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Original article

Floristic inventory in two agroforestry systems of the San Francisco enclosure of the El Anegado parish

Inventario florístico en dos sistemas agroforestales del recinto San Francisco de la parroquia El Anegado

Inventário florístico em dois sistemas agroflorestais do recinto San Francisco da freguesia de El Anegado

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ABSTRACT

Agroforestry systems are an alternative land use and constitute a combination of agronomic and forest species. With the objective of characterizing the agroforestry systems of the San Francisco enclosure of the El Anegado parish, a floristic inventory was carried out and information was collected on the use and management of the components of the farms, between February and March, 2022; Margalef, Simpson, Shannon and Pielou Equity

diversity indices were calculated. Among the inventoried species, *Coffea arabica* L., *Handroaunthus billbergii* (Bureau & K. Schum.) S. O. Grose and *Theobroma cacao* L. stand out; while, *Cedrela montana* Moritz ex Turcz.; *Cecropia maxima* Snethl. and *Handroanthus chrysanthus* (Jacq.) SO, Grose, are categorized as vulnerable. In the El Palmital farm, food use predominates (54.55%) and in La Fortuna, timber prevails (51.72 %). The diversity indices in both farms showed high, medium and low values, according to the Margalef, Simpson and Shannon indices, respectively. The largest use of land in El Palmital is the planted area 74.23% (1.80 ha) and in La Fortuna the non-agricultural area dominated 55.88 % (0.95 ha). The characterization of agroforestry systems provides a better view of them, by conducting inventories of species that reflect their importance, management and organization, allowing redesign and optimization of their operation.

Keywords: Floristic inventory; indices; diversity; redesign; farms.

RESUMEN

Los sistemas agroforestales son una alternativa del uso de tierra y constituyen una combinación de especies agronómicas y forestales. Con el objetivo de caracterizar los sistemas agroforestales del recinto San Francisco de la parroquia El Anegado, se realizó un inventario florístico y se recopiló información sobre el uso y manejo de los componentes de las fincas, entre febrero y marzo de 2022; se calcularon índices de diversidad de *Margalef, Simpson, Shannon* y la *Equidad* de *Pielou*. Entre las especies inventariadas, sobresalen, *Coffea arabica* L., *Handroaunthus billbergii* (Bureau & K. Schum.) S. O. Grose y *Theobroma cacao* L.; mientras que, *Cedrela montana* Moritz ex Turcz.; *Cecropia maxima* Snethl. y *Handroanthus chrysanthus* (Jacq.) SO Grose, están categorizadas como vulnerables. En la finca El Palmital predomina el uso alimentario (54,55 %) y en La Fortuna prevalece el maderable (51,72 %). Los índices de diversidad en ambas fincas mostraron valores altos, medios y bajos, según los índices de *Margalef, Simpson y Shannon*, respectivamente. El mayor uso de tierra en El Palmital es de área sembrada 74,23 % (1,80 ha) y en La Fortuna predominó la superficie no agrícola 55,88 % (0,95 ha). La caracterización de los sistemas agroforestales brinda una mejor

visión de ellos, mediante la realización de inventarios de especies que reflejan la importancia, manejo y organización, permitiendo rediseñar y optimizar su funcionamiento.

Palabras clave: Inventario florístico; índices; diversidad; rediseño y fincas.

RESUMO

Os sistemas agroflorestais são uma alternativa de uso da terra e constituem uma combinação de espécies agronômicas e florestais. Com o objetivo de caracterizar os sistemas agroflorestais do recinto San Francisco da freguesia de El Anegado, foi realizado um inventário florístico e coletada informação sobre o uso e manejo dos componentes das fazendas, entre fevereiro e março de 2022. Os índices Margalef, Simpson, Shannon e Pielou Equity foram calculados. Dentre as espécies inventariadas, destacam-se *Coffea arabica* L., *Handroaunthus billbergii* (Bureau & K. Schum.) S. O. Grose e *Theobroma cacao* L.; enquanto, *Cedrela montana* Moritz ex Turcz.; *Cecropia maxima* Snethl. e *Handroanthus chrysanthus* (Jacq.) SO Grose, são classificados como vulneráveis. Na fazenda El Palmital predomina o uso alimentar (54,55 %) e em La Fortuna prevalece o uso madeireiro (51,72 %). Os índices de diversidade em ambas as fazendas apresentaram valores altos, médios e baixos, de acordo com os índices de Margalef, Simpson e Shannon, respectivamente. O maior uso da terra em El Palmital é a área plantada 74,23% (1,80 ha) e em La Fortuna a área não agrícola predominou 55,88% (0,95 ha). A caracterização dos sistemas agroflorestais proporciona uma melhor visualização dos mesmos, por meio da realização de inventários de espécies que refletem a importância, manejo e organização, permitindo redesenho e otimização de sua operação.

