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Tree cover on cattle farms in the southeast region of Guatemala

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***MAGISTER SCIENTIAE* IN AGROFORESTRY AND SUSTAINABLE AGRICULTURE**

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Dedicated to:

Mother EARTH for its beauty and grace.

My father Florentino Solis and my mother Clarissa Flores for their eternal love and guidance.

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List of abbreviations

AC: Area of Canopy

AFS: Agroforestry Systems

AGDP: Agricultural Gross Domestic Product

ASS: Agri-silvicultural Systems

AU: Animal Unit

C: Carbon

CATIE: Centro Agronómico Tropical de Investigación y Enseñanza

CC: Climate Change

CH_4: Methane

cm: Centimeter

CO_2: Carbon Dioxide

DBH: Diameter Above Breast Hight

F: Natural Forest

FAO: Food and Agriculture Organization of the United Nations

FB: Fodder Banks

FP: Forest Plantation

GDP: Gross Domestic Product

GHG: Greenhouse Gases

GLP: Good Livestock Practices

GPS: Global Positioning System

Ha: Hectare

HLTI: High Level of Technological Innovation

INAB: Instituto Nacional de Bosque

INE: Instituto Nacional de Estadísticas - Guatemala

IPCC: International Panel of Climate Change

Km: Kilometer

LF: Live Fences

LLTI: Low level of Technological Innovation

m.a.s.l: Meter Above Sea Level

m: Meter

mm: Millimeter

NO_2: Nitrous oxide

NPV: Net Present Value

NWFP: Non-Wood Forest Products

ODK: Open Data Kit

PINFOR: Programa de Incentivos Forestales

RF: Riparian Forest

SFM: Sustainable Forest Management

SPS: Silvopastoral Systems

STP: Scattered Tress in Paddocks

t: Ton

UNDP: United Nation Development Program

Yr: Year

Tree cover in cattle farms in the southeast region of Guatemala

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Summary

Livestock activity is often related to deforestation and loss of natural resources such as soil and water quality and quantity. The strategies that come from this perception seek for the minimization of livestock effect into the environment. Silvopastoral systems are being used as an alternative to increase tree cover on livestock farms, mitigate the effects of climate change, and make farmers more resilient to these. This research is focused on the characterization of livestock farms and the floristic composition of tree cover in the southeast region of Guatemala. This region belongs to the dry corridor of Central America and presents high vulnerability to drought. Two farms were selected in each of the fifteen municipalities from three departments of the southeast region of Guatemala, which resulted in a total of thirty farms for data collection. A socioeconomical survey was applied to recollect biophysical, socioeconomical, and productive information. As a result, two groups of farms were identified: 1) farms with a high level of technological innovation (HLTI) and 2) farms with a low level of technological innovation (LLTI). Tree data was obtained from individuals with a diameter above breast height (DBH) of >5 cm. Composition, richness, and abundance of tree species were evaluated using Q-Hill Diversity Index. The study area was 790 ha and there were 143 plots distributed randomly in the different stratum found in the 30 farms. Live fences were also present in 1.691 km (169.1 ha) with forty-four transects. Moreover, seven land uses were identified: scattered tress in paddocks, natural forest, agri-silvicultural systems, fodder banks, forest plantation, riparian forest, and live fences. The total amount of individuals were 4,678 that belong to eighty-three species and thirty-seven families of trees. It was found that 77.27 % of the total inventory is dominated by ten species. The percentage of tree cover was determined for each land use. There were marked differences of richness by individuals and density of species accumulated by land use.

Keywords: dry region, floristic composition, livestock farm typologies, richness and abundance of species, silvopastoral systems

1. Introduction

Population and wealth growth as well as urbanization, among other aspects, are translating into increased demand for livestock products, particularly in developing countries (FAO 2017). Livestock is key for food security because products such as meat, milk, and eggs provide 34% of the protein consumed globally as well as essential micronutrients. Hundreds of millions of vulnerable people rely on livestock in a changing climate, because of animals' ability to adapt to marginal conditions and withstand climate shocks (FAO 2017).

The expansion of livestock systems is becoming increasingly visible in the countries in Central America, where forests are being lost each year because of this productive activity, which turn increases the pressure on natural resources and the livelihoods of small farmers. According to FAO (2015), deforestation and forest degradation are among the world most pressing land-change problems. In 1990, the world had 4,128 million ha of forest, by 2015, this area had decreased to 3,999 million ha.

Cherrington *et al*. (2011), state that in 1990, forests made up approximately 269,296 km² or 52% of Central America's land cover, while in 2008, that figure was approximately 241,073 km² or 46.5% of the region's land cover. It is estimated that Guatemala forest cover in 2006 was 3.87 million ha and in 2010 it was 3.72 million ha, of which 1.94 million ha were in protected areas and 1.77 million ha were outside protected areas. The rate of gross deforestation in Guatemala for the period 2006-2010 was 132,137 ha/yr. In relative terms the loss of forest has occurred in broadleaved, followed by mixed, coniferous, and mangrove forest (Monterroso *et al*. 2012).

Feed crops are growing in one-third of total cropland, while the total land area occupied by pasture is equivalent to 26% of the ice-free terrestrial surface (FAO 2018). In Central America there is a total area of 49 million hectares for agricultural and livestock use, of which 10 million are in pastures; approximately 20% of the soil in the region is devoted to activities related to livestock. El Salvador (31%) is the country with the highest percentage of pastureland, followed by Costa Rica (26%), Nicaragua (25%), Panama (21%), Guatemala (18%), and Honduras (16%). Of the 14,839,624 head of cattle in the region in 2012, 34% was in Nicaragua, 19% in Guatemala, 14% in Honduras, 13% in Costa Rica, 12% in Panama, and 9% in El Salvador (Acosta and Valdés 2013).

Livestock production continues to be dominated by conventional production systems, which are associated with low incomes for families, degradation of biodiversity and ecosystem services, increased vulnerability to climate change, and increased greenhouse gas emissions. According to Casasola *et al*. (2015), the transformation of conventional livestock production into sustainable[1] livestock production systems, based on silvopastoral systems (SPS) and good livestock practices (GLP), contribute to improve the livelihoods of families that base their economy in livestock activities. They also improve the resilience of farms to climate change and the conservation of biodiversity (FAO 2009).

It has been demonstrated that livestock farms in the tropical regions managed under ecological principles can contribute to the biodiversity because they can host a great diversity of tree species, whether they are natural regeneration, forest remnants, or plantation of species with timber potential (Villanueva *et al*. 2003). One of the main reasons why farmers remain motivated to conserve or plant trees on the farm is because of the provision of goods like firewood, post, timber, forage, shade, and food, and perhaps for their environmental services such as soil formation, conservation of water resources, connectivity, or carbon supply (Duffy 2016, Russo y Botero 2014, Sánchez *et al*. 2013).

The present research study can contribute to a better understanding of the different typologies of livestock farms, based on good practices criteria that make farmers more resilient to the effects of drought in the region. It also determines the structure of tree cover inside of these livestock farms and its contribution to sustain biodiversity and mitigate the effects of climate change inside of the southeast region of Guatemala. According to Acosta and Valdés (2013), livestock production systems constitute a capitalization mechanism for rural families, serve as a system of resilience to shocks as well as collateral support for both formal and informal credit, and constitute a food source for diet diversification.

The results of this research study will be available not only to scientists, but also to farmers, private and government institutions that oversee decision making to reduce vulnerability (drought and desertification) and increase the environmental and economic benefits of livestock activity.

[1] This includes rational management of pastures, food and nutrition, genetics and animal health, water management and integrated manure management.

1.1 Objectives

General Objective

Evaluate the tree cover on livestock farms in the southeast region of Guatemala.

Specific Objectives

- **Specific objective 1:** Describe representative livestock farms from the department of Jutiapa, Jalapa, and Santa Rosa.

Specific objective 1 research question

- Which are the typologies of livestock farms in the study area?

- **Specific objective 2**: Determine the floristic composition of tree cover from representative farms of the department of Jutiapa, Jalapa, and Santa Rosa.

Specific objective 2 research questions

- Which are the most abundant timber and non-timber species found in the livestock farms?
- How is the diversity of tree cover presented on livestock farms?
- How is the tree cover structure presented on livestock farms?

2. Literature review

2.1 Importance of livestock in Central America

According to the Food and Agriculture Organization of the United Nations (FAO 2017), livestock contributes to 40 percent of the value of world agricultural production and sustains the livelihoods and food security of nearly 1.3 billion people. The livestock sector is one of the fastest growing sectors of the agricultural economy. The growth and transformation of the sector offers opportunities for agricultural development, poverty reduction, and improvement in food security.

Livestock in Central America is undergoing a process of transformation, as in all parts of the world. It is influenced by the demand for meat and milk, which puts great pressure on limited natural resources (Steinfeld 2000). This same author mentions that about 38% (94 million ha) of the total area of Central America is constituted by grazing lands. Land use for intensive grazing systems has steadily increased over the past few decades and this has mainly occurred in forestland. In some countries such as Nicaragua and El Salvador there was a dramatic reduction in forest area. The predominant factors that have intervened in the increase of milk and meat production have been: the change in the demand for animal products, widespread change in national policies, international trade, changes in species and their functions (livestock not only produces food, but also provides other goods and services), geographical displacements, structural changes, and technological changes.

Acosta and Valdés (2013) point out that in economic terms, cattle farming is one of the most important agricultural subsectors for Central America. In the region, gross domestic product (GDP), comprising meat and dairy products, accounts for a range between 1.3 and 20% of agricultural gross domestic product (AGDP). As a result, from the economic point of view, it becomes the most important agricultural subsector for Central America followed by the banana, sugar cane, poultry, and coffee plantations subsector. According to these authors, if each of the sectors is analyzed independently, it is revealed that the livestock subsector has a role in the economy of each country in the region. It can be observed that its greatest contribution to the gross domestic product of agriculture is in Nicaragua (38%), followed by Panama (31%), Honduras (20%), Costa Rica (20%), El Salvador (16%), and Guatemala (8%), respectively.

2.2 Livestock production in Guatemala

According to the Government of Guatemala (2012), the cattle inventory of the country in 2003 was about 1.8 million cattle heads (Table 1). However, in more recent data derived from 2005 and 2007 from agricultural surveys, Guatemala livestock inventory could reach 2.9 million cattle heads, of which 49% are used for dual purposes (meat and milk), 35% are meat producers, and 16% are dedicated to specialized milk production. Livestock provide about US$ 500 million/ year in direct income to the country. These revenues come from the production of 1.4 million liters of milk per day and the sale of half a million head of cattle for meat. Of the AGDP, 16.2% is represented by livestock activity, which is distributed by productive activity in: poultry farming 8.3%, cattle 5.9%, pig 1.9%, sheep and goats with around 0.1%.

Table 1. Heads of cattle on farms and dwellings by departments in Guatemala (INE 2003).

