Academic year 2018-2019

COST, BENEFITS, RISK AND UNCERTAINTY IN THE IMPLEMENTATION OF A SILVOPASTORAL SYSTEM CONSIDERING CLIMATE CHANGE IMPACTS IN THE PETÉN REGION, GUATEMALA

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Thesis submitted in partial fulfilment of the requirements for the joint academic degree of International Master of Science in Rural Development from Ghent University (Belgium), Agrocampus Ouest (France), Humboldt University of Berlin (Germany), Slovak University of Agriculture in Nitra (Slovakia), University of Pisa (Italy) and University of Córdoba (Spain) in collaboration with Can Tho University (Vietnam), China Agricultural University (China), Escuela Superior Politécnica del Litoral (Ecuador), Nanjing Agricultural University (China), University of Agricultural Science Bengaluru (India), University of Pretoria (South-Africa) and University of Arkansas (United States of America)

This thesis was elaborated and defended at Ghent University within the framework of the European Erasmus Mundus Joint Master Degree “International Master of Science in Rural Development " (Course N° 2015 - 1700 / 001 - 001)

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Acknowledgement

I would like to thank to my promoter Professor Speelman for his expert advice and co-promoter Dr. Raes for his extraordinary support in this process. The comments and suggestions given by Stijn Speelman and Leander Raes were not only helpful for my thesis, but also for my professional career. I appreciate their guidance, comments, and correction to improve the content of my thesis; without their positive encouragement, it would not have been possible to successfully finish my master dissertation.

This master dissertation would have not been possible without the admission to the master program from the IMRD consortium and the financial support of the VLIR-OUS scholarship that allowed me to accomplish one of my life goals. I appreciate the University of Gent, the University of Cordoba and the University of Can Tho where I spent two years acquiring new knowledge and skill to be able to succeed in my professional and personal life. Also, I want to thanks the professors and Ph.D. students for their teachings and helpful advice that allow me to finish the master's program.

I extend my thanks to my IMRD colleagues whom I share this master's program for two years. The unique experience shared in this master's program with people from different backgrounds was a rewarding process for me. A special thanks to Seonhwa Lee for her companionship and support for these two years.

Moreover, I dedicate my master thesis to my parents Martha Gutiérrez and Rodolfo Munguía, who gave me their unconditional love and support to achieve everything that I have done. A special dedication to my grandparents Ruperto Munguía and Bertilda Hernández that always encouraged me to never stop studying and accomplish every goal in my life. I also want to thank my brother Juan Pablo and my family Darling, Briseida, María de Jesús for their support. Also, I want to thank my friends Braynell, Edvin, Francisco, Jonathan, Ronald, Scarlet and Wilfredo who have been always there for me.

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Acronym

AR4	Fourth Assessment Report
CBA	Cost-Benefit Analysis
EbA	Ecosystem based Adaptation
ES	Ecosystem Services
FAO	Food and Agriculture Organization of the United Nations
FLR	Forest Landscape Restoration
GDP	Gross Domestic Product
INBA	Guatemala National Forest Institute
IUCN	International Union for Conservation of Nature
MAGA	Guatemala Ministry of Agriculture, livestock and Food
Masl	Meter above sea level
MNRPG	Mesa Nacional de Restauración del Paisaje Forestal de Guatemala
NPV	Net Present Value
OECD	Organization for Economic Co-operation and Development
PES	Payment for Ecosystem Services
PROBOSQUE	Promotion for the Establishment, Recovery, Restoration, Management and, Production of forests
SPS	Silvopastoral system

Abstract

Latin American countries, particularly Guatemala, are highly vulnerable to climate change. The increase in the temperature and variation of precipitation will have a significant effect on livestock production, hence the livelihoods of rural families are going to be affected. An alternative to adapt to the impacts of climate change is the adoption of silvopastoral systems (SPS). SPS provides ecosystem services that are beneficial to the cattle and livelihoods of rural families. Despite this, SPS is not widely implemented in Guatemala. To overcome the lack of implementation of SPS, the government of Guatemala, through the PROBOSQUE program has tried to increase the implementation of SPS. One of the actions of the program is to give monetary incentives to livestock producers to implement SPS. However, it is not clear how climate change could potentially affect the implementation of SPS in Guatemala. This study provides a comparison of the profitability of a traditional system and SPS considering the climate change impacts.

The study first calculates the profitability, using Cost-Benefit Analysis (CBA), to compare the impact of implementing a SPS in the Region of Petén in Guatemala considering a no-climate change scenario. Also, the profitability of a SPS in the PROBOSQUE program to assess the impact on the implementation. Second, a stochastic approach was implemented in the CBA models, using the Monte Carlo simulation, to include the risk and uncertainty of climate change. The results show that under a no-change scenario, a SPS is more profitable than a traditional system. However, once risk and uncertainty are considered, the profitability of a traditional system and SPS can be the same even when the monetary incentives of PROBOSQUE are considered. Offering payment for the environmental services created by the SPS may be a better way to increase the impact of the PROBOSQUE program, thus increasing the implementation of SPS in the Petén region in Guatemala.

Keywords: Climate change • Cost Benefit Analysis • Stochastic • Profitability • Implementation • Silvopastoral system • Guatemala

1. Introduction

1.1. Context

Livestock production in Latin America has become an important part of the livelihoods of rural families. According to FAO (2014) 64.5% of the agricultural population in Latin America has livestock production and it represents 46% of the regional agricultural Gross Domestic Product. Although livestock production in Latin America is one of the main drivers of the economic development of the region; livestock production is going to be affected by climate change.

In the last decade, significant trends of increasing temperature and variability in precipitation have been observed in Central and South America (Magrin et al., 2014). The increase in temperature produces heat stress on the livestock, affecting the productivity of the cattle (Nardone et al., 2010). The decrease in the productivity of livestock production is going to affect the livelihoods of rural families that depend on it, and therefore, the economic development of Latin America.

In Latin American, Guatemala is considered one of the most risk and vulnerable countries in the region towards climate change. The global risk index of the organization German Watch put Guatemala at the ninth place of countries most affected by extreme weather events between 1996-2015 (Kreft et al., 2017). The ND-Gain country index summarizes the country's vulnerability towards climate change , puts Guatemala in the position 111 out of 181 (ND-GAIN, 2017).

The extreme weather events and the change in weather conditions are going to affect livestock production in Guatemala. Livestock production in Guatemala is characterized for low productivity, extensive production system and it does not consider elements for environmental conservation (MAGA, 2012). Furthermore, livestock production has been displaced to environmental fragile zones, such as the department of Petén. As a consequences, there is an advance of the agricultural frontier and deforestation in the northern part of Guatemala (Segeplan, 2013).

The impacts of climate change on livestock production will have detrimental effects on the livelihoods of rural families. For this reason, it is an important to adopt practices that can reduce or enable rural families to adapt to change in weather conditions. At the same time, it is important also to reduce other negative impacts of the livestock extensive production system that affects the environment in a negative way.

1.2. Problem statement

Climate change will bring negative impacts to the livestock sector in Latin America and one of the solutions to reduce/mitigate these negative effects is the adoption of agroforestry practices in cattle system production. This type of system is called a silvopastoral system. The benefits from this system have already been demonstrated, including how the adoption of the system can help farmers to adapt to the negative impacts of climate change (Montagnini et al., 2015, Chapter 12; Murgueitio et al., 2014).

However, the impacts of climate change on livestock production can also affect the performance of silvopastoral systems due to the increase in the variability of weather conditions. With the uncertainty of climate change, it is unclear if the adoption of silvopastoral systems will remain profitable. Therefore, it is important to reduce the uncertainty in the adoption of agroforestry practices to become a viable option towards climate change.

The adoption of silvopastoral system has been use to increase the adoption of agroforestry practices in livestock production system. The implementation of incentives schemes, such as Payments for Ecosystem Services (PES), has been successful to incentivize farmers to adopt silvopastoral systems (Garbach et al., 2012; Pagiola et al., 2016; Pagiola et al., 2010). A PES scheme consists in a voluntary transaction between service users and service providers, that agree in conditional natural resource management, to generate offsite services (Wunder, 2015). This mean that a landholder/land user can be motivated by a monetary transaction to provide an Ecosystem Service (ES) and hence is more likely to adopt a set of practices.

In order to guarantee the continuation or/and adoption of silvopastoral systems; policy makers/project managers and livestock producers need to consider the possible impacts on the profitability of the system. Even if silvopastoral systems can be more resilient compared to the traditional systems, this does not mean that they are not going to be affected by climate change. Thereby affecting the adoption of silvopastoral practices if they do not continue to be a viable (profitable) option for farmers to adapt to climate change.

Therefore, there is a need to understand how climate change can affect the profitability of a traditional livestock versus a silvopastoral system. Incentives schemes can have an impact on the profitability of silvopastoral system by reducing the implementation cost. Therefore, it is important to assess how incentives schemes will impact the profitability of silvopastoral system in the context of the risk and uncertainty that climate change will bring in the coming years.

1.3. Research question

- What is the impact in the profitability, expressed as Net Present Value (NPV), of adopting a silvopastoral system versus continuing a traditional system?
- What is the impact of the PROBOSQUE program on the adoption of silvopastoral system?

1.3.1. Specific questions

- What is the NPV of traditional and silvopastoral system in Guatemala in a no change scenario?
- What is the impact of climate change on the traditional and silvopastoral systems?
- What is the impact of the Probosque incentives on the NPV of implementing a silvopastoral system including the impact of climate change, and how does this compare no change scenario?

1.4. Importance/significance of the study

The effects of climate change on the livestock production sector have been widely discussed in the literature (Nardone et al., 2010; Rojas-Downing et al., 2017; Thornton et al., 2009). And an alternative to adapt to climate change is silvopastoral systems, however, the silvopastoral system is not widely adopted in Guatemala (MAGA, 2012). Research in quantifying the impact that climate change will have in the livestock systems is limited (IPCC, 2018). Therefore, the importance of knowing if the higher risk, implementation costs or other factors limit the implementation of SPS and if the monetary incentives can contribute to overcome these limitations.

Recently there have been studies that quantify the impacts of climate change on the profitability of the agricultural sector in Guatemala (CEPAL et al., 2018; Sain et al., 2017). However, these studies focus on the impacts on agricultural activities and not on the livestock system. Therefore, this study will focus on first obtaining the profitability of the traditional system and silvopastoral system in the region of Petén in Guatemala and second Monte Carlo simulation will be apply to the CBA models to calculate the density distribution of the NPV and compare which systems (traditional, SPS or SPS with PROBOSQUE) has a higher profitability with the uncertainty and risk of climate change.

2. Literature review

2.1. Impact of climate change on livestock production

The impacts of climate change on livestock can be classified in the following categories: heat stress, water stress, livestock and vector diseases, feed intake. All these categories are related to the increase in temperature and its effects on livestock and on the inputs of the livestock production system (Nardone et al., 2010; Rojas-Downing et al., 2017; Thornton et al., 2009).

One of the mayor effects of an increase in temperature for the cattle is heat stress. Thornton et al. (2009) in their review of impacts of climate change on livestock mention that an increase in temperature and humidity can lead to heat stress for cattle, triggering a process called acclimation. This process triggers metabolic changes such as a reduction of feed intake, which means less energy. This in turn results in weight loss hence a reduction of milk and meat production is expected (Nardone et al. 2010).

In Latin America the recent trends in climate conditions show a significant increase in temperature between +1.6° C to +4° C and a decrease or increase in the precipitation by the year 2100 (Magrin et al., 2014). For the case of Guatemala, the projection of temperature increase is between 1° and 2° C by 2050 (CEPAL et al., 2018). This will create a problem for the livestock sector in Guatemala since the cattle will be exposed to much higher temperatures, thus triggering the acclimation process.

As mentioned before heat stress on cattle is one of the reasons for a decrease in production of milk and beef. For the scenario of an increase in temperature and precipitation, the AR4 predicts a decrease in the productivity of beef and dairy cattle between 0.9 and 3.2% (Magrin et al., 2014). The decrease in the productivity means a decrease in the profitability of the livestock production thus affecting the livelihoods of rural families that depends on livestock production.

The increase in temperature is not only going to affect the productivity of the livestock sector through heat stress, but in addition, it will also increase cattle mortality. Baylis and Githeko (2006) mention that climate change may affect diseases in cattle in five different forms: effects on pathogens, on the host, on vectors, on the epidemiology and indirect effects. The increase in temperature will lead to an increased rate in the development of pathogens in the categories previously mentioned. This causes the cattle to have lower resistance to new pathogens and higher transmission rates of diseases, hence the health of the cattle and their productivity will be affected, and in the worst case, the mortality rate will increase.

Howden et al. (2008) found that an increase in temperature between one and five degrees Celsius might induce high mortality in cattle production. At the same time, high temperatures may compromise the reproductive efficiency of farm animals of both sexes and hence negatively affect milk and meat production (Nardone et al. 2010). Having a lower reproductive efficiency results in a lower number of calves born, this will lead to a reduction of the herd on the farm hence a reduction of the profitability of the system.

There are other impacts of climate change on the livestock sector that need to be considered, however these impacts are not easy to measure because they affect the sector in an indirect way. For example the use of water for the livestock sector does not only include the direct usage of water in the system, but also the water used for feeding the crops, processing, etc. (Thornton et al. 2009).

Although, the use of water of livestock production is difficult to measure, methods that calculate the direct and indirect use of water exist. Life cycle assessment is use to evaluate the environmental impacts of a product along their production chain (Finkbeiner et al., 2010). This approach include the evaluation of the water footprint of the production and consumption of a product (Hoekstra, 2017). However, the calculation of this method is focused on an entire system and not in the use of a single farm or unit of production.

2.2. Impact of livestock on climate change

As has been discussed, livestock can be affected by an increase in temperature through heat stress. Furthermore, these impacts can become worse, as the current livestock production systems also contribute to the greenhouse gas (GHG) emissions. The contribution of the global livestock sector to the annual anthropogenic GHG is 14.5% (IPCC, 2007). The main source of this GHG within the livestock sector comes from the fodder production, transportation and land-use change for pasture or feed (Gerber et al., 2013).

Land-use change is one the main drivers of deforestation in tropical forest such as those in Guatemala. The reason for land-use change can be divided in two categories: direct and underlying causes. The direct causes are related with monetary incentives, where the combination of the timber and later the production of agricultural goods makes that the forest has more value cut down than standing (Lawlor et al, 2009). The underlying causes are linked with drivers related to an increase (or decrease) in the activity (e.g. food production) of the reduction of the forest.

Cattle production is vulnerable to changes in temperature and precipitation, and thus climate change is going to have an impact on the cattle production system. At the same time, cattle production contributes to climate change through the emision of GHG. To be able to adapt to climate change and simultaneously reduce the impact of livestock on climate change one of the alternatives is through Ecosystem-based Adaptation.

2.3. Forest Landscape Restoration as Ecosystem based Adaptation

Ecosystem-based Adaptation (EbA) is defined by Convention of Biodiversity (2009) as: *"the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change"*. The strategies used in the EbA aim to manage, conserve and/or restore of ecosystems, in order to maintain and increase the resilience and adapt to the effects of climate change. According to Noble et al., (2014) EbA are becoming an integral approach for adaptation to climate change.

A more concise definition is given by Vignola et al. (2015, p. 128):

"*EbA is defined in agricultural systems as agricultural management practices which use or take advantages of biodiversity or ecosystem services or processes (either at the plot, farm, or landscape level) to help increase the ability of crops or livestock to adapt to climate change and variability".*

Based on these definitions there is a different set of actions to implement EbA according to the aim and the scale of the different types of actions. These actions can include sustainable water management, disaster risk reduction, sustainable management of grasslands and rangelands, establishment of diverse agricultural systems, strategic management of forest and establishing and effectively managing protected area systems (Colls et al., 2009).

EbA can be cost-effective strategies (Convention on Biodiversity, 2009) for climate change despite relatively high cost as compare to conservation of intact ecosystems. Moreover, EbA are accessible options for small-scale households since they bring benefits such as diversifying income, provision of ES and reduction of GHG emissions (Rojas-Downing et al., 2017; Vignola et al., 2015).

It is important to restore the functionality of the landscapes affected by livestock production and using biodiversity and ES. The change in the land use results in deforestation as mentioned before, therefore it is important to recover the forest to the landscape. One of the alternatives is trough Forest Landscape Restoration (FLR) as an EbA to adapt to climate change.

FLR is a long-term process with the objective of regaining ecological functionality and increasing human well-being in deforested or degraded forest landscapes (IUCN & WRI, 2014). By increasing the number of trees in the landscape it is expected to recover and provide a way to adapt to climate change and improve the livelihoods of rural families. The benefits of implementing trees in the livestock production will be shown in the next section.

2.4. Silvopastoral system as a Forest Landscape Restoration

One of the recommended alternatives to accomplish strengthening climate resilience, while decreasing emissions or increasing carbon sequestration, is through the implementation of trees in a cattle production system. The increase in the number of trees in a landscape is part of the action of FLR and can function as an EbA to climate change. The implementation of tress in a cattle production system is known as agroforestry.

An agroforestry arrangement "*uses the combination of livestock with fodder plants, shrubs and trees for the nutrition of the animal and complementary uses*" (Murgueitio et al., 2011, p. 1655). This type of livestock systems is called a silvopastoral system (SPS). Agroforestry arrangements contribute to maintain the balance between the agricultural production, environmental protection and carbon sequestration to offset greenhouse gas emission (Rojas-Downing et al., 2017).

In addition, SPSs provide environmental services such as preventing soil erosion and compaction, improved nutrient cycling and shade which help to retain soil moisture and maintaining green grasses for longer time (Hoosbeek, Remme, & Rusch, 2016). Calle et al.(2009) found that cattle benefit from a diversified diet and from the tree's shadow, as this helps to reduce heat stress and energy waste.

Moreover, the SPS present lower mortality rate from calves and cows (Ferguson et al., 2013), since through the incorporation of trees the air and soil temperatures are less extreme (Callaway & Pugnaire, 1999). It is expected that the reduction of heat stress, energy waste, lower mortality rates contribute to maintain or increase the productivity and profitability of the SPS compared to a traditional system, because it reduces the impacts of climate change on the cattle.

The SPS can have positive effect in the profitability of livestock production compare to a traditional system. Frey et al. (2012) found that the small and medium-scale farmers are likely to state a positive response about the cash flows of SPS when they adopted it. This is important due to the cash restriction that small and medium-scale farmers usually face. In contrast the large-scale farmer stated a positive response about the total returns of the SPS.

SPS can have different arrangement according to the environmental conditions of a given zone, characteristics of the farm and the producer. As an example, Cubbage et al. (2012) did a comparison of SPS in eight regions of the world. They found that in Uruguay owners of forest plantation allowed farmers to graze in the plantation to reduce the likelihood of wildfire, while the farmer obtained feed for their cattle. While in Brazil, a forest company found a way to amortize the initial establishment and maintenance cost of the plantations and provide constant cash flows by producing livestock for the first years of the plantation.

The motivation for farmers to adopt a SPS is not only based on economic incentives, but also non-economic incentives play a role in the adoption of SPS. Garen et al. (2009) found that in Panama farmers planted trees as part of their system, not only for economic reasons, because farmers considered that the inclusion of trees are an important step toward resolving environmental problems, such as increase in temperature and water shortage.

Farmers have different motivations to incorporate a practice into their systems, however it is also important to identify the limitations that farmers face to convert from traditional systems to SPS. These can be related to economic and non-economic reasons.

Shrestha (2004) found that some of these limitation are: fire hazards, uncertainty about government regulations, and the length of time for SPS to become profitable. Those were the major obstacles to the adoption of SPS. In addition, a study in the north of Argentina identified a negative perception of farmers before adopting a SPS, claiming that there would not be enough sunlight for good pasture, difficulty with the forest management, high initial capital investment and not enough financial incentives from the government (Frey et al., 2012; Ibrahim et al., 2001)

The implementation of the SPS due to financial reason is one of the important obstacles for the adoption. One of the alternatives to overcome the implementation cost of SPS are incentive type schemes, such as PES.

2.5. Incentives schemes to adopt silvopastoral systems

The idea of PES schemes is to deal with the lack of a market to internalize the environmental externalities that come with the production of commodities (Lant et al., 2008). Due to this, PES schemes have been promoted as a form to increase the adoption of SPS (Garbach et al., 2012; Van Hecken et al. 2015; Van Hecken et al., 2016).

It is important to know the different motives farmers have to participate in PES schemes, and therefore to adopt SPS. There are different studies that have investigated the motives/preferences of rural families to adopt SPS (Anfinnsen et al., 2009; Chouinard et al., 2015; Méndez-López et al., 2015; Pagiola et al., 2005; Raes et al., 2017), where they mention economic and non-economic incentives to participate or not in this type of schemes.

The economic incentives to adopt a certain conservation practices are related to the possibility of increased of benefits (Honlonkou, 2004; Lichtenberg, 2004), where a farmer decides to adopt a certain practice if the benefits increase or at least the profits do not decrease. In addition, Pagiola et al. (2005) mentions five obstacles to participate in PES: profitability of PES practice, tenure of land, amount of implementation costs, technical constrains and transaction costs. The profitability of a system can thus be an important factor for farmers to participate in PES schemes, since farmers will opt to implement PES practices that help them increase their profits.

Monetary incentives can be particular useful to incentivize farmers to adopt agroforestry practices, especially with the uncertainty that climate change will bring in the future. The additional income received from PES schemes, can help to overcome some of the barriers of participating and adopting conservation practices.

Chouinard et al. (2015) mentions that if this was true; farmers with similar characteristics (farm size, age, education, etc.) would have the same production systems. However, farm practices vary across farmers. The characteristics of the farmers such as age, education, farm size and the attitude towards environmental problems (Anfinnsen et al., 2009; Méndez-López et al., 2015; Raes et al., 2017) are non-economic motives that are important to take into account for the adoption of agroforestry practices.