Palavras chave: inventário florístico; índices; diversidade; redesenhar; fazendas.

INTRODUCTION

According to the United Nations (2018), agroforestry contributes to objectives 1: end of poverty, 2: promote sustainable agriculture, objective 12: responsible production and objective and objective 15: life of terrestrial ecosystems; Therefore, through agroforestry

systems, it is sought to cover the needs of people in the world with respect to the four objectives mentioned above, providing a better quality of life, production and diversification of agricultural products, agricultural sustainability and sustainable terrestrial ecosystems.

According to agroforestry systems and according to the summary version of the state of the world's forests (Food and Agriculture Organization of the United Nations [FAO], 2022), there are three interrelated pathways based on forests and trees that can support economic and environmental recovery. These pathways are as follows: 1) stop deforestation and conserve forests; 2) restore degraded lands and expand agroforestry; and 3) using forests and creating green value chains in a sustainable way.

Agroforestry systems in the regions of Ecuador are utilization systems of great socioeconomic and biophysical relevance due to the diversification of products and services they provide (Riofrío *et al*., 2013). On the coast of Ecuador, it is common to find traditional agroforestry practices on farms resulting from peasant experiences. Although there is no characterization of these systems, it is possible to mention the existence of some practices used by local people. Among them are: trees in association with perennial crops, home gardens, silvopastoral practices and trees on boundaries (Aguirre *et al*., 2001).

The main objective of this research was to characterize the agroforestry systems of the San Francisco precinct of the El Anegado parish. All of the above based on the problem that there is a need to characterize agroforestry systems in the southern area of Manabí, as a contribution to the conservation of biological diversity at the local, regional and national level, so that small producers maintain their farms as well as their families.

MATERIALS AND METHODS

Study Area Location

The San Francisco enclosure belongs to the El Anegado rural parish of the Jipijapa canton in the province of Manabí, covers a territorial area of 121.96 km^2 and is located at kilometer 16

of the Jipijapa - Guayaquil Road, bordering to the north with the La América parish, to the south and east with the Paján canton and to the west with the Julcuy parish (GAD Parroquial de El Anegado, 2019). The work was carried out between February and March 2022 (Figure 1).

Figure 1. - *Georeferencing of the San Francisco enclosure and the farms under study*

Methodology

Inventory of Plant Species on the Farms Object of Study of the

San Francisco Campus of El Anegado Parish

The study included the identification of the plants present on the farms, which was resolved through inventories in order to determine diversity. Field tours were carried out, with the participation of the owner of the farms under study, the species were identified and information on their use and management was collected (Salazar *et al*., 2019). For the sampling, the transect method was used, according to the criteria of Mostacedo and Fredericksen, (2000) and Hernández *et al*. (2019) who mention that the transect method is

widely used due to the speed with which it is measured and for the greater heterogeneity with which the vegetation is sampled.

Diversity Indices

The diversity indices analyzed were taken according to the criteria of Lopez *et al.* (2017); Jimenez *et al.* (2017) and Salazar *et al.* (2019). In addition, Microsoft Excel was used to calculate the data and later verified with the free software Past version 3.04 for Windows.

Margalef Index

This index allows to evaluate the specific richness or alpha diversity, it is evaluated from counting all the species present in the selected farms. It is mathematically evaluated from Equation 1:

$$\boldsymbol{D_{MG}} = \frac{S-1}{\ln N} \quad (1)$$

Where:

S = number of species

N = total number of individuals

Simpson's Index

Known as dominance index and allows to evaluate which is the species that is found in greater proportion. According to this index, the dominant species is defined by applying Equation 2:

$$\boldsymbol{D} = \sum p_i^2 \quad (2)$$

Where pi is the proportion of individuals in the i-th species. To calculate the appropriate shape index for a finite community, Equation 3 is used:

$$\boldsymbol{D} = \sum \left(\frac{ni(ni-1)}{N(N-1)} \right) \quad (3)$$

Where: N = Total number of individuals

For the D value, the closer the value is to one (≤ 1), the less diversity there will be in the community, otherwise when D tends to 0 there will be less dominance and greater equitability. Dominance-based indices are inverse parameters to the concept of community uniformity or evenness. Since its value is the inverse of evenness, the diversity can be calculated as 1 λ.