Departments	Total cattle's	On farm		In homes	
		Num. Farms	Num. Cattle's	Num. Homes	Num. Cattle's
Total in the Republic	1,775,831	106,789	1,627,522	44,858	148,309
Petén	322,039	6,167	315,819	788	6,220
Escuintla	231,669	3,787	222,714	1,287	8,955
Izabal	166,505	2,819	159,699	828	6,806
Jutiapa	124,393	6,967	110,938	2,468	13,455
Santa Rosa	108,787	2,621	105,217	552	3,570
Retalhuleu	107,250	1,587	104,749	512	2,501
San Marcos	82,380	16,581	70,827	4,898	11,553
Alta Verapaz	81,706	6,724	76,957	2,012	4,749
Suchitepéquez	78,304	1,542	74,566	891	3,738
Quiche	64,903	10,797	46,246	7,573	18,657
Quetzaltenango	57,569	9,898	51,480	2,958	6,089
Huehuetenango	55,255	9,676	46,562	2,546	8,693
Chiquimula	54,457	4,730	51,069	907	3,388
Zacapa	51,134	2,045	45,941	770	5,193
Jalapa	46,075	2,931	37,903	1,572	8,172
Baja Verapaz	43,369	4,940	32,884	2,815	10,485
Guatemala	32,278	2,521	27,503	1,467	4,775
Chimaltenango	25,848	3,428	16,249	4,497	9,599
El Progreso	18,437	1,241	17,001	296	1,436
Totonicapán	14,116	4,827	8,286	3,014	5,830
Sololá	5,562	480	1,871	1,950	3,691
Sacatepéquez	3,795	480	3,041	257	754

2.3 Environmental problems generated by livestock production

Livestock is responsible for most of the world's land use. Grasslands and croplands dedicated to the production of livestock food represent almost 80% of all agricultural land in the world (FAO 2017). The main causes of degradation of livestock soils include trampling, surface erosion due to rainfall, and mass erosion because of overgrazing. Some of the structural causes of overgrazing are poor pasture management, inadequate pasture rotation schemes, excessive grazing duration, reduced rest periods, poor food preservation, and lack of knowledge of the importance of association with grasses as mentioned by Acosta *et al*. (2013).

Ríos *et al*. (2007) state that in livestock production systems the problem of pasture degradation exerts negative effects on the soil water balance. Loss of soil cover resulting from overgrazing reduces water infiltration by compaction, increases erosion, and has negative effects on the soil moisture retention capacity. Among the main greenhouse gases (GHG) generated by livestock activity are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (NO_2) (Steinfeld *et al.* 2006).

Production of methane (CH_4) is a natural part of the digestion process of ruminants. Nitrous oxide (NO_2) is a product of the decomposition of excreta and carbon dioxide (CO_2), which is mainly associated with the change in the use of land from forests to pastures (Herrero *et al*. 2011). Furthermore, the use of nitrogen chemical fertilizer in pasture areas increases the effect of cattle sector over climate change (CC) due to the production of nitrous oxide (NO_2).

2.4 Socioeconomic benefits of silvopastoral systems

The location where the silvopastoral systems (SPS) are developed influences the capacity of their economic contribution, since a higher profitability has been reported in the SPS in relation to conventional livestock in areas where the land has a lot of slope. It has been found by Pérez (2006) that with SPS there is a larger net present value (NPV) of US$ 213/ ha compared to the US$ 46/ ha of conventional breeding. The profitability and adoption of SPS will depend on the biophysical and socioeconomic conditions of each community or farmer.

Pérez (2006) sustains that an important input of SPS is the contribution to family consumption, especially the use of products from the trees (firewood, poles, cuttings and fruits, among others) that are designated for self-consumption, generate income not necessarily in cash. These important contributions are not regularly considered in most of the economic analysis carried out in SPS due to their difficult measurement and in many cases their role in the farm is often neglected.

2.5 Contribution of silvopastoral systems to the generation of ecosystem services

SPS in the tropics have contributed to increase pasture production and quality, restoration of degraded soils, improved water resources, carbon sequestration, greenhouse gases and biodiversity conservation. The benefits provided by agroforestry practices can be spatial and temporal. The global reach of some of them, such as carbon sequestration and biodiversity, demonstrates the urgent need to introduce agroforestry as a fundamental tool for animal production in the tropics, starting with the implementation and generalization of technologies adapted to climate change (Alonso 2011).

2.5.1 Soil conservation and restoration

Agroforestry systems (AFS) and SPS act through several complementary mechanisms to protect the soil from direct sun radiation through canopy cover and litter supply (McNeely and Schroth 2006). AFS and SPS increase the entrance of atmospheric nitrogen by the presence of shrubs and trees associated with bacteria specialized in fixing this element. Moreover, they increase nutrient availability because of the higher production and decomposition of the biomass of the trees with greater recovery of nutrients from the deep layers of the soil thanks to the longer roots of the trees (Nair 2011) and they also improve the properties and the increase in microbial activity due to the penetration of the roots of the trees (Nair *et al*. 2008 and Vallejo *et al*. 2012).

Some of these factors in turn reduce the vulnerability of these systems to extreme climatic phenomenon by conserving soil moisture and reducing the desiccant effect of high temperatures and wind on the productive stratum. In highland or temperate climates, trees and shrubs also contribute to reduce the impact of frost on pastures (Murgueitio *et al*. 2013).

2.5.2 Protection of water resources

According to Villanueva *et al.* (2009), one of the most important consequences of the establishment of SPS is the impact of trees and shrubs on the water balance of the system. When woody and pastures share the same space, the lower temperature present in the herbaceous stratum under the crown of the trees causes a decrease in the rate of transpiration through the stomata and less evaporation. Woody pastures and a good herbaceous cover throughout the year are efficient in rainwater harvesting because they increase the infiltration (which benefits the recharge and groundwater sustenance) and show less surface runoff, decreasing the laminar erosion (Ríos *et al.* 2007).

The hydrological benefits that SPS provide may be translated into payments to farmers who manage environmentally friendly livestock systems. Therefore, an adequate management of livestock farms in the tropics implies the introduction of the woody component in pastures and the management of fragments of forests in those critical areas (areas of water recharge, nascent, or vulnerable to landslides), to sustain the productive and economic base of the farm and simultaneously preserve its integrity (Villanueva *et al*. 2009).

2.5.3 Carbon sequestration

In SPS, carbon can be accumulated in four components: soil biomass, litter, root systems, and soil organic carbon. Soil biomass in SPS is mainly divided into woody biomass and biomass of the herbaceous stratum: grasses and legumes. Grass is the main herbaceous component of SPS (Arias, 2007). The amount of carbon captured in SPS can be variable according to their different strata and composition. According to McGroddy *et al.* (2015), SPS may increase carbon pools in pastures while maintaining productivity. Adding trees to pasture provides carbon sinks in woody biomass and may improve degraded soils and increase the stability of soil carbon pools.

Montagnini *et al.* (2013), point out that SPS of pastures with planted trees show a range of tree carbon (C) stock of 0.31-91.8 t/ha and SPS of pastures with natural trees show tree C stocks of 2.43-74 t/ha. Calculated C sequestration values are 0.08-4.59 t/ha/yr for the pastures with planted trees and 0.49-4.93 t/ha/yr for the pastures with natural trees. This reflects the heterogeneity of the SPS, which differ in their design, species and site conditions. Due to their design and management, fodder banks cannot reach high values of C stock. Therefore, it is highly recommended to include other trees, especially timber or fruit species which can attain higher values of C sequestration rates and stock.

2.6 Adaptation and mitigation to climate change

Adaptation is the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities.

In some natural systems, human intervention may facilitate adjustment to expected climate and its effects (IPCC 2014).

Mitigation can be defined as the human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHGs) (IPCC 2014).

According to FAO (2011), adaptation and mitigation are the two main responses to CC. They are two sides of the same coin: mitigation addresses the causes of CC and adaptation addresses its impacts. Murgueitio *et al.* (2014), state that tropical and subtropical areas are in an increasingly vulnerable situation due to the exacerbation of extreme CC situations. The most frequent oscillations are during dry seasons or excessive rain. SPS with high density of trees, shrubs, and improved pastures favor the adaptation to the CC because they maintain the soil humidity and reduce the high ambient temperatures in the paddocks. In addition, they improve the productivity and quality of the forages and reduce the seasonality of meat and milk production.

A major contributor to reducing vulnerability and increasing production within the system is the diversity of animal and plant species (Murgueitio *et al.* 2015). The inclusion of trees and shrubs in the SPS allows the generation of additional products that contribute to diversify incomes or reduce costs within the system, while increasing the economic alternatives of the farmers. In addition, many tree species produce fruits rich in sugars and protein that contribute with important nutrients to the animals during the most critical periods of the year (Cardozo 2007).

SPS such as fodder banks and trees in pastures are tools for adaptation to climate change of livestock systems. They offer food resources (foliage and fruits) that can be used as animal feed in the dry season when pastures reduce their availability and quality of edible dry matter. Moreover, in high-temperature areas, trees shade mitigates the caloric stress of livestock, which contributes to increased milk and meat production (Villanueva *et al.* 2009).

2.7 Importance of timber and non-timber species on livestock farms

The effect of shade may favor the efficiency of dairy cattle, which tolerate less heat because of the large amount of metabolic heat they produce, generated by the high consumption of dry matter to maintain the high level of production and increase in their metabolic rate (Navas, 2010). From the economic point of view, the effect of shade increases milk production within a range of 10% to 22% compared to no-tillage pastures (Villanueva *et al.* 2009).

In dry tropical conditions, SPS displays enormous potential for increasing biomass and soil carbon stocks compared to the grass monoculture and can be used as a greenhouse gas mitigation strategy in livestock production systems. SPS can store up to eight times more carbon in short time, compared to the livestock systems in pasture monocultures. SPS stores similar amounts of carbon in their biomass and soil as dry tropical forests (López-Santiago *et al*. 2018).

Nicodemo and Da-Silva (2018) indicate that the choice of tree species for a silvopastoral system takes into account its intended uses (timber, fodder, fuel, fiber, and environmental services), biophysical limits (altitude, temperature, rainfall, water deficit, soil, and tolerances and constraints), management and market, among others.

The services and benefits of trees make a difference in the production and sustainability of smallholder farms, such as water balance regulation, timber sales, biomass provision for livestock in the dry season, and payments for environmental services (Villanueva *et al*. 2009).

Timber in SPS is mainly harvested when there is a crisis in production, which may represent a risk for the maintenance of system sustainability. Natural regeneration management is an approach to maintain timber production, tree cover, and other environmental benefits of trees in SPS. The management of natural regeneration provides advantages for farmers, reducing investments on seedling production, nurseries, and planting, as well as reducing the dependency on external seed sources and foreign technologies (de Sousa *et al*. 2017).

According to FAO (2014), non-wood forest products (NWFP) are "goods of biological origin other than wood derived from forests, other wooded land and trees outside forests". NWFP may be gathered from the wild or produced in forest plantations, agroforestry schemes, and from trees outside forests. Examples of NWFP include products used as food and food additives (edible nuts, mushrooms, fruits, herbs, spices and condiments, aromatic plants, and game), fiber (used in construction, furniture, clothing, or utensils), resins, gums, and plant and animal products used for medicinal, cosmetic, or cultural purposes. NWFP have also attracted considerable global interest in recent years due to the increasing recognition of their contribution to environmental objectives, including the conservation of biological diversity.

