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The Agroforestry Heritage System of Sabana De Morro in El Salvador

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Abstract: Traditional agroforestry systems are recognized as having great importance for providing multiple benefits for local communities all over the world, especially in tropical countries. Thanks to their multifunctional role, they can support small farmers, contribute to hydrogeological risk reduction, water regulation, preservation of soil, agrobiodiversity and landscape, as well as being examples of mitigation and adaptation towards climate change. The Globally Important Agricultural Heritage Systems (GIAHS) programme of the Food and Agriculture Organization (FAO) aims to identify agricultural systems of global importance, preserving landscape, agrobiodiversity and traditional knowledge, through dynamic conservation principles. The Sabana de Morro is a traditional agroforestry system located in El Salvador based on cattle grazing in pastures with the presence of *Crescentia alata* and *Crescentia cujete* trees, locally called Morro or Jícaro. We documented the main characteristics of this system, that has never been deeply studied, in the Municipality of Dolores, in accordance with the five GIAHS criteria, and through detailed land use mapping, to assess the relations between landscape structure, agrobiodiversity and traditional silvopastoral practices. Sabana de Morro proved to be based on strong interactions between trees, cattle and farmers. The pulp of the Morro fruits is eaten by grazing cattle, completing their feeding and giving a peculiar taste to the locally produced cheese. Morro trees provide shade for the animals while cattle contribute by spreading their seeds that also take advantage of the manure. Results show that this agroforestry system contributes to the preservation of a rich agrobiodiversity and of the traditional landscape. At the same time, it supports local farmers' livelihood and is consistent with the aim of the GIAHS programme, even if further surveys and research are needed to assess the real possibility of the inclusion in this FAO programme.

Keywords: agricultural heritage; *Crescentia alata*; *morro*; GIAHS; El Salvador; traditional agroforestry

1. Introduction

In the last decades, traditional agroforestry systems have received increasing attention, being examples of sustainable systems able to provide multiple benefits for local communities all over the world, especially in tropical developing countries. In fact, these realities are often characterized by a multifunctional role [1–3]. The range of functions can be wide, depending on multiple factors as agroforestry systems can meet financial, social and environmental objectives [4]. Traditional agroforestry systems may potentially support livelihood improvement for small farmers and their families through simultaneous production of food, fodder and firewood [5], and they are often characterized by more stable levels of total production per

unit area than high-input systems [6]. Moreover, they could contribute to hydrogeological risk reduction, water regulation, preservation of soil, agrobiodiversity and other natural resources [7]. Finally, traditional agroforestry systems might represent important tourist destinations for rural tourism, as well as examples of mitigation and adaptation towards climate change [8].

At the international level, the growing interest on topics related to rural areas' sustainable development, based on traditional agricultural systems, has contributed to the establishment of a FAO (Food and Agricultural Organization) programme called GIAHS (Globally Important Agricultural Heritage Systems). This programme, launched in 2002, has the aim of identifying and preserving agricultural systems of global importance with their landscapes, agro-biodiversity, traditional knowledge and associated culture. However, the aim is not only the preservation of these systems, but also to apply dynamic conservation principles in order to promote sustainable development of rural areas, with direct and indirect benefits for the community [9].

The Sabana de Morro, also known as Morrales, is a traditional agroforestry system located in El Salvador based on free cattle grazing in pastures characterized by the presence of *Crescentia alata* and *Crescentia cujete* trees, locally called Morro or Jícaro. The Sabana de Morro zone is distributed in different areas all over the country, as in the upper valley of the Lempa river, as well as in other regions such as Acajutla (Punta Remedios) in the plain of Ahuachapán, Santa Ana (Candelaria de la Frontera), Cabañas (Dolores), San Vicente (San Ildefonso) and Morazán (San Carlos). In some areas (Dolores, Chalatenango, San Miguel, Morazán and San Vicente), local farmers use the Morro fruit to integrate the cattle feeding because in the dry season there is shortage of green fodder, while in other parts of the country the use of the Morro fruits for cattle feeding is not traditionally applied by farmers [10]. The presence of *Crescentia* spp. trees in pastures is common also in other Central American countries and cattle are reported to frequently eat the pulp of the fruits [11–13].

The current research focused on Dolores Municipality where the tradition of cattle breeders and cheese makers is heritage-derived from the Spanish colonization and is supposed to have started with the foundation of the settlement in 1681 and still practiced today with very few changes. In this area, the Sabana de Morro represents a silvopastoral system based on strong interactions between trees, cattle and farmers. Morro trees provide shade to animals during the hottest hours of the day and the pulp of the fruits is eaten by the grazing cattle. Morro trees also take advantage from the cattle, as cows do not cause damage to young trees and contribute to spread the seeds that also take advantage of the manure to germinate. Farmers apply specific and traditional management of the pastures to ensure the renovation of Morro trees, as they believe that Morro fruits give a peculiar taste to the milk and to the locally produced cheese that is particularly appreciated and can guarantee a fair income to the families of the local farmers.

The main aim of the research was to investigate relationships between specific landscape structure, agrobiodiversity and the maintenance of traditional silvopastoral practices. Despite the fact that different studies in the American tropics mention the presence of *Crescentia* spp. trees in pastures, no specific studies have been carried out [14]. The research was based on detailed land use mapping, that might also represent a starting point for future monitoring, and on an accurate description of the system based on GIAHS criteria, since one of the aims was to verify if the Sabana de Morro has the characteristics to be proposed for the inscription in the GIAHS programme. Sabana de Morro, in fact, could represent an example of a traditional agroforestry system important for sustainable rural development, local farmers' life quality and preservation of related agrobiodiversity, traditional knowledge and landscape. This paper is also one of the output of the "GIAHS Building Capacity" project, funded by the Italian Agency for Development Cooperation (AICS) and by the Department of Agriculture, Food, Environment and Forestry (DAGRI) of the University of Florence, with the aim of spreading knowledge about GIAHS-related issues and for identifying potential GIAHS sites.

2. Materials and Methods

2.1. The Study Area

The site coveres 14,823 ha and corresponds to the Municipality of Ciudad Dolores (Department of Cabañas, El Salvador) (Figure 1). Dolores municipality is divided between the City (124 ha) and 6 Cantones: Cañafistula (4047 ha), Curarén (1511 ha), Chapelcoro (2459 ha), El Rincón (3194 ha), Niqueresque (590 ha), San Carlos (1656 ha). Dolores municipality has an approximate population of 6347 habitants (3064 males and 3283 females) with a density of population of 43 people/km^2. Rural activities are particularly important, as only 22.3% of the population is classified as urban.