Shannon Wiener index

Expresses the uniformity of importance values across all species, measures structural proportional abundance. This index is based on the count of individuals in a population, assuming that all species are represented in the assessment and is calculated by applying Equation 4:

$$\boldsymbol{H'} = -\sum p_i \, In \; p_i \quad (4)$$

Where:

S = Number of species (species richness)

pi= Proportion of individuals of species i with respect to the total number of individuals (that is, the relative abundance of species i), ni/N

ni= Number of individuals of species i

N = Number of all individuals of all species

The Shannon-Wiener index acquires values between zero, when there is only one species, and the logarithm of S, when all species are represented by the same number of individuals.

Equity of Pielou J´

Indicates the observed diversity in relation to the expected maximum. This index is interpreted in ranges from 0 to 1, while closer to one express that the species are equally abundant, values equal to or close to zero indicate that there is no uniformity (Jimenez et al. 2017). Equation 5 was applied to calculate Pielou's equity.

$$J' = \frac{H'}{H'_{max}} \quad (5)$$

Where:

H'max = ln(S)

H' = Shannon-Wiener Index

Plant Species Threat Category inventoried

To find out the threat category of the plant species inventoried on the farms under study, the Red List of the International Union for Conservation of Nature (IUCN, 2022) was consulted, namely: EX Extinct, EW Extinct in the wild, CR Critically Endangered, EN Endangered, VU Vulnerable, NT Near Threatened, LC Least Concern, DD Data Deficient Species, NE No Data.

The scientific names of the species cited in the San Francisco enclosure were verified by reviewing the Catalog of Life (Bánki *et al*., 2022). On the other hand, the common names were provided by the owner of the farms.

RESULTS AND DISCUSSION

Results of the Inventory of Plant Species on the Farms under Study

The results of the diversity inventory in the two farms showed that, in El Palmital, of all the sampled species, a large part is for food use, followed by timber use. Unlike La Fortuna, timber use predominates over food; it is worth mentioning that in both sites the lowest percentage of species was for other uses (ornamental and medicinal); the detailed information of the species with their respective use is shown in Table 1.

Within the framework of the previous observations, it is worth mentioning that, in both farms, the lowest frequency of uses was medicinal and ornamental. These results differ from the research carried out by Navarro *et al*. (2012), related to the diversity of useful species in

agroforestry systems; These authors report seven different types of uses where the highest frequency was for firewood with 41 species, followed by medicinal with 30, utensils 29, wood 25, food 23, fodder 20 and six for live fences.

On the other hand, the results of El Palmital and La Fortuna differ from those obtained by Hernández *et al*. (2019), who classified the use of the species into three groups, namely: 81 % are honey, 70 % medicinal and 37 % timber. In this sense, the results obtained in the El Palmital farm are corroborated with those of Salazar *et al.* (2019), who reported that in the municipality of Restrepo the greatest use is for food with 51 species, followed by forestry with 38, medicinal with 27 and ornamental with 9. In the municipality of Riofrío, 34 species are used for food and five for forestry. It is worth mentioning that medicinal, fodder and ornamental uses are low in both municipalities of Valle del Cauca.