Some NWFP may offer the potential to create employment and generation of opportunities and income; however, but the realization of this potential will require investments in other areas. Investment in NWFP can help to improve the capacity and get better access to resources, but external conditions as market forces or opportunity costs make people prefer other activities than the production of NWFP (López 2008).

3. Materials and methods

3.1 Localization and description of study area

The study was developed in three departments from the southeast region of Guatemala (Figure 1): Jalapa is located at latitude 14°38'02" and longitude 89°58'52" with a territorial extension of 2,063 km^2, Jutiapa is located at latitude 14°16'58" and longitude 89°53'33" with a territorial extension of 3,219 km^2, and Santa Rosa is located at latitude 14°16'42"and longitude 90°18'00" with a territorial extension of 2,295 Km^2. It covers the basin of the Lagoon of Ayarza (3,112.5 ha) and the upper and middle parts of the Ostúa River basin (30,729 ha and 52,239 ha, respectively).

This region presented an average altitude of 1148.9 ± 410.1 meters above sea level (m.a.s.l). The variable of precipitation had an average of 1228.30 ± 293.03 millimeters (mm) annual rainfall. According to PNUD (2014) the orography in this region goes from flat to slightly inclined, that is from 500 to 2600 m.a.s.l. This region belongs to the dry mountainous area that receive on average 975 mm of rain, which confirms the level of drought in these departments.

This region includes two of the departments with the highest threat of desertification in the country (Jalapa and Jutiapa) and a greater susceptibility to drought. Of the fifteen municipalities prioritized, there is a positive annual exchange rate of forest cover in only three of them: Mataquescuintla (3.31%), San Carlos Alzatate (4.8%), and San Manuel Chaparrón (8.18%). These three municipalities belong to Jalapa’s department. In all other municipalities of Jalapa, Jutiapa, and Santa Rosa, the rate of deforestation is negative. Loss of forest cover is mainly due to the advance of the agricultural frontier, livestock activity, deforestation of forests for firewood and wood extraction, forest fires, and to a lesser extent, the demand for land for urbanization and housing construction in the rural area (PNUD 2014).

The priority region is located within the so-called dry corridor. There is a low threat of desertification in Jalapa (25.5%), which covers all the municipalities in the department, Jutiapa (9.5%) in the municipalities of Agua Blanca and Santa Catarina Mita, and Santa Rosa (1.5%) in the municipality of Casillas. There is a high threat of desertification in the department of Jalapa (13.8%) in the municipalities of San Pedro Pinula, Jalapa, San Luis Jilotepeque, San Manuel Chaparrón and Monjas, and in the department of Jutiapa (18.9%), in the municipalities of Agua Blanca, Santa Catarina Mita, El Progreso, and Jutiapa. In turn, the region is susceptible to droughts, mainly in the municipalities of San Pedro Pinula, San Luis Jilotepeque, San Manuel Chaparrón, and Monjas in the department of Jalapa, and Agua Blanca, Santa Catarina Mita, Jutiapa and Asunción Mita, in the department of Jutiapa (PNUD 2014).

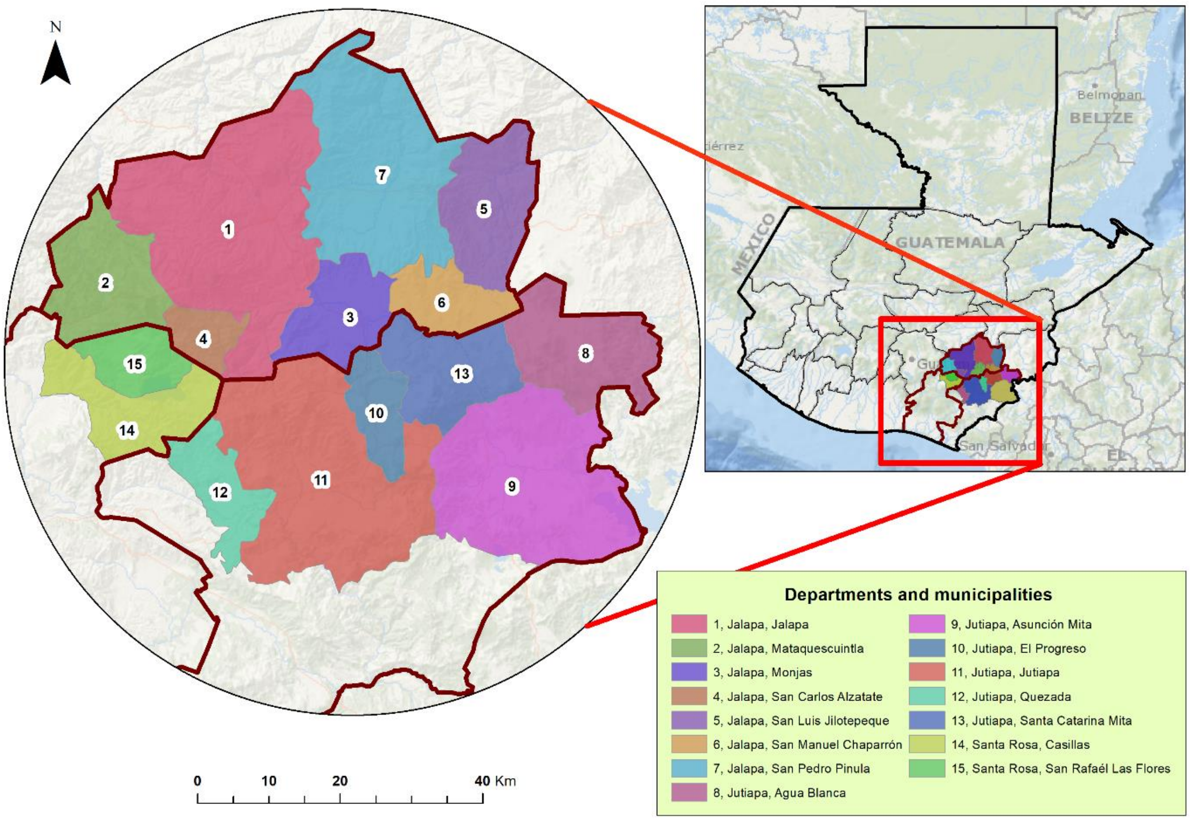

Figure 1. Study area in the southeast region of Guatemala.

3.2 Selection of farms

There was a selection of 60 farms based on the following general criteria: 1) the main economic activity is cattle raising, 2) the family owns the farm, 3) the farm represents one of the typologies of environmental livestock present in the are, 4) there is forest cover, scattered trees or other tree presence on the farm, 5) the property is not on sale, 6) the family has long-term plans for the livestock activity, and 7) there are good animal husbandry practices such as genetic improvement, improved nutrition, and animal welfare.

Those farms selected were part of the database of the project "Sistemas de producción ganaderos climáticamente inteligentes basados en sistemas silvopastoriles en 15 municipios del suroriente de Guatemala" carried out from 2016-2018.

Out of the sample of sixty farms, there was a second selection of thirty farms based on sixteen criteria that involves the level of technological innovation[2] such as: 1) woody fodder bank; 2) grass fodder bank; 3) live fences, among others. A score was given for each criterion (appendix 1) and these were the base to identify which farms were in a high level of technological innovation and which ones were in a low level of technological innovation. It is important to highlight that there are no international standards that classify livestock farms according to the level of technological innovation; this thesis is an attempt in doing so in the southeast region of Guatemala that is located in the dry corridor of Central America.

A semi-structured interview was conducted in the thirty farms to obtain biophysical (area of the farm, land use, size of paddocks, among others.), socioeconomical (family size, farmer's age, among others.), and productive (milk production in dry and rainy season) information of each farm.

3.3 Characterization of trees on the farms

Before getting into the characterization of trees, it is important to manage the following definitions:

Agrosilvicultural systems (ASS): They are a combination of crops and trees, such as alley cropping or home-gardens.

Fodder banks (FB): It is an enclosed area of concentrated forage legumes reserved for dry season supplementary grazing.

Forest plantation (FP): It is a project that is established with the main objective of producing sawmill wood or raw material to supply the forestry industry.

Live fences (LF): They are trees that are mainly related to the delimitation of farms and pastures; it may be made up of only woody species only or a combination of woody species with dead poles.

Natural forest (F): It is the ecosystem where trees are the dominant and permanent plant species, they are originated by natural regeneration without influence of human beings.

[2] Innovation is the successful introduction of new knowledge and technology in both social and production processes (Cuevas *et al*, 2013).

Riparian forest (RF): It refers to the arboreal and shrub vegetation located in the margins of rivers, streams, and other streams or bodies of water.

Scattered trees in paddocks (STP): These are trees that can be originated from natural regeneration or by plantations; the presence of trees depends on the availability of seed sources in or near pastures where regeneration is controlled by environmental factors, (water, light, and nutrients), type, and mobility of dispersing agents.

Tree cover information was collected from trees scattered in paddocks, live fences, forest plantations, among others, following the protocol of Detlefsen *et al.* (2012). In each farm, in cooperation with the owner and using a map from Google Earth, a review and delimitation of the perimeters of the farm, the land use, and length of live fences was estimated. Each farm's location and the coordinates of the different measurement plots were registered with the Global Positioning System (GPS). All trees with a diameter at breast height (DBH) greater than 5 cm were recorded.

The uses of land and live fences were verified and evaluated to determine if they were homogeneous or heterogeneous (by topography, species, density of cover, and management). The size of the plot to sample the tree cover was 1000 m^2 (0.1 ha). In regard to land uses, "trees scattered in paddocks" and "forests" in these plots were established in a circular manner using a radius of 18 m. In forest plantations, rectangular plots using 20 by 50 m were used and they were distributed randomly.

In relation to live fences, the segment[3] for sampling was 25 m with one meter on each side of the fence, and the location was at the midpoint of the live fence. The intensity of sampling varied between 1-5% depending on the size of the stratum. The criterion defined was that the greater the area used, the lower the sampling intensity (Detlefsen *et al*. 2012) (Table 2).

[3] The recommended segment to sample live fences is between 25 m, in this research study it varies because of the lack of homogeneity in the stratum so there was census application in some of the areas. These are pointed out in the database in each farm.

Table 2. Level of sampling intensity by stratum size in land use of thirty livestock farms located in the southeast region of Guatemala.

Stratum area in land use (ha)	Intensity of sampling (%)
< 10	5
10-20	4
21-50	3
>50	1

3.4 Data collection

In each tree plots the information collected was common name and scientific name of the tree, the DBH was measured at 1.30 m using a diametric tape. When several axes were presented, each stem was measured independently, and the mean square diameter was calculated ($DCM = \sqrt{\Sigma DBH / n^2}$) per individual (Snowdon *et al*. 2002). The commercial height and total height was estimated with the use of a Suunto clinometer, the Radius of crown axis one and two were measuring tape of 50 m, and the sanitary state of the tree was evaluated by observation (healthy, sick, dead).

The information was collected with the help of the ODK[4] using a smart phone; this tool is important because it helps to decrease the errors while recording the data collected and it also permits the restriction of data that does not coincide with the information of the area where the study is carried out.

Data of the total head of cattle and category of each one was collected through the socioeconomic survey. This helps to calculate the total animal unit and stocking rate in each department of the study using the formula presented by Eusse (2013) and CORFOGA (2000).