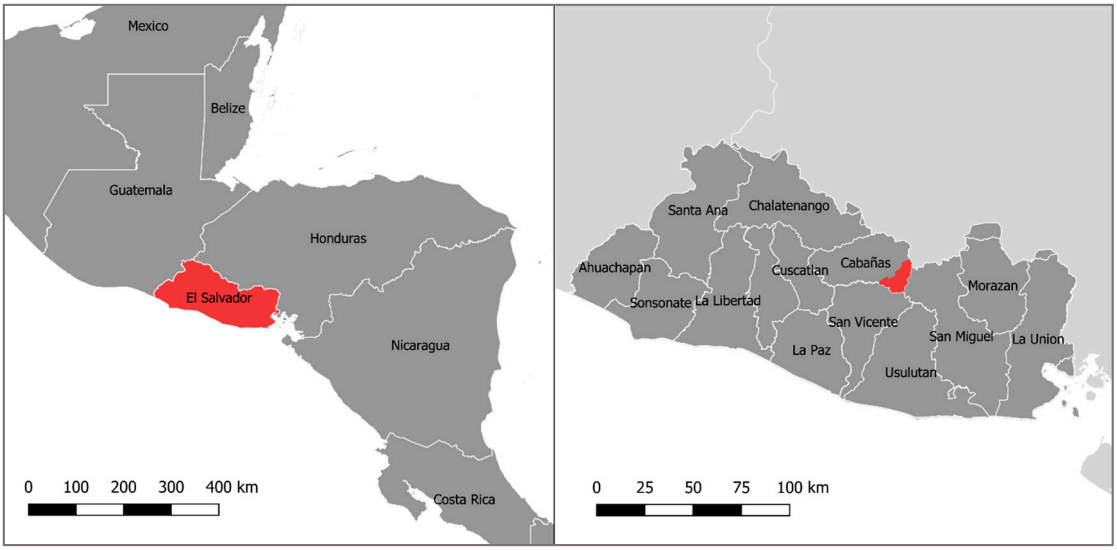


Figure 1. El Salvador is a small country in Central America (**left**). The Municipality of Dolores (13,581 ha) is in the south eastern part of Cabañas Department (**right**).

Dolores municipality has an elevation ranging from 33 to 577 m above sea level., with an average altitude of 195 m above sea level. However, most of the area is flat or with gentle slopes (half of the surface has a slope between 0% and 20%, and only 10% of the surface has a slope greater than 50%). There are higher and steeper slopes, especially in the western part of the area. The site is crossed by a rich hydrography. The eastern boundary is defined by the Rio Lempa and the southern one by the Rio Titihuapa, while smaller rivers cross the area, such as the Rio Gualpuca, the Rio Sisicua and the Rio Marcos.

According to the Köppen-Geiger climate classification, the local climate is Aw-Equatorial savannah with dry winter [15], with average rain per year of 1823 mm, and average temperature of 26.6 °C [16].

2.2. Methodology

The applied methodology was divided in two parts. The first was based on the creation of a detailed map of the Sabana de Morro agroforestry system. In fact, an exhaustive land use map represents a crucial instrument to study the transformations that could have affected the site in the past or could affect the site in the future. Moreover, a detailed land use map allows to deeply describe the landscape structure and the interrelation among the five GIAHS criteria. The land use map was realized through photointerpretation of Google Satellite images of November 2017 using Quantum GIS 3.10.3 and applying a minimum mapping surface of 250 m^2.

A Digital Terrain Model (DTM) was used to calculate slope classes. The DTM used had a 30 m resolution and was provided by the US Geological Service. It was processed using Quantum GIS 3.10.3, with support of the GRASS plug-in, to obtain the following informative layers: slopes (and slopes class), aspects and elevation class. From these layers, each characteristic was linked to each land use

patch to obtain the corresponding value for each patch. At the end of this process, the attribute table of the land use layer included, for each patch, the land use categorization, the elevation class, the slope class and the dominant exposure.

Two indexes were applied to evaluate the land use structure. The first was the LSI (Landscape Shape Index), an index derived from the Edge Density, that was used to evaluate the degree of fragmentation for each land use through segmentation of edge based on the perimeter and the area [17]. The higher the *LSI* value, the greater the fragmentation. This index was calculated by the following formula:

$$LSI = \frac{p_i}{2\sqrt{\pi a_i}}$$

where p_i is the perimeter of each patch in meters and a_i is the area of the patch in hectares. After calculating the *LSI* for each patch, an average value for each land use was calculated.

The other index applied was Hill's Diversity Number that is used to obtain indications about the effective number of land uses that contribute to the diversity of the landscape [18]. It was calculated according to the following formula:

$$N_1 = e^{-\Sigma\left(\frac{n_1}{N}\right)*\ln\left(\frac{n_1}{N}\right)}$$

where n_1 is the total surface of the i land use class, and N is the total area of the study area.

The second part of the study was the description of the Sabana de Morro agroforestry system according to the five GIAHS criteria. Since one of the aims of the research was to verify if this agroforestry system could be a potential GIAHS site, it was important to carefully analyse the site peculiarities according to the concept of global importance and to the five GIAHS criteria, that are:

1. Food and livelihood security.
2. Agro-biodiversity.
3. Local and Traditional Knowledge systems.
4. Cultures, Value systems and Social Organisations.
5. Landscapes and Seascapes Features.

The concept of global importance is related to the contemporary relevance of the system, that is, according to FAO, "established by its present and future capacity to provide food and livelihood security, to contribute to human well-being and quality of life, and to generate other local, national and global economic and environmental goods and services to its community and wider society".

This second part of the paper is mainly based on bibliographic research, official statistical data, field surveys and observations made by the authors. The main source for statistical data was the IV Censo Agropecuniario [19]. Unfortunately, this survey refers to 2007 and there is no more recent reliable data, but it proved to be crucial for delineating the socioeconomic and productive framework.

3. Results

3.1. Land Use Structure

Detailed land use mapping refers to 2017 (Figure 2). Most of the analyzed area is occupied by forests (34.3%) and by Sabana de Morro (27.9%), followed by pastures (14.1%), shrublands (9.3%), cultivations (5%) and other land uses (9.4%) (Table 1). Different types of cultivations can be found in 5% of the surface, mainly located near the river where the soil is more fertile or near the main urban area, the city of Dolores. Urbanized areas account for 2.3% of the surface and mainly consist of Dolores city, while other urbanized areas are made of very small villages.