3. Case Study: Petén, Guatemala.

3.1. Location

The area of focus in the study is the department of Petén, it is found in the north of Guatemala (see figure 1). Petén lies between 15°90´-17°81´north latitude and 89° 22’-91° 43´ west longitude. Petén has an area of 35,854 km2 and it is the biggest department of Guatemala. The department of Petén is important due to the biodiversity and natural resources, for this reason, the government created the Maya Biosphere Reserve that occupies 60% of the extension of Petén. The reserve is divided into four areas: core areas, cultural areas, multiple-use areas, and recovery areas.

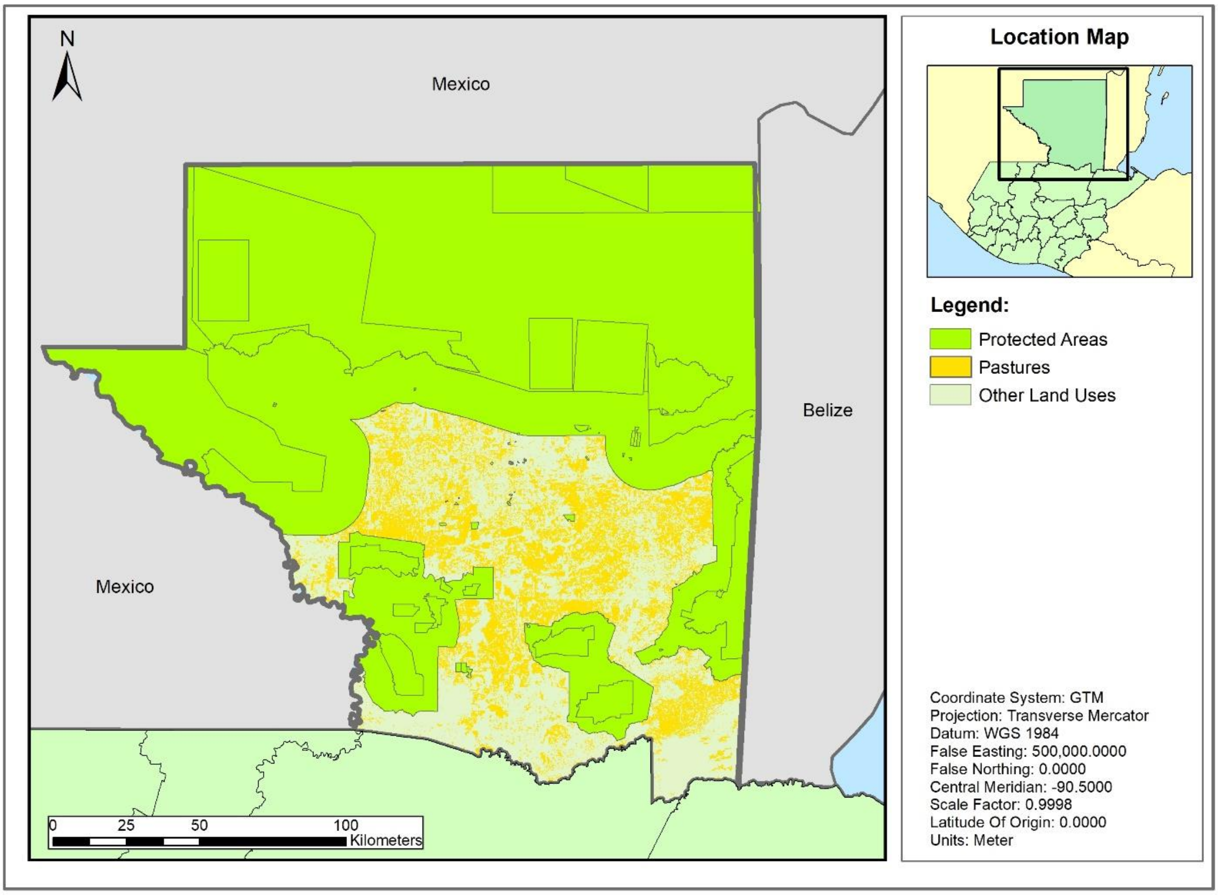

Figure 1. Location of Petén, Guatemala

Source: Elaborated by Putzeys, 2019

3.2. Agroecological conditions

The average temperature of Petén varies between 21° to 32° degrees during the year. The rainy season extends from May-June and ends in December-January, with an average annual precipitation of 2,000 mm. The average elevation of Petén is 127 meters above sea level (masl), which the department is classify as lowlands in Guatemala. According to Segeplan (2013), Petén has two live zone:

- Warm subtropical humid forest: is located in the northern part of Petén and covers 63% of the department. It has an annual temperature between 22°-27°, annual precipitation between 1160-1700 mm and the elevation range from 50 to 275 masl. The most appropriated uses are forest management and agroforestry.

- Warm humid subtropical forest: is located in the south part of Petén and covers 37% of the department. The annual precipitation is between 1587-2000 mm and the elevation ranges from 80 to 160 masl. The most appropriated uses are forest management and SPS.

3.3. Economic activities

The principal activities in Petén are agriculture, livestock and agroforestry. These three activities take 68% of the economically actives population in Petén (Segeplan, 2013). The natural condition of Petén allows a high productivity for the production of staple food (maize and beans) and is one of the main livelihoods for the farmers. In the case of the livestock production, the cattle production is increasing in the department of Petén (MAGA, 2012) . The cattle production system in Petén has a low productivity hence the production of cattle is done in an extensive way without the investment in intensification (Segeplan, 2013). For the agroforestry activities the production of timber from *Swietenia macrophilla* and *Cedrela odorata* are the main timber production, which an annual production of 40,000 m^3 (Gómez, 2008).

3.4. Cattle farming in Guatemala

For this study, the focus will be in cattle production. According to MAGA (n.d.) the typology of cattle producer farmers for milk and beef is the following:

- Farm with low level of inputs: deficient level of feed for the cattle due to the limitation of land and bad management. Also, inappropriate management of sanitary and reproductive management of the cattle.

- Semi-technical production system: they possess good infrastructure for the management of the cattle, have acceptable sanitary and reproductive management of the cattle. In addition, they possess enough area of land for an extensive system production. For farmers that focus on beef production, 75% them are categorized as semi-technical production system.

- Technical production system: These farms are specialized in the production of beef or milk; they have excellent sanitary and reproductive management. For the feed of the cattle they use improved pasture. They keep control of the inventory of cattle, income and costs of the farm.

For the purpose of the study, the semi-technical production system was used to compare the profitability of the traditional system and SPS. The reason for this is due to the high percentage of cattle farmers in this category. This will allow to have a general farmer type to compare the profitability of both systems.

Other important characteristic of the cattle production in Petén is the state of the pasture in the farms. According to Betancourt et al. (2007) in a study done in the department of Petén 70% of the pasture present moderate to severe degradation, which contribute to a reduction of available dry matter. This characteristic is important to take into account for the cattle production system, since a decrease in the reduction of feed will affect the productivity of the system, hence there will be a decrease in the profits of the system.

In the following section an overview of the traditional and SPS will be shown. The traditional systems follow the characteristic describe of semi-technical production and the SPS will incorporate agroforestry practices in the semi-technical production system. The information presented will be used to calculate the costs and benefits of each system and compare the profitability of both systems.

3.4.1. Traditional system

The overview of production factors of the traditional system can be seen in table 1. The focus of the system is on fattening calves and then sell them in the market. The farmer will buy the steer at a weight of 160 kg and raise it until the animal reaches 400 kg; then it will sell the cattle to the market.

The pasture used in the system is *Hyparrhenia rupha*, popularly known as *Jaragua* in Guatemala. This is one of the native pastures that are present in the Petén region (Lumes, 2007). This pasture is well adapted to this region, as it is resistant to fire and droughts. Based on the characteristics of the pasture (see table 2), the productivity chosen was 12,000 kg of dry matter per year.

Table 1. Production factors traditional system

	Production factors – traditional system
Inputs	• 1 hectare • 4 calves • 1,500 meters of wire • 3 pounds of staples • 150 post for the perimeter • 6 kilos of seeds of pasture • 3 doses of vitamins per animal • 4 vaccination per animal • 4 deworming per animal • 3 kg of salt per animal
Labor	• 14 days of labor to prepare the land for sowing the pasture • 3 days for the installation of the fences • 3 days of labor for purchasing the calves • 3 days for maintenance of the fences

For a complete list of sources see annex 9.2

It is important to take into account the degradation of pasture, therefore a degradation of 20% of the area of pasture was used in a period of five years (Holmann et al., 2004 found in Barcellos, 1986). After the establishment of the pasture every year there will be a four percent degradation of the pasture until fourth year, where it reaches 16% of total degradation with respect of their initial productivity. This implies a loss in the productivity of the pasture in the system of the same amount as the degradation. For the fifth year, in order to recover the productivity, the farmer will renew 20% of the pasture area in order to recover the initial productivity of the pasture (Holmann et al., 2004). This five-year cycle will continue until the end of the production of the system.

Table 2. Characteristics of pasture hyparrhenia rupha

	Altitude	Precipitation	Productivity
Hyparrhenia rupha	0 – 1,000 masl	7000 – 3,000 mm per year	12,000 – 15,000 kg of dry matter per ha

Source: INATEC (2016b) and Peters et al. (2011)

The farmer will give vitamins to each animal three times per year (INATEC, 2016a), application of vaccines for black leg and anthrax two times a year each and internal deworming which needs to be done two times a year (INATEC, 2017) and external deworming which has to be done when it is necessary however it was assume that is also two times a year. In addition, the labor for the maintenance is taken into account.

The number of cattle that the farm will manage is calculated according to the carrying capacity of the farm. The carrying capacity is calculate dividing the annual consumption of dry matter of one animal and the total dry matter production of the pasture (INATEC, 2017). In this case the traditional system will have four calves to be fattened and sold at the end of the year. In addition the mortality rate of the traditional system is five percent (Pérez et al., 2006). For a complete information of the production factors and the source see annex 9.2.

3.4.2. Silvopastoral system

The implementation of the SPS in the livestock production needs to be in line with the reduction of the negative impacts towards climate change at the same time, adapt to the variation of the weather conditions. All of this needs to be done while maintaining the profitability of the systems in order to protect the livelihoods of the rural people. For this study the production factors of the SPS are shown in table 3.

Table 3. Production factors SPS

Production factors – traditional system	
Inputs	• 1 hectare • 5 calves • 1,500 meters of wire • 100 trees of *Cedrela odorata* • 150 trees of *Gliricidia sepium* • 3 pounds of staples • 4 kilos of seeds of pasture • 3 doses of vitamins per animal • 4 vaccination per animal • 4 deworming per animal • 3 kg of salt per animal • 4.2 kg of urea per hectare • 4.2 kg of 18-46-0 per hectare
Labor	• 18 days of labor to prepare the land for sowing the pasture • 1 plow service • 4 days of labor for sowing • 6 days for the installation of the fences • 8 days of labor to apply the veterinarian inputs • 3 days of labor for purchasing the calves • 6 days of labor for maintenance of the fences • 12 days of labor for pruning the trees • 6 days of labor for control of pasture

For a complete list of sources see annex 9.2

The pasture used for this system is *brachiaria brizantha*, which is an improved pasture. *Brizantha* already has been introduced in the department of Petén (Lumes, 2007). Based on table 4, the productivity chosen for the system is 15,000 kg of dry matter per hectare per year. The reason for this is because the pasture will benefit from the environmental services that the trees in the system provide and the productivity will increase.

Table 4. Characteristic of pasture brachiaria brizantha

	Altitude	Precipitation	Productivity
Birzantha	0 – 1,800 masl	1,000 – 3,500 mm per year	8,000 – 20,000 kg of dry matter per ha

Source: INATEC (2016b) and Peters et al. (2011)

The degradation of the pasture was also taken into account in the SPS with a rate of 10% per year (Holmann et al., 2004). However, the producer in the SPS will have a better management of the pasture thus the farmer will renew the pasture at the same rate as the degradation, and therefore the productivity of the pasture is not reduced throughout the lifecycle of the system.

For the tree component in the system two types of trees were chosen based on their functionality. In table 5 the characteristics of the two trees to be implemented in the system can be seen. The timber of *Cedro* is highly valuable and is one of the main offers of forest plantation products in the region of Petén, Guatemala (Gómez, 2008). The timber from *Cedro* is mainly used in light constructions, interior decoration, boat building (covers and linings), fine furniture, etc. (INAB, 2017).

Table 5. Characteristics of trees in the SPS

	Cedrela odorata	***Gliricidia sepium (Jacq.) kunth ex Walp (family fabaceae)***
Altitude	0 – 800 masl	0 – 1,200 masl
Temperature	20° – 32° Celsius	20° and 27° Celsius
Precipitation	1,200 - 2,000 mm per year	600 – 1,500 mm per year
Function	Timber production	Fire wood, post, light construction and shadow
Number of trees in the system	100	150

Source: INAB (2017) and INAB & FAO (2016, p. 15)

It was considered that having Cedro has a timber product alongside the cattle production will benefit the profitability of the system in the long run. In order to comply with the criteria of PROBOSQUE the system will have 100 trees per ha, however according to a study the mortality rate for Cedro is 7% (Vera-castillo & Carrillo-anzures, 2008), to anticipate to this the farmer will plant in the year of implementation 107 trees in order make for the death of the trees.

The other tree to complement the system is *Gliricidia sepium (Jacq.) kunth ex Walp (family fabaceae)*, or better known in Guatemala as *Madre cacao*. The wood is used for house construction, live fences, firewood for the household and the leaves can be used as forage for the cattle and it helps restore poor and degraded soils (INAB & FAO, 2016, p. 14). In addition, the *Madre cacao* provides shadow in the system reducing heat stress among the cattle.

The carrying capacity was calculated the same as the traditional system, due to a higher availability of dry matter in the SPS the number of calves to be fattened in this system is five. The mortality rate of calves for the SPS is 3.5%[1]. The reason for this since it has been reported that in a SPS the mortality rate of calves is lower than in traditional cattle systems.

The benefits of the systems consist of the sale of the cattle at the end of each year and for the income of the timber the farmer will sell the timber after 20 years. The reason for this is because in order to obtain the benefits of the timber production in the SPS in a short period of time it needs 18 to 25 years (INAB, 2017). As a result, a period of 21 years was chosen to have an in-between point to compare the profitability of both systems. For a complete information of the production factors and the source see annex 9.2.

3.5. Incentives for FRL in Guatemala – PROBOSQUE

The government of Guatemala, through the law for the Promotion for the Establishment, Recovery, Restoration, Management and, Production of forests[2] in Guatemala is aiming to increase the forest coverage in the country. With this law the National Forestry Institute (INAB for its acronym in Spanish) established different objectives, namely: to increase the forest coverage through the establishment, restoration, management, production and protection of the forest to generate environmental services. At the same time, they intent to encourage the rural economies with public investment to create employment in the activities and services that are related to the establishment, restauration, management, production and protection of the forest (INAB, 2015).

PROBOSQUE covers the following modalities:

a) Establishment and maintenance of forest plantation for industrial use

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[1] M. Mema, research assistance in Tropical Forages Program at CIAT, personal communication, May, 5,2019

[2] In Spanish: Fomento al Establecimiento, Recuperación, Restauración, Manejo, Producción de Bosques en Guatemala.

b) Establishment and maintenance of forest plantation for the production of energy
c) Establishment and maintenance of agroforest system
d) Management of natural forest with production purposes
e) Management of natural forest for protection and provision of environmental services

The study also assesses if the PROBOSQUE program has an impact on the profitability of the SPS in Guatemala. Although there exists a wide range of SPS arrangement, the PROBOSQUE program has four specific criteria on the implementation of SPS. The criteria were established by INAB (2016) and are the following:

- Minimum Area of 0.5 hectare
- Trees establish in the perimeter should not have a distance greater than 2 m between each them
- Minimum initial density of 250 trees in SPS
- At least 20% of the trees should be timber species

To assess the second question of the study, a third system was included taking into account the criteria presented above. In addition to the criteria, the incentives received (table 6) and administrative costs (table 7) for the implementation of SPS in the PROBOSQUE program are included in this third system

Table 6. Incentives of PROBOSQUE program

Incentives Q/ha		
Year	Phase	Amount
0	Establishment	1200
1	Maintenance	500
2	Maintenance	500
3	Maintenance	500
4	Maintenance	500
5	Maintenance	800

Source: PROBOSQUE law, 2016

Table 7. Administrative cost for agroforestry system PROBOSQUE

	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Administrative Cost	Q. 328.33	Q. 590.56	Q. 488.33	Q. 440.39	Q. 434.03	Q. 434.03

Source: Velásquez (2016, p. 26)

3.6. Climate change scenarios for Guatemala

Since the uncertainty in the study is related with the climate change scenario that is going to take place in the future, it was decided to set different climate change scenarios to evaluate the impact of the climate change on the production variables of both systems. The climate change scenarios used to predict the weather conditions in Central America are A2 and B2. Bárcena et al. (2011) argue that the use of the scenarios A2 and B2, done by the IPCC, are consistent with the type of development observed in the region and they are also widely used in regional studies; therefore this allows the results to be compared with other studies.

As a result, the projections of climate change for Guatemala for the study will be taken from the document of CEPAL et al. (2018). In this document there are calculation of the future temperature and precipitation in Guatemala based on the scenarios A2 and B2. These scenarios are summarized in table 8, where the average increase in temperature and the variation of precipitation is presented for the years 2030 and 2040. The reason for selecting these two years is because they are in the same time period as the CBA. For more details on the climate change scenarios see annex 9.1.

Table 8. Increase in temperature and variation of precipitation for scenarios A2 and B2 for 2030 and 2040

Scenario A2			
Year	Reference data	2030	2040
Annual increase temperature (Celsius)	23.62	0.99	1.4
Annual variation precipitation (mm)	2676.51	-111.44	-198.5
Scenario B2			
Year	Reference data	2030	2040
Annual increase temperature (Celsius)	23.62	0.98	1.2
Annual variation precipitation (mm)	2676.51	109.79	103.4

Source: Own calculation based on CEPAL et al. (2018)

From the table, it can be seen that in scenario A2 the temperature is expected to increase with 1.4° C by 2040 according to the calculation assuming linear growth, and the precipitation is expected to be reduced with 198.5 mm by 2040 in comparison to the reference data. In the case of the scenario B2, the temperature is also expected to increase, however with a lower increment compared to the scenario A2. However, the difference in the scenario B2 comes from an expected increase of the annual precipitation for 2030 and 2040. After the selection of the climate change scenarios to be used in the survey, in the following section the description and the logic of the survey will be explained.

4. Methodology

The objective of the study is to assess and compare the variability of the profitability of a traditional system and a SPS including the impact of climate change. A CBA was first conducted based on a series of assumptions for the traditional system and SPS that will be explained in detail in the following sections. To calculate the CBA for each system first the gross benefits and cost were calculated. Second, different discount rates were used to bring future cost and benefits to net present value to compare the profitability of each system. The calculation of the present value was done for a plot of one ha and a time period of 21 years.

After obtaining the profitability of each system, Monte Carlo simulation was used in the results to include uncertainty in the calculation of the profitability of each system. Key variables such as dry matter consumption, dry matter production and mortality rates were selected based on the effect that climate change will have on them.

4.1. Cost-Benefit Analysis

Following the description of the traditional and SPS systems, the next step is to develop a deterministic model using the method of Cost Benefit Analysis (CBA) for both systems. The objective of this CBA is to obtain an estimate of the profitability of both systems, to understand which one gives – on average - higher profits to farmers. CBA has been used to evaluate the profitability or the social impact that some activities, projects, practices or investments can have. The use of the CBA is straightforward because it compares the flows of benefits and costs from different alternatives (OECD, 2018; Staehr, 2006). A third CBA also was carried out to incorporate the monetary incentives and administrative cost of the PROBOSQUE program. In the following sections, the calculation of the CBA for the two systems will be explained step by step.

4.1.1. Gross benefits

4.1.1.1. Dry matter production and annual feed intake

For the calculation of the dry matter production, the amount of production of dry matter for each system is the same as the one described in the traditional system and the SPS from the previous chapter. Also, the degradation was taken into account to calculate the final dry matter production. The annual feed intake for each cattle was calculated multiplying the daily dry matter consumption (8 kg of dry matter/day) and 365 days to obtain the annual dry matter of one cattle, thus resulting in 2,920 kg of dry matter/year.

4.1.1.2. *Meat production*

To calculate the net income of the two systems, first the gross benefits of each systems needs to be calculated. The gross benefits are obtained by adding all the benefits of a particular system. The benefits for the traditional system are calculated using the formula 1.1 and multiplying it with the price Q. 14.55[3] per kg of meat.

$$Meat\ production = \left(\frac{Daily\ Consumtion*365}{Convertion\ rate}\right)\left(\frac{Dry\ matter\ production}{Annual\ feed\ intake}\right) + \ (160 * Number\ Calves) \quad (1.1)$$

The daily consumption was calculated by multiplying the mean of the initial weight (160 kg) and the final weight (400 kg) of the cattle by three percent, which is the amount of daily dry matter consumption of the animal (FAO, n.d.). The conversion rate is the amount of dry matter that the cattle needs to eat in order to produce one kilo of meat. In this case the amount is ten kg of dry matter is equal to one kg of meat (Smil, 2002).

4.1.1.3. *Timber production*

To calculate the production of timber of the SPS, first the calculation of the increase of volume of timber from *Cedrela* was done using the formula in Gutierrez et al. (2013) and using the data from INAB (2014).

$$Volume\ increase\ per\ year = \left[\left(\frac{\pi}{4} * \ \mathrm{DBH} * H * 0.57\right) * 100\ \right] / \ 20 \qquad (1.2)$$

The DBH variables refers to the Diameter at the Breast Height of the tree and H is the Height of the tree. The number 100 is to obtain the volume of wood produced by 100 trees and the number 20 is to obtain the yearly increase in volume, assuming a linear growth.