3.5 Calculating the percentage of tree cover

Tree coverage was estimated in each one of the different land uses. The percentage of tree cover was obtained by the measurement of the perpendicular diameters of the area occupied by the tree canopy presented in each plot. The calculation of the tree canopy was done using the following formula:

AC: $(\pi * R1 * R2)/4$

Were:

AC: Area of crown

[4] They are a set of tools that allow to collect data through mobile devices and send data to an online server even if there is no internet connection or access to a mobile network at the time of data collection.

R1: Radius of crown axis 1

R2: Radius of crown axis 2

Π: 3,1416

In order to obtain the percentage of CC for each land use, there was a summation of all AC and after a division between the area of the plot and multiplied by 100, the result obtained was used to calculate the average percentage of tree cover according to the number of plots by land use. This coverage was estimated for all timber and non-timber species using the following formula.

CC%=(∑AC/Ap)*100

Was:

CC: Crown cover (in percentage)

∑AC: Summation of crown area (m^2) of al tree species

Ap: Area of the plot were sample was taken (m^2)

100= Conversion factor in %

3.6 Data analysis

Infostat (software that covers all the basic needs for descriptive statistical analysis and the production of graphics for the exploratory analysis (Di Rienzo *et al.* 2008)) was used to make a conglomerate analysis (dendrogram of the typologies of livestock farms), bar graphics of tree cover percentage, and classification of diametrical type of all trees. Q-eco (statistical software for analysis of ecological data) was used applying community- diversity- diversity index. Moreover, community ordinations, unconstrained – nonmetric multidimensional scaling of all tree species were used (Oksanen *et al.* 2018). This allowed the calculation of:

a. Rényi Hi = ln (Nq), where Nq corresponds to the values of the series of Hill numbers. Inn a profile of the series of Hill numbers, this expresses that one site is more diverse with respect to another site if the diversity profile is maintained above in parallel. $Nq = \frac{1}{1-a}\ln(\sum_{i=1}^{S} Pi^{a})$ Hill's series of numbers measure the effective number of species in a sample, when each species is weighted by its relative abundance.

4. Results and discussion

4.1 Description of livestock farms in the southeast region

Farmers in this region have owned his farm for a long time. These lands usually are inherited, and it makes the distribution of the farms by size very heterogeneous. The production unit is usually composed of a single farm, but it is common to find fractionation of the production unit in different areas at different gradients in the agricultural landscape.

Workforce is mainly composed of family members; however, in many of the cases there are permanent employees who work on the farm. In the dry season there are other employees hired occasionally (day labor) to do maintenance work on the farm. Similar data of livestock farms was found by Holguin *et al.* (2008).

Out of the thirty surveys conducted, 97% of farmers were male and 3% female. Livestock farms in the southeast region presented family size of 5 ± 1.68 individuals, farmer's age presented an average of 47 ± 12 yrs, and academic level had an average of 9 ± 5.55 yrs among all farmers in the three departments. This presented an average of 26.33 ± 22.4 ha, with stocking rate of 3.39 ± 3.35 AU/ha (Table 3). According to the Government of Guatemala (2012), in general farms have an area of less than 40 ha. Similar data was found by Villacís *et al.* (2003), were stocking rate was 3.07 AU/ha, with variations from 0.5 to 9.2 AU/ha.

In addition to the livestock component, farms have agricultural activities, forestry, and agroforestry systems. Nevertheless, livestock was the most common land use on the farms. The proportion of land use reflects the tradition of livestock as an economic activity in this region for many years.

Table 3. Parameters utilized to classify livestock farms in the different departments from the southeast region of Guatemala.

Criteria	Variable	Departments Jalapa (n=14) Media ± E.E	Jutiapa (n=12) Media ± E.E	Santa Rosa (n=4) Media ± E.E	Global (n=30) Media ± E.E
Socioeconomic	Size of family (Ind/fam)	5 ± 0.44	5 ± 0.36	7 ± 0.91	5 ± 1.68
	Age of farmer (yrs)	47 ± 3.76	46 ± 3.00	47 ± 5.76	47 ± 12
	Academic level (yrs)	8 ± 1.24	12 ± 1.71	6 ± 1.49	9 ± 5.55
Productivity	Farm Area (ha)	36.9 ± 6.9	18.2 ± 4.44	13.7 ± 4.9	26.33 ± 22.4
	Lv. area (ha)	21.8 ± 19.5	14.7 ± 13.9	9.4 ± 7.4	17.3 ± 16.4
	T\t. Animal unit (Head-cattle)	80.3 ± 71.6	40.8 ± 27.2	36.6 ± 13.7	58.67 ± 55
	Stocking rate (AU/ha)	3.68 ± 3.67	2.77 ± 1.95	3.89 ± 1.85	3.39 ± 3.35
	Milk production L/ha/yr	3161.8 ± 2975.7	3281.3 ± 2367.4	6403.8 ± 5971.1	3315.3 ± 3188.9
Environmental	m.a.s.l (m)	1256.9 ± 442.7	881.5 ± 163.6	1573.5 ± 313.1	1148.9 ± 410.1
	Precipitation (mm)	1260.93 ± 336.37	1078 ± 154.44	1567 ± 76.21	1228.30 ± 293.03
	Temperature (°C)	22.31 ± 1.	23.9 ± 0.9	21.9 ± 0.4	22.60 ± 1.1

4.2 Typologies of livestock farms

In the southeast region of Guatemala, there were identified two typologies of farms (Figure 2): those with a high level of technological innovation (HLTI) and farms with a low level of technological innovation (LLTI). The number of farms according to each typology was 15 and 15 respectively. The level of technological innovation was based on the total points that each farm received when applying the sixteen criteria listed (appendix 1).

Cluster (C1) belongs to the group of farms with HLTI and they presented the majority of score from the criteria evaluated. These farms had forest plantation, natural forest, live fences, trees in boundaries, among others. They presented 61% of all criteria evaluated.

Farms with HLTI had a total land average of 26.93 ± 20.91 ha; the area dedicated to livestock activity had an average of 14.96 ± 11.03 ha. This group presented stoking rate of 6.09

± 4.81 AU/ha. Herd’s size had an average of 56.80 ± 32.70 animal unit, with an average of milk production of 5125.2 L/ha/yr. Age of farmers presented an average of 45 yrs and the average of education level was 10.6 yrs. It was found that farms in this group presented 14 % of natural forest. These are known for the implementation of silvopastoral systems and sustainable practices and livestock activity is based on a specialized dairy system.

C2 were farms with LLTI; this group presented 41% of all criteria used in the evaluation. Farms inside this group had a total land average of 25.74 ± 24.56 ha, in average land dedicated to livestock activity was 19.68 ± 20.59 ha, and they presented stocking rate of 4.41 ± 3.93 AU/ha. Herd’s size had an average of 60.5 ± 72.04 animal unit, with average of milk production of 2071.1 L/ha/yr. Age of farmers presented an average of 49 yrs; the average of education level was 7.77 yrs. Farms in this group presented 9.6 % of natural forest. These farms are known for the low implementation of silvopastoral system and sustainable practices on the farm; livestock activity is based on double purpose.

According to Velasco-Fuenmayor *et al.* (2009) farmers with a low level of education have higher probability to belong to the group with a low level of technological innovation; meanwhile, farmers with a higher level of education tend to belong to the group with better technological innovation. In addition, the size of the herd and the farm is a determinant factor that influences in the level of technological innovation. Farmers with large areas of land tend to adopt more innovation than those with small areas and it may be because producers with big farms have more capacity of investment and they work with economies of scale.

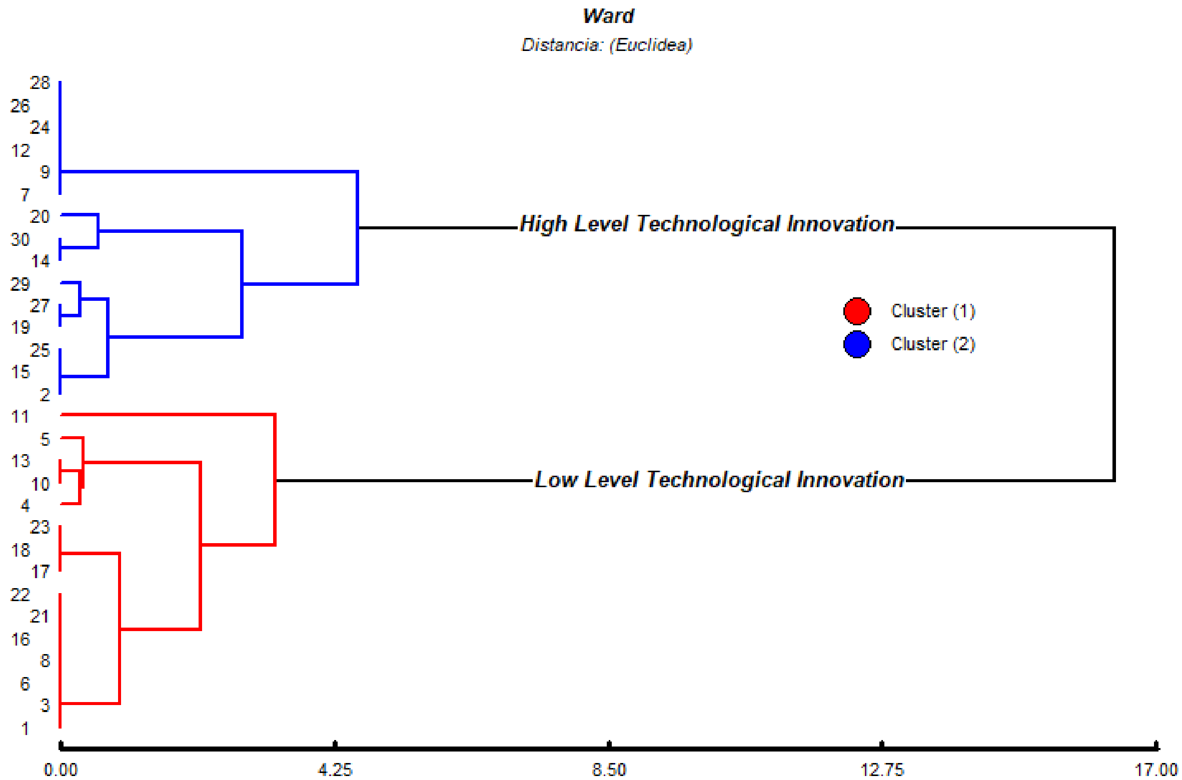

Figure 2. Dendrogram of classification according to technological level of innovation of thirty livestock farms located in the southeast region of Guatemala.

4.3 Percentage of tree cover inside the three departments of study

Jalapa Department presented the highest percentage of tree cover (Figure 3), inside F the percentage was 40.72%, it was the only department that presented FB with 2.09%. Jutiapa Department presented a high percentage of tree cover in STP approximately 27.27% in average, but in F it presented only 12.29%. Santa Rosa Department presented approximately 38.17% of tree cover in F and 41.65% in FP. In both land use, cattle grazing occurs during the dry period of the year. RF was also present in this department with approximately 1% of tree cover, which helps build a spring protection inside the farms. It is important to highlight that in the three departments there is tree cover present in lower extent in ASS, FB, and RF.