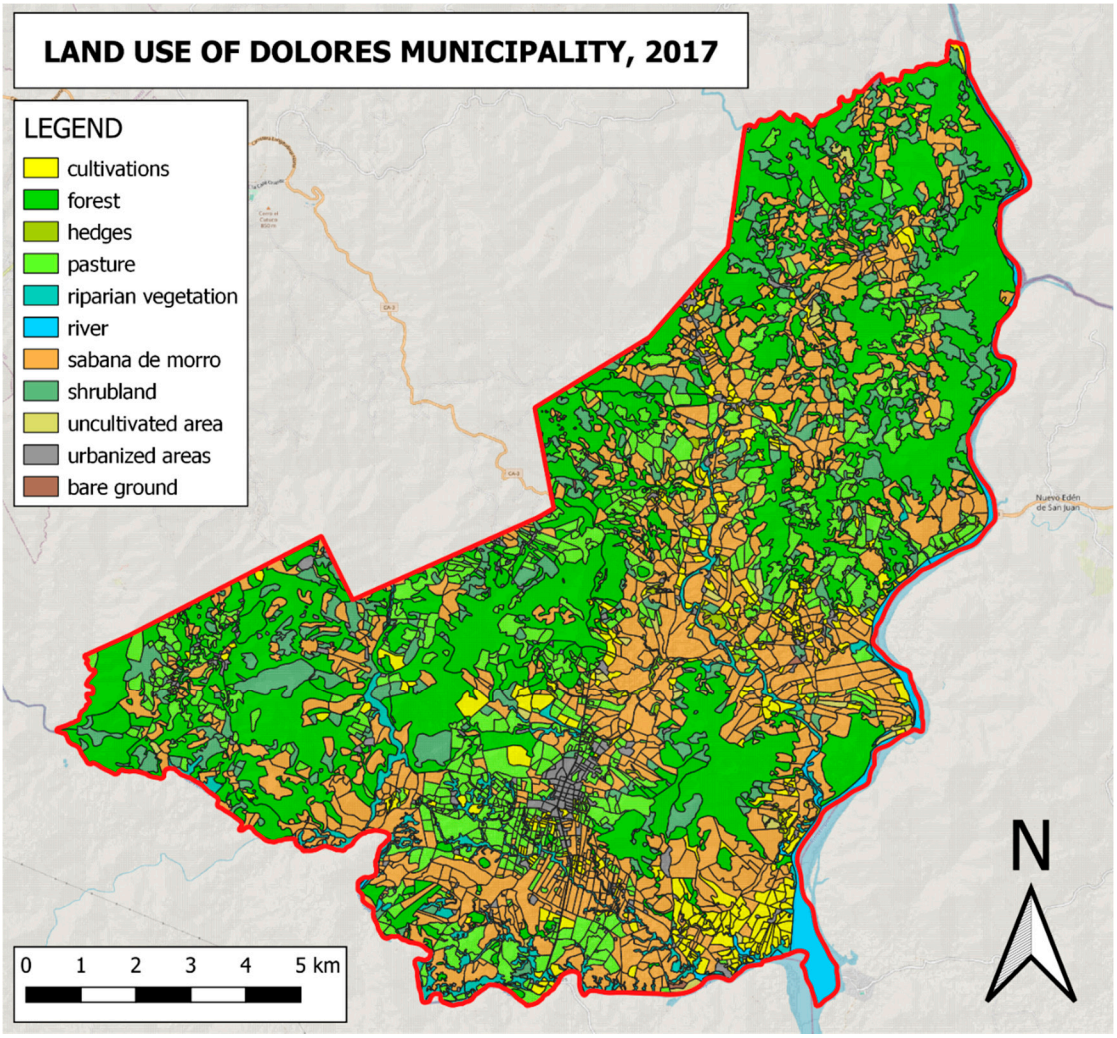


Figure 2. Land use map of 2017 for the municipality of Dolores, El Salvador.

Table 1. Different land uses, their surfaces and the Landscape Shape Index (LSI) for the Dolores municipality 2017.

Land Use	Surface (ha)	Surface (%)	LSI
bare ground	137	0.1	139.3
cultivations	745.6	5.0	136.2
forest	5080.7	34.3	211.0
hedges	137.8	0.9	247.4
pasture	2087.5	14.1	139.2
riparian vegetation	429.9	2.9	283.9
river	326.5	2.2	299.9
sabana de morro	4132.9	27.9	145.1
shrubland	1376.9	9.3	150.2
uncultivated area	151.0	1.0	143.8
urbanized areas	341.7	2.3	135.4
Total	14,824.3	100.0	

The total number of land uses was 11, while the Hill's Diversity Index was less than half [5.7), highlighting that the landscape is mainly characterized by a small number of land uses. In fact, the local landscape structure is based on big forested patches and smaller patches occupied by Sabana de Morro (average area of 3.9 ha) and cultivations (average area of 1.6 ha).

In Dolores, Sabana de Morro and cultivations are arranged in regular plots, as highlighted by the LSI values (Table 1), often divided by hedges, creating a complex mosaic at the lower altitudes (Figure 3). Despite the total small surface occupied, land uses such as hedges (0.9%) and riparian vegetation (2.9%), are particularly important for biodiversity, as they represent ecological networks, and for the preservation of a peculiar landscape structure. These land uses are also characterized by a high shape complexity since their LSI values are higher than those of other land uses, highlighting the ecological and landscape importance of these vegetal structures.

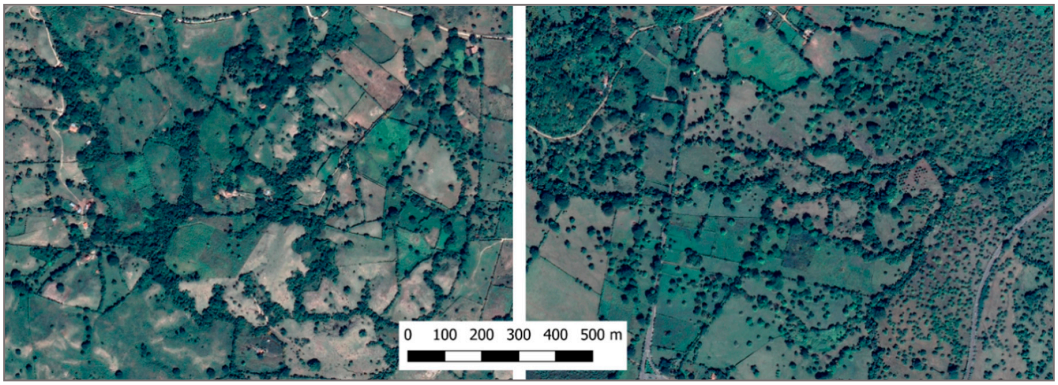


Figure 3. The presence of riparian vegetation and hedges of different width contributes in shaping a complex and aesthetically valuable landscape structure. These vegetal structures have also a great importance for biodiversity.

The density of the Morro trees varies from few trees to a high density where the crowns of the trees are almost connected to one another [20]. During our research, a survey of Morro trees density was done based on 10 different plots. The result confirmed the density variability, as detected Morro trees density varied from 8 trees/ha to 45 trees/ha (Figure 4).