After the calculation of the volume increase per year, the timber production for a hectare with a density of 100 trees was calculated following formula 1.3. Where 20 is the number of years of the lifecycle of the SPS. The variable 0.6 is a factor to obtain the portion of the timber that can be sold in the market (Detlefsen & Somarriba, 2012).

$$Timber\ production = Volume\ increase\ per\ year\ * 20 * 0.6 \quad (1.3)$$

[3] O. Ramirez, program Officer IUCN Guatemala Office, personal communication, June, 27,2019

It is important to mention that the trees in the system of the SPS produce fuelwood and posts for the household. There are studies showing that these play an important role in the economy of the household (Sibelet et al., 2019), however the main income from the implementation of trees comes from timber therefore only the production of timber from *Cedrela* was taken into account. The income from timber production was obtained multiplying the total volume of timber production times Q. 5,088 [4]per m^3.

4.1.2. Costs

The costs for the traditional system and SPS are divided in two main categories: implementation costs and maintenance cost, and the cost for inputs and labor are included in both categories. The implementation costs are related to activities to adopt the system (e.g. preparation of land, posts, wire, seeds, etc.) and are once time costs. The maintenance costs are required, often annually, throughout the period of 20 years.

In addition to the cost categories presented in the description of the livestock systems, for the third CBA model with the PROBOSQUE program there are administrative costs related to the implementation of SPS (see table 7), therefore these costs will be used for the calculation of the costs for the SPS with PROBOSQUE program.

4.1.3. Data sources to calculate costs and benefits

For the data used to calculate the NPV of the two systems, two main sources of information were used as input data for the CBA models: a literature review, data from program officers from the International Union for Conservation of Nature[5] (IUCN), UICN (2014) and Colomer et al. (2018) . The literature review was done using manuals related to the management of cattle, pasture and trees and personal communication with an expert of livestock production. The data related to the prices of inputs and sales prices were obtained from the program officers of IUCN's Guatemala office that have on field knowledge in Guatemala.

It should be noted that an expert in tropical cattle production system was consulted via personal communication, with the purpose of guaranteeing that the assumptions and data used for the CBA for the traditional and SPS were consistent with the environmental conditions of Petén, Guatemala. For a complete list of the variables, data and source of the information see annex 9.3.

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[4] O. Ramirez, program Officer IUCN Guatemala Office, personal communication, June, 27,2019

[5] IUCN also implements FRL programs https://www.iucn.org/news/forests/201905/restoration-opportunities-heart-drc

4.1.4. Net Present Value

The net benefits of each system are obtained using the formula 1.4. Since the benefits and cost of the systems will be generated in the future, it is expected that they have a different value for people. Individuals will normally put more value on current benefits rather than benefits in the future (Brent, 2006). The implementation of a system involves forgoing consumption in the present for future benefits. Also, the opportunity cost of investing a unit of currency is the interest rate that you can obtain if you deposit the money in the bank.

$$Net\ benefits = Gross\ benefits - Gross\ Costs \quad (1.4)$$

Due to the value of the money in the future is different from the present, there is a need to add the time discounting to the formula (1.4). The application of a discounting rate to the future benefits and costs is to bring them to present values to be comparable with the same base year to be able to know the profitability of the investment (Brent, 2006).

For this reason, the formula from 1.4 needs to be adapted to include discounting of the benefits and cost in the future. The Net Present Value (NPV) will be calculated as shown in formula 1.5. The NPV is the summation of the discounted values of net benefits for each period of time using a discount rate (Staehr, 2006). Where T represent the number of years of the investment, r represents the discount rate to be used for the calculation of the present values.

$$NPV = \sum_{T=0}^{T} \frac{(Benefits - Costs)}{(1+r)^T} \qquad (1.5)$$

Having a higher discount rate means that money in the present has a higher value compared to the money in the future. Likewise, if the discount rate is smaller, this mean that the value of the money in the present is not that high compared to the value of the money in the future.

Period of evaluation for CBA

The results of the three CBA models will be compare over a period of 21 years to compare the present value of each system and see which one has a higher profitability. This first analysis of the CBA will be conducted with a deterministic approach, meaning that the values of the model are fix. In the next section the stochastic approach is explained.

4.2. Risk and uncertainty in Cost Benefit Analysis

The deterministic model created to calculate the profitability of the systems helps to see which one produces higher income based in the three CBA proposed. However, this deterministic approach does not take into account the risks and uncertainty of the implementation of the systems due to the predicted impacts of climate change.

Risk and uncertainty are related to the possibility that the variables of the CBA can take different possible values. The principal difference between both concepts lies in knowing the probability of the different values (OECD, 2018). Both concepts deal with a form of randomness, however only risk can have a probability distribution, while uncertainty cannot. Risk comes from a process that can be repeated many times and uncertainty comes from infrequently occurring and discrete events (Staehr, 2006). For this reason if the benefits and cost of the CBA model have risks and uncertainty attached to them, the variables could take a different range of values and therefore in an ex-post situation the NPV can be lower compared to the initial calculation of CBA without considering risk and uncertainty (OECD, 2018).

To deal with the risk and uncertainty of climate change, it is necessary to adapt our deterministic approach of CBA to a stochastic approach. This means that instead of having an exact value for the variables in the CBA models, the variables of the CBA model will have a random probability distribution and then the model will take a value between that distribution to calculate the NPV. Therefore, the approach will change from a deterministic to a stochastic approach when the uncertainty and risk of climate change are taken into account.

In this study the uncertainty is related to the randomness of predicting climate change scenarios, whereas the risk is related to how the scenarios will affect the behavior of the variables in the model. Staehr (2006) argues that even though any environmental project or human activity is affected by uncertainty, this does not imply that it is practically impossible to assess the reliability of findings from the CBA and it has its usefulness.

To calculate the NPV with the inclusion of probabilities the expectation operator *E[]* is used. The expectation operator is applied to all the variables entering the calculation to find the average value expected to take from their probability distribution. For this reason, formula 1.5 needs to be adapted to include the expectation operator, and the results is show in formula 1.6:

$$E[NPV] = E_0\left[\sum_{T=0}^{T} \frac{(Benefits_t - Costs_t)}{(1+r)^t}\right] \quad (1.6)$$

The expected NPV is found by using the formula above. To be able to calculate the NPV with the inclusion of risk and uncertainty in the CBA it is necessary to attach a distribution to the variables of the model to obtain their expected value and hence obtaining the NPV. To assess the inclusion of risk and uncertainty in a CBA there are different of methods, however for this study the focus will be in two: sensitivity analysis and Monte Carlo simulation.

The two methods applied in this study will be explained in detail in the next section. The first method is a sensitivity analysis using different discount rates to assess the impact of how the profitability change for each system. The second method is using a Monte Carlo simulation on the CBA models to add distribution to certain variables to calculate the expected NPV of each system.

4.2.1. Sensitivity analysis

Sensitivity analysis allows to understand how the NPV of a system is affected by a change in a specific variable(s) in a CBA model. If there is some uncertainty about the values which important variables (i.e. discount rate) will take, then a sensitivity analysis can be applied to understand how sensitive the NPV is to the change in that parameter (OECD, 2018)

For the reason that the discount rate plays an important role in the determination the NPV, since it represents the opportunity cost of forgoing present benefits for future benefits; it is also important to decide which discount rate is appropriate to use, since having a higher discount rate means that the futures benefits and costs are considered less important than the present ones.

A recent study of the cost and benefits of eight different Climate-Smart Agricultural practices using a probabilistic CBA used a discount rate of 12% (Sain et al., 2017). In addition, a study done by Kometter (2012) used a discount rate of 12% to do an evaluation of ES in Guatemala. Other studies have used different types of discount rates in order to value the agricultural activities or the impact of climate change in Guatemala. For example, the study of the impact of climate change in Guatemala done by CEPAL et al. (2018), used a four discount rates (0.5%, 2%, 4% and 8%) to calculate the costs of the impact of climate change on natural resources and agricultural activities in terms of the gross domestic product of Guatemala. A study done by MNRPFG (2018) used a discount rate of 5%, 12% and 20%, to assess the change in the profitability of restoration actions in Guatemala.

Based on the previous studies mentioned above, it was decided to incorporate to the analysis three different discount rates: 4%, 12% and 20%. First, the three discount rates will be used to carry a sensitivity analysis on the NPV of each CBA model to assess and compare the effect on the profitability. Second, the three different discount rates were used to create a triangular distribution to assess the uncertainty of the opportunity cost in the overall results in the Monte Carlo simulation.

4.2.2. Monte Carlo Simulation

As it was mentioned before, the CBA analysis was done following a deterministic approach. The values of the variables were chosen based on specific criteria. To add risk to the calculation of the CBA, a stochastic approach needs to be taken, therefore it is necessary to attach distributions to the variables of the CBA model.

A representation of these two approaches is shown in figure 2, where it can be seen that the deterministic model uses different independent variables with a fixed value. The outcome of the deterministic CBA model is always going to be the same, unless there is a change in at least one independent variable. In the case of changing the value of a variable there will be a change in the outcome, similar to the results of changing the discount rate in the calculation as is done in sensitivity analyses (MNRPFG, 2018).

A stochastic model draws a value from a distribution attached to the variables. Then the model is run 'n' amount of times, as a result a distribution of the NPV is obtained (OECD, 2018; Staehr, 2006). This means that using this method, a distribution of the profitability or NPV of the three CBA models can be obtained with the inclusion of risk and uncertainty.

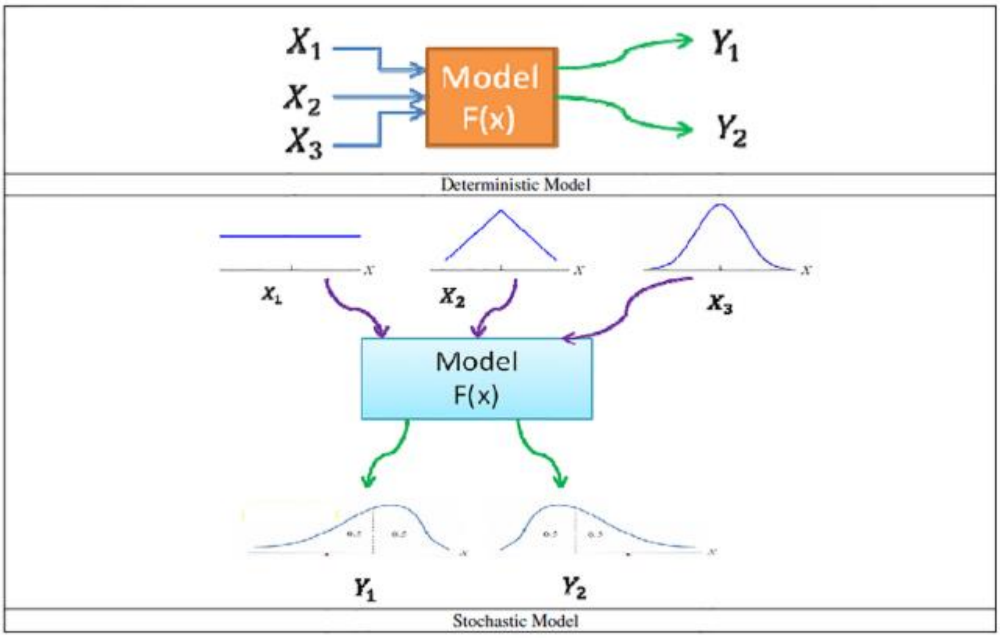

Figure 2. Deterministic and stochastic models

Taken from: Platon & Constantinescu (2014)

The stochastic models follow the principle of Monte Carlo simulation. The objective of the Monte Carlo simulation is to attach a distribution to variables in the CBA model and then simulate a large number of draws form these distributions in order to find the resulting distribution of NPV (Platon & Constantinescu, 2014; Staehr, 2006).

Monte Carlo simulations allows calculating the NPV a large number of times using different values gathered from the distribution attached to the variables. To apply the Monte Carlo simulation it is important to first select the variables that will include risk as stochastic variables, and secondly to assign a distribution to the variables in the CBA model (Amigun, Petrie, & Gorgens, 2011; USA EPA Technical Panel, 1997; Kallio, 2010).

The application of Monte Carlo simulation is suitable for analyzing results of a CBA under uncertainty or risk conditions (Neudert et al., 2018). For this reason, Monte Carlo simulations have been widely used by researchers and project management in order to assess the benefits of environmentally friendly activities, project management, research, agricultural production and risk management (Acuña, Rubilar, Cancino, Albaugh, & Maier, 2018; Mahdiyar et al., 2016; MINIRENA, 2014; Neudert et al., 2018; Ray, Hasan, & Goswami, 2018; Sain et al., 2017; Verdone & Seidl, 2016).

Selection variables for the Monte Carlo simulation

For the Monte Carlo simulation the first step is to choose variables that will be subject to risk in the calculation of the profitability of the systems. The criteria to select the variables is related to the literature review, since the variables related to the production of livestock are going to be affected by climate change, whereas is not clear how prices of inputs and outputs will be affected. The variables selected for both systems are the following:

Table 9. Key variables for traditional system and SPS

Variable	Change in conditions	Results	Source
Daily dry matter consumption for the cattle	An increase in temperature triggers heat stress	Decrease in dry matter intake	(Nardone et al., 2010; Thornton et al., 2009)
Dry matter production from pasture	Change in temperature and precipitation conditions	Change in the availability of feed	(Rojas-Downing et al., 2017)
Mortality rate of calves	An increase in temperature	Increase spread of diseases on cattle, thus mortality rate is increase	(Baylis & Githeko, 2006)

Table 10. Additional key variable for the SPS

Variable	Change in conditions	Results	
Production of timber of *Cedrela*	Change in temperature and precipitation conditions	Decrease in the timber production	(Esmail & Oelbermann, 2011; Venegas-González et al., 2018)
Mortality rate of *Cedrela* trees	Change in temperature and precipitation conditions	Increase in the mortality rate	(Vera-castillo & Carrillo-anzures, 2008)

For the Monte Carlo analysis 1,000 simulation were done for each CBA mode. The analysis was carried out in the statistical program R with the use of the package 'Monte Carlo' by Christian Hendrik Leschinski. Through this method the distribution of the profitability of each CBA model were obtained.

4.3. Survey

Once the variables have been selected, it was needed to have a reliable way to obtain a range of values or a distribution. The method for obtaining this information was through the application of an online survey. The structure of the survey was divided in three part; the first part contained the main characteristics of the two livestock system propose for this study, the second part showed the information of the climate change scenarios that were selected and described annex 9.1. Finally, the third section of the survey is where the impacts of climate change to the variables were assessed based on the information of the previous part of the survey.

The assessment for the impact of climate change was based on a lower range and a high range, since it will facilitate the estimation of the impacts compared to assessing a single value for the change. The assessment was carried out by experts on SPS, livestock production, climate change experts that have expertise in Latin America. The survey was sent to 145 experts of livestock production and/or SPS in Latin America. 27 completed the survey (40 declined, 78 did not answer). The survey was implemented using Qualtrics, the time frame for the recollection of the data was during between 17 of June and 6 of August. To see the complete survey, see annex 9.3.

4.4. Specifying the random variable distribution

The variables subject to risk and uncertainty of the traditional and SPS are shown in table 11 and table 12 respectively. The tables show the assumption of the distribution for each variable use for the stochastic approach. The distributions of the variables were chosen using a visual inspection on the distribution of the data obtained from the survey.

Four theoretical distributions were created using the mean, standard deviation, minimum and maximum of each variable. The four distribution are the normal distribution, log-normal distribution, triangular distribution, and log triangular distribution. Each one was compared to the real distribution of the data; the theoretical distribution that was more similar to the distribution from the data of the survey was the chosen one (see annex 9.4).

For the case of timber production, previous studies have used the log-normal distribution as the one that has a better fit for timber production (De Lima et al., 2017; Kayes et al., 2012; Nanang, 1998). The previous studies use the log-normal distribution due to the shape of the data, the distribution of the diameter growth of trees is positively skewed (or right-skewed distribution). The data of the production and mortality rate of timber from the survey has the same positive skewness as a log-normal distribution, therefore for the variables related to timber, the log-normal distribution was chosen.

Table 11. Assumption of distribution functions for traditional system

Variable	Year	Assumed distribution	Average and std. dev.
Consumption dry matter	2030	Normal distribution	(7.571574, 1.231574)
Consumption dry matter	2040	Log normal distribution	(1.946223,0.2049401)
Calf mortality rate	2030	Triangular distribution	(0.01, 0.055,0.1)
Calf mortality rate	2040	Log norm distribution	(-2.828026, 0.4233372)
Pasture dry matter production	2030	Normal distribution	(11100.46, 1697.091)
Pasture dry matter production	2040	Normal distribution	(10459.81, 2121.923)

Table 12. Assumption of distribution functions for SPS

Variable	Year	Assumed distribution	Average and std. dev.
Consumption dry matter	2030	Log normal distribution	(2.12611, 0.1582205)
Consumption dry matter	2040	Log normal distribution	(2.088184, 0.1767976)
Calf mortality rate	2030	Normal distribution	(0.03728846, 0.01130914)
Calf mortality rate	2040	Normal distribution	(0.038625, 0.0136696)
Pasture dry matter production	2030	Normal distribution	(14598.15, 2207.781)
Pasture dry matter production	2040	Normal distribution	(14423.15, 2428.952)
Timber production	2030	Log norm distribution	(-0.6003329, 0.2434163)
Timber production	2040	Log norm distribution	(-0.6540536, 0.1690232)
Timber mortality rate	2030	Log norm distribution	(-2.58245, 0.2369048)
Timber mortality rate	2040	Log norm distribution	(-2.548319, 0.3208663)

5. Results

5.1. Deterministic CBA

5.1.1. Cash flow model and financial analysis

In order to obtain the NPV for the three proposed models, the flows of benefits and cost of each model needs to be calculated throughout their lifecycle. This was done using the recollected data mentioned before, with the aim to observe the difference in the structure of the benefits and costs of the two systems. Some categories of costs were grouped together for easiness of presenting the results.

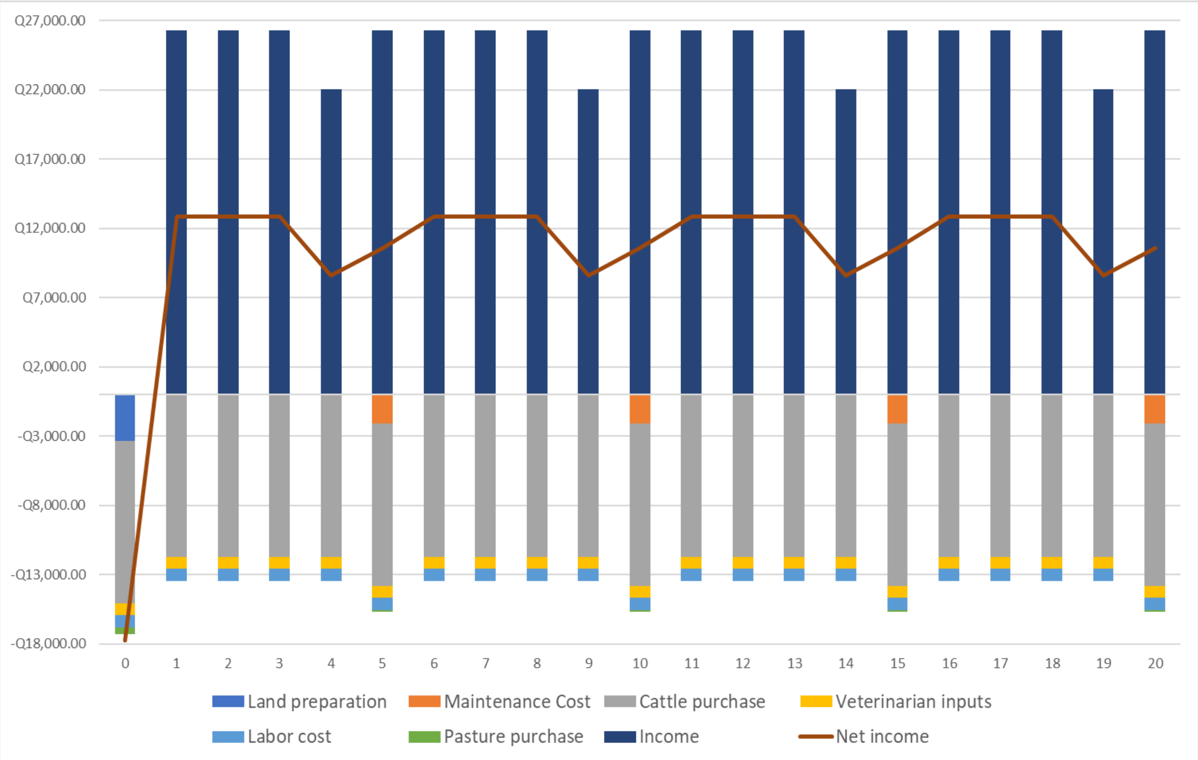

Figure 3. Financial results of traditional system in Quetzals per hectare

The first results are presented in figure 3, where the flows of benefits and costs of the traditional systems can be observed. In the Year 0 there is a higher cost due to the installation of the system therefore having an implementation cost of $2,311[6] (Q. 17,728), and since it is the first year there is no production of meat. Then it can see that the biggest part of the cost of the system is the cost of cattle, since the other inputs of the system are relatively cheap. It

[6] An exchange rate of Q. 7.6 to $1 on 21/08/2019 was used. Source: Nation Bank of Guatemala http://www.banguat.gob.gt/default.asp

can be seen that the next biggest category of expenses is the maintenance cost, which is related to the reparation of fences of the paddock. This cost only appears in a cycle of every five years.

Concerning the benefits, a trend can be seen where the income stays the same for four years $3,430 (Q. 26,306) until it drops in the fifth year $2,876 (Q. 22,057). This matches with the year were the degradation of the pasture is at the highest point in the system. As a consequence, the farmer cannot fatten the four cows in the system and will have to just fatten three thereby reducing the profitability of the system. The continued degradation of the pasture affects the system every year by four percent, reducing the availability of the feed for the cattle and after it is at the point where the system gets compromised due to not having enough feed, the farmers will decide to renew the pasture in order to recover the profitability of the system. As it was mentioned before the degradation of pasture is highly common in Guatemala and it is one of the variables that affects the productivity of the livestock systems.