Table 1. - *Distribution of agrobiodiversity inventoried on farms according to their use*

No.	Species		Applications	
	Scientific name	**Common name**	**El Palmital**	**The Fortune**
1	*Albizia Guachapele* (Kunth) Dugand	Guachapeli dark	Tm	Tm
2	*Albizia saman (Jacq.) Merr.*	Saman	-	Tm
3	*Artocarpus altilis* (Parkinson) Fosberg	Breadfruit	Ed	-
4	*Bravaisia integerrima* (Spreng.) Standl.	Manguillo	Ed	-
5	*Bromeliad penguin* L.	Piñuela	-	Orna
6	*Brosimum alicastrum* Sw.	Linden	-	Tm
7	*Carica papaya* L.	Papaya	Ed	Ed
8	*Cecropia maxima* Snethlage	Guarumo	Mdcl	Mdcl
9	*Cedrela montana* J. Moritz ex Turczaninov	Cedrela	Tm	Tm
10	*Chrysophyllum cainito* L.	Caimito	-	Ed
eleven	*Citrus aurantium* L.	Toronaj	Ed	-
12	*Citrus japonica* Thunb.	Chinese mandarin	Ed	-
13	*Citrus limon* L.	Lemon	Ed	Ed
14	*Citrus sinensis*	Orange	-	Ed
fifteen	*Coffea arabica* L.	Coffee	Ed	Ed
16	*Cordia alliodora* (Ruiz & Pav.) Oken	Laurel	-	Tm

17	*Cordia eriostigma* Pittier	Tomtumbo	-	Tm
18	*Erythrina velutina* Willd.	Pepito Colorado	Tm	Tm
19	*Ficus obtusifolia* Kunth	Mata palo colorado	Tm	-
21	*Ficus pertusa* L. fil.	Mata palo blanco	Tm	-
	Ficus spp.	Mata palillo	Tm	-
22	*Geoffroea spinosa* Jacq.	Seca	Tm	-
23	*Guazuma ulmifolia* Lam.	Guasmo	-	Tm
24	*Handroanthus chrysanthus* (Jacq.) SO, Grose	White guayacan	Tm	Tm
25	*Handroaunthus billbergii* (Bureau & K. Schum.) SO, Grose	Dark guayacan	Tm	Tm
26	*Inga edulis* Mart.	Liana guava	Ed	-
27	*Inga spectabilis* (Vahl) Will.	Machete guava	Ed	Ed
28	*inga marginata*	Green guava	Ed	Ed
29	*Inga sapindoides* Willd.	Monkey guava	Ed	-
30	*Leucaena trichodes* (Jacq.) Benth.	Mijan	-	Tm
31	*Musa acuminata* Colla	Orito banana	-	Ed
32	*paradisiacal muse* L.	Banana	Ed	Ed
33	*Ochroma pyramidale* (Cav.) Urban	Raft	Tm	-
3. 4	*Ocotea spixiana* (Nees) Mez	Brown Jigua	Tm	-
35	*Passiflora ligularis* A. Juss.	Passion Fruit	-	Ed
36	*American Persea* Mill.	Avocado	Ed	-
37	*Phytelephas aequatorialis* Spruce	Cade	S	-
38	*Pouteria spp* Aubl.	Mameycillo	Ed	-
39	*Prosopis pallida* (Willd.) Kunth	Carob tree	-	Tm
40	*Pseudobombox guayasense* A. Robyns	Saibilla	Tm	-
41	*Pseudobombox millei* (Standl.) A Robyns	Beldacus	Tm	Tm
42	*Psidium guajava* L.	Guava	Ed	-
43	*Schizolobium parahyba* (Vell.)SFBlake	Pachaco	-	Tm
44	*Spondias purpurea* L.	Ovo	-	Ed
Four. Five	*Theobroma cacao* L.	Cocoa	Ed	Ed
46	*Triplaris cumingiana* Fisch. & Mey. ex CA Mey.	Fernan Sanchez	-	Tm
47	*Vitex gigantea* Kunth	Pechiche	Ed	-

48	*Zea mays* L.	Corn	Ed	-

Ed= Edible; Tm= Timber; Orn = Ornamental; Mdcl= Medicinal; S= Sale.

Diversity Indices

According to the values presented in Table 2, the specific richness of Margalef was higher in El Palmital, however, the values of both show a high diversity in species. Regarding the Simpson diversity index, the El Palmital farm presented a higher value indicating a high diversity, unlike the La Fortuna farm, which shows a medium diversity. The dominance values imply that these farms have a greater abundance of species and that some species are dominant.