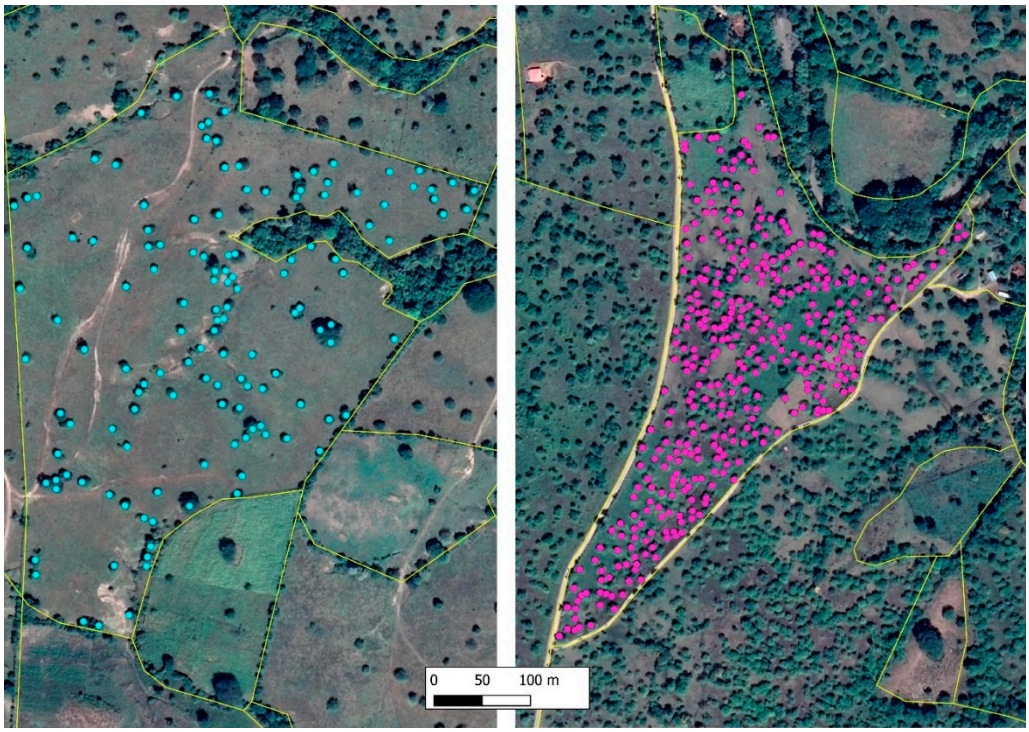
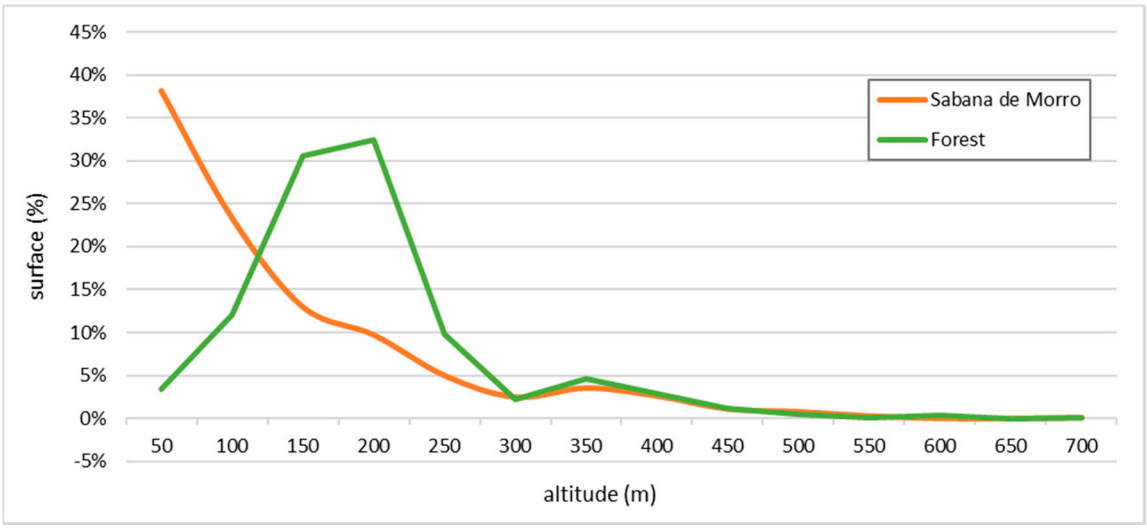
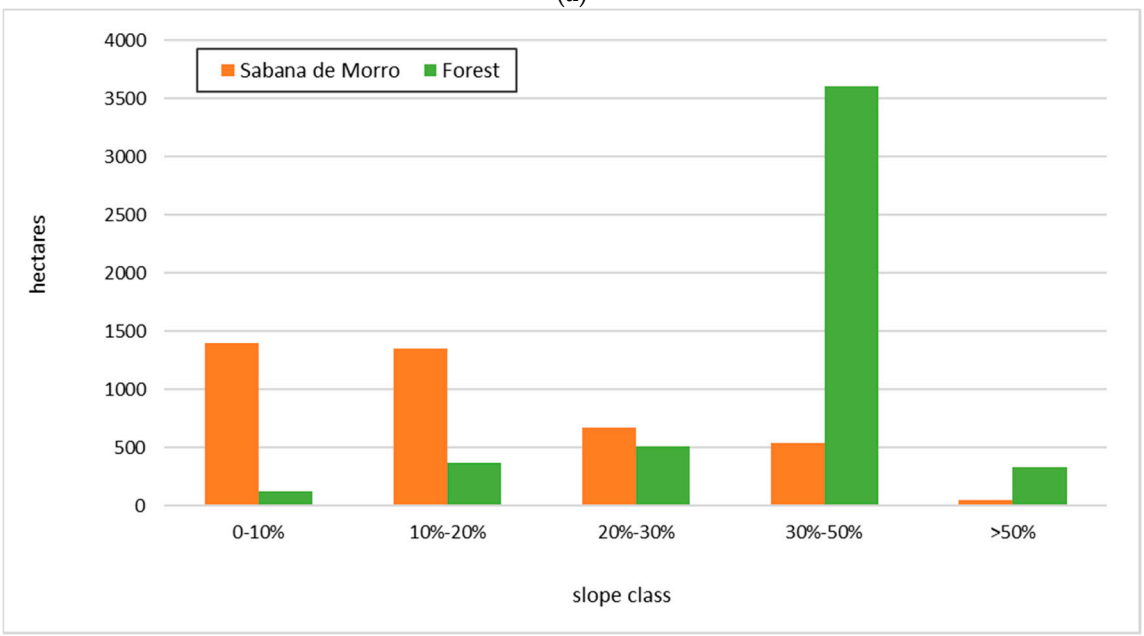


Figure 4. The density of Morro trees is very variable, ranging from 8 trees/ha (**left**) to 45 trees/ha (**right**).

In addition, it was possible to identify a specific disposition of Sabana de Morro and forest patches, the two main land uses characterizing the landscape, both regarding altitude and slope class (Figure 5). Sabana de Morro is mainly located in areas characterized by an altitude lower than 200 m above sea level and a slope gradient between 0 and 20%. Forests can be mainly found at altitudes between 100 and 250 m, and on slopes in the range 30–50%. On the contrary, there seemed to be no correlation between the exposure of the slopes and land use distribution, except for a slightly greater presence of the forests on the slopes with a predominantly northern exposure.