For the first SPS, without the PROBOSQUE program, the results can be seen in figure 4. One of the first things that can be noticed in the figure 4, is the higher income of the SPS in comparison with the traditional system. From the first up to the nineteenth year the income is $4,287 (Q. 32,883) this is due to having one extra livestock unit in the systems. However, in the last year of the lifecycle of the project it can see an increase of the benefits by a big margin, this is due to the sale of the timber of representing $4,564 (Q. 35,004). The capacity of the system to offer more feed originates from the incorporation of the trees since they help to enhance the production of dry matter available for cattle and at the end of the life cycle the farmers can obtain benefits by selling the timber.

Another detail that is important to mention is that constant amounts of income are obtained every year. Although the SPS also includes the degradation of the pasture every year, the assumption for this system is that it has a better management, the farmer will renew the pasture every year at the same rate of the degradation, thus avoiding a decrease in the availability of feed for the cattle. This gives stability to the income in comparison to the traditional system.

Although the SPS has higher benefits than the traditional systems throughout the lifecycle, the costs of the SPS are also higher due to the incorporation of the trees and the improved pasture in the system, which increases the installation costs of the first year $3,131 (Q. 24,016) compared to the traditional system that was presented before. The cost structure of the system follows the same trend as the traditional system, where the biggest expense category is the purchase of the calves, however in contrast to the traditional systems the second biggest cost in the systems is related to the labor costs.

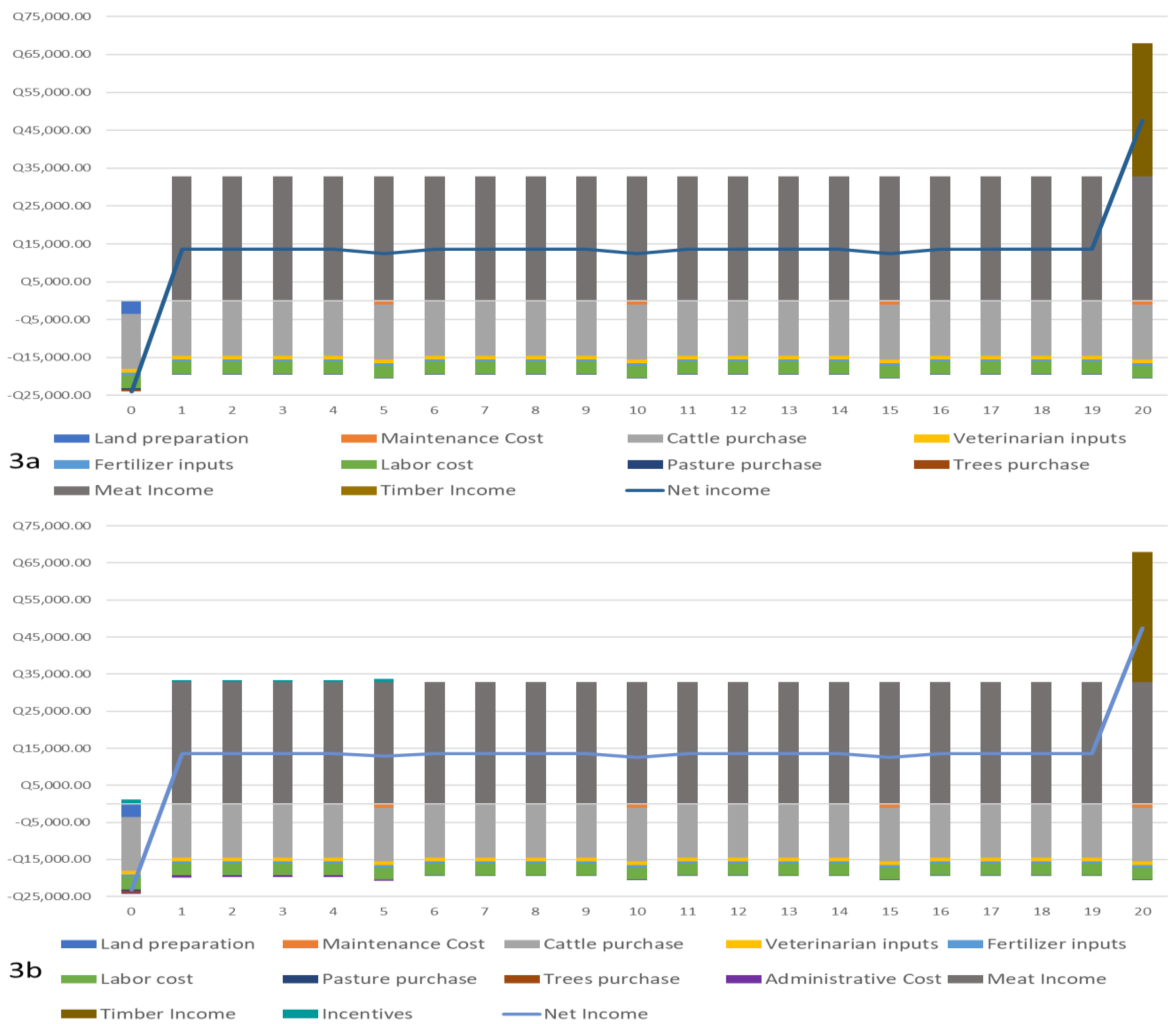

Figure 4. Financial results for SPS (3a) and SPS+PROBOSQUE (3B) in Quetzals per hectare

The higher labor costs are related to the additional activities that the farmer needs to do in the system, these activities are control of the pasture and pruning of the trees. For this reason, the SPS demands more labor to maintain the system. And since these activities are done every year the maintenance cost is reduced because the reparation of the fences does not require to change the post for the reason that the trees fulfill the function of live fences.

The last CBA model, can be seen in figure 4. It depicts the flows of benefits and costs of the SPS with the PROBOSQUE program. As explained before the objective of the PROBOSQUE law is to establish, restore, manage, produce and protect the forest, therefore farmers can opt to be incorporated in one of the different activities that PROBOSQUE supports. One of them is the implementation of agroforestry practices in conjunction with a livestock system.

For this last model the difference is related to the benefits and costs of the PROBOSQUE program, where the incentives and the administrative cost are taken into account for the calculation of the flow of benefits and cost of the SPS. The inclusion of the PROBOSQUE program will only affect the results of the installation year and the first five years of the systems. With this changes the net cost of the systems in the first-year decreases to $3,046 (Q. 23,154) comparing this with the net cost of the second model, this is a reduction of 3.63% in the total costs of the first year.

However, for the other years there is not a substantial difference between the net benefits, this is because the amount of money received for the implementation of the trees in the systems is not that high and also the farmers incur extra expenses for the project, thus only having a reduction in the year of installation were the farmers received the highest amount in order to buy and implement the trees. Apart from the differences mentioned before, the structure of the benefits and cost follows the same structure as the SPS without the PROBOSQUE incentives.

5.1.2. Net Present Values of the production systems

After seeing the flows of benefits and costs of the three different models, in this section present the results of the three models will be presented. As it was discussed before the discount rate (r) represents the opportunity cost of the individual of implementing a system or saving the money in a bank account.

For the calculation of the NPV formula 1.5 was used, the results are shown in table 13. All the three CBA models have a positive NPV with three different discount rates. As it is expected a lower discount rate will produce a higher NPV because the present values obtained in each year has more value attached to them than the ones obtain with higher discount rates.

The effect that the discount rate has on the calculation of the NPV can be seen not only in the results of the higher discount rates, but also in the different NPV of the model with the same discount rate, especially for the lowest discount rate. Since using a lower discount rate increases the value of the last benefits, it can see that there is a large difference between the NPV of the traditional systems and both of the SPS systems. This is due to the fact that for both SPS at the end of the lifecycle the sales of the timber factors in and as observed in the previous figure it represented a big portion of the income of that given year. And since the future benefits are discount less using 4%, the SPS systems have a bigger margin of profitability in comparison to the traditional system.

Table 13. NPV of the livestock systems with different discount rates (in Quetzals)

	Livestock systems		
Discount rate	**Traditional**	**SPS**	**SPS+PROBOSQUE**
4%	140,587	173,856	175,061
12%	70,308	79,800	80,892
20%	40,441	42,330	43,348

However, if the discount rate is increased, the difference between the NPV of the traditional and SPS systems becomes relatively small compared to that under 4%. As the discount rate is increased the benefits are being discounted more (giving less value to future benefits and costs), therefore the income of the timber at the end of the lifecycle has less weight, since the income of the meat is relatively similar in both systems as it can be seen in the previous graphs.

Based on this sensitivity analysis, the change of NPV calculated when the discount rate is changed and this will depend on the opportunity cost of the money in the point of view of the farmer. However, it is important to consider other factors that can affect the CBA such as the production variables of the CBA model. Because the high vulnerability of Guatemala against climate change; it is important to know and understand how these changes in the climate are going to affect the profitability of the livestock systems.

This is where the strength of using a stochastic model is shown, since the distribution obtained from the survey can be use to attach a distribution to the production variables of the livestock systems. As a result, the distribution of the NPV is obtain and the impact of climate change to the profitability of each CBA model can be observed.

5.2. Survey results: Impact of climate change on livestock production

Before looking at the stochastic model, the impact of climate change based on the results of the survey are presented in this section. The results based on the survey, with 27 observations, for both scenarios of climate change (A2 and B2) were combined to obtain the mean, minimum and maximum of variable for the year 2030 and 2040 for each system.

Table 14 presents the change in the variables of the traditional system. The results show an increase in temperature translates to a reduction in the consumption of feed for the cattle and an increase in the mortality rate of calves for the traditional system. Also, the reduction and variability of the precipitation decrease the productivity of the pasture hence a reduction of the availability of the food for the cattle.

Table 14. Impact of climate change on traditional system

Variable	Base line	Year 2030			Year 2040		
		Mean	Min	Max	Mean	Min	Max
Consumption of daily dry matter	8	7.57	5	13	7.15	4	13
Mortality rate of calves (%)	5	5.59	1	10	6.45	1	20
***Hyparrhenia rupha* dry matter production (kg/ha)**	12,000	11,100	6,800	15,000	10459	6,000	16,000

The change of the SPS is shown in table 15. Unlike the traditional system, the consumption of dry matter in the SPS does not decrease; on the contrary, it is higher for both 2030 and 2040, although in the year 2040 it decreases compared to the year 2030. It seems that the benefits of the trees to cast a shadow in the plots have a positive effect, as mentioned in the literature.

Although the consumption of feed does not seem to be affected by the increase in temperature, the other variables of the SPS are. The increase in temperature and the change in the precipitation increase the mortality rate of calves and tress. Also, the production from the *Cedrela* trees and *Brizantha* is affected by climate change.

Table 15. Impact of climate change on SPS

Variable	Base line	Year 2030			Year 2040		
		Average	Min	Max	Average	Min	Max
Consumption of daily dry matter	8	8.49	5	15	8.2	5	15
Mortality rate of calves (%)	3.5	3.7	1	7	3.86	1	10
***Hyparrhenia rupha* dry matter production (kg/ha)**	15,000	14,598	8,500	21,000	14,423	8,000	21,000
Timber production (m3/ha)	0.5733	0.571	0.35	2.57	0.527	0.3	0.8
Mortality rate of *Cedrela* (%)	7	7.79	5	20	8.3	4	25

Indeed, there is a reduction in the production variables of both systems as the literature suggested. Nevertheless, it seems that the impact on the SPS is lower compared to the traditional system based on the results of the survey. To understand how much of an impact these changes will have in both livestock systems, it is necessary to introduce these new values in the three CBA models proposed for this study.

5.2. Monte Carlo simulation results

For the results of Monte Carlo, the summary statistics of the NPV of the three CBA models are presented in table 16. Figures 5 and 6 illustrated the NPV distribution for the CBA models. Both figures have a vertical bar that shows the average of the NPV. In table 16, the results for the SPS are both higher than the traditional system, and figure 5 confirms this different.

The overlap between the two distribution reflects the probability that both systems have equal NPV due to the impact of climate change. However, the distribution of the NPV for both SPS reaches a higher NPV, meaning that the SPS is more profitable compared to the traditional system. This can be seen in the table 16, where both SPS have higher maximum value.

Table 16. Summary statistics of NPV of Monte Carlo Simulation

	Average (Q)	Std Dev	Minimum	Maximum
Traditional system	64,146.11	15,660.38	37,160.56	119,536.7
SPS	88,829.52	25,685.52	45,962.3	180,925.4
SPS with PROBOSQUE	88,702.93	25,661.02	45,569.45	180,047.6

Based on the results presented in the last section, it is clear to see that climate change has a bigger impact on the production variables of the traditional system compare to the SPS. Although the traditional system presents a lower average of the NPV, it also presents a lower standard deviation, meaning there is less risk involve to obtain certain amount of profit. As it can be seen in figure 5, the density distribution of the traditional system is less wide than the SPS. Therefore, this means less variability for the NPV of the traditional system.

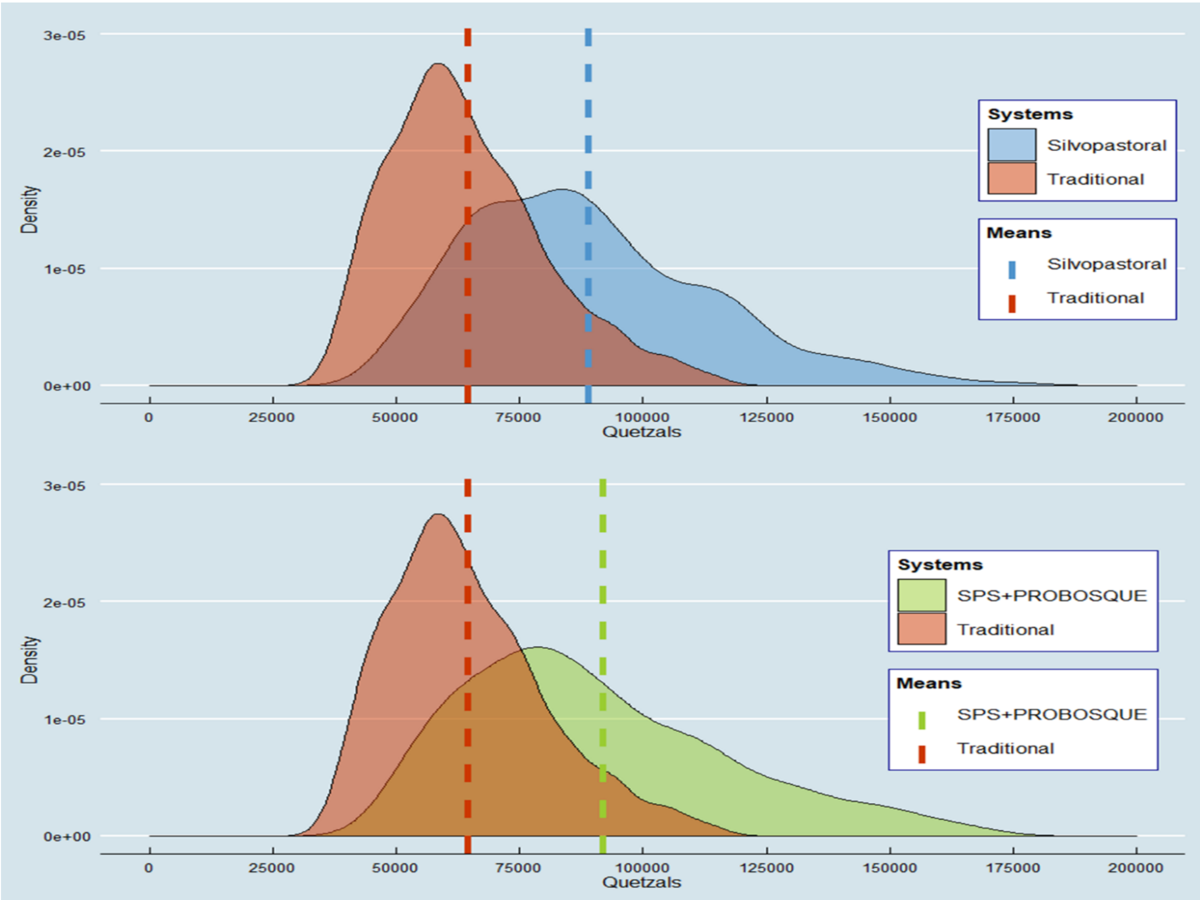

Figure 5. NPV distribution per hectare of traditional and SPS (top) and NPV distribution of traditional and SPS+ PROBOSQUE (bottom) from Monte Carlo simulation

Although both SPS present a higher NPV than the traditional system, it seems that there is no difference between the SPS and the SPS with the PROBOSQUE program. Figure 6 shows the comparison of the distribution of NPV for both SPS; there is almost a complete overlap between them despite the monetary incentives of PROBOSQUE. The results from the average, standard deviation, minimum and maximum show little variation between both SPS.

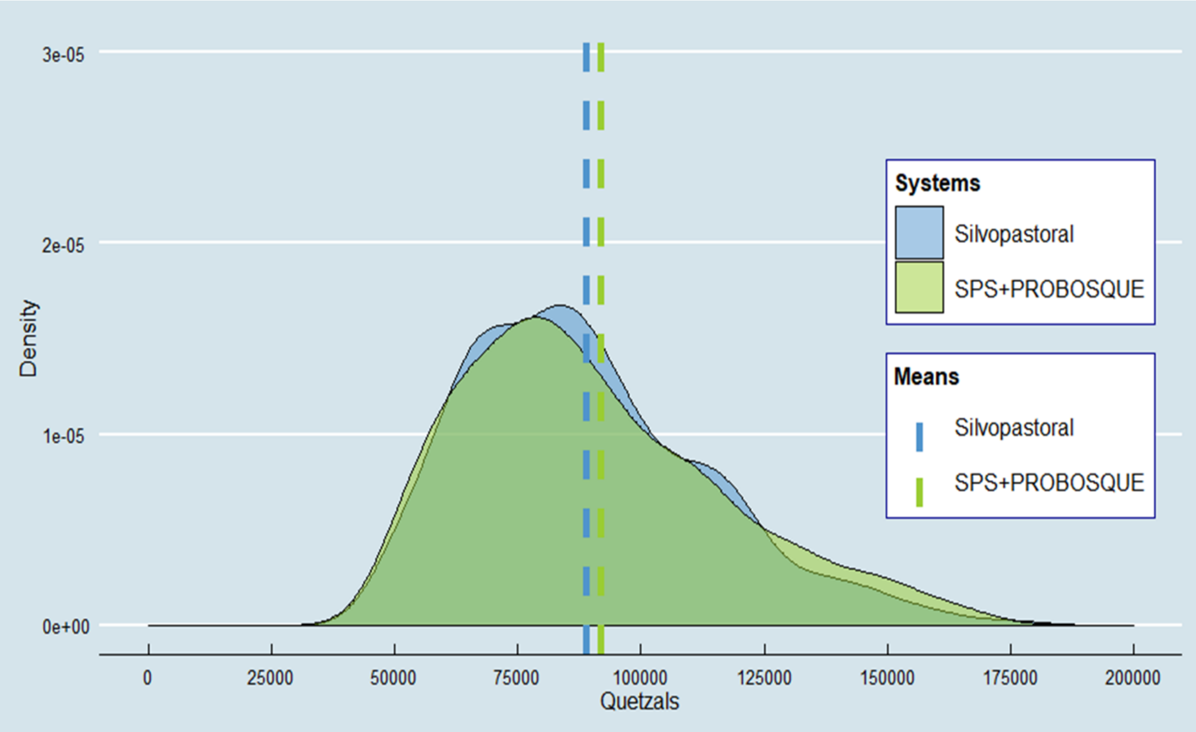

Figure 6. NPV distribution per hectare of SPS and SPS+PROBOSQUE program from Monte Carlo simulation

A one sided two sample t-test was carried out to observe if there is a significant difference between the average of the NPV results. In table 17, the results are presented. From the t-test, both NPV of SPS have a significant difference in the average compared to the traditional system. However, when performing the statistical on sided two sample t-test to observe if there is a different between the NPV of both SPS, the results show that based on the p-value (<5%). Thus, the NPV of the SPS is not significantly different than the NPV of the SPS with PROBOSQUE incentives.

Table 17. T-test for NPV of Monte Carlo results

	P-value	Result
Traditional and SPS	2.2e-16	Mean NPV of traditional system significant lower that SPS
Traditional and PROBOSQUE	2.2e-16	Mean NPV of traditional system significant lower that SPS+PROBOSQUE
SPS and PROBOSQUE	0.3217	Mean NPV of SPS not significant different that SPS+PROBOSQUE

6. Discussion

6.1. Costs and Benefits associated with traditional system and SPS in no change scenario

The analysis of the cost and benefits for the implementation of the traditional system and SPS depends on strong assumptions and information from different sources. Nonetheless, these assumptions were based on the literature and expert knowledge and allow to create a baseline to compare the profitability of both systems in Petén, Guatemala.

To answer if the adoption of SPS in Guatemala is more profitable compared to a traditional livestock production system in the long-run, a CBA was implemented. CBA is commonly implemented to see if an investment is beneficial for the individual or society (Brent, 2006). This tool allows in this study two things: to compare the financial flow and to calculate the NPV of both systems.

The benefits of the SPS are higher compared to the traditional system since the incorporation of trees has positive effects on the preservation of soil and the available feed in the farm as mentioned by Calle et al. (2009). The benefits to the soil and the better management in the SPS contribute to having a higher availability of feed throughout the years, in comparison with the traditional system. The degradation of the pasture in the traditional systems affects the productivity of the pasture when it reaches a degradation of 20%. At this point, the feed available for the cattle is not enough to maintain the same level of productivity, leading to a reduction of the income in that year.

Another benefit of the SPS is the sales of the timber in year 20, this increases the benefits at the end of the lifecycle in the study. As it was mentioned in the literature, SPS has several benefits related to the production of not only timber but also firewood, fruits and medicines (Lima et al., 2017; Murgueitio et al., 2011). The inclusion of this contributes to an increase in the yearly benefits of the SPS. However, this was not taken into account in this study because the timber production was considered the main source of income from the implementation of trees on the farm.

