592.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	9,152.0	76,524.8
Net cash flow	**48,831.0**	**-12,316.0**	**-862.2**	**177.8**	**931.4**	**1,315.4**	**83.4**	**1,315.4**	**1,523.4**	**1,315.4**	**275.4**	**1,315.4**	**1,315.4**	**1,315.4**	**275.4**	**68,688.2**