(**a**)



(**b**)

Figure 5. Distribution of Sabana de Morro and forests according to altitude (**a**) and slope class (**b**).

3.2. Description of the Agroforestry System according to the GIAHS Criteria

3.2.1. Food and Livelihood Security

Agricultural activity creates important job demands for families living in the area. Cattle breeding is one of the main agricultural activities here (Figure 6), and 260 breeders still use Morro fruits to integrate cattle feeding. The number of cattle, according to 2007 data for Dolores Municipality, amounts to 14,139, with 3888 calves, 2997 steers, 485 bulls, 64 oxen, 3064 cows not in production and 3642 cows

under milk production [19]. The fact that local livelihood is based on cattle breeding and crops is also confirmed by a work of the World Food Program and the Government of El Salvador [21] that classified the municipality of Dolores in the class "western zone of basic grains and cattle".

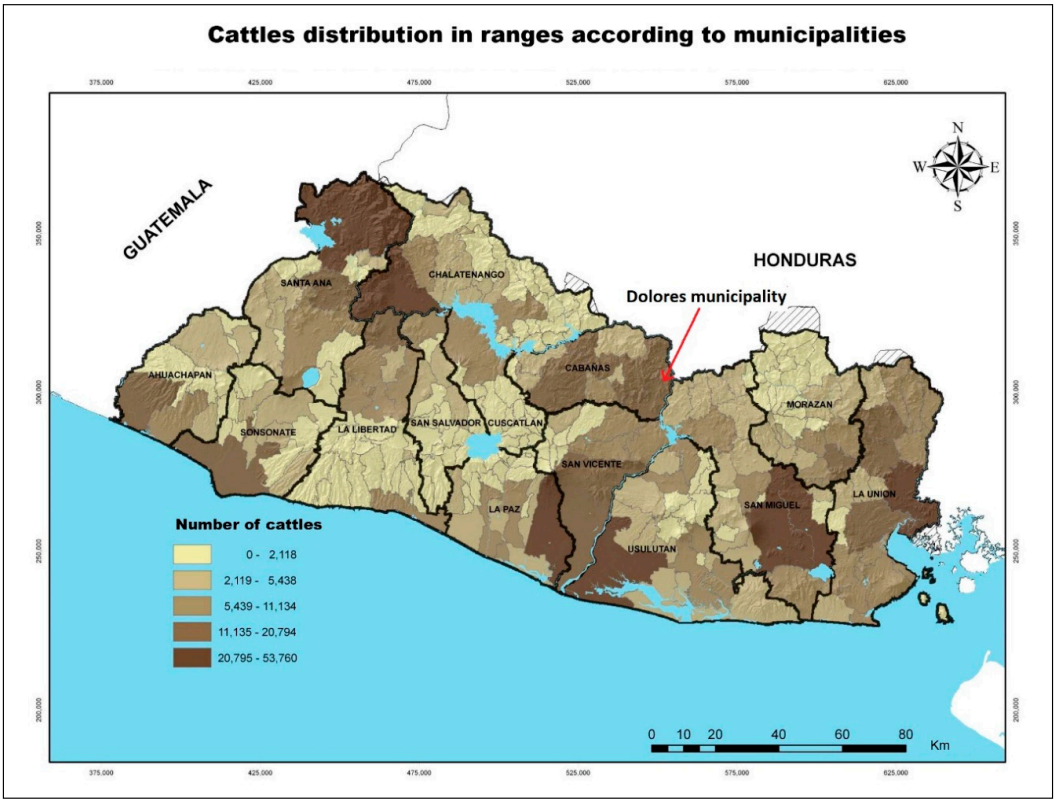


Figure 6. Dolores is one of the municipalities with a higher number of bovines in El Salvador (Source: Ministerio de Economia 2009, modified by the authors).

Average milk production, according to local farmers, is equal to 8 L/cow (11 bottles), in line with values of 4–8 L per day recorded by Ortéz et al. [22]. Almost all the local farmers sell their production of milk to processors of cheese. They say that in the past they used to produce Puebla Cheese on their own, but nowadays it is more practical and economically feasible to sell the entire milk production to big local cheese producers.

Beside cattle breeding, local farmers cultivate different crops, the main ones being maize (*Zea mays*), sorghum (*Sorghum vulgare*) and beans (*Phaseolus vulgaris*, Chaparrastique variety), with two production cycles per year (Table 2). Sorghum is used for feeding animals, and other forage species on smaller surfaces can be found in the areas such as *Hyparrhenia rufa*, *Digitaria swazilandesis*, *Digitaria decumbens*, *Brachiaria decumbens*, *Pennisetum purpureum*, *Cynodon* spp.

Table 2. Production (quintals) of maize, sorghum and beans in Dolores Municipality in 2017 [19].

	Human Consumption	Animal Consumption	For Seeds	To Sell
Maize	21,128	6802	17	14,713
Sorghum	-	8478	66	2379
Beans	464	-	8	83

Poultry and pigs that, respectively, are 858 and 514 in Dolores, are mainly raised for self-consumption or sold at the weekly local market that is an important place for farmers to sell animals and animal products. According to 2007 data, beside cattle, poultry and pigs, there were also 55 equines, 10 goats, 25 pelibueyes sheep and 33 beehives [19]. In the Department of Cabañas, migration of young people

towards bigger cities is frequent, and the hiring of Honduran workers for agricultural activities is a usual practice.

Regarding the composition of Morro fruits, Benavides [23] found it had 17% of crude protein and 32% of in vitro digestibility of the dry matter. Zamora et al. [24] recommended giving 3.56–4.4 kg/animal/day of Morro fruit to adult cows and bulls after a period of adaptation. The quality of Morro fruit for cattle feeding is very good based on chemical analysis (Table 3), with 22.54% of crude protein in the pulp.

Table 3. Chemical analysis of Morro fruit. Values are expressed in percentages (Source: Department of Agricultural Chemistry, Faculty of Agronomic Science, UES).

	Humidity	Dry Matter	Ashes	Crude Protein	Ethereal Extract	Crude Fiber	Carbohydrates
Pulp	5.77	11.41	8.17	22.54	15.91	12.00	41.38
Peel	4.18	28.50	6.20	6.99	0.42	39.69	46.69

3.2.2. Agro-Biodiversity

The Sabana de Morro derives from the natural vegetation of El Salvador and represents a case of typical wooded savanna but can also adopt characteristics of steppe [12]. Sabana de Morro traditional management allows the growth of different herbaceous species on the pastures, resulting in a rich agrobiodiversity.

Typical plants of this agroforestry system are *Crescentia alata* and *Crescentia cujete*, locally called Morro and Jícaro, and can be recognized easily by the shape of their fruits. *Crescentia alata* is a small tree (4–8 m, max 18 m), with a diameter at chest height of 30 cm (max 60), slow growth, originally from Mexico and tolerant of temporary floods and soils with bad drainage. Fruits are round shaped with a diameter of 7–10 cm (max 15 cm), while *Crescentia cujete* is very similar but its fruits are bigger (15–30 cm). Morro trees start to produce after 15 years and, according to local farmers, can still produce after 50 years. Fruit production can reach up to 27 kg/tree/year from the 8th year, and varies between 10–200 (averages of 60–80) per tree [25].