Although the benefits are higher for the SPS, one of the limitations of the adoption is the high capital investment for the SPS (Frey et al., 2012; Ibrahim et al., 2001). In the results, it is shown that the SPS has a higher cost in the implementation phase and for the maintenance. As one would expect this additional cost is related to the implementation of the trees in the farm and the maintenance of the SPS. Despite the higher costs, to know and compare the profitability of both systems it is important to look at the NPV.

Based on the results of the financial flow, it is clear that the SPS has a higher flow of benefits. However, these benefits are going to be received in the future. Farmers will put more value to current benefits instead of future ones (Brent, 2006). For this reason, the discount rate was used to take into account this difference in value between present and future benefits and cost.

To complement the CBA in the study a sensitivity analysis was also carried out. Other studies have also implemented a sensitivity analysis with different discount rates to account uncertainty into the calculation of the NPV for the implementation of environmental practices (CEPAL et al., 2018; Mesa Nacional de Restauración del Paisaje Forestal de Guatemala, 2018).

The results of the NPV of the SPS are always higher with the different discount rates used, this gives the idea that even with the uncertainty attached to the value of the discount rate the SPS is more profitable than the traditional system. The inclusion of the direct benefits from the trees in the livestock production system helps to increase the productivity of the system and hence the profitability, even though the benefits of the SPS are only received in the future.

6.2. PROBOSQUE program in no change scenario

The study shows that a SPS is more profitable than the traditional system, so how does the PROBOSQUE program as an EbA impact the profitability. NPV of the SPS with the PROBOSQUE program show little difference compared to the NPV of the SPS. The cash flows between both SPS are similar; the difference comes from the first six years due to the monetary incentives received. However, the administrative cost for participating in the program almost negates the benefits of the monetary incentives.

This outcome is explained for two reasons: i) the objective of the PROBOSQUE program and ii) how the monetary incentives were calculated. The first reason is related to PROBOSQUE as an EbA, EbA integrated biodiversity and ES as part of adaptation strategies to contribute to climate change (Convention on Biodiversity, 2009).

PROBOSQUE aims to change the land use from mono production of livestock to SPS and not to implement a SPS from the beginning. Therefore, the monetary incentives aim to motivate farmers to change their land use. The second reason is related to the monetary incentives, which just cover 33% of the cost of implementing and maintaining the tree components for the first six years (Velásquez, 2016).

Although the monetary incentive of PRBOSQUE does not change in a significant way the NPV of the SPS, this does not imply that the PROBOSQUE program cannot incentivize the adoption of agroforestry practices. One of the limitations mentioned in the literature for adoption was the high capital investment for the implementation of a SPS. The monetary incentives of PROBOSQUE can reduce the implementation cost of the agroforestry component.

Until this point, the impact of climate change on the profitability of each system was not taken into account. The expected impacts on the productivity of the livestock were addressed in the stochastic approach that is presented next.

6.3. Profitability of the livestock systems taking into account climate change

The results from the deterministic approach for the calculation of the NPV shows that a SPS is more profitable compared to the traditional system, therefore farmers will be inclined to adopt agroforestry practices since economic incentives to adopt new practices are related to the increase of profits (Honlonkou, 2004; Lichtenberg, 2004). However, it is important to understand how the profitability of both systems is affected by climate change and if it can affect the adoption of the SPS.

The results of the NPV values for the Monte Carlo simulation are higher than the NPV of the deterministic CBA obtain using the discount rate of 12% in section 5.1.2. This is because the discount rate used for the Monte Carlo simulation was done using the triangular distribution with 4% as the minimum value and 20% as the maximum value for the distribution.

The stochastic approach allows incorporating uncertainty and risk to the calculation of the NPV of the three CBA models. Once risk and uncertainty are included in the model as the different distribution of the production variables and discount rate, the Monte Carlo simulation shows the impacts of climate change on the NPV. The results of the simulation can be visualized with the distribution plots shown in figure 5.

The density distribution shows the range of the different values that the NPV of each CBA model could potentially take when the impact of climate change is taken into account. The impact of climate change can be seen in the shape of the distribution density because the results are concentrated in the lower tail of the density meaning that they are skewed to the right. This means that lower results of NPV are more likely than higher values. This is expected since the impact of climate change is expected to affect the productivity of livestock production (Magrin et al., 2014).

Based on the results both the SPS and the SPS with PROBOSQUE program, show that on average they present a higher NPV compared to the traditional system even when the impacts of climate change are included. However, using the average of the NPV is misleading because it does not show the different values that the NPV can take. Comparing the density plots of the NPV of the CBA models allows observing if there is an overlap between the density distribution.

The overlap of the distribution, as it can be seen in figure 5, displays that there is a probability that the traditional system could have the same NPV as the SPS in the context of climate change. The repercussion of both livestock production systems to have the possible NPV is that farmers will not be motivated to implement agroforestry practices on the farm. The economic incentive does not justify the adoption if both systems have the same profit. Likewise, in the figure it can be seen that there is also the probability that the NPV of the SPS is higher than the traditional, thus, in this case, farmers will be inclined to adopt SPS due to the increase in profits.

The results of the SPS with the PROBOSQUE program are also shown in figure 5. When comparing both graphs, there is no difference between the distribution of the SPS and the SPS with PROBOSQUE program NPV. In figure 6, it shows the distribution of the NPV of the SPS and SPS with PROBOSQUE program. There is a complete overlap between the distribution of the NPV for both CBA models with SPS.

Even considering the scenario where the administrative costs are assumed by the PROBOSQUE program (see figure 7), there is not enough shift in the NPV distribution of the SPS with the PROBOSQUE program to see a meaningful impact. As mentioned before the monetary incentives are aimed to cover only 33% of the cost of implementing trees in the livestock system, as a result, there is not a bigger impact in the profitability of the SPS.

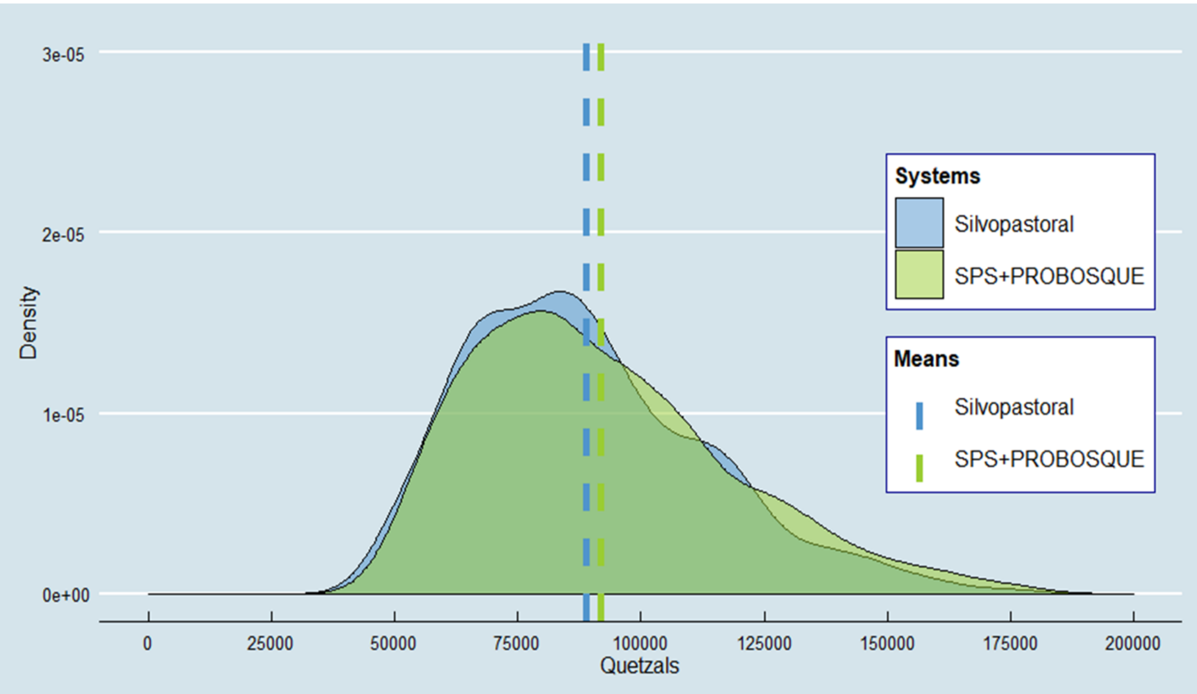

Figure 7. NPV distribution per hectare of SPS and SPS+PROBOSQUE program (without administrative costs) from Monte Carlo simulation

These results imply two things: i) farmers could not have economic incentives to adopt agroforestry practices in their livestock production system and ii) PROBOSQUE does not have an impact on the profitability of the SPS. Based on this, if farmers that have a traditional system obtain the same amount of income as the SPS, even under the impacts of climate change, the farmers will not participate in an incentive scheme (Pagiola et al., 2005).

If the impact of climate change does not make any difference to the NPV of the traditional system and SPS, the strategy for implementing SPS as an EbA does not make sense in economics terms for farmers. EbA aims to help with the adaption to climate change (Vignola et al., 2015), but in the case of both systems having the same results in economic terms, farmers will not have an economic motive to adopt SPS.

The implementation of EbA such as SPS is to adapt to climate change using ES and biodiversity. SPS provides different ES (Calle et al., 2009; Murgueitio et al., 2011), that not only improve the productivity of the system but also improve the welfare of the rural people. As mentioned in the literature, there is a lack of market to internalize the environmental externalities of the production (Lant et al., 2008). Due to this, PES schemes aim to deal with this by creating voluntary transactions with farmers, who generate offsite services (Wunder, 2015).

The failure to internalize the environmental externalities affects the calculation of the profitability of the SPS. The lack of not having a value attached to the production of ES is typically one of the weaknesses in the traditional economic approach (Scrieciu et al., 2013) since these non-market elements of the SPS contribute to the adaptation of the impacts of climate change.

A one sided two sample t-test was carried out to see if there is a different between both system when the administrative costs are not included. The result shows no significant different[7] between the mean NPV of the SPS and the mean NPV of the SPS+PROBOSQUE without the administrative costs.

Although, there is no significant impact of PRBOSQUE it is important to take into account that there is a different (average, sd, min and max) with the traditional system, therefore there is an opportunity for PROBOSQUE to have an impact in the adoption. If the amount of incentives is increased by valuation of the provision of ES, and this amount contributes to a shift in the NPV distribution of the SPS to the right until there is no overlap with the traditional system, the PROBOSQUE program could have an impact as an EbA for farmers.

6.4. Limitations

The limitations of the study are related to the uncertainty of the impact of climate change in the traditional system and SPS. Data limitation of the magnitude of the impact of climate

[7] The p-value was 0.17 > 5%

change was overcome using a survey to get the assessment of experts on livestock production, SPS and climate change in Latin America. However, a weakness of the recollected data is the number of observations (n=27) used for the distribution.

The assumptions for the CBA were based on literature, expert's opinions and information of IUCN officials. To improve the CBA field surveys can be used to get a more accurate estimate of the costs and benefits of the traditional system and SPS. Another limitation of the study is related to the non-inclusion of ES in the NPV of SPS, which could increase the benefits of the SPS.

The low number of observations can affect the distribution of the data, hence the results in the Monte Carlo simulation are subject to assessment of the 27 experts contacted for the survey. To obtain more accurate information about the impact of climate change, a higher number of observations should be obtained.

Another possibility to estimate the impact of climate conditions on livestock production is with climate prediction models in Guatemala. This will require a robust data set of previous climate conditions and its impact on livestock production in the region of Petén, Guatemala. With this data set, it will be possible to obtain the marginal change in the productivity of livestock when the temperature and/ or precipitation change.

7. Conclusion

Livestock production is expected to be negatively affected by climate change. The increase in temperature and variation of precipitation are going to affect the livestock due to heat stress, increase in mortality rate, availability of feed, etc. Hence a reduction of beef and milk production is expected. To adapt to the change of climate conditions SPS has been proposed as an EbA to help reduce and adapt to climate change.

Incentive schemes, such as PES, can aim to increase the adoption of agroforestry practices. The benefits of having a SPS are reflected in the increased productivity of the system hence an increase in the profits of the system compared to the traditional system. In addition, SPS provide ES that can increase the welfare of rural families.

Despite the benefits that SPS has, there are obstacles to the implementation of agroforestry practices, such as: high implementation costs, expected time to recover the implementation costs of the system, lack of knowledge on agroforestry practices, etc. Due to this, incentive schemes focus on reducing the cost of implementation by giving a financial incentive for the adoption of these practices. The intention is to helps farmers adapt to climate change. Particularly, the profitability of the systems is one of the factors that contribute to the adoption of this system. However, it is not clear how climate change will affect the profitability of the SPS and hence hinder the adoption of Agroforestry as an EbA alternative.

This study investigates the impact of the PROBOSQUE program on the NPV of the SPS and traditional system in the context of climate change in the Petén region of Guatemala, using a CBA. CBA provides a practical way of looking at economic factors that affect the profitability of a system, which can be improved by the inclusion of risk and uncertainty in the CBA. In the first part of the study, a deterministic approach was taken to create a base line in a BAU situation. The economic assessment for the traditional system and SPS in Guatemala, confirms that SPS is more profitable than a traditional system. Moreover, it also shows that there is a small impact on the NPV with the PROBOSQUE program.

The deterministic approach does not allow to include the risk and uncertainty in livestock production. To add risk and uncertainty to the calculation of the NPV a stochastic approach was taken. The study uses Monte Carlo simulation to include the risk and uncertainty for the calculation of the NPV. The data from the survey was used to get the impact of climate change on the production of the traditional system and SPS. The data shows that experts estimated a reduction in the consumption of dry matter, mortality rate, production of dry matter and timber in livestock production due to the increase in temperature and variation of precipitation for 2030 and 2040.

The study estimated the NPV of the two livestock production systems taking into account the impact of climate change to compare the variability of the profits. Also, the study aimed to know if the PROBOSQUE program could play a role in the adoption of SPS by increasing the profitability of SPS. The findings in the study illustrated the distribution of the NPV from the three CBA models.

Unlike the results from the deterministic approach, it is not clear if the profitability of the SPS is higher with the risk and uncertainty induced by climate change. The distribution of the NPV from the traditional system and SPS overlap in some parts, meaning there is a probability for the traditional system to be as profitable as SPS in the context of climate change. Furthermore, the results show that the distribution of the NPV for SPS and SPS in the PROBOSQUE program almost overlap completely. This implies two things: i) there is a not significant difference with the PROBOSQUE program on the NPV of SPS and ii) there is no reason to adopt SPS if the profitability is the same as the traditional system.

The non-inclusion of the ES provided by the SPS could affect the calculation of the profitability of the systems. Further assessments of the profitability of the SPS in the context of climate change needs to include an evaluation of ES from SPS. The valuation of the ES by PROBOSQUE could increase the profitability of the SPS and help reduce the uncertainty of the profits to be received. By doing this the program will guarantee the implementation of SPS, because farmers will be incentives to adopt agroforestry practices if the profits are higher than continuing with the traditional system.

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9. Annex

9.1. Climate change scenarios

For the climate change scenarios, the scenarios developed by the Intergovernmental Panel on climate change (IPCC) in their special report in 2000 were consider. According to the IPCC (2000), the GHG emissions are a results of a complex dynamics systems, which are determinate by driving forces such as demographic, technological change and socio-economic development, so having different alternatives scenarios of how the future might unfold can be used as a resource to analysis or assess the impacts, adaptation and mitigation for climate change.

According to the IPCC (2000), a different scenarios were developed to represent the variety of driving forces and emissions in the scenario literature to reflect the current knowledge and understanding about the underlying uncertainties in climate change. The assumption of the for main families of scenarios propose by the IPCC are presented in table A18. In the four different scenarios the main drivers of GHG (demographic, economic and technological forces) are presented with a different range of possibility according to the literature in climate change in order to compare the different outcomes in the next century. However, the IPCC does not offer any judgement in the probabilities of occurrence of any of the scenarios (IPCC, 2000). Therefore, it is necessary to find literature to be able to select our climate change scenarios for Guatemala in order to apply it to our CBA models.

Table A18. Characteristics of the four families of climate change scenarios

Family Scenario	Description
A1	• Rapid economic growth • Population growth peaks in mid-century and decline afterwards • Rapid introduction of new and more efficient technologies • Convergence among regions • Capacity building • Increase cultural and social interaction with a substantial reduction in regional difference in per capita income
A2	• Heterogenous world • Self-reliance and preservation of local identities • Fertility patterns across regions converge very slowly, which results in continuously increase global population • Economic development is primarily regional oriented • Per capita economic growth and technological change are more fragmented and slower than other family scenarios

B1	• Convergent world • Population growth peaks in mid-century and decline afterwards • Rapid changes in economic structures towards service and information economy, causing a reduction in material intensity • Introduction of clean and resource-efficient technologies • Emphasis on global solutions on economic, social and environmental sustainability, but without additional climate initiatives
B2	• Emphasis in on local solutions to economic, social and environmental sustainability • Increase global population at a lower rate than A2 • Intermediate levels of economic development • Less rapid and more diverse technological change than in B1 and A1 scenarios • Scenario oriented toward environmental protection and social equity, it focuses on local and regional levels

Source: own elaboration base on IPCC (2000)

In table A19 and A20 the monthly temperature and precipitation change are shown. It can be seen that the temperature will increase in both scenarios for the year 2030 and 2050, with just slightly higher increase for scenario A2 compare to the B2 scenario. Although for the year 2050 the difference in increase in temperature is not different, for the year 2100 the temperature is expected to increase to 4.9 degrees Celsius for scenario A2 and 2.9 degrees Celsius for scenario B2.

For the precipitation the scenarios show different trends, for the scenario A2 it can be seen in table A20 that for 2050 the annual precipitation will decrease 285.49 mm in the year; in the other hand in scenario B2 it shows that the annual precipitation is going to increase by 97.03 mm. However, it is important to observe behavior of the monthly variation for the scenario B2 shows that most months will decrease the precipitation. Also even though the scenario B2 shows that for the year 2050 the annual variation for precipitation will increase, in the estimation of the CEPAL et al. (2018), it shows a decrease of 9.4% by the year 2100.

Table A19. Monthly temperature increase in year 2030 and 2050 in scenarios A2 and B2

		A2		B2	
	1980-2000	**2030**	**2050**	**2030**	**2050**
January	21.39	0.92	1.72	0.62	1.09
February	22.18	1.05	1.6	0.91	1.39
March	23.54	0.94	1.89	1.16	1.76
April	24.88	0.95	1.67	1.06	1.43
May	25.22	0.93	1.83	0.65	1.23
June	25.18	0.81	1.8	1.03	1.43

July	24.52	1.09	2.31	1.17	1.55
August	24.44	1.17	2.27	1.1	1.52
September	24.12	1.14	2.15	0.98	1.6
October	23.64	1.1	1.71	0.86	1.32
November	22.59	0.9	1.61	1.1	1.58
December	21.73	0.87	1.71	1.08	1.57
Annual	**23.62**	**0.99**	**1.86**	**0.98**	**1.46**

Taken from: CEPAL et al. (2018)

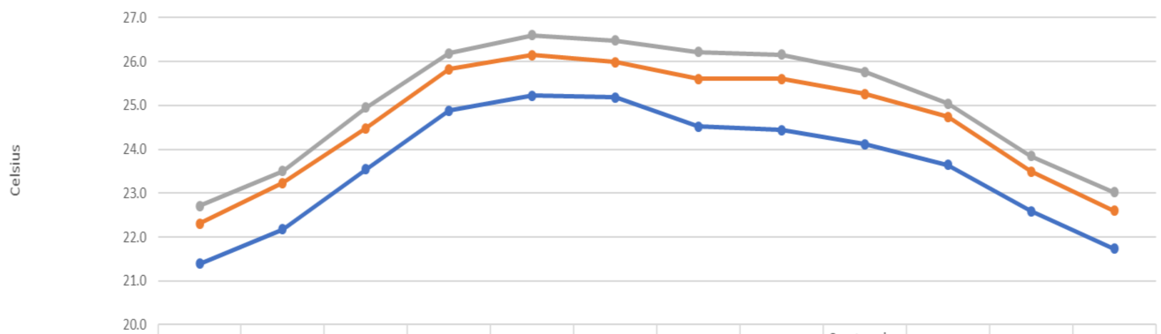
Table A20. Monthly precipitation variation in the year 2030 and 2050 scenario A2 and B2

		A2		B2	
	1980-2000	**2030**	**2050**	**2030**	**2050**
January	74.71	-34.93	-40.06	-29.75	-36.32
February	51.6	-23.19	-29.48	-11.92	-15.83
March	66.29	-26.31	-35.81	-1.94	-1.7
April	95.81	-14.7	-18.25	81.29	81.78
May	246.87	-51.6	-71.18	196.82	173.01
June	397.06	49.89	-43.25	127.3	129.33
July	352.53	-28.08	-130.75	21.02	49.88
August	349.85	-14.35	-27.6	-18.14	-59.03
September	447.06	92.53	90.73	-84.34	-71.93
October	332.5	34.11	119.05	-41.61	-33.66
November	158.43	-39.31	-38.91	-76.36	-63.45
December	103.8	-55.5	-59.98	-52.58	-55.05
Annual	2676.51	-111.44	-285.49	109.79	97.03

Taken from: CEPAL et al. (2018)

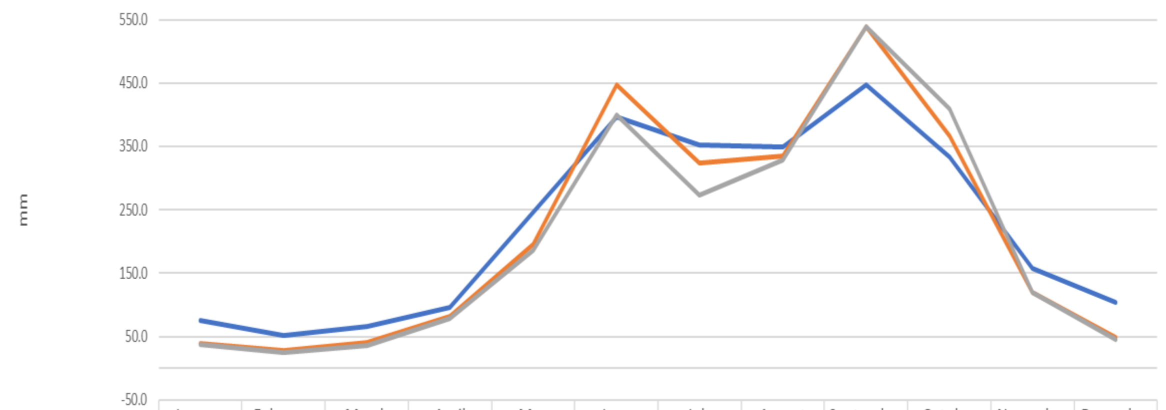
Based on this information the calculation of the temperature and precipitation made by CEPAL et al. (2018) will be use. In order to infer the impact of the climate change on the calculation in our CBA, it is needed to adequate the data for precipitation and temperature to the years 2030 and 2040. For this reason, it is necessary to calculate the temperature and precipitation for the year 2040. To be able to do this, it was assumed that the temperature and the precipitation will behave in a linear way, therefore the calculation of the temperature and precipitation for 2040 was a simple average increase between the data of 2030 and 2050.