Table 2. - *Values of diversity indices, Margalef, Shannon-Weaver and Simpson of the inventories carried out on the farms under study*

Sitio San Francisco	**Índices de Diversidad**						
	Especies (S)	**Individuos (Ni)**	**Margalef**	**Simpson 1-D**	**Dominancia D**	**Equidad J´**	**Shannon H**
El Palmital (1)	33	3 835	3,88	0,78	0,22	0,51	1,79
La Fortuna (2)	29	3 604	3,42	0,65	0,35	0,40	1,36

Equity resulted with values of 0.51 and 0.40, this indicates that there is no similarity between species and individuals evaluated since they are not close to 1, that is, in both farms, there is clear evidence of the dominance exercised by some species in the sampling areas. On the other hand, the results of the Shannon Weaver index show that both farms have values less than 2 (< 2) and this is interpreted as having a relatively low diversity of species.

When evaluating the diversity indices, it was obtained that the specific richness of Margalef in the farms under study showed a high diversity of species, this index was the one that best recorded the diversity difference. On the other hand, the Simpson index showed that in the El Palmital farm there is a high diversity, unlike La Fortuna, which shows a medium diversity.

In the same order and sense of the previous ideas, these results coincide with the studies carried out by Blanco *et al.* (2014), and Milián *et al*. (2018); who stated that the Shannon index presents a low diversity in peasant farms, in turn the high values in the richness of Margalef ratify high biodiversity of the farms under study, this demonstrates a balance between the number of species and the number of individuals present in the evaluated systems.

Regarding equity, it denoted that there is no similarity between the number of individuals and species; thus, regarding the Shannon Weaver index in both farms studied in San Francisco, the values point to a low diversity; these data coincide with the results described by Lores *et al.* (2008) where the farms studied by these authors show low biodiversity according to the Shannon index, because the systems are not heterogeneous enough to sustain a high specific diversity.

With reference to the above, the results obtained in the farms studied in the San Francisco enclosure differ from the values reported by Salazar *et al.* (2019) who determine the composition and diversity of species in two municipalities; where the Margalef, Simpson and Shannon indices show a high specific richness.

Threat Categories of Inventoried Plant Species

Based on the list of species inventoried on both farms, Table 3 was prepared, showing the threat category of each one of them.

Table 3. - *Plant species categorized according to their threat category*

No.	Species	IUCN Categories								
		EX	**ew**	**CR**	**IN**	**VU**	**NT**	**LC**	**DD**	**NE**
1	*Albizia Guachapele* (Kunth) Dugand							X		
2	*Albizia saman (Jacq.) Merr.*							X		
3	*Artocarpus altilis* (Parkinson) Fosberg									X
4	*Bravaisia integerrima* (Spreng.) Standl.							X		
5	*Bromeliad penguin* L.									X
6	*Brosimum alicastrum* Sw.							X		

7	*Carica papaya* L.			X	
8	*Cecropia maxima* Snethlage	X			
9	*Cedrela montana* J. Moritz ex Turczaninov	X			
10	*Chrysophyllum cainito* L.				X
eleven	*Citrus aurantium* L.				X
12	*Citrus japonica* Thunb.				X
13	*Citrus limon* L.				X
14	*Coffea arabica* L.				X
fifteen	*Cordia alliodora* (Ruiz & Pav.) Oken		X		
16	*Cordia eriostigma* Pittier		X		
17	*critus sinensis*				X
18	*Erythrina velutina* Willd.				X
19	*Ficus obtusifolia* Kunth		X		
twenty	*Ficus pertusa* L. fil.		X		
twenty-one	*Ficus spp.*				X
22	*Geoffroea spinosa* Jacq.		X		
23	*Guazuma ulmifolia* Lam.		X		
24	*Handroanthus chrysanthus* (Jacq.) SO, Grose	X			
25	*Handroaunthus billbergii* (Bureau & K. Schum.) SO Grose		X		
26	*Inga edulis* Mart.		X		
27	*Inga spectabilis* (Vahl) Will.				X
28	*inga marginata*		X		
29	*Inga sapindoides* Willd.		X		
30	*Leucaena trichodes* (Jacq.) Benth.		X		
31	*Musa acuminata* Colla		X		
32	*paradisiacal muse* L.				X

Note. Note. EX= extinct; EW= extinct in the wild; CR= critically endangered; EN= endangered; VU= vulnerable; NT= almost threatened; LC= least concern; DD= data deficient; NE= not evaluated.