Natural herbaceous species growing on Sabana de Morro pastures mainly belong to Gramineae, Leguminosae or Asteraceae families. Common herbaceous plants include *Cynodon dactylon* (barrenillo), *Echinocloa frumentacea*, *Echinocloa polystachya* (pasto alemán) and *Digitaria sanguinalis* (pata de gallina). Some of them are considered weeds, such as *Cyperus michelianus* and *C. difformis* (coyolillo) or Stylosanthes hamata. The Morrales are also rich in epiphytes: *Tillandsia caput-medusae* and *T. schiedeana* (both known as gallitos), and Orchids like *Laelia rubescens*. *Hylocereus undatus* (pitahaya) can also be found in the area. If the Sabana de Morro is not used for some years, spontaneous shrubs grow, starting an ecological succession towards Sabana de Arbustos Espinosos (thorny bushes savannah) that is formed by *Acacia farnesiana* and *Acacia cornigera* [26].

Regarding cattle breeding, local farmers used to cross different breeds, some of European origin (Holstein, Brown Swiss) that have good production of milk, with Brahman (*Bos indicus*) that is more tolerant to tropical conditions but produces less milk. An exception is the Gyr (*Bos indicus*) breed, recently introduced, with a high amount of milk production and good adaptation to the tropical climate. Pigs are also raised locally. Unfortunately, the number of traditional Creole breeds is decreasing with respect to the introduced Dalland breed. Local varieties of chickens, turkeys, goats, horses and sheep can be found in smaller numbers.

The different habitats that originate from the Sabana de Morro agroforestry systems are homes to a variety of wild animals including birds (*Polyborus plancus*, *Buteo nitidus*, *Icterus pectoralis*, *Columbina talpacoti*, *Eumomota superciliciosa*, *Zenaida asiatica*), reptiles (*Ctenosaura similis*, *Iguana iguana*, *Drymarchon melanurus*, *Boa constrictor*) and mammals (*Dasypus novemcinctus*, *Didelphis marsupialis*, *Canis latrans*, *Odocoileus virginianus*, *Sylvilagus floridanus*). Among the mammals, the coyote (*Canis latrans*) can cause significant economic losses for local farmers as it can attack pigs, poultry and cattle calves. Rivers and torrents are also rich in fish, shrimps and crabs.

3.2.3. Local and Traditional Knowledge Systems

The most common way for cattle to consume Morro fruits is to freely eat them when they fall on the ground. This system does not require a workforce or costs for the farmers, but it can be dangerous for the animals as entire fruits can remain stuck in their throats and even cause death by asphyxia (enmorradas). Farmers can intervene rapidly to avoid animal death by pushing the fruit down the throat of the animal with the thin stick obtained from the central part of the stem of a banana tree. Another way for farmers to supply the Morro fruit is by collecting the fruits from the trees, cutting them with a machete and leaving them on the ground. This method can cause problems too, as cutting the fruit can result in sharp edges of the hard fruit peel that can cause internal lacerations. The third way is to harvest the Morro fruits when they are ripe, or just before, cutting the fruit, extracting the pulp and putting it in the cattle feeder. The traditional animal-feeder is called a *canoa*, a long and rectangular shaped wooden container. In the last years, the use of Morro fruits for cattle feeding has been decreasing, as it is more profitable to sell the fruits for handicrafts ($ 40.00/1000 fruits) than pay workers to harvest and give the pulp to the cattle. However, some farmers still apply this traditional practice with the involvement of all the family members.

Cattle breeding is carried out according to traditional practices too. The management of pasture consists of letting the cattle graze in one plot until the grass lasts and then moving the cattle to another plot to allow vegetation growth. In recent years, farmers have not relied only on free grazing for milk producing cows but have usually integrated grazing with concentrated nutrition to get maximum milk production while the rest of the animals are fed only on pasture. In the dry season, farmers feed all the cattle with silage, which is prepared by farmers at the end of the rainy season with maize or sorghum that is cultivated by themselves. During the flowering of the Morro trees, after pollination when petals fall on the ground, farmers collect petals or send the animals on the pasture since Morro flowers can represent a source of food for the cattle. When a calf is born, the farmer lets the cow and the calf together for a week and during this first week the total milk production is used to feed the calf. After a week, the farmer starts manually milking with the calf tied to the leg of the cow, with three quarters of the milk for the farmer and one for the calf. After milking, the farmer releases both the cow and the calf and lets them stay together so that the calf learns to eat grass, separating them only during the night. This management lasts approximately five and a half months after the calf is born.

Even the transformation of milk into the traditional square-shaped cheese follows the same techniques of centuries ago, and is part of the cultural heritage of local farmers. After milk is collected it is deposited in a pot where rennet is added. Once the milk is curdled it is cut into cubes with a knife while buttermilk is drained from the cubes of cheese curd and put in a barrel, adding salt to prepare brine. The cubes of cheese are immersed in the brine for three days after which the cubes of cheese are put on a wooden square mold wrapped in tissue. Cheese curd is pressed using a wood press for two days to drain the remaining buttermilk and brine and to mature the curd. The result is a square Puebla cheese ready to consumption.

3.2.4. Cultures, Value Systems and Social Organizations

In Dolores municipality, according to 2007 data, there were 1005 farmers and about 2257 employed in agricultural activities [19]. These data mean that about 15.8% of the population was made of farmers and another 35.7% employed in agriculture, without taking into account that family members are often involved in farming activities too, so the social structure of Dolores was particularly based on rural activities. The importance of small farmers in Dolores was confirmed by 2007 official data [19], as only 290 farmers were classified as commercial farmers (18.6% women), while 714 were classified as small-producers (11.1% women), and 275 were family-farms (Figure 7). As these data show, the role of women as conductors of farms was, unfortunately, subordinate. Moreover, 56.7% of farms had a surface smaller than 1 ha, and 16% between 1 ha and 5 ha.