The results of this are presented in the following figures:



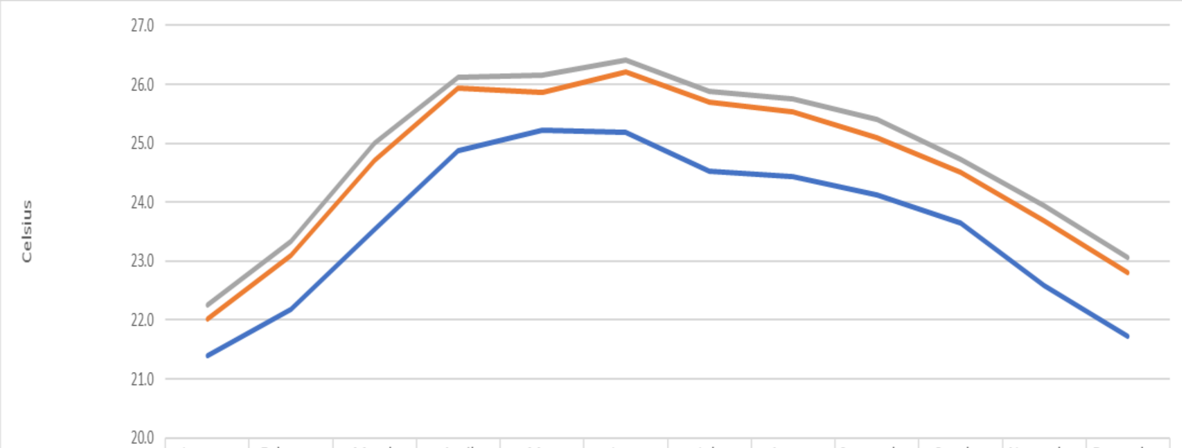
	January	February	March	April	May	June	July	August	Septembe r	October	November	December
Reference year	21.4	22.2	23.5	24.9	25.2	25.2	24.5	24.4	24.1	23.6	22.6	21.7
2030	22.3	23.2	24.5	25.8	26.2	26.0	25.6	25.6	25.3	24.7	23.5	22.6
2040	22.7	23.5	25.0	26.2	26.6	26.5	26.2	26.2	25.8	25.0	23.8	23.0

Figure A8. Monthly temperature year 2030 and 2040 scenario A2



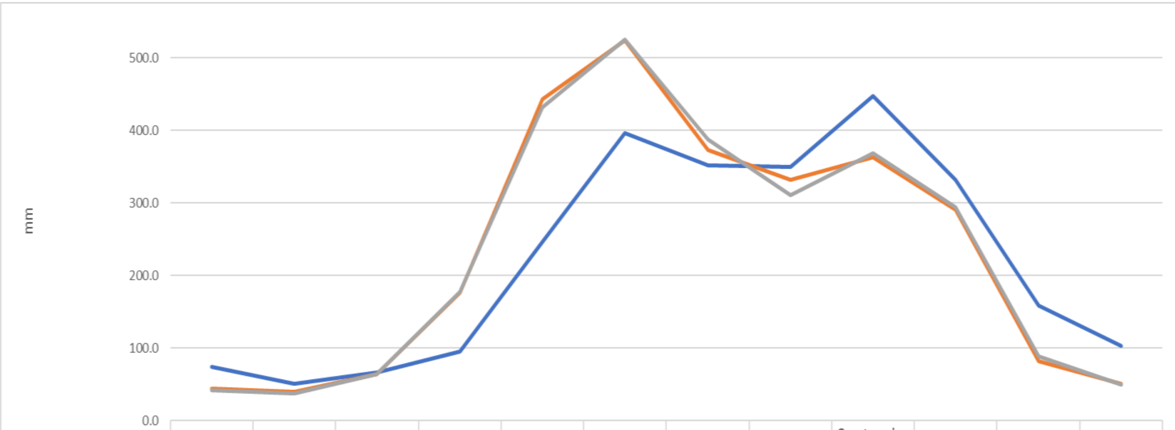
	January	February	March	April	May	June	July	August	September	October	November	December
Reference year	74.7	51.6	66.3	95.8	246.9	397.1	352.5	349.9	447.1	332.5	158.4	103.8
2030	39.8	28.4	40.0	81.1	195.3	447.0	324.5	335.5	539.6	366.6	119.1	48.3
2040	37.2	25.3	35.2	79.3	185.5	400.4	273.1	328.9	538.7	409.1	119.3	46.1

Figure A9. Monthly precipitation year 2030 and 2040 scenario A2



	January	February	March	April	May	June	July	August	September	October	November	December
Reference year	21.4	22.2	23.5	24.9	25.2	25.2	24.5	24.4	24.1	23.6	22.6	21.7
2030	22.0	23.1	24.7	25.9	25.9	26.2	25.7	25.5	25.1	24.5	23.7	22.8
2040	22.2	23.3	25.0	26.1	26.2	26.4	25.9	25.8	25.4	24.7	23.9	23.1

Figure A10. Monthly temperature year 2030 and 2040 scenario B2



	January	February	March	April	May	June	July	August	Septembe r	October	November	December
Reference year	74.7	51.6	66.3	95.8	246.9	397.1	352.5	349.9	447.1	332.5	158.4	103.8
2030	45.0	39.7	64.4	177.1	443.7	524.4	373.6	331.7	362.7	290.9	82.1	51.2
2040	41.7	37.7	64.5	177.3	431.8	525.4	388.0	311.3	368.9	294.9	88.5	50.0

Figure A11. Monthly precipitation year 2030 and 2040 scenario B2

9.2. Data sources

Table A21. Data source of traditional system specification

Data	Value	Reference
Average number of cattle	4	(INATEC, 2017)
Daily consumption of dry matter	8 kg/animal	(FAO, n.d.)
Mortality rate of calves	5%	Pérez et al., 2006
Yaragua dry matter production	12,000 – 15,000 kg/ha	INATEC, 2016b and Peters et al., 2011
Conversion rate of dry matter to meat	10 kg DM / 1 kg meat	(Smil, 2002)
Labor days	27	M. Mema, research assistance in Tropical Forages Program at CIAT, personal communication, May, 5,2019
Vitamins	3 dose / animal	(INATEC, 2016a)
Vaccines	4 doses / animal	(INATEC, 2017)
Deworming	4 doses / animal	(INATEC, 2017)
Salt	9.125 kg / animal	M. Mema, research assistance in Tropical Forages Program at CIAT, personal communication, May, 5,2019
Wires	1,500 meters	
Posts	150 units	
Yaragua seeds	6 kg	INATEC, 2016b and Peters et al., 2011

Table A22. Data source silvopastoral system specification

Data	Value	Reference
Average number of cattle	5	(INATEC, 2017)
Daily consumption of dry matter	8 kg/animal	(FAO, n.d.)
Mortality rate of calves	3.5%	M. Mema, research assistance in Tropical Forages Program at CIAT, personal communication, May, 5,2019
***Brizantha* dry matter production**	8,000 – 20,000 kg/ha	INATEC 2016b and Peters et al. 2011
Conversion rate of dry matter to meat	10 kg DM / 1 kg meat	(Smil, 2002)
Increase Diameter breast height per year	0.0077	INAB, 2014
Increase height per year	0.54	INAB, 2014
Form Factor of *Cedrela*	0.57	Gutierrez et al., (2013)
Timber production of *Cedrela*	0.5733 m3 / tree	Own calculation based on the formula 1.2

***Cedrela* mortality rate**	7%	(Vera-castillo & Carrillo-anzures, 2008)
Labor days	59 days	M. Mema, research assistance in Tropical Forages Program at CIAT, personal communication, May, 5,2019
Vitamins	3 dose / animal	(INATEC, 2016a)
Vaccines	4 doses / animal	INATEC, 2017
Deworming	4 doses / animal	INATEC, 2017
Salt	9.125 kg / animal	M. Mema, research assistance in Tropical Forages Program at CIAT, personal communication, May, 5,2019
Fertilizer (Urea)	4.2 kg/ha	M. Mema, research assistance in Tropical Forages Program at CIAT, personal communication, May, 5,2019
Fertilizer (18-46-0)	4.2 kg/ha	M. Mema, research assistance in Tropical Forages Program at CIAT, personal communication, May, 5,2019
Cedros	107 units	
Madrecacao	150 units	
Wires	1,500 meters	
Posts	150 units	
***Brizantha* seeds**	4 kg	INATEC, 2016b and Peters et al., 2011
Plow service	1	

Table A23. Data source of prices of inputs of livestock systems

Variable	Data	Reference
Cost of pasture *brizantha* and Jaragua	80 Q. per kilogram	O. Ramirez, program Officer IUCN Guatemala Office, personal communication, June, 27,2019
Sales price timber	5,088 Q. per m3	O. Ramirez, program Officer IUCN Guatemala Office, personal communication, June, 27,2019
Price of live cattle	14.55 Q. per kilogram	O. Ramirez, program Officer IUCN Guatemala Office, personal communication, June, 27,2019
Cost of wired	0.699 Q. per meter	E. AC, program Officer IUCN Guatemala Office, personal communication, June, 20,2019
Plow services	500-800 Q. per hectare	E. AC, program Officer IUCN Guatemala Office, personal communication, June, 20,2019
Fertilizer	4.2 Q. per kilogram	E. AC, program Officer IUCN Guatemala Office, program Officer IUCN Guatemala Office, personal communication, June, 20,2019
Madre cacao tree	1.4 Q. per unit	E. AC, program Officer IUCN Guatemala Office, personal communication, June, 20,2019
Cedro tree	3.5 Q. per unit	E. AC, program Officer IUCN Guatemala Office, personal communication, June, 20,2019

Cost of calf	2,800 Q. per unit	E. AC, program Officer IUCN Guatemala Office, personal communication, June, 20,2019
Staples	25 Q. per pound	E. AC, program Officer IUCN Guatemala Office, personal communication, June, 20,2019
Post	5 Q. per unit	E. AC, program Officer IUCN Guatemala Office, personal communication, June, 20,2019
Daily wage	90.16 Q. per day	Recovered from: https://www.prensalibre.com/economia/salario-minimo-2019-guatemala-publicado-en-el-diario-de-centroamerica/ June, 1,2019

9.3. Survey

Introduction

This survey aims to quantify the impact of climate change on certain variables that are considered relevant for the operation and profitability of cattle in the municipality of Petén in Guatemala. In the survey two types of livestock systems are proposed, with which it is intended to know how they would be affected were variable in two periods of time (year 2030 and 2040) in two different scenarios of climate change. Given their knowledge of livestock issues in Latin America, it is pertinent to send this survey to their participation.

Livestock systems

The livestock systems to be evaluated in this survey are: traditional extensive system and SPS in the department of Petén, Guatemala. The main focus of both livestock systems is meat production. Due to this, in both systems the purchase of steers with an initial weight of 160 kg is assumed and they are fattened up to 400 kg.

In the traditional system it is considered a system with pastures with great extension and a rotation of the cattle not adequate, which does not guarantee a good recovery of the grass. In addition, there are no trees in the pastures. In contrast, the SPS incorporates *Cedrela* and Gliricidia sepium trees as living fences and scattered trees that have the function of generating shade and complementing cattle feed. In addition, there is a greater division of pastures and adequate rotation. The purpose of the *Cedrala* is of commercial value so at the end of 20 years it will come as precious wood, while that of *Gliricida sepium* is to provide shade to the cattle in the pasture and when pruning and thinning it is possible to obtain fodder, firewood and posts

The reason for comparing these two systems is because we want to know what the profitability of the systems is in the future scenarios of climate change. So, you have to take into account the benefits that exist on SPS due to temperature and precipitation variations and how these changes would affect the variables presented in the following table:

	Traditional system	SPS
Average daily consumption per animal of Dry Matter (kg / day)	8	8
Average mortality rate of calves	5%	3.5%
Average dry grass matter production (kg / ha / year)	12,000	15,000
Average production of *Cedrela* wood (m3 / year)	-	0.5733
Average *Cedrela* mortality rate	-	7%

The objective of these variables presented in the previous table is to know how livestock systems are affected by the variation of temperature and precipitation, since in the literature consulted it is considered that an increase in temperature has an effect on the consumption of cattle feed and also affects livestock mortality rates. On the other hand, the increase in temperature and variation in precipitation affects the availability of food and tree growth.

Climate change Scenario

To measure the possible impact of climate change that the selected variables may have for both livestock systems, the temperature and precipitation projections made by ECLAC et al. (2012). In which the projections of the year 2030 were taken, and to have data from 2040 a simple average was made with the data of 2030 and 2050.

The following tables show the projections made for the two types of scenarios A2 and B2, in both of them a reference base is presented, which is the starting point of both scenarios and represents the annual average temperature and rainfall for the period 1980-2000 in Guatemala. Then, for each scenario, 2030 and 2040 are presented for each year, the variation in temperature and precipitation always with respect to the base year presented for each scenario.

Scenario A2

Year	Reference data	2030	2040
Annual increase temperature (Celsius)	23.62	0.99	1.4
Annual variation precipitation (mm)	2676.51	-111.44	-198.5

Scenario B2

Year	Reference data	2030	2040
Annual increase temperature (Celsius)	23.62	0.98	1.2
Annual variation precipitation (mm)	2676.51	109.79	103.4

Now taking into account the variations in temperature and precipitation for each year and each scenario, you answered the following questions of the survey. The impact of climate change must also take into account the type of livestock system described above.

Instructions

Below are a series of questions to get your opinion on the possible impact of temperature and precipitation variations on the variables presented above. The objective is to quantify the expected change for that variable according to the year, scenario and livestock system. Likewise, a lower average is asked which corresponds to the smallest change that the variables may have with respect to data for the year 2019 without climate change and a higher average that is the largest change that the variables can experience with respect to the data of the year 2019 without climate change.

** Note * As far as possible you are asked to try to give an estimate of the impact of the climate change scenarios on the selected variables, in case you consider that you cannot really give an estimate, you can leave the box that you think you can't really give an estimate.*

Assessment

Traditional Livestock System

Q1. What would be the impact of climate change expected by 2030 in scenarios A2 and B2 in the traditional livestock system?

	Scenario A2 – Year 2030		**Scenario B2 – Year 2030**	
	Low average	High average	Low average	High average
Average dry matter consumption per day (kg / day / animal) Data without climate change for 2019: 8 kg / day / animal				
Average mortality rate of steers Data without climate change at 2019: 5%				
Average dry matter production in natural grass (Kg / ha) Data without climate change at 2019: 12000 kg / ha				

Q2. What would be the impact of climate change that is expected by 2040 in scenarios A2 and B2 in the traditional livestock system?

	Scenario A2 – Year 2040		**Scenario B2 – Year 2040**	
	Low average	High average	Low average	High average
Average dry matter consumption per day (kg / day / animal)				

Data without climate change for 2019: 8 kg / day / animal				
Average mortality rate of steers Data without climate change at 2019: 5%				
Average dry matter production in natural grass (Kg / ha) Data without climate change at 2019: 12000 kg / ha				

Silvopastoral livestock system

Q3. What would be the impact of climate change expected by 2030 in scenarios A2 and B2 in the SPS?

	Scenario A2 – Year 2030		**Scenario B2 – Year 2030**	
	Low average	High average	Low average	High average
Average dry matter consumption per day (kg / day / animal) Data without climate change for 2019: 8 kg / day / animal				
Average mortality rate of steers Data without climate change at 2019: 3.5%				
Average dry matter production in natural grass (Kg / ha) Data without climate change at 2019: 15000 kg / ha				
Average annual production *Cedrela* (M3 / tree) Data without climate change for 2019: 0.5733 m3 / tree				
***Cedrela* average mortality rate** Data without climate change at 2019: 7%				

Q4. What would be the impact of climate change expected by 2040 in scenarios A2 and B2 in the SPS?

	Scenario A2 – Year 2040		**Scenario B2 – Year 2040**	
	Low average	High average	Low average	High average
Average dry matter consumption per day (kg / day / animal)				

Data without climate change for 2019: 8 kg / day / animal				
Average mortality rate of steers Data without climate change at 2019: 3.5%				
Average dry matter production in natural grass (Kg / ha) Data without climate change at 2019: 15000 kg / ha				
Average annual production *Cedrela* (M3 / tree) Data without climate change for 2019: 0.5733 m3 / tree				
***Cedrela* average mortality rate** Data without climate change at 2019: 7%				

9.4. distribution for Monte Carlo

The distribution presented here were the chosen one for the Monte Carlo analysis.

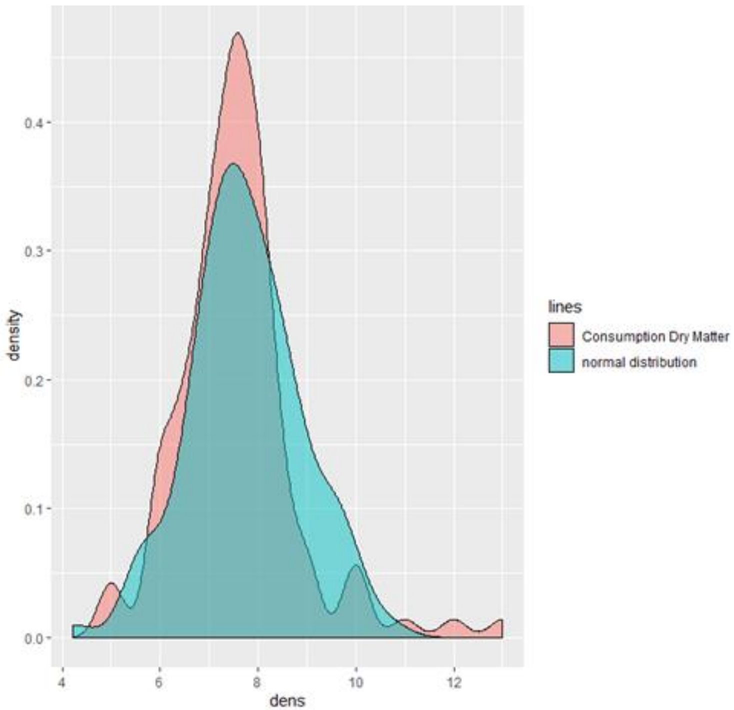


Figure A13. Density plot consumption of dry matter 2030, traditional system and log normal distribution

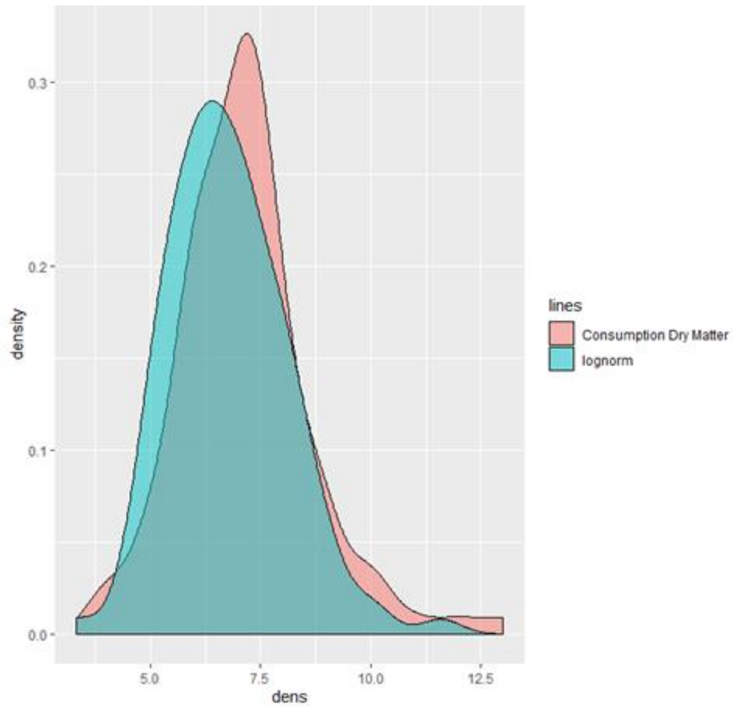


Figure A12. Density plot consumption of dry matter 2040, traditional system and normal distribution