This region is characterized by its high rate of deforestation. The loss of forest cover is mainly due to the advance of the agricultural frontier, cattle activity, the depredations of the forest for the extraction of firewood and wood, the forest fires, and to a lesser extent, the demand of the land for urbanization and construction of houses in the rural area. This can explain to some extend the low percentage of forest cover inside each farm, but at the same time, it highlights the effort of these farmers of keeping trees in the different land use on the farm (PNUD 2014).

According to INAB *et al.* (2012) Jalapa Department had a forest cover of 22,408 ha in 2010. It was determined that during the 2006-2010 period, there was a loss of 6,234 ha of forest; however, during that same period, 5,225 ha were recovered. The rate of deforestation for this department was 202 ha/yr.

In regard to Jutiapa Department, it had 2010 had a forest cover of 12,730 ha in 2010. Although it was determined that during the period 2006-2010, there was a loss of 5,682 ha of forest, however, during that same period, 2,762 ha were recovered. The rate of deforestation for this department was 555 ha/yr. in relation to Santa Rosa Department, it had a forest coverage of 46,304 ha in 2010. It was determined that during the period 2006-2010, there was a loss of 15,319 ha of forest; however, during that same period 10,579 ha were recovered. The rate of deforestation for this department was 1,281 ha/yr (INAB *et al.* 2012).

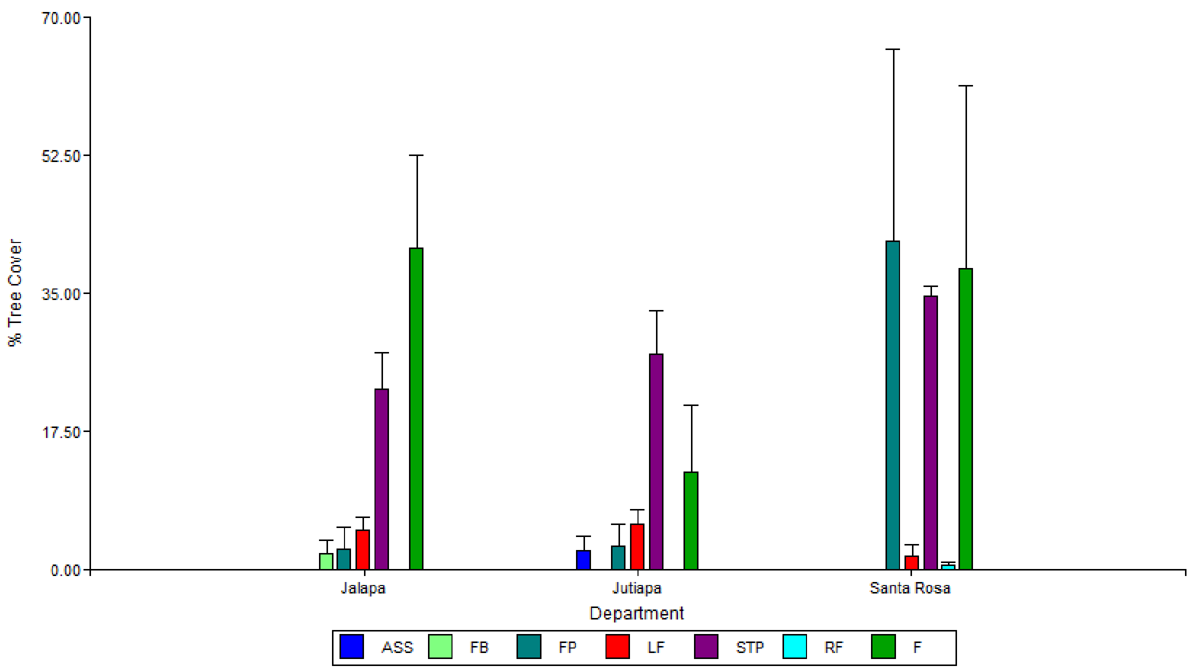

Figure 3. Percentage of tree cover by land use at Department level.

4.4 Percentage of tree cover inside farms typologies

Farmers with HLTI presented an average of 31.2% of tree cover in F and 23.4% of tree cover in STP. Farms with LLTI presented 26.8% inside of F of tree cover and 28.9% of tree cover in STP. In both levels of technological innovation ASS, FB and RF had a low percentage of tree cover inside the system (Figure 4). It is important to highlight that farms with HLTI presented a higher percentage of tree cover within their livestock system, compared to those that had LLTI.

In a research study carried out by Chica (2011) it was found that STP inside of double purpose farms presented an average of 13% in paddocks. Villanueva *et al.* (2006) found in active paddocks with *Brachiaria brizantha* that the average of tree cover in dual purpose systems varies between 16.4 ± 1.8 and in meat production systems it varies between 17.8 ± 2.1%. Ramírez (2012) found in specialized milk systems that paddocks with high coverage presented an average of 24%, in intermediate coverage an average of 8%, and in low coverage an average of 4%.

According to García and Ibrahim (2013) in Rivas, Nicaragua, it was found that the shade of trees reduces the caloric stress of the cattle, which means increases in milk production between 1 and 3 L/cow/day. It is important to consider the diversity of trees to ensure shade throughout the year because some have leaves all over the year and others in certain months of the year. Apart from the shade, the trees offer another series of benefits such as nutrients for the soil, feed for livestock (foliage and fruits), production of timber products (wood, poles and firewood), and favor wildlife and carbon sequestration.

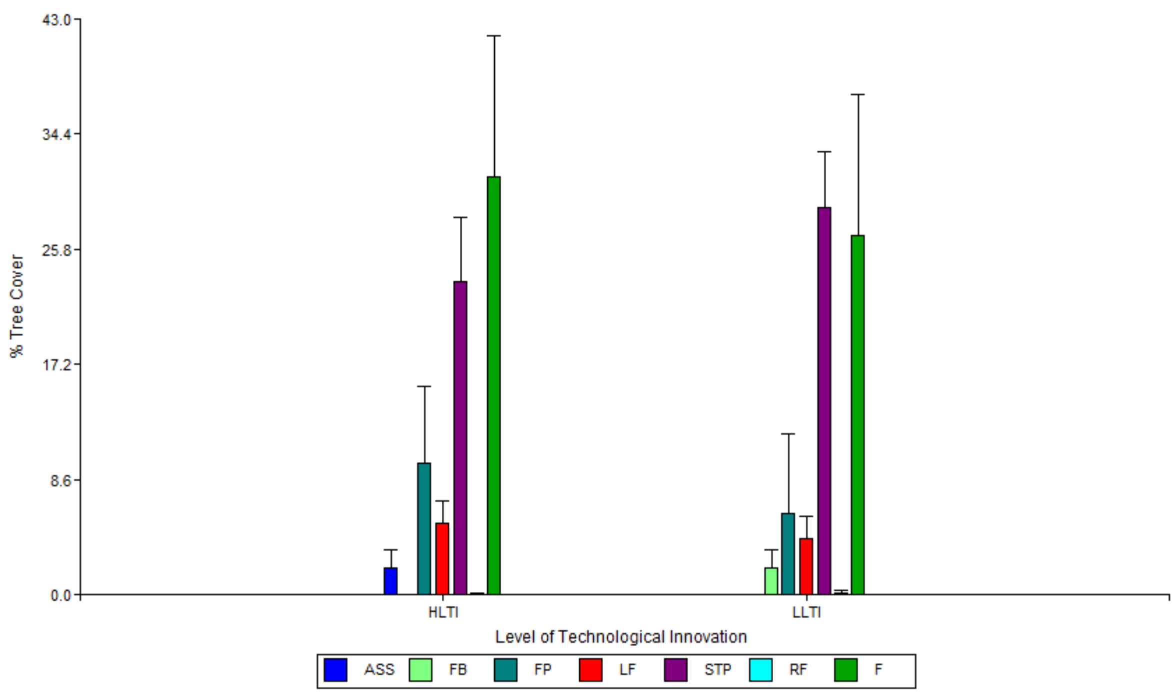

Figure 4. Percentage of tree cover by level of technological innovation in the different land use.

4.5 Floristic composition of tree cover

There are two remarked gradients of tree distribution based on altitude, temperature, and precipitation (Figure 5). Trees in high altitude are related to high precipitation and low temperature; and trees in low altitude are related to low precipitation and high temperature. This figure explains 63% of the floristic composition inside the livestock farms systems studied in the southeast region of Guatemala. In areas with high altitude, the land use with more density of trees was F, followed by STP, LF, and FP. In areas with low altitude, STP dominates much of the land use, followed by LF, F, ASS, FB, RF, and FP.

In the study area there was a total of 4,678 individuals recorded and these belong to eighty-three and thirty-seven families in an area of 790 ha out of which 169.1 ha presented LF. When analyzing the phytosanitary state of trees, it was found that 98% were in a healthy condition, 1.2% were identified as sick (fungus disease), and 0.8% were dead. This reflects that livestock landscape plays an important role in the conservation of tree diversity.

The most abundant classes of timber present in the study area were *Pinus spp* and *Quercus spp;* the most abundant non-timber species found were *Gliricidia sepium* and *Acacia pennatula.* According to farmers, this timber species have a high adaptability in the region and also have an important value in the wood market. The canopy (when they are present in STP) allows the penetration of sunlight in the pasture area, which favors the grazing area were cattle normally feed the entire year. The non-timber species found are easy to propagate and they are an important source of forage and fruit for the livestock during the dry season.

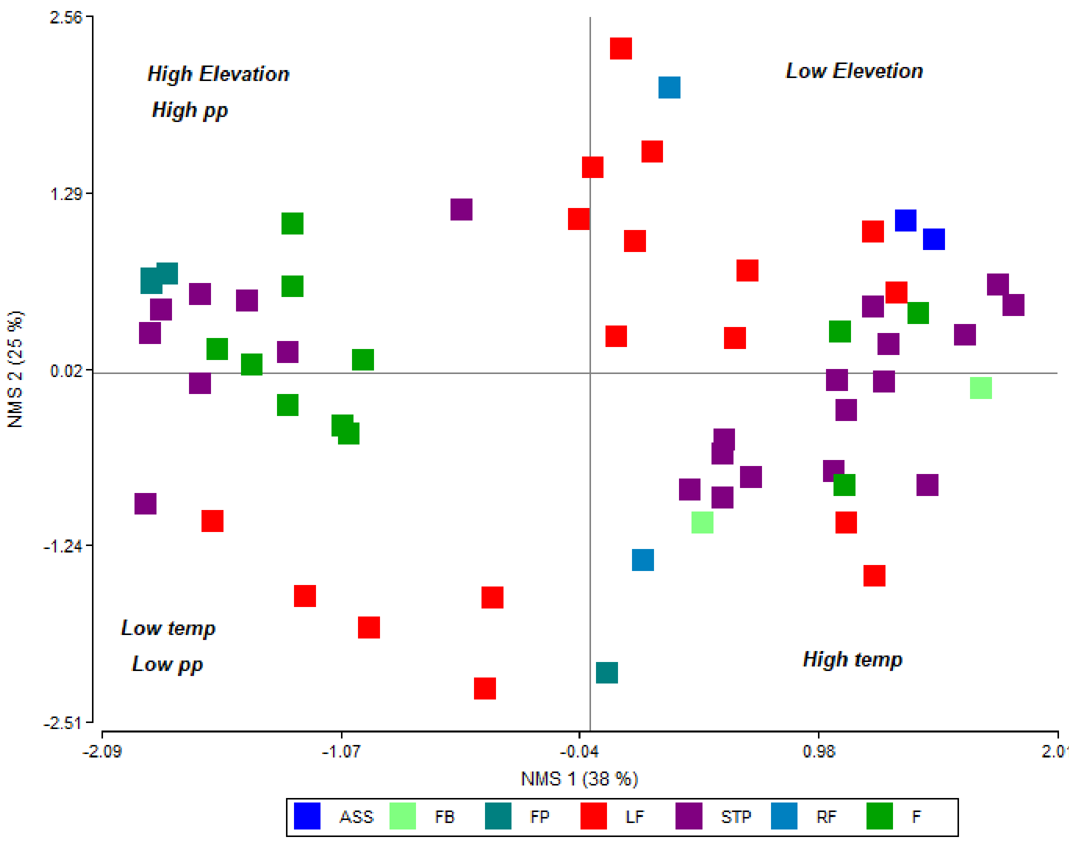

Figure 5. Tree distribution in relation to altitude, temperature, and precipitation of thirty livestock farms located in the southeast region of Guatemala.