***Table 4**. - Continuation. Plant species categorized according to their threat category*

No.	Species	IUCN Categories								
		EX	ew	CR	IN	VU	NT	LC	DD	NE
33	*Ochroma pyramidale* (Cav.) Urban							X		
3. 4	*Ocotea spixiana* (Nees) Mez									X
35	*Passiflora ligularis* A. Juss.									X
36	*American Persea* Mill.							X		
37	*Phytelephas aequatorialis* Spruce						X			
38	*Pouteria spp* Aubl.									X
39	*Prosopis pallida* (Willd.) Kunth							X		
40	*Pseudobombox guayasense* A. Robyns								X	
41	*Pseudobombox millei* (Standl.) A Robyns								X	
42	*Psidium guajava* L.							X		
43	*Schizolobium parahyba* (Vell.)SFBlake							X		
44	*Spondias purpurea* L.							X		
Four. Five	*Theobroma cacao* L.									X
46	*Triplaris cumingiana* Fisch. & Mey. ex CA Mey.							X		
47	*Vitex gigantea* Kunth							X		
48	*Zea mays* L.							X		

Note. Note. EX= extinct; EW= extinct in the wild; CR= critically endangered; EN= endangered; VU= vulnerable; NT= almost threatened; LC= least concern; DD= data deficient; NE= not evaluated.

Adapted from: Union for the Conservation of Nature (2020).

As observed in Table 4, there was a greater number of species in the category of least concern (LC), in this order of things, the species *Cedrela montana* J. Moritz ex Turczaninov, *Cecropia maxima* Snethlage and *Handroanthus chrysanthus* (Jacq.) SO, Grosse (Figure 2), they are reported as vulnerable (VU).

***Figure 2**. - Vulnerable plant species according to the IUCN threat category San Francisco enclosure*

Note. A: *Cedrela montana* J. Moritz ex Turczaninov (La Fortuna farm); B: *Cecropia maxima* Snethlage (La Fortuna farm); C: *Handroanthus chrysanthus* (Jacq.) SO, Grose (La Fortuna farm).

Phytelephas aequatorialis Spruce is listed as Near Threatened (NT) (Figure 3).

***Figure 3**. - Image of individuals of the species Phytelephas aequatorialis Spruce Finca El Palmital*

It is worth mentioning that the threat species identified in the agroforestry systems of the San Francisco enclosure are generally due to their use in the timber and non-timber industry and sometimes due to agricultural expansion.

Regarding the threat category of the species *Phytelephas aequatorialis,* it is listed as almost threatened (NT), according to the IUCN red list (IUCN, 2022); this particular is dealt with by Jiménez *et al*. (2018), who explain that in 1997 the IUCN classified it as Vulnerable (VU) under criterion A. More recently, Valencia *et al*. (2013), place it in the Not Threatened category, however, they mention that it should be reconsidered and classified as vulnerable.

In relation to the tree species inventoried in the San Francisco enclosure, according to the IUCN red list, the species *Handroanthus chrysanthus* and *Cedrela montana are categorized as vulnerable;* this information differs from that described by Valderrama *et al*. (2018), where the species *Handroanthus chrysanthus is categorized* as Least Concern (LC). In the same way Ascencio *et al*. (2021) mention that the *Cedrela montana* species is included in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (CITES, 2019), due to indiscriminate extraction in areas of natural distribution motivated by the qualities of its wood.

In accordance with what has been previously described, the species *Cecropia maxima* classified as Vulnerable (VU) coincides in the same way with the study carried out by Romero and Pitman (2003), who place it in the same category, while Berg *et al.* (2005) differ specifying that the genus *Cecropia* is not threatened.

CONCLUSION

Among the species inventoried on the El Palmital and La Fortuna farms, *Coffea arabica* L., *Handroaunthus billbergii* (Bureau & K. Schum.) S. O. Grose and *Theobroma cacao* L. stand out; while, *Cedrela montana* Moritz ex Turcz.; *Cecropia maxima* Snethl. and *Handroanthus chrysanthus* (Jacq.) SO, Grose, are categorized as vulnerable. Among the uses, the most frequent were for the El Palmital farm, food (54.55 %) and in La Fortuna timber prevails

(51.72 %). In relation to the use of land in El Palmital, the planted area predominates 74.23 % (1.80 ha) and in La Fortuna the non-agricultural area 55.88 % (0.95 ha).

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