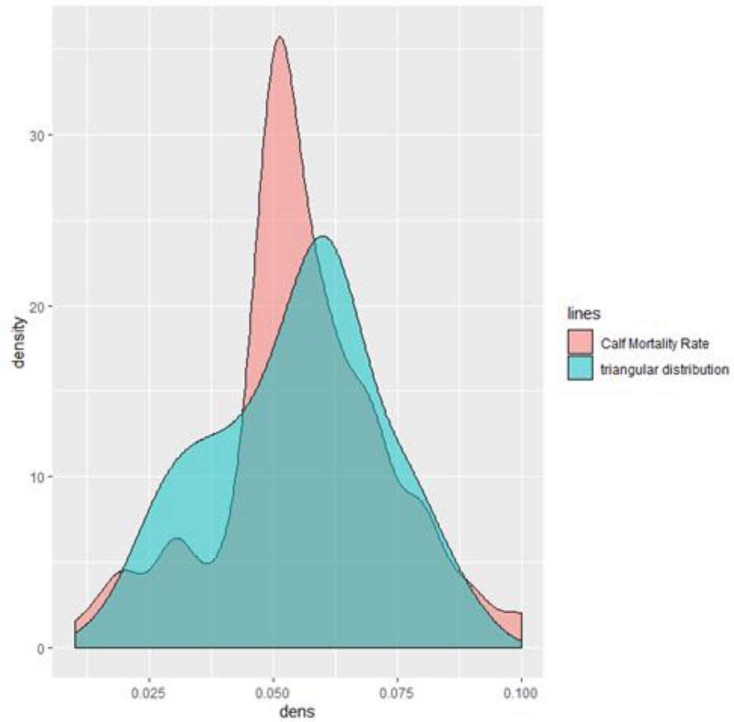


Figure A14. Density plot calf mortality rate 2030, traditional system and triangular distribution

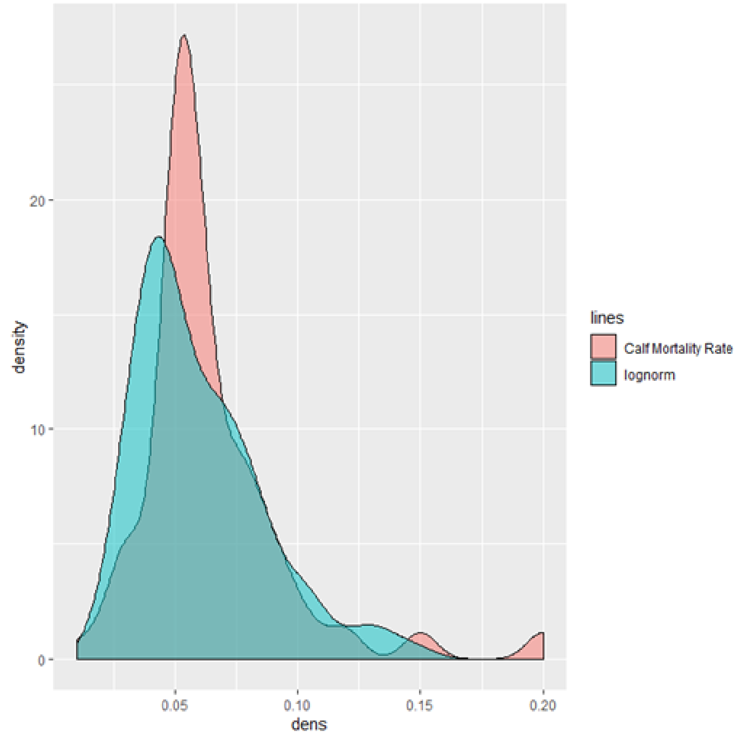


Figure A15. Density plot calf mortality rate 2040, traditional system and log normal distribution

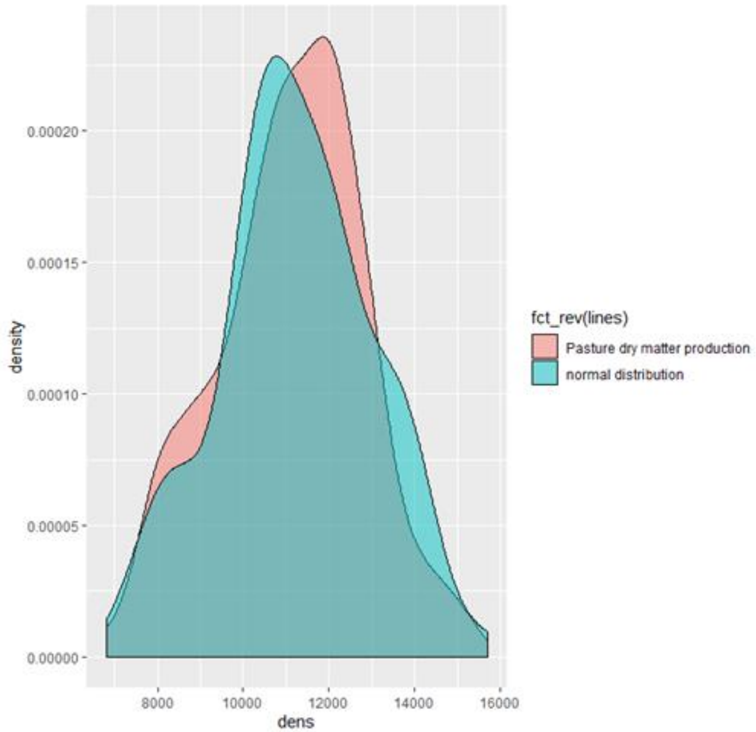


Figure A17. Density plot pasture dry matter production 2030, traditional system and normal distribution

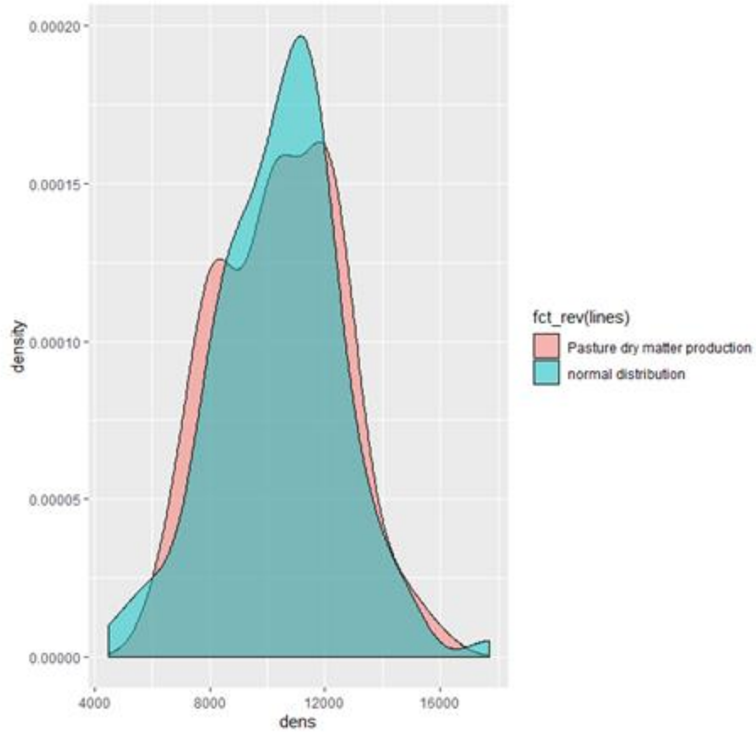


Figure A16. Density plot pasture dry matter production 2040, traditional system and normal distribution

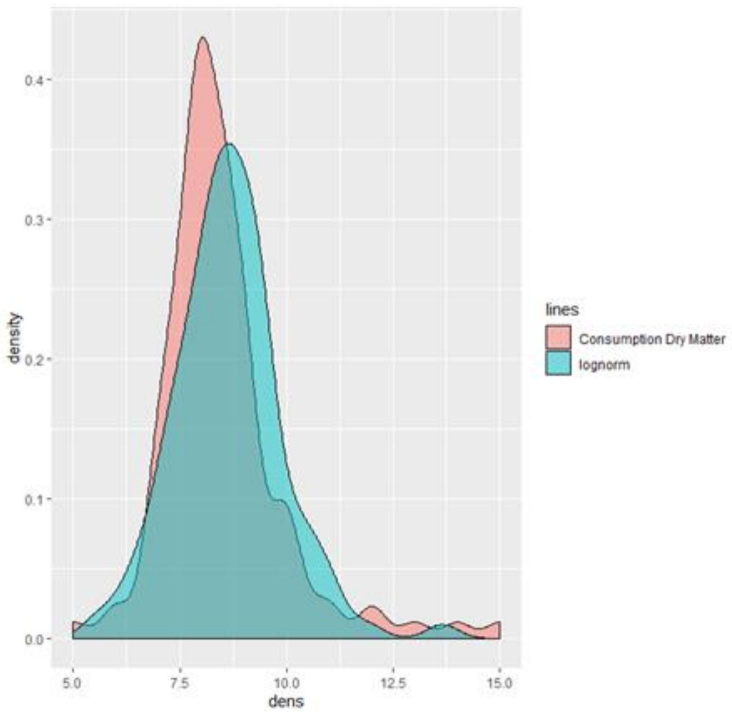


Figure A19. Density plot consumption of dry matter 2030, SPS and log normal distribution

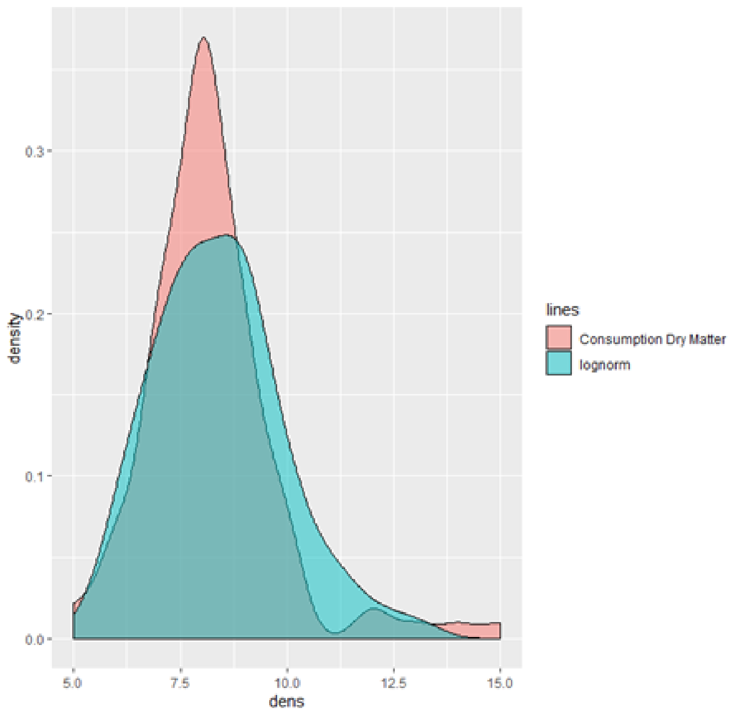


Figure A18. Density plot consumption of dry matter 2040, SPS and log normal distribution

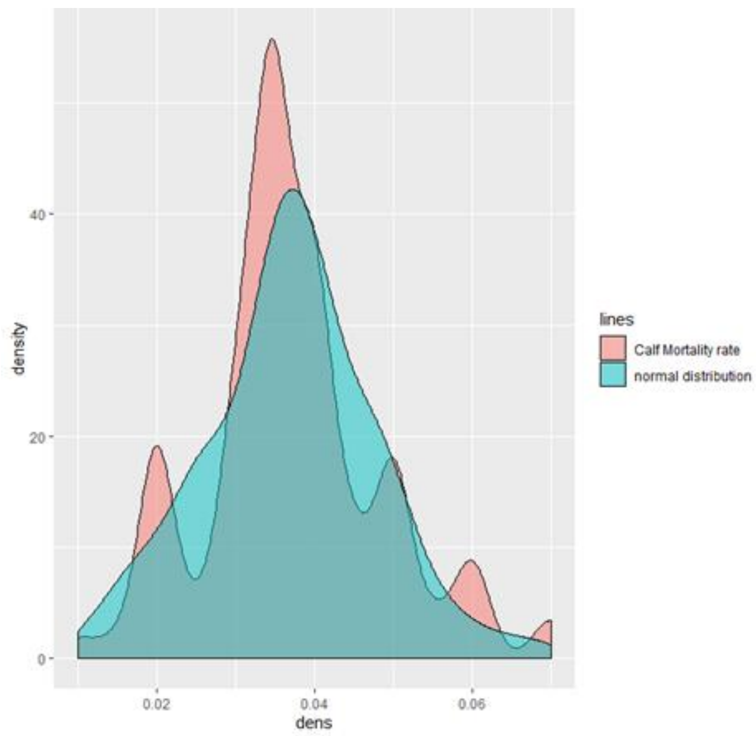


Figure A21. Density plot calf mortality rate 2030, SPS and normal distribution

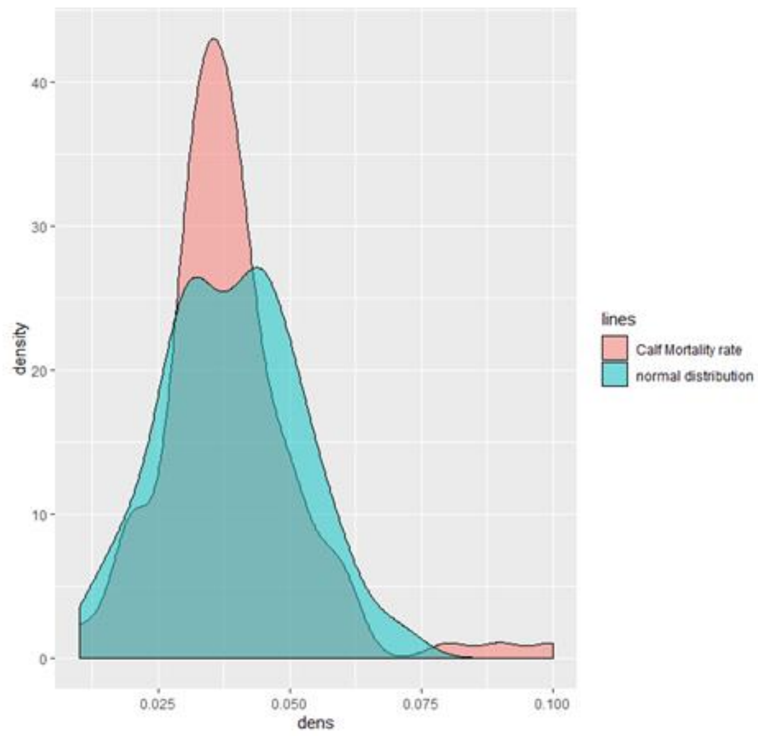


Figure A20. Density plot calf mortality rate 2040, SPS and normal distribution

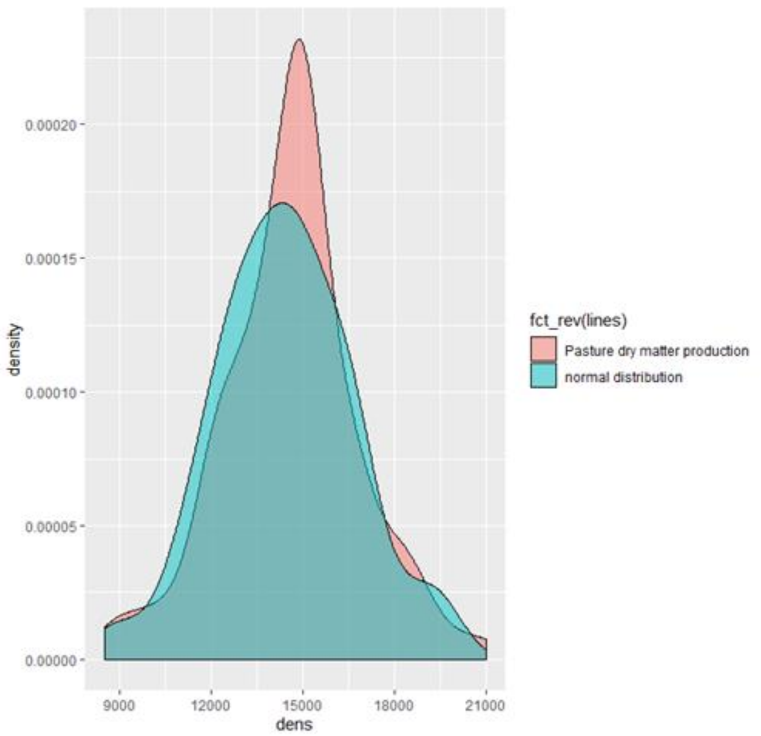


Figure A23. Density plot pasture dry matter production 2030, SPS and normal distribution

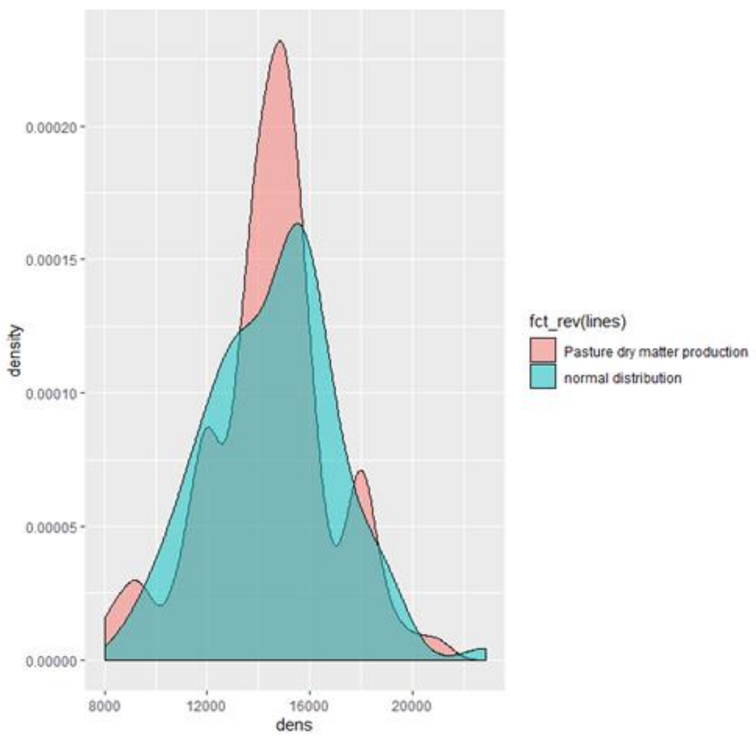


Figure A22. Density plot pasture dry matter production 2040, SPS and normal distribution

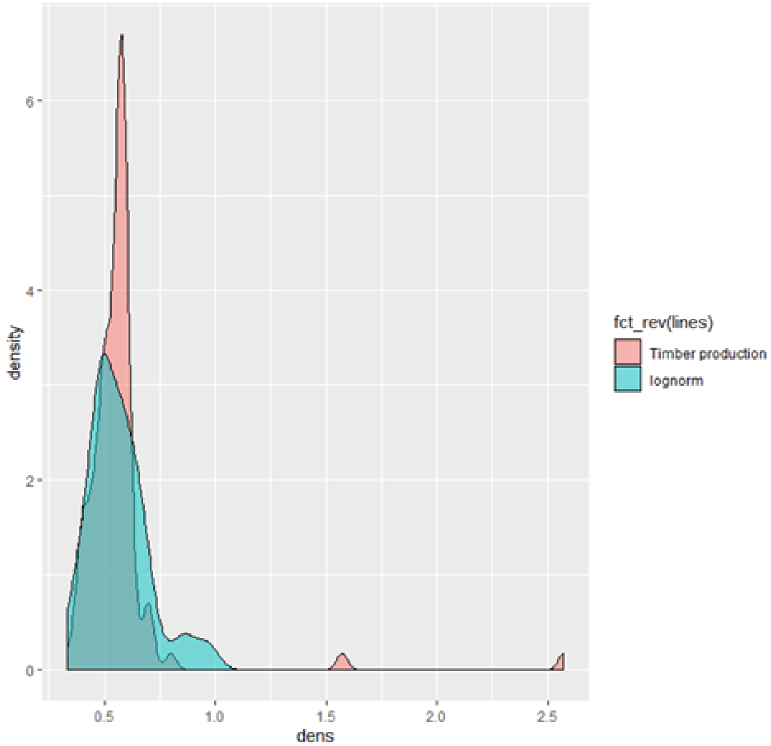


Figure A25. Density plot timber production 2030, SPS with log normal distribution

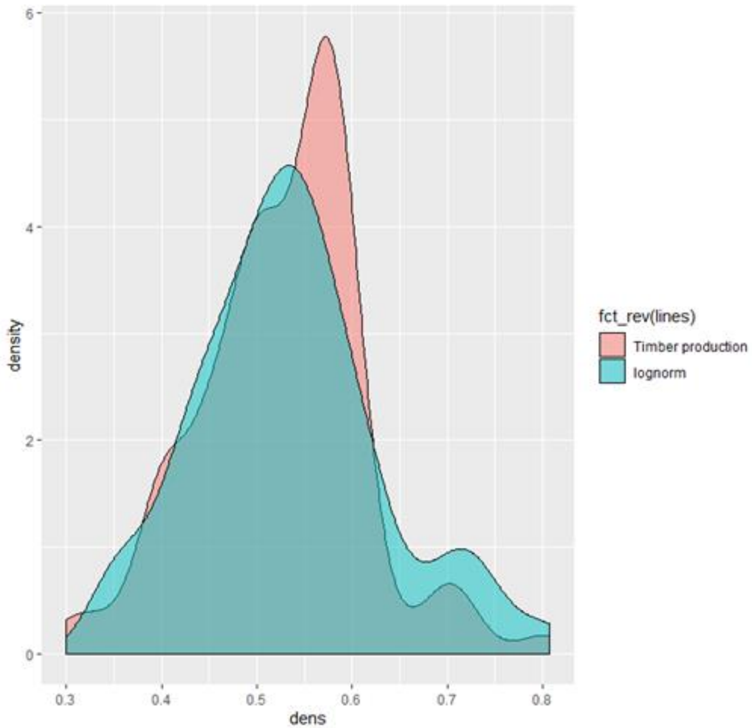


Figure A24. Density plot timber production 2040, SPS with log normal distribution