When the composition and abundance of species and individuals by land use (Figure 6) were compared, it was taken into account the ten species with more abundance of individuals. As a result, it demonstrate that among the different land use, LF presented the higher number of species, followed by STP. Land use with ASS, FB, FP, RF, and F presented few species within its composition.

ASS presented a total of sixty-two individuals that belong to seven species and six families, out of which the three most abundant constitute 90.2%. *Gliricidia sepium* was the most abundant species. Farmers in this region managed these species because of the provision of shade and organic matter, provided by the leaves on the ground, which benefits coffee plants. Cannavo *et al*. (2011) found in a recent study in Costa Rica that the level of water infiltration in a coffee agroforestry system was greater than in a coffee monoculture. According to Benegas *et al*. (2014), tree roots swell, shrink, die, and decompose, all of which promote macropore formation. In addition, trees also add organic matter to the soil via pruning and deposition of residues in the soil and root turnover. This coincides with the statement of farmers who manages AFS in the southeast region of Guatemala.

FB presented a total of thirty-six individuals that belong to six species and two families, the three most abundant constitute 91.5%. These farmers use species like *Acacia pennatula* that is characterized by its open branches that not only allow the penetration of sunlight and present low competition for the main crop, but also give fruits that are used for cattle feeding during the dry season. Ong and Kho (2015), found that tree shade reduces light penetration to understory crops, limiting their rate of photosynthesis. While crop yield penalties are expected because of tree-crop competition for resources, farmers still maintain trees in their farms. On-farm trees are also maintained for their social and cultural values (Gustad *et al*. 2004).

FP presented a total of 413 individuals that belong to seven species and six families, out of which the three most abundant constitute 96.8%. *Pinus spp* held the highest percentage in this group because of farmers preference (quality wood and resin) and the easy adaptability of adaptation of this species in the region.

In the study area there were few farmers with FP, although they are economic incentive by PINPEP (Forest Incentives Program for Small Farm owners with Forest or Agroforestry Land) and PROBOSQUE (another Incentives Program of the National Forest Policy), offer economic incentives to the owner of forest land for carrying out reforestation or natural forest management projects (INAB 2018). Both programs are working towards the mitigation of climate change and the conservation of biodiversity in the region.

Larrazábal *et al*. (2009), found that annually, the number of PINFOR (now PROBOSQUE) users increases annually. It has socially benefited the population in the Guatemalan rural area because the State has invested Q918 million (equivalent to US $ 122.4 million), which has generated 203,783 jobs and benefited 2.6 million people.

According to the Australian Government Department of Agriculture, Fisheries and Forestry (2003) farm forestry could potentially provide: carbon credits, based on carbon sequestered by plantations; salinity credits, based on the positive impact of plantations on dryland and irrigation salinity; water filtration credits, based on farm forestry reducing salt, excess nutrients, and turbidity in our waterways; and biodiversity credits, where farm forestry activities maintain and restore a region's natural flora and fauna. Ibrahim *et al.* (2006) state that farms can increases their potential of livestock farms by inserting some areas with forest plantations and releasing areas not suitable for agricultural production, to give way to the natural regeneration of secondary forests.

LF presented a total of 635 individuals in a total area of 1.691 km. These individuals belong to forty-six species and twenty-two families, out of which the three most abundant constitute 43.5%. There were few species of high commercial value in the sampling area. Nevertheless, this can be an important opportunity for farmers design a plan that integrates species of high commercial value that can adapted to the climate condition and present desirable characteristics such as rapid growth inside of their LF. It was found that the productive role of LF on the farms was to divide pastures and serves as barrier to animal movement; similar results were found by Harvey *et al.* (2005) where LF was also used as a source of fodder, firewood, timber, and fruit.

STP presented a total of 1,537 individuals that belong to fifty-one species and twenty-four families, out of which the three most abundant constitute 52.7%. Farmers in the southeast region of Guatemala retain tree species in STP because of their value in the provision of shade, fruits, or foliage that can be eaten by the cattle or because these are important firewood or timber species that the family can make use of. Similar data was collected by Harvey *et al.* (2011) and Villacís *et al*. (2003) who find out that tree are retained because of their value as shade, fodder, timber, firewood, and post for division inside of the farms.

RF presented a total of sixty-six individuals that belong to nine species and six families, out of which the three most abundant constitute 80.1%. *Inga edulis* was the most abundant species according to the farmers. These species are conserved due to the role they play in maintaining the water springs that are used for the different activities on the farm, especially for the livestock production.

De Sosa *et al.* (2018) found in a recent research study that riparian forests prevent freshwater pollution and they represent one of the most valuable management tools for preventing excess nutrient loss from land to water. This coincides with the statement of the farmers that manifest that RF are important because they can help control the bank erosion and loss of valuable paddock soil to the river.

F presented a total of 1,929 individuals that belong to fifty species and thirty families, out of which the three most abundant constitute 70.4%. *Quercus spp.* and *Pinus spp*. were the most abundant species in the study area. Farmers with F indicates that they receive benefits such as wood, poles, firewood and shade for the cattle during days with high temperature. Similar results were found by Muñoz *et al.* (2003) where farmers manage the tree cover to provide shade, forage to livestock, and obtain products such as fruits, timber, firewood, and poles. Just 6% of farmers received economic compensation by PINFOR for maintaining the forest land and few express the benefits of F for the biodiversity in their productive system.

In the seven different land uses studied, it is clearly demonstrated that tree cover inside livestock production systems is important because of the positive relation of these with the provision of goods to the family and the capacity of carbon sequestration, generated by the activity. It also gives a high value to the property and make farmers more resilient to the effects of climate change because of the provision of wood and non-wood products, that they receive throughout the year.

Harvey *et al.* (2008) found that many agricultural landscapes, despite being highly fragmented and deforested, still retain abundant on-farm tree cover in the form of small forest patches, live fences, forest fallows, and isolated trees. The existent patterns of on-farm tree cover reflect farmer decisions to plant, retain, or remove trees on their farms.

According to Harvey *et al.* (2008), forest patches, isolated trees, and windbreaks are important for conserving both local and regional biodiversity because they provide important food sources, nesting sites, and habitats for a variety of animal species (particularly birds) and may serve as stepping stones or corridors that facilitate animal movement across the agricultural landscape. Moreover, they help to conserve plant diversity because the trees themselves often represent forest species that would otherwise be absent from the landscape and also the trees serve as a host for numerous epiphytic plants.

Diversity and greater structure of the arboreal coverage from the wooded paddocks and forest have a series of functional traits with potential for the development of sustainable livestock production systems with positive effects at both farm and landscape levels. At the productive and socioeconomic level, trees in pastures and live fences can diversify and increase the economic income of the families through products such as wood, poles, firewood, seeds, forage, fruits, and other goods and services with potential to be commercialized or used on the farm according to Villanueva *et al.* (2018). It is suggested that live fences offer an opportunity to increase habitat availability and maintain some degree of landscape connectivity in agricultural landscapes (Chacon and Harvey 2008).

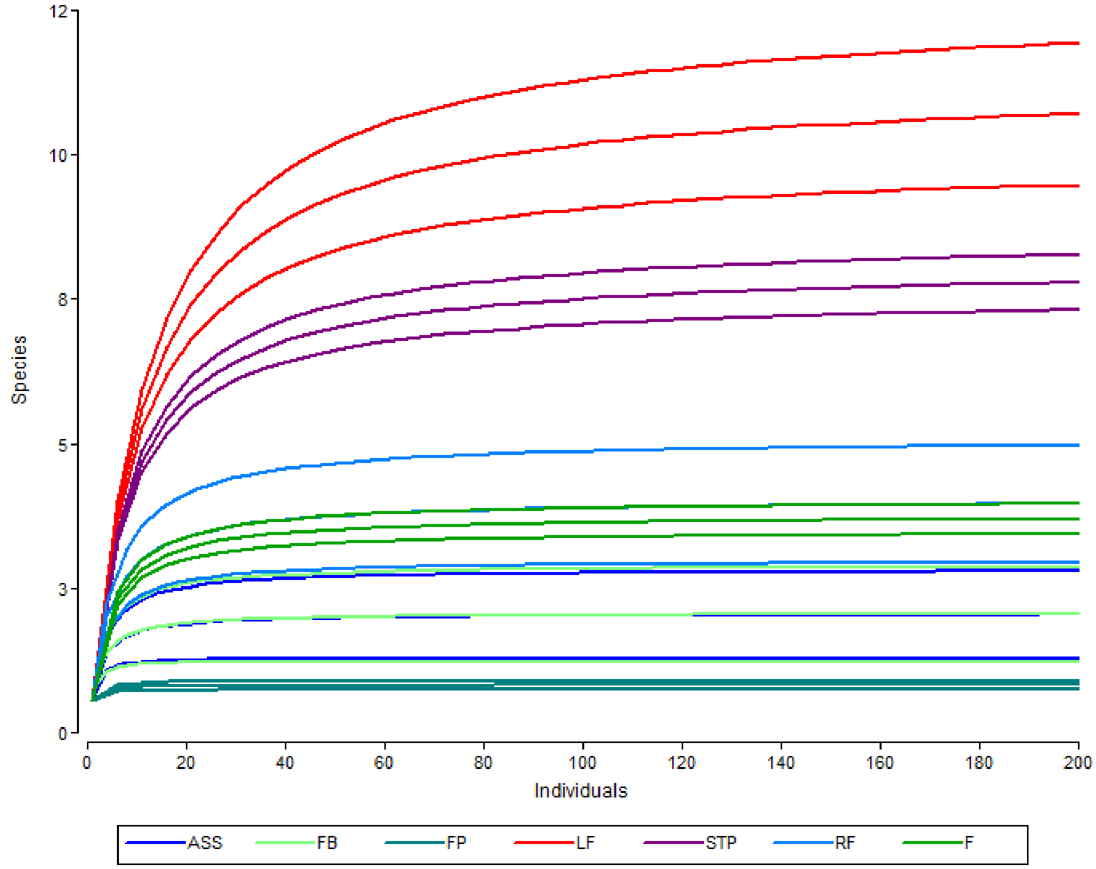

Figure 6. Number of species and individuals in the different land uses of thirty livestock farms located in the southeast region of Guatemala.