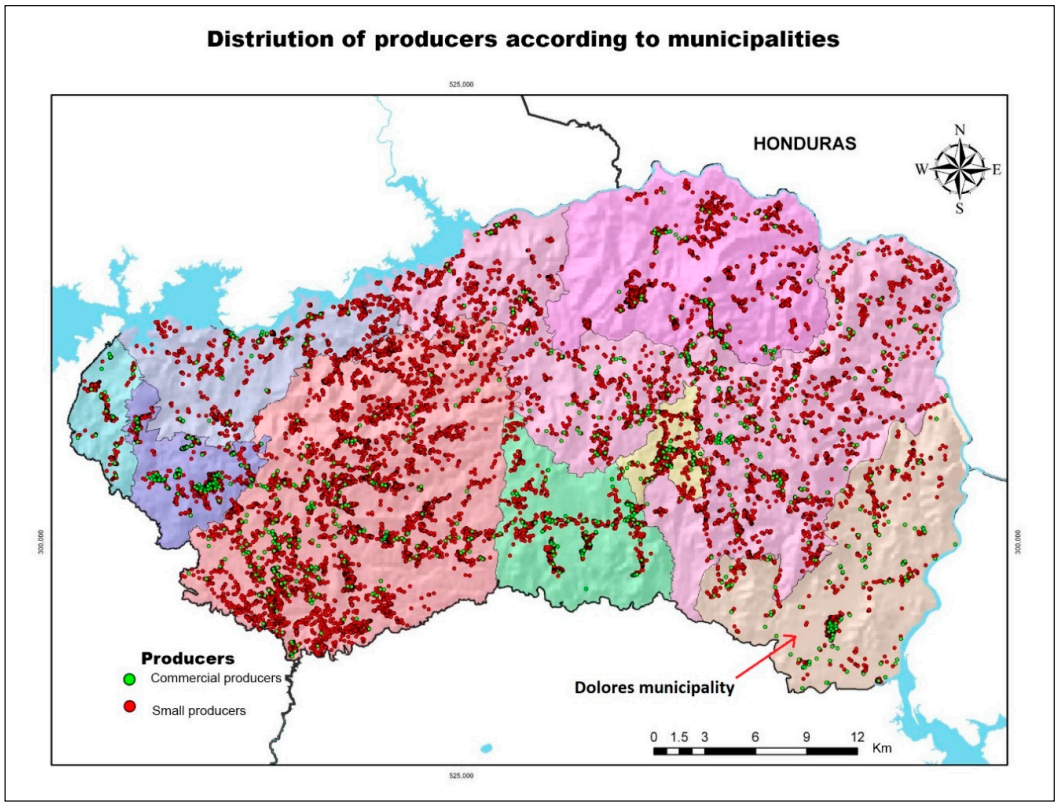


Figure 7. Official data about the presence of commercial farms (green) and small farms (red) in Cabanas department (Source: Ministerio de Economia 2009, modified by the authors) highlights the importance of small-producers and family-farming.

The main social organization related to cattle breeding in Dolores is a cooperative called ASOPUEBLA de RL, constituted by 27 breeders. Moreover, the government of El Salvador through the CENTA (Centro Nacional de Tecnologia Agropecuaria y Forestal) agency located in Guacotecti (Cabañas), gives technical support to at least 12 families of the municipality of Dolores in their agricultural and cattle breeding activities. According to 2007 data, 54 farmers requested and obtained subsidies for agricultural activities, and 27 for breeding activities, from public or private banks or from NGOs (Table 4).

Table 4. Number of farmers who requested subsidies for agricultural and breeding activities and financing institutions (Data source: Ministerio de Economia 2009).

Total Number of Subsidies Requests	Number of Farmers Who Asked and Received Subsidies for Agricultural Activities	Number of Farmers Who Asked and Received Subsidies for Breeding Activities	Private Banks	National Bank	ONGs	Local Lender
69	54	27	8	42	5	16

3.2.5. Landscapes and Seascapes Features

The Sabana de Morro is not only an ecosystem or an ecological classification of tropical dry forest, but also represents a very defined landscape (Figure 8) characterized by specific vegetation and plain or smooth slope morphology. The main features of the landscape structure are reported in Section 3.1. The landscape is mainly made of Sabana de Morro patches surrounded by bigger forested patches. Local forests are classified as Tropical Dry Forest typical of the climate Tropical Arid Low-Hot Land (below 700 m above sea level.) with 4–7 months rain-free dry season. These forests are characterized by the fall of leaves every year during the dry season and represent the potential forest type of El Salvador at lower altitudes that has been largely cut in the past to obtain land for agricultural activities. The most common species are *Byrsonima crassifolia* (Nance), *Apeiba tibourbou* (Peine de mico), *Curatelia americana* (Chaparro), *Stemmadenia donnell-smithii* (Cojon de puerco),

Bursera simaruba (Jiote), *Gliricidia sepium* (Madre cacao), *Luehea candida* (Cabo de hacha), *Cochlospermum vitifolium* (Tecomasuche), *Guazuma ulmifolia* (Caulote), *Tabebuia chrysantha* (Cortez), *Ipomoea arborescens* (Siete pellejos). All these species are not commonly used to obtain high-quality timber but for firewood or for fence poles, like *Gliricidia sepium* and *Bursera simaruba* [12,26–31].

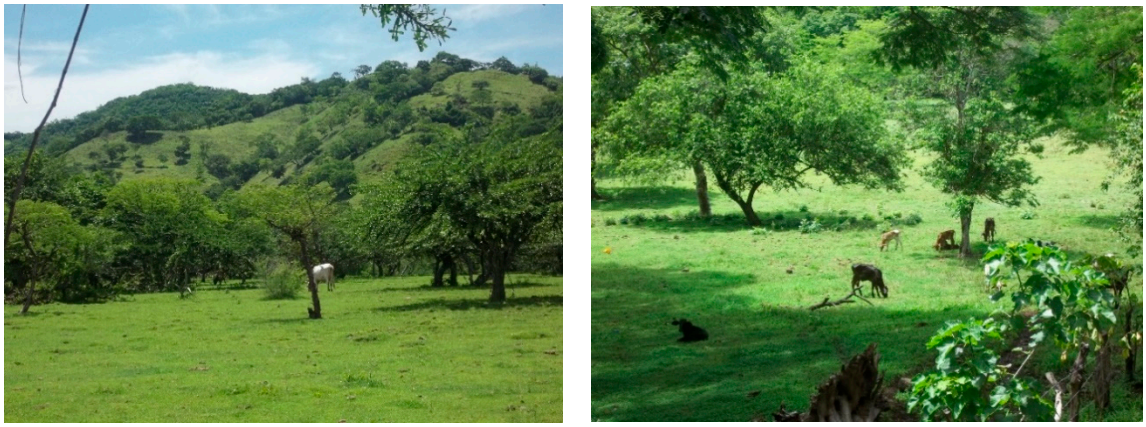


Figure 8. Pictures of Sabana de Morro in Dolores Municipality, El Salvador.

Beside rural features, the landscape is also characterized by small settlements. The biggest one is the city of Dolores with the main church, a remnant from the time of the Spanish colony that over the centuries has been renovated several times due to damages caused by earthquakes. Some houses of Dolores still preserve the traditional design of colonial houses with a shingle roof and a porch in front of the entrance to create a cool and shaded place.

4. Discussion

According to the results of this study, Sabana de Morro seems to be a well-preserved traditional agroforestry system driven by a rural economy mainly focused on free cattle grazing. Sabana de Morro probably originated through the incremental development of an adaptive strategy, as farmers decided to leave Morro trees in the pastures because they provided multiple services, and therefore they have incidentally become engaged in a type of agroforestry and have also incidentally changed the landscape [14]. Local communities intervened on the environment, selecting and preserving useful ecosystem services with positive effects on the environment and on the production system, being based on a mutual exchange between the Morro trees, the cattle and the farmers.