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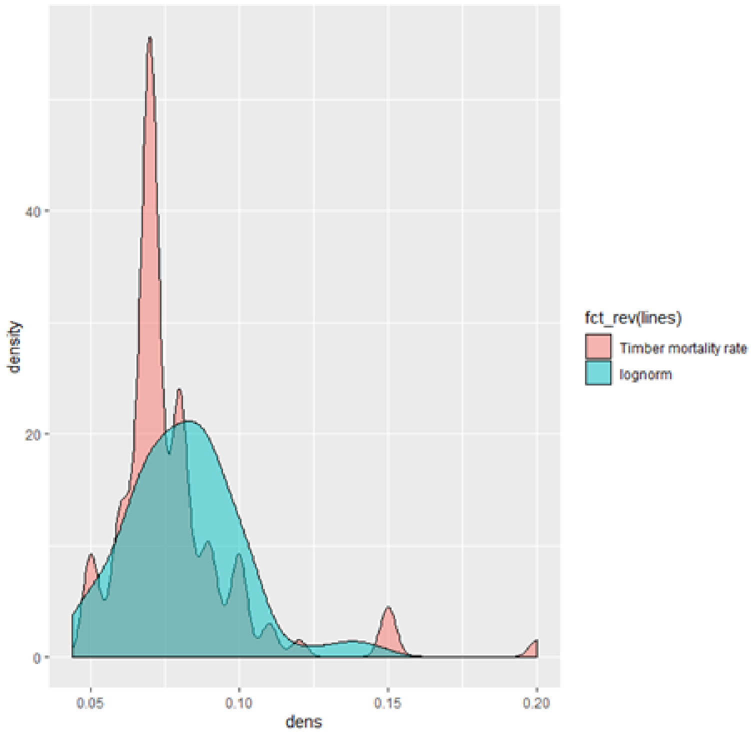

Figure A27. Density plot timber mortality rate 2040, SPS and log normal distribution

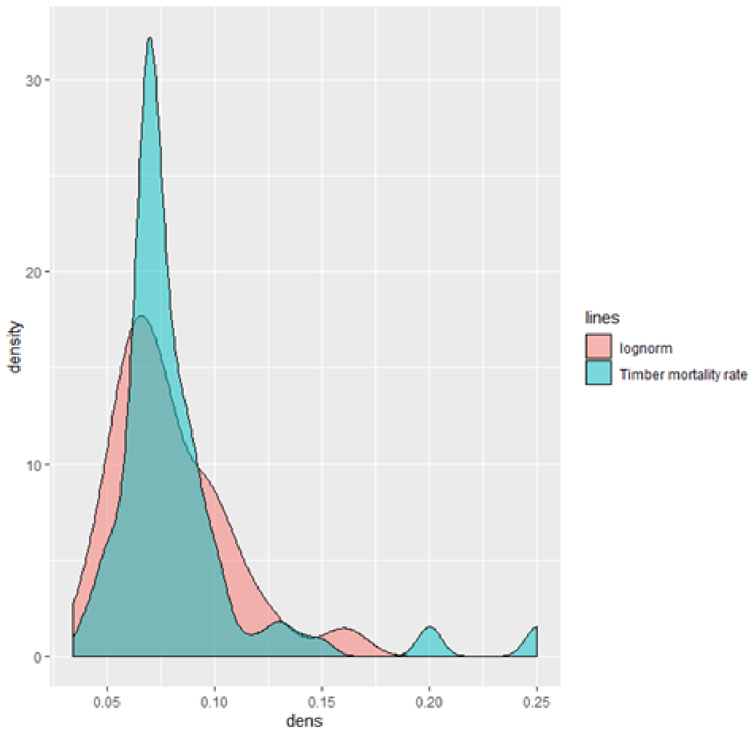

Figure A26. Density plot timber mortality rate 2030, SPS and log normal distribution

9.5. CBA models

Traditional livestock production

Inputs variables		Parameters (This will have distribution)		Agronomic equivalences	
Area (Ha)	1	DM produce by pasture (Ton/ha/year)	12	Equivalent of Animal Unit (kg)	400
Wage	90.16	Increase of weight (kg/ha/day)	0.3	Daily consumption of DM per AU (%)	0.03
Price of steer (160 kg)	2800	Mortality rate of livestock	0.05		
Price of meat (kg)	17.6	**Discount rate**	**0.12**		
Carrying capacity (UA/HA)	4.11				

				Years																				
Investment	Units	Price	No/ha	0	1	2	3	4	5	5	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Wires	Meters	0.669	1,500	-1004					-1004					-1004					-1004					-1004
Staples	Pounds	25.0	3	-75					-75					-75					-75					-75
Post	Units	5.0	150	-750					-750					-750					-750					-750
Pasture (Jaragua)	Kg	80.0	6	-480					-96					-96					-96					-96
Livestock	Units	2,800.0	4	-11760	-11760	-11760	-11760	-11760	-11760	-11760	-11760	-11760	-11760	-11760	-11760	-11760	-11760	-11760	-11760	-11760	-11760	-11760	-11760	-11760
Total Investment cost				-14069	-11760	-11760	-11760	-11760	-13685	-11760	-11760	-11760	-11760	-13685	-11760	-11760	-11760	-11760	-13685	-11760	-11760	-11760	-11760	-13685
Inputs																								
Vitamins	Dose	30.0	3	-360	-360	-360	-360	-360	-360	-360	-360	-360	-360	-360	-360	-360	-360	-360	-360	-360	-360	-360	-360	-360
Vaccines	Dose	6.0	4	-96	-96	-96	-96	-96	-96	-96	-96	-96	-96	-96	-96	-96	-96	-96	-96	-96	-96	-96	-96	-96
Deworming	Dose	15.0	4	-240	-240	-240	-240	-240	-240	-240	-240	-240	-240	-240	-240	-240	-240	-240	-240	-240	-240	-240	-240	-240
Salt	Kg	3.0	9	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110
Total inputs cost				-806	-806	-806	-806	-806	-806	-806	-806	-806	-806	-806	-806	-806	-806	-806	-806	-806	-806	-806	-806	-806
Labour																								
Purchasing Cattle	work days	90.2	3	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270
Land preparation	work days	90.2	14	-1262																				
Instalation of fences	work days	90.2	3	-270					-270					-270					-270					-270
Maintenance of fences	Work days	90.2	3	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270
Veterinarian inputs	Work days	90.2	4	-361	-361	-361	-361	-361	-361	-361	-361	-361	-361	-361	-361	-361	-361	-361	-361	-361	-361	-361	-361	-361
Total labour cost				-2434	-902	-902	-902	-902	-1172	-902	-902	-902	-902	-1172	-902	-902	-902	-902	-1172	-902	-902	-902	-902	-1172
Total Cost				**-17308**	**-13467**	**-13467**	**-13467**	**-13467**	**-15662**	**-13467**	**-13467**	**-13467**	**-13467**	**-15662**	**-13467**	**-13467**	**-13467**	**-13467**	**-15662**	**-13467**	**-13467**	**-13467**	**-13467**	**-15662**
Income meat																								
DM produce by pasture	Kg		12,000		11520	11040	10560	10080	12000	11520	11040	10560	10080	12000	11520	11040	10560	10080	12000	11520	11040	10560	10080	12000
Annual consumption of DM per AU	Kg		2,920.0		2920	2920	2920	2920	2920	2920	2920	2920	2920	2920	2920	2920	2920	2920	2920	2920	2920	2920	2920	2920
Convertion rate of MS to Meat	DM/KG		10		10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Meat produce per animal per year			292		292	292	292	292	292	292	292	292	292	292	292	292	292	292	292	292	292	292	292	292
Time to reach 400 kg			10		10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Number of animals			4.00		4	4	4	3	4	4	4	4	3	4	4	4	4	3	4	4	4	4	3	4
Production of meat	kg	14.55			26306	26306	26306	22058	26306	26306	26306	26306	22058	26306	26306	26306	26306	22058	26306	26306	26306	26306	22058	26306
Total income				**0**	**26306**	**26306**	**26306**	**22058**	**26306**	**26306**	**26306**	**26306**	**22058**	**26306**	**26306**	**26306**	**26306**	**22058**	**26306**	**26306**	**26306**	**26306**	**22058**	**26306**
Net income				**-17308**	**12839**	**12839**	**12839**	**8591**	**10644**	**12839**	**12839**	**12839**	**8591**	**10644**	**12839**	**12839**	**12839**	**8591**	**10644**	**12839**	**12839**	**12839**	**8591**	**10644**
Discount fator				**1.00**	**1.12**	**1.25**	**1.40**	**1.57**	**1.76**	**1.76**	**2.21**	**2.48**	**2.77**	**3.11**	**3.48**	**3.90**	**4.36**	**4.89**	**5.47**	**6.13**	**6.87**	**7.69**	**8.61**	**9.65**
Present value				**-17308**	**11464**	**10235**	**9139**	**5460**	**6040**	**7285**	**5808**	**5186**	**3098**	**3427**	**3691**	**3296**	**2942**	**1758**	**1945**	**2094**	**1870**	**1670**	**997**	**1103**
Net Present Value				**71199**																				

Figure A28. CBA of traditional livestock production

Silvopastoral sistem with improve pasture, live fences, and disperce trees

Inputs variables	
Area (Ha)	1
Wage	90.16
Price of the livestock (160 kg)	2800
Price of meat (kg)	17.6
Carrying capacity (UA/HA)	5.14
Price of wood	3.00

Parameters (This will have distribution)	
DM produce by pasture (Ton/ha/year)	15
Increase of weight (kg/ha/day)	0.5
Mortality rate of livestock	0.035
Mortality rate of Cedro	0.07
Timber production per tree after 20 years (m3)	11.47
Discount rate	**0.12**

Agronomic equivalences	
Equivalent of Animal Unit (kg)	400
Daily consumption of DM per AU (%)	0.03

	Average annual growth	20 years
Diamter breast height (m)	0.0077	0.154
Prevailing height (m)	0.54	10.8
Form factor	0.57	
V per tree at 20 years (m3)		0.1147
Number of Cedro		100
V per hectar at 20 years (m3)		11.467

Investment	Units	Price	No/ha	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Cedro	Units	3.5	107	-375																				
Madrecacao	Units	1.4	150	-210																				
Wires	Meters	0.7	1,500	-1004					-1004					-1004					-1004					-1004
Staples	Pounds	25.0	3	-75					-75					-75					-75					-75
Pasture(Brizantha)	Kg	80.0	4	-320	-32	-32	-32	-32	-32	-32	-32	-32	-32	-32	-32	-32	-32	-32	-32	-32	-32	-32	-32	-32
Plow	Service	650.0	1	-650																				
Livestock	Units	2,800.0	5	-14490	-14490	-14490	-14490	-14490	-14490	-14490	-14490	-14490	-14490	-14490	-14490	-14490	-14490	-14490	-14490	-14490	-14490	-14490	-14490	-14490
Total Investment cost				-17123	-14522	-14522	-14522	-14522	-15601	-14522	-14522	-14522	-14522	-15601	-14522	-14522	-14522	-14522	-15601	-14522	-14522	-14522	-14522	-15601
Inputs																								
Vitamins	Dose	30.0	3	-450	-450	-450	-450	-450	-450	-450	-450	-450	-450	-450	-450	-450	-450	-450	-450	-450	-450	-450	-450	-450
Vaccines	Dose	6.0	4	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120
Deworming	Dose	15.0	4	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300
Salt	Kg	3.0	9.1	-137	-137	-137	-137	-137	-137	-137	-137	-137	-137	-137	-137	-137	-137	-137	-137	-137	-137	-137	-137	-137
Fertilizer (Urea)	Kg	4.2	135	-570	-570	-570	-570	-570	-570	-570	-570	-570	-570	-570	-570	-570	-570	-570	-570	-570	-570	-570	-570	-570
Fertilizer (18-46-0)	Kg	4.2	2	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
Total inputs cost				-1585	-1585	-1585	-1585	-1585	-1585	-1585	-1585	-1585	-1585	-1585	-1585	-1585	-1585	-1585	-1585	-1585	-1585	-1585	-1585	-1585
Labour																								
Purchasing Cattle	Work days	90.2	3	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270
Land preparation	Work days	90.2	14	-1262																				
Instalation of live fences	work days	90.2	6	-540																				
Sowing	Work days	90.2	4	-360	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36
Control of pasture	Work days	90.2	6	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541
Pruning of trees	Work days	90.2	12	-1082	-1082	-1082	-1082	-1082	-1082	-1082	-1082	-1082	-1082	-1082	-1082	-1082	-1082	-1082	-1082	-1082	-1082	-1082	-1082	-1082
Maintenance of live fences	Work days	90.2	6	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541
Veterinarian inputs	Work days	90.2	8	-721	-721	-721	-721	-721	-721	-721	-721	-721	-721	-721	-721	-721	-721	-721	-721	-721	-721	-721	-721	-721
Total labour cost				-5317.44	-3192	-3191.6	-3191.6	-3191.6	-3191.6	-3191.56	-3192	-3191.6	-3191.6	-3191.6	-3191.6	-3191.56	-3192	-3191.6	-3191.6	-3191.6	-3192	-3191.6	-3191.6	-3191.6
Total Cost				-24025.8	-19299	-19299	-19299	-19299	-20377	-19298.9	-19299	-19299	-19299	-20377	-19299	-19298.9	-19299	-19299	-20377	-19299	-19299	-19299	-19299	-20377
Income meat																								
DM produce by pasture	Kg		15,000		15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
Annual consumption of DM per AU	Kg		2,920		2920	3066	3066	3066	3066	3066	3066	3066	3066	3066	3066	3066	3066	3066	3066	3066	3066	3066	3066	3066
Convertion rate of MS to Meat	DM/KG		10		10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Meat production per animal per year			292		292	292	292	292	292	292	292	292	292	292	292	292	292	292	292	292	292	292	292	292
Time to reach 400 kg			10		10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Number of animals			5.0		5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Production of meat	kg	14.55			32883	32883	32883	32883	32883	32883	32883	32883	32883	32883	32883	32883	32883	32883	32883	32883	32883	32883	32883	32883
Income timber																								
Production of timber	m3	5,088	11.467																					35005
Total income				**0**	**32883**	**32883**	**32883**	**32883**	**32883**	**32883**	**32883**	**32883**	**32883**	**32883**	**32883**	**32883**	**32883**	**32883**	**32883**	**32883**	**32883**	**32883**	**32883**	**67888**
Net income				**-24026**	**13584**	**13584**	**13584**	**13584**	**12506**	**13584**	**13584**	**13584**	**13584**	**12506**	**13584**	**13584**	**13584**	**13584**	**12506**	**13584**	**13584**	**13584**	**13584**	**47511**
Discount fator				**1.00**	**1.12**	**1.25**	**1.40**	**1.57**	**1.76**	**1.97**	**2.21**	**2.48**	**2.77**	**3.11**	**3.48**	**3.90**	**4.36**	**4.89**	**5.47**	**6.13**	**6.87**	**7.69**	**8.61**	**9.65**
Present value				**-24026**	**12129**	**10829**	**9669**	**8633**	**7096**	**6882**	**6145**	**5486**	**4899**	**4026**	**3905**	**3487**	**3113**	**2780**	**2285**	**2216**	**1978**	**1766**	**1577**	**4925**
Net Present Value				**79801**																				

Figure A29. CBA of SPS

Silvopastoral sistem PROBOSQUE

Inputs variables	
Area (Ha)	1
Wage	90
Price of the livestock (160 kg)	2800
Price of meat (kg)	18
Carrying capacity (UA/HA)	5
Price of wood	3

Parameters (This will have distribution)	
DM produce by pasture (Ton/ha/year)	15.00
Increase of weight (kg/ha/day)	0.50
Mortality rate of livestock	0.04
Mortality rate of Cedro	0.07
Timber production per tree after 20 years (m3)	11.47
Discount rate	**0.12**

Agronomic equivalences	
Equivalent of Animal Unit (kg)	400
Daily consumption of DM per AU (%)	0.03

Average annual growth		20 years
Diamter breast height (m)	0.01	0.15
Prevailing height (m)	0.54	10.80
Form factor	0.57	
V per tree at 20 years (m3)		0.11
Number of Cedro		100
V per hectar at 20 years (m3)		11.47

				Years																				
Investment	Units	Price	No/ha	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Cedro	Units	4	107	-375																				
Madrecacao	Units	1	150	-210																				
Wires	Meters	1	1,500	-1,004					-1,004					-1,004					-1,004					-1,004
Staples	Pounds	25	3	-75					-75					-75					-75					-75
Pasture(Brizantha)	Kg	80	4	-320	-32	-32	-32	-32	-32	-32	-32	-32	-32	-32	-32	-32	-32	-32	-32	-32	-32	-32	-32	-32
Plow	Service	650	1	-650																				
Livestock	Units	2,800	5	-14,490	-14,490	-14,490	-14,490	-14,490	-14,490	-14,490	-14,490	-14,490	-14,490	-14,490	-14,490	-14,490	-14,490	-14,490	-14,490	-14,490	-14,490	-14,490	-14,490	-14,490
Total Investment cost				-17123	-14522	-14522	-14522	-14522	-15601	-14522	-14522	-14522	-14522	-15600.5	-14522	-14522	-14522	-14522	-15600.5	-14522	-14522	-14522	-14522	-15601
Inputs																								
Vitamins	Dose	30	3	-450	-450	-450	-450	-450	-450	-450	-450	-450	-450	-450	-450	-450	-450	-450	-450	-450	-450	-450	-450	-450
Vaccines	Dose	6	4	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120
Deworming	Dose	15	4	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300
Salt	Kg	3	9	-137	-137	-137	-137	-137	-137	-137	-137	-137	-137	-137	-137	-137	-137	-137	-137	-137	-137	-137	-137	-137
Fertilizer (Urea)	Kg	4	135	-570	-570	-570	-570	-570	-570	-570	-570	-570	-570	-570	-570	-570	-570	-570	-570	-570	-570	-570	-570	-570
Fertilizer (18-46-0)	Kg	4	2	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
Total inputs cost				-1585.3	-1585.3	-1585.3	-1585.3	-1585.32	-1585.3	-1585.3	-1585.3	-1585.3	-1585.32	-1585.32	-1585.3	-1585.3	-1585.3	-1585.3	-1585.32	-1585.3	-1585.3	-1585.3	-1585.3	-1585.3
Labour																								
Purchasing Cattle	Work days	90	3	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270	-270
Land preparation	Work days	90	14	-1,262																				
Instalation of live fences	work days	90	6	-540																				
Sowing	Work days	90	4	-360	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36
Control of pasture	Work days	90	6	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541
Pruning of trees	Work days	90	12	-1,082	-1,082	-1,082	-1,082	-1,082	-1,082	-1,082	-1,082	-1,082	-1,082	-1,082	-1,082	-1,082	-1,082	-1,082	-1,082	-1,082	-1,082	-1,082	-1,082	-1,082
Maintenance of live fences	Work days	90	6	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541	-541
Veterinarian inputs	Work days	90	8	-721	-721	-721	-721	-721	-721	-721	-721	-721	-721	-721	-721	-721	-721	-721	-721	-721	-721	-721	-721	-721
Total labour cost				-5,317	-3,192	-3,192	-3,192	-3,192	-3,192	-3,192	-3,192	-3,192	-3,192	-3,192	-3,192	-3,192	-3,192	-3,192	-3,192	-3,192	-3,192	-3,192	-3,192	-3,192
Total Cost				**-24026**	**-19299**	**-19299**	**-19299**	**-19298.9**	**-20377**	**-19299**	**-19299**	**-19299**	**-19298.9**	**-20377.4**	**-19299**	**-19299**	**-19299**	**-19299**	**-20377.4**	**-19299**	**-19299**	**-19299**	**-19299**	**-20377**
Gastos administrativos				-328	-591	-488	-441	-434	-434															
Income meat																								
DM produce by pasture	Kg		15,000		15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000
Annual consumption of DM per AU	Kg		2,920		2,920	2,920	2,920	2,920	2,920	2,920	2,920	2,920	2,920	2,920	2,920	2,920	2,920	2,920	2,920	2,920	2,920	2,920	2,920	2,920
Convertion rate of MS to Meat	DM/KG		10		10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Meat production per animal per year			292		292	292	292	292	292	292	292	292	292	292	292	292	292	292	292	292	292	292	292	292
Time to reach 400 kg			10		10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Number of animals			5		5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Production of meat	kg	15			32,883	32,883	32,883	32,883	32,883	32,883	32,883	32,883	32,883	32,883	32,883	32,883	32,883	32,883	32,883	32,883	32,883	32,883	32,883	32,883
Income timber																								
Production of timber	m3	5,088	11																					35,005
Total income				**0**	**32,883**	**32,883**	**32,883**	**32,883**	**32,883**	**32,883**	**32,883**	**32,883**	**32,883**	**32,883**	**32,883**	**32,883**	**32,883**	**32,883**	**32,883**	**32,883**	**32,883**	**32,883**	**32,883**	**67,888**
Incentives PROBOSQUE (silvopastoril)				1,200	500	500	500	500	800															
Total income + Incentives				**1,200**	**33,383**	**33,383**	**33,383**	**33,383**	**33,683**	**32,883**	**32,883**	**32,883**	**32,883**	**32,883**	**32,883**	**32,883**	**32,883**	**32,883**	**32,883**	**32,883**	**32,883**	**32,883**	**32,883**	**67,888**
Net income				**-23,154**	**13,494**	**13,596**	**13,643**	**13,650**	**12,872**	**13,584**	**13,584**	**13,584**	**13,584**	**12,506**	**13,584**	**13,584**	**13,584**	**13,584**	**12,506**	**13,584**	**13,584**	**13,584**	**13,584**	**47,511**
Discount fator				**1.00**	**1.12**	**1.25**	**1.40**	**1.57**	**1.76**	**1.97**	**2.21**	**2.48**	**2.77**	**3.11**	**3.48**	**3.90**	**4.36**	**4.89**	**5.47**	**6.13**	**6.87**	**7.69**	**8.61**	**9.65**
Present value				**-23154**	**12048**	**10838**	**9711.1**	**8674.88**	**7303.7**	**6882.14**	**6144.76**	**5486.4**	**4898.57**	**4026.47**	**3905.1**	**3486.7**	**3113.1**	**2779.58**	**2284.73**	**2215.86**	**1978.4**	**1766.47**	**1577.2**	**4925.27**
Net Present Value				**80892.7**																				

Figure A30. CBA of SPS + PROBOSQUE