Table 4 provides information on the three most common species found in each land use. In ASS, *Gliricidia sepium* presented 61.2% of individual abundance, but in FB it presented 11.1% and in STP it was 22.3%. This species was found in three different land uses, which shows its importance for farmers in the region.

In FB the most abundant species was *Acacia pennatula* with 61%. This species was also found in STP where it represented 16.9% of all individual abundance. It is important to highlight that this species is used by farmers as an alternative source of food during the dry season because it provides seeds.

Land use with FP presented 89.5% of individual abundance of *Pinus spp*. This species in STP presented 13.5% and in F it presented 23.3% of individual abundance. Farmers appreciate this species not only for its commercial value in the national and international market, but also because of its high potential of natural regeneration inside the farm.

In LF *Tabernaemontana donnell-smithii* was the species that presented the largest number of individuals with 19.4%. This species was also found in F where it presents just 3.9% of individuals. There is a high preference to have this species in LF because of its tolerance to drought. According to farmers, this guarantees a perfect barrier between livestock and annual crops on the farm, at the same time, it does not affect the level of production.

Land use with STP presented *Gliricidia sepium* with 22.3% of individuals; this species is considered the most abundant. According to farmers, this species grows rapidly, it is easy to propagate and it is also very resistant to drought. This species presented an open crown, which allows the penetration of sun light to the pasture areas and reduce the competition by over shading. It serves as an energy source on the farm (firewood) and it can also be used as forage for ruminants.

It was found that RF had an abundance of 37.8% of *Inga edulis*, followed by two other species that are also important for the farmers. According to farmer's knowledge, this species is highly adapted to the climate condition of the area and they provide shade for the water springs on the farms. In addition, they reduce the evaporation of the water and provide valuable fruits that can be traded in the market or consumed by the family and wildlife in the surrounding area.

Land use that is dedicated to F had *Quercus spp* that presented 43.2% of all individual's abundance. This species was the most abundant due to the natural regeneration in the different gradients area of the research and because it is highly resistant to droughts and changing temperature. According to farmers, this species is very valuable in the national market as timber, firewood, carbon, and poles inside livestock farms.

According to Casasola (2000), in the dry zone of Nicaragua, where animals graze in scrublands with greater variety of species than in paddocks, the consumption levels were between 2.0 and 3.67% of live weight, while in paddocks with fewer trees it was found between 1.33 and 2.0% of live weight.

Restrepo-Sáenz *et al.* (2004), stated that the presence of live fences on farms is an easy way to integrate trees to the paddocks because the interaction with the grass can be more easily managed with selective pruning of the trees. They also continue to provide nutrients, shade, or foliage to livestock. Botero *et al.* (1999) found that labor cost is increased in livestock systems and that the planting of timber trees in live fences increases the generation of income.

SPS constitutes a productive option that generates tangible benefits (wood, fruits, fodder) and, at the same time, prioritize environmental services (conservation of watersheds, soil protection, carbon fixation, and storage). These goods and services make SPS an effective strategy for the mitigation and adaptation of livestock to climate change (Ibrahim and Zapata 2012).

Sousa *et al.* (2016) found a high annual increase of timber volume that was correlated to SPSs with *P. oocarpa* and LFs with *C. odorata* as the most abundant species. In El Cua, Nicaragua and Copan, Honduras, there were identified eleven species in SPS all from natural regeneration or maintained since the systems were established. Ninety-five percent of the individual trees were *Pinus oocarpa, Byrsonima crassifolia, Quercus oleoides, Tabebuia rosea, Zanthoxylum riedelianum* and *Psidium guajava* (Sousa *et al.* 2017). This information highlights the opportunity that farmers have to improve the tree cover on their farms and, at the same time generate additional incomes and environmental services inside of their productive system and therefore the region.

Table 4. Three most common tree species found in each land use in the thirty livestock farms evaluated in the southeast region of Guatemala in descending order of abundance.

ASS		FB		FP	
Species	Abundance (%)	Species	Abundance (%)	Species	Abundance (%)
Gliricidia sepium	61.2	*Acacia pennatula*	61	*Pinus spp*	89.5
Inga jinicuil	16.1	*Crescentia alata*	19.4	*Pachira aquatica*	4.6
Yucca gigantea	12.9	*Gliricidia sepium*	11.1	*Eucalyptus spp.*	2.7
n. Ind	62		36		413
LF		STP		RF	
Species	Abundance (%)	Species	Abundance (%)	Species	Abundance (%)
Tabernaemontana donnell-smithii	19.4	*Gliricidia sepium*	22.3	*Inga edulis*	37.8
Jatropha curcas	15.9	*Acacia pennatula*	16.9	*Acacia pennatula*	22.7
Bursera simaruba	8.18	*Pinus spp*	13.5	*Caesalpinia velutina*	19.6
n. Ind	635		1537		66
F					
Species	Abundance (%)				
Quercus spp.	43.2				
Pinus spp	23.3				
Tabernaemontana donnell-smithii	3.9				
n. Ind	1929				

To improve the composition and structure of tree cover in Guatemala, regarding legislative matters, the forest law of 1996 is still in place and it provides framework in legal matters for Sustainable Forest Management (SFM). The law established that 80% of the yearly amount of PINFOR shall be allocated to plantations and the remaining funds could be destined for the managing of natural forest. The incentives is a cash payment that the government grants to the owner of forest in order to promote reforestation projects or managing the natural forest as indicated by de León (2010).

According to INAB (2017), PROBOSQUE law is established in the article 2-2015 and it pursues five objectives, two of which are highlighted in this research: 1) increase forest productivity through the establishment of forest plantations for industrial and energy purposes and the productive management of natural forests, decreasing the pressure on natural forests and other associated resources and 2) promote forest diversification in land suitable for agriculture and livestock and the restoration of degraded forest lands, through agroforestry systems, forest plantations, and other modalities that contribute to the provision of wood in rural areas and the recovery of the productive and protective base of degraded forest.

Establishment of pilot farms in the region, capacitation to technicians and farm owners are key points in the contribution to conserve and increase forest cover inside livestock systems. These successful experiences demonstrate that it is possible to combine trees and animals in the same space and at the same time create a positive interaction while mitigating the effects of methane gas emission into the environment.

4.6 Richness and structure of tree species

According to Q-Hill (Figure 7) there are few species with high abundance and a significant group of species are only represented by few individuals. The ten most abundant species found in the study constitutes 77.27% (3,215 individuals). Trees inside of F, STP, and LF have a high number of species and individuals inside the plant's community. Land use with RF, ASS, FB, and FP apparently have an equitable distribution of tree species and few individuals through the land use. There were marked differences of richness by individuals and density of species accumulated by land use.

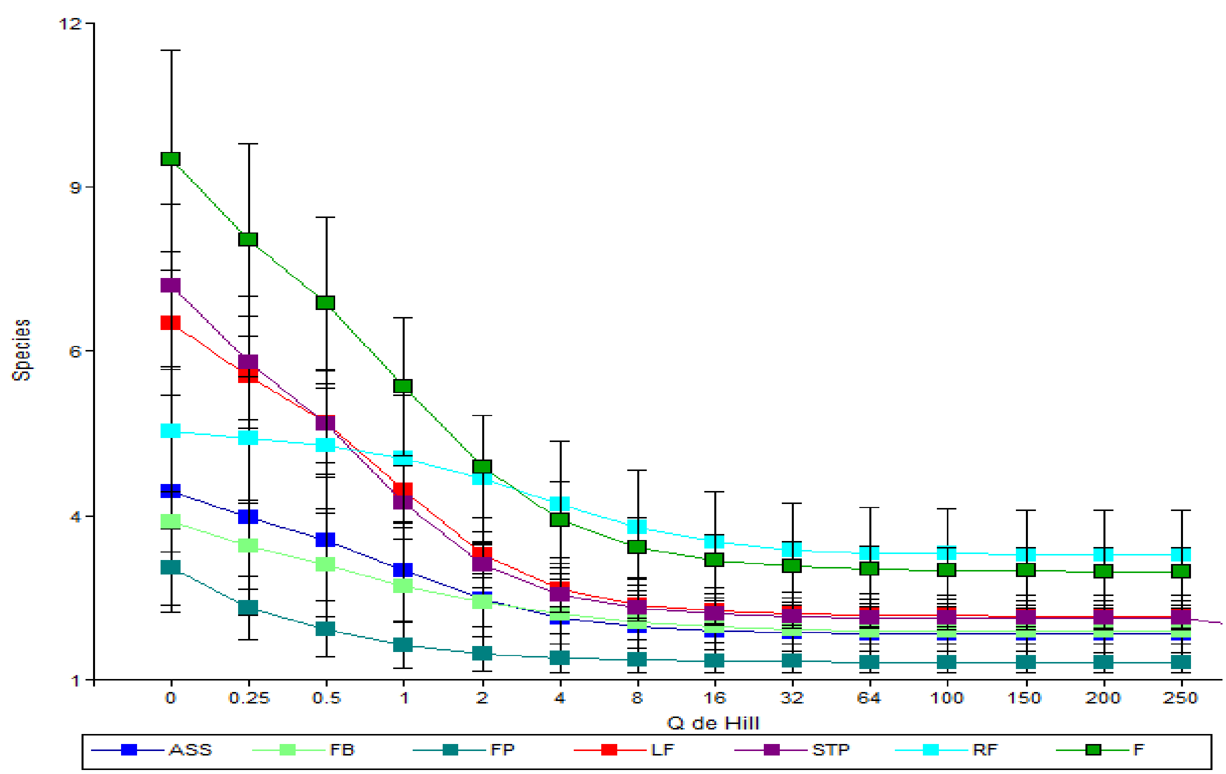

Figure 7. Tree species distribution using Index of Rényi (Q-Hill) with data gathered from thirty livestock farms located in the southeast region of Guatemala.

It was found that species inside of ASS presented low diameter class (Figure 8.a and 8.b); it can be due to the selection made by the farmer and the purpose of these in the system. FB presented a low number of individuals with the highest point for diameter class between 10 and 20 cm. In FP there is a significant group of individuals with diameter between 10 and 20 cm and few species were found in the diametrical class from 30 and 40 cm.

LF presented a high number of individuals and species in diameter class between 5- and 10 cm (Figure 8.a and 8.b). In this land use there were few species recorded with diameter greater than >50 cm. STP presented a high number of individuals in diameter class 5 and 10 cm, but a much greater number of species between 10 and 20 cm diameter. Trees in this land use presented approximately thirteen species and 100 individuals in the diameter class 30 and 40 cm. There were also species with few individuals above >50 cm diameter class. Contrary to these research Esquivel *et al.* (2011) found in STP a small number of individuals in the DBH category (10-20 cm), thus this indicates a low rate of natural regeneration which they associate with grass species sown and paddocks management practices, particularly weed control.