At the national level, this agroforestry system has undergone an important decrease while it has been maintained in this area constituting one of the main sources for local sustenance. In fact, at the national level, this plant formation covers 1.38% of the territory [32] which, compared to the 2.82% reported by Flores [33] for 1978, shows a significative decrease. In twenty-two years about 29,321 ha of Sabana de Morro have disappeared in the country, with an average of 1332 ha/year, mainly due to abandonment of grazing activities and transformation into sugar cane cultivation in suitable soil conditions. In Dolores Municipality, soils are of poor quality because the high amount of clay can lead to water stagnation during the rainy season, and to dehydration and to the formation of cracks in the dry season. Therefore, transformation of Sabana de Morro into cultivations, or in improved pastures by sowing productive forage species to integrate with natural pastures, is not possible, and the Sabana de Morro agroforestry system is the most efficient way to provide an income to local farmers, contributing to its maintenance. The ecology of Morro trees contributes to the preservation of the agroforestry system, since they do not require specific management, their seeds are efficiently dispersed and fertilized by cattle and the young trees are not damaged by the animals.

These are the main reasons that have contributed to the maintenance of this agroforestry system in Dolores, where the main traditional features seem to be well-preserved. This is important considering

that the conversion of traditional forest formations is the most important driver of tropical biodiversity loss and associated ecosystem services in the tropics [7]. The comparison of our land use mapping of 2017 with the data of the Censo Agropecuario 2007 [19] showed little changes compared to the rest of the country. Cultivated areas showed a decrease in the last ten years from 1025 ha to 724 ha, while different types of pastures decreased from 6600 ha to 6041 ha.

Silvopastoral systems with the presence of *Crescentia alata* or *C. cujete*, can also be found in other Central America countries. In Mexico, leaves and fruits are used to integrate the alimentation of lambs during the dry season, with evidence of good fiber supply for the diet of the animals and good growth of young lambs [34]. In the Caribbean region of Colombia 83% of local farmers include *Crescentia cujete* among the four trees on which they are "highly dependent" during periods of pasture shortage [35]. For Costa Rica, Janzen [36] reported that horses break the hard, ripe fruits of *Crescentia alata* with their incisors and swallow the small seeds embedded in the sugar-rich fruit pulp. According to the same study, Morro indehiscent fruits fall to the ground and rot without being touched by dispersal agents so that seeds usually die without germinating. Horses, therefore, become the main dispersing agents, and the seeds also take advantage of the manure to germinate, as happens in the Dolores pastures thanks to the presence of cattle. Bass [14] described in great detail the origin and use of *Crescentia* spp. trees in Honduran pastures, stating that farmers protect and encourage their presence in semiarid pastures where they serve as food for cattle when the dry season drastically reduces herbaceous forage.

As with other traditional silvopastoral systems, the Sabana de Morro represents an option for productive and sustainable landscapes [37]. In many tropical landscapes, agroforestry systems are the major ecosystems that resemble natural forest [38–40]. As these systems potentially have a high biodiversity conservation value [41,42], protection of pristine habitat needs to be combined with such environmentally friendly and sustainable land-use systems [7]. As demonstrated for other traditional agricultural models in Latin America [6], and in other tropical countries [3], the Sabana de Morro agroforestry system represents a promising example for other areas as it promotes biodiversity, supporting, at the same time, the livelihood of local farmers. The tree component, if appropriately managed as happens in Sabana de Morro, can enhance nutrient cycling, benefit pastures, provide complementary tree products in the form of fodder, timber, firewood and other tree products, and improve animal productivity [43]. While conventional cattle ranching has proved to be a major source of greenhouse gas emissions, traditional silvopastoral systems can have a crucial role as examples of adaptation and mitigation of climate change. Sabana de Morro can be compared to similar silvopastural systems for cattle breeding in Latin America where the presence of trees on pastures can increase carbon sequestration above and below ground, with values of carbon stock (2.43–74 Mg/ha) and of carbon sequestration (0.49–4.93 Mg/ha/year) on average higher for traditional pastures with natural trees compared to pastures with planted trees [42]. At the same time, temperatures can be 2–5 °C lower under the tree canopy compared to temperatures measured outside the tree canopy [44]. The shade effect of the trees is particularly important. Braun et al. [37] reported that the shade provided by trees on pastures can improve animal welfare, increasing milk production from 12 to 15% and reducing the number of veterinary services.

Sabana de Morro can also be compared to other traditional silvopastoral systems in Europe, such as the Dehesa in Spain, the Montado in Portugal and pastures with carob trees in southern Italy. European silvopastoral systems, beside their importance for environmental-related issues, are considered a legacy of traditional land use and areas where traditional practices and their associated cultural values still exist [45]. Moreover, they can be examples, if adequately supported and promoted through public policies, of a significative economic resource thanks to their recreational use and high-quality products [46].

5. Conclusions

The main vulnerability of this agroforestry system is linked to the risk of abandonment of cattle breeding due to the aging of farmers and to emigration of young people, while the main cost for the farmers relates to the harvesting of Morro fruits and extraction of the pulp to feed animals. Even though the habitants of Dolores have a strong sense of place, and all the interviewed farmers were born in

Dolores, the socioeconomic situation of the country can lead to a decrease in the number of farmers, especially among the younger generations. It must be considered that the Municipality of Dolores is one of the most backward in the country, where illiteracy reaches 32.9%, twice compared to the national rate (16%) in a country where 42.2% of people in the range 15–29 years seriously consider leaving the country [47].

The programme promoted by FAO focuses on sites that can be considered of global importance, a concept exemplified by the five criteria requested for inscription. This agroforestry system is the result of interaction between trees, cattle and farmers and has a long history rooted in the country. The cattle breeders' and cheese makers' traditions derive from the Spanish colonization and are still practiced today with very few changes. The maintenance of the Sabana de Morro system not only guarantees the protection of local traditions, but is also a sustainable way to provide good livelihood conditions while respecting the surrounding environment. Moreover, the diversity of land use, the landscape structure, the presence of hedges and of scattered trees in the pastures, play a fundamental role in agrobiodiversity protection and richness.

Results of this research proved that this agroforestry system has some important characteristics, in accordance to the five GIAHS criteria. The main findings are related to the effects of Sabana de Morro in preserving the traditional landscape and high levels of agrobiodiversity. Despite the maintenance of important environmental, socioeconomic and cultural services, further surveys and researches are needed to assess the effective potentiality of this agroforestry system to be included in the GIAHS programme, especially to precisely evaluate the contribution of this system to the local livelihoods and the problems related to a scarce generational turnover. In addition, it should be necessary to update the 2007 statistical data of the Censo Agropecuario to assess the recent evolution of the local socioeconomic and productive sector.

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