RF presented approximately seven species between 5 and 10 cm of diameter class (Figure 8.a and 8.b); however, there was a very low number of individuals in comparison with the rest of land use in the different sites where of the study was carried out. F was the land use with the greater number of species with diameter class between 5 and 10 cm. It also presented also the highest number of individuals between the diameter class 10 and 20 cm. It is necessary to mention that the information (Figure 8.a and 8.b) is the accumulation of species and individuals founded in each land use.

Making a synthetic analysis of the different land use, it is evident that the majority of species and individuals are found in low diameter class, which represents a high tendency of some species to become extinct in the region because of the absence of seed and seedling for the natural regeneration and the establishment of a forest plantation. These can be species of high commercial value or species with an important value for biodiversity inside of the dry corridor region.

It is important to promote silvicultural management inside of the different land use. It can help to decrease the pressure on tree coverage in each farm, contributing to the selection and retention of mother trees as a source to obtain seed and seedling with desirable characteristics.

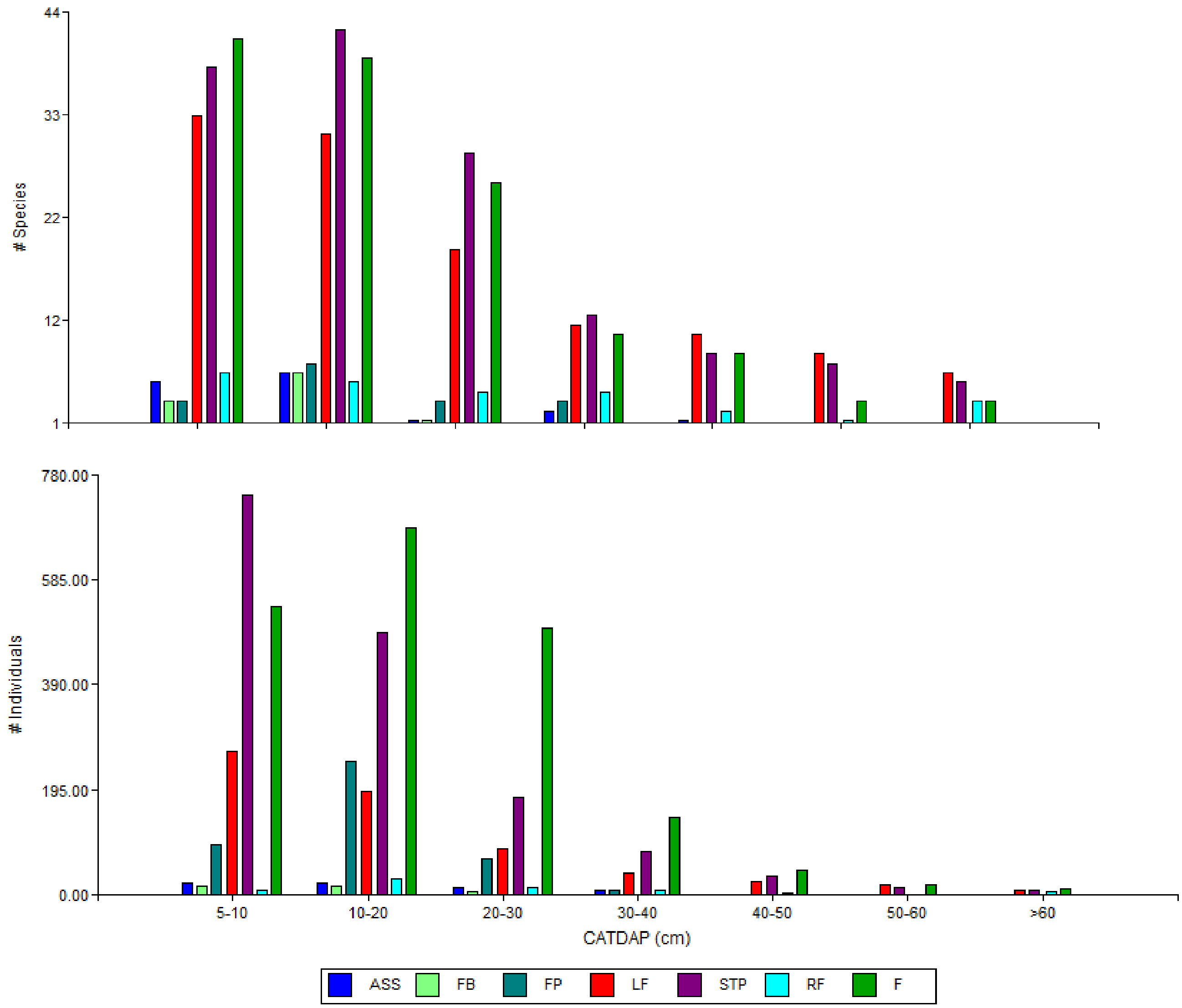

Figure 8. Diameter class for thirty livestock farms located in the southeast region of Guatemala.
a) Number of species in each land use and diameter class.
b) Number of individuals in each land use and diameter class.

5. Conclusions

In the group of livestock farm analyzed in the southeast region of Guatemala, there were two typologies of farms identified: high level technological innovation farms (HLTI) and farms with a low level of technological innovation (LLTI). The predominant livestock activity in HLTI was specialized dairy and in LLTI it was dual purpose.

All the land use found in the study area presented certain percentage of tree cover; inside the plots sampled there were 4,678 individuals registered that belongs to eighty-three species and thirty-seven families of trees.

Farmers that integrated this study considered tree cover of importance. It is reflected in the percentage of tree cover found inside the thirty farms: F presented 29% of tree cover, the percentage of tree cover outside the forest was 26.2% in STP. and 7.9% in FP. Tree cover was also present in LF, FB, ASS, and RF but in a lower extent.

Based on the different latitudes, farmers select species that are more suitable to their conditions. Figure 5 represent the most abundant timber species were in high altitude between 1017 – 2039 m.a.s.l, *Pinus spp* and *Quercus spp* were the group with more individuals. Non-timber species with more individuals were *Gliricidia sepium* and *Acacia pennatula*. These were dominant in low altitude from 463 – 993 m.a.s.l.

Farmers conserve a high number of tree species on their farms for different purposes, when analyzing the information, it was determined that Fabaceae and Pinaceae were the families with more abundance of individuals found on the thirty farms.

6. Recommendations

To the Ministry of Agriculture, Livestock, and Food of the Republic of Guatemala should encourage the adoption of silvopastoral systems in the region and reward those farms that are adopting this system with forest plants of high commercial value and environmental benefits. This can contribute to the mitigation of livestock activity on climate change through the carbon capture.

The farmers that were part of the project “Sistemas de producción ganaderos climáticamente inteligentes basados en sistemas silvopastoriles en 15 municipios del suroriente de Guatemala” should keep on with the establishment and conservation of trees on their farms. This will consequently generate beneficial effects in the production system providing shade, fruits, forages, and other good that are used inside of the farm.

CATIE university and institutions in Guatemala should promote future studies in this region on farms with SPS, evaluating the socioeconomical impact these systems have on the family’s incomes and also identifying the adequate management that has to be considered for its sustainable implementation.

Farmers and institutions involved in silvopastoral systems should promote forest management inside the system, so there can be mother trees for seed and seedling in the same farm and this can help to reduce the externalities on this input.

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8. Appendices

Appendix 1. Criterion for the evaluation of the level of technological innovation on farms

No.	Indicator	Criterion	Score
1	**Woody fodder banks**	It is determined in relation to the months of the dry period that the forage bank is used to feed the cattle. For example, if the woody fodder bank reaches: Four – three months then it is rated with 3 points Two months then is rated with 2 points One month is rated with 1 point Don't have a fodder bank is rated with 0 points.	
2	**Grass fodder bank**	It is determined in relation to the months of the dry period that the forage bank is used to feed the cattle. For example, if the grass forage bank reaches: Four – three months then it is rated with 3 points Two months then is rated with 2 points One month is rated with 1 point Don't have a fodder bank is rated with 0 points	
3	**Scattered trees in pastures**	The score is in relation to the proportion of total paddocks that have scattered trees, for example: 10 paddocks all with STP 3 points 9-4 with STP 2 points 3-1 with STP 1 point No paddocks with STP 0 score	
4	**Live fences**	The score is in relation to the proportion of the total living fences. For example: Total area with LF 3 points 50% are LF 2 points 25% LF 1 point No LF 0 points	
5	**Trees on boundaries**	The score is in relation to the proportion of the total area with trees on boundaries. For example: Total area with trees on boundaries 3 points 50 % trees on boundaries 2 points 25% trees on boundaries 1 point No trees on boundaries 0	
6	**Block plantations**	The score is in relation to the surface of the covered farm. For example: 10% coverage 3 points 7% coverage 2 points 3% coverage 1 point No coverage 0	
7	**Natural forest**	The score is in relation to the surface of the farm coverage. For example: 10% coverage 3 points 7% coverage 2 points 3% coverage 1 point No coverage 0	

8	**Improved pasture**	The score is in relation to the proportion of paddocks with improved pastures in relation to the total. For example: 10 paddocks all with improved pasture 3 points 9-4 with improved pasture 2 points. 3-1 with improved pasture 1 points No improved pasture 0	
9	**Grazing system**	The score is in relation to the number of total paddocks on the farm. For example: > 6 paddocks 3 points 5-3 paddocks 2 points 2-1 paddocks 1 point No paddock 0 point.	
10	**Supplementation with external inputs**	Uses them with criteria to complete nutritional requirements = 3 points Uses them but with low criteria = 2 points Uses them without criteria= 1 point Do not use them= 0 points	
11	**Mineral supplementation**	Free access to mineral supplementation 3 points Controlled access to mineral supplementation 2 points Sporadic application 1 point Does not supply 0 point	
12	**Excreta management**	Yes = total advantage of excreta 3 points Yes = almost total advantage 2 points Yes= partial use 1 point No = 0 points	
13	**Water source**	The score is in relation to the number of paddocks of the total that have access to water. For example: 100% have access 3 points 50% have access 2 points 25% have access 1 point If they only drink water in the pen score would be 0 points	
14	**Milking hygiene**	Yes = total application of milking hygiene 3 points Yes = almost total application 2 points Yes= basic application 1 point No = 0 points	
15	**Prophylactic plan**	The score is in relation to the frequency and application of the plan. For example: If the farm has a prophylactic plan and meets it 3 points. If the farm has a prophylactic plan and partially meets it 2 points If the application is sporadic 1 point Do not have a plan the score is 0	
16	**Use of farm records**	Yes = use a farm record 3 points Yes= partial use of farm record 2 points Yes= basic use of farm record 1 point No = 0 points	

Appendix 2. Product handout given to participant farmers

ÁRBOLES DE MI FINCA

Dimitri Olmedo Hernandez

Nombre común	Nombre científico	Cantidad de individuos muestreados
Almacigo	*Bursera simaruba*	4
Anona	*Annona squamosa*	1
Barreto	*Tecoma stans*	1
Copal	*Tabernaemontana donnell-smithii*	4
Espino negro	*Acacia pennatula*	14
Guachipilín	*Diphysa robinioides*	2
Guaje	*Leucaena leucocephala*	2
Güiligüiste	*Karwinskia calderonii*	6
Ixcanal	*Acacia hindsii*	2
Nance	*Byrsonima crassifolia*	10
Piñón	*Jatropha curcas*	14
Sare	*Acacia angustissima*	2
Total		**62**