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Characterization of cocoa (*theobroma cacao*, l.) producing farms in the canton of yaguachi, Guayas Province

Caracterización de fincas productoras de cacao (*theobroma cacao*, l.) Nacional agroforestales renovadas, en el cantón yaguachi, Provincia Guayas

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Abstract

There is scarce information on the area under cocoa cultivation and inventory of species in renewed agroforestry farms in the Union de Organizaciones Campesinas Cacaoteras del Ecuador (UNOCACE); the purpose of this research was to georeference the area of dynamic agroforestry systems in national cocoa (*Theobroma cacao L*) producing farms and inventory the flora. The georeferenced coordinate method was used to determine the area of the farm; and, the global positioning system (GPS), to locate the species that make up the agroforestry system, using for this case the KoboCollect and GPS Status applications, downloaded on a smart mobile device (cell phone). Between 2016 and 2017, the small producers of the "El Deseo" precinct, installed 15 farms, resulting in a total of 11.8873 ha of dynamic agroforestry systems, being the area range from 0.3 to 2.0 hectares. The agroforestry systems evaluated, present different results according to each individual, species and family that compose it. In these agroforestry systems, it is recommended to complement with cocoa (*Theobroma cacao L.*), using national cocoa varieties 800 and 801; and, to establish fruit, timber, biomass, musaceae and palm tree crops, to optimize and generate value to the agroforestry systems.

Key words: cocoa, georeferenced coordinate, agroforestry systems, global positioning system.

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Resumen

Existe escasa información de la superficie cultivada de cacao e inventario de especies en las fincas agroforestales renovadas en la Unión de Organizaciones Campesinas Cacaoteras del Ecuador (UNOCACE); esta investigación tuvo como propósito georreferenciar el área de los sistemas agroforestales dinámicos en lasfincas productoras de cacao nacional (*Theobroma cacao L*) e inventario de la flora. Se utilizó el método de coordenada georreferenciada para determinar el área de la finca; y, el sistema de posicionamiento global (GPS), para ubicar las especies que integran el sistema agroforestal, utilizando para este caso las aplicaciones KoboCollect y GPS Status, descargados en un dispositivo móvil inteligente (celular). Entre los años 2016 y 2017, los pequeños productores del recinto "El Deseo", instalaron 15 fincas, resultando un total de 11,8873 ha de sistemas agroforestales dinámicos, siendo el rango de área desde 0,3 hasta 2,0 hectáreas. Los sistemas agroforestales evaluados, presentan diferentes resultados de acuerdo con cada individuo, especie y familia que la componen. En estos sistemas agroforestales, se recomienda complementar con cultivo de cacao (*Theobroma cacao L.*), utilizando variedades de cacao nacional 800 y 801; y, establecer cultivos de frutales, maderables, biomasa, musáceas y palmeras, para optimizar y generar valor a los sistemas agroforestales.
Palabras Clave: cacao, coordenada georreferenciada, sistemas agroforestales, sistema de posicionamiento global.

Introduction

"The agroforestry system implies the rationalization of sustainability that occurs through an adequate and integral management of the combination of each of its components tree, shrub and fruit tree." (Caicedo & Amanda, 2021). "The association of cash crops with forest species is important because they contribute to the conservation of soil, fertility and preserve water sources that are indispensable for tree planting" (Intriago & Gortaire, 2018)..

"The advantage of agroforestry systems, lies in that: 1) helps soil conservation, prevents soil erosion, increases micro and meso fauna, improves its texture and structure; 2) affects the climate, decreasing wind speed and mortality in animals; 3) help retain moisture and reduce evaporation from the soil; 4) influences frost by irradiation coming from the shrub layer; 5) contributes to the protection of the atmosphere through the absorption of CO_2 that occurs through the process of photosynthesis and increases water because it decreases evapotranspiration; 6) protects biodiversity, as it becomes a refuge for birds, insects and other beneficial animals; and, 7) produces economic income, with the sale of the products of agricultural harvest, forestry and animal production." (Carbo, 2018).

"The disadvantage of agroforestry systems, occurs when: 1) too many trees or incompatible species are implemented which can cause a decrease in crop production; 2) it can cause loss of nutrients when wood and other forest products are harvested and exported outside the plot; 3) the amount of water reaching the soil is reduced as it is intercepted by rain; 4) when trees are

harvested or pruned eventual mechanical damage to associated crops occurs, or also when raindrops fall from tall trees; and, 5) trees can hinder mechanical harvesting on crops." (Magnet, 2019).

"The diversified crop system is used to efficiently use the main agricultural area where different species such as corn, bananas, plantains, cassava, timber trees or even implement animal production, which improve soil nutrition and also contribute to the economy of small producers until the cocoa crop begins to produce. Some of the advantages that can be obtained from short-cycle crops are: 1) soil protection; 2) diversity of products (fruits, wood, firewood); 3) increases the monetary income of farming families; 4) income is obtained throughout the year; 5) produces natural oxygen in such a way that it helps to conserve the environment; and, 6) provides organic matter to the soil." (Intriago & Gortaire, 2018)..

"The cocoa crop has aspects very similar to a forest, so it is considered as an ecosystem created by humans; however, its appearance will depend on the management provided by the producer to it. There are several activities that affect its characteristics, such as the excessive use of chemicals used in production, the presence of only one type of plant residue such as cocoa leaves and inadequate management of irrigation water". (Imán, 2019).

"When biodiversity-friendly practices are employed, cocoa cultivation generates benefits such as the recovery of habitats and ecosystems, protection of endangered species and improves the connection between natural forests, where even endangered species find a refuge to develop. A clear example of this is the native forest species or some bird species that are highly endangered. The cultivation of cocoa guarantees the long-term sustainability of resources due to the protection of water sources, soil and other associated ecosystems, raising the conservation potential of a region that allows expanding areas of biodiversity." (Larrea, 2008).

According to Imán (2019), in agroforestry systems, soil management techniques should be used to reduce erosion risks and maintain or improve soil fertility, meeting the following objectives: 1) protect the soil surface with vegetation cover to reduce the impact of sun and rain, and reduce erosion risks; 2) maintain organic matter content in the surface soil strata to improve nutrient and water retention; 3) sustain a shallow root system to conserve soil structure and absorb nutrients found in the surface layer; 4) reduce the removal of organic matter and nutrients after harvesting, i.e., plant residues should be left in the soil to provide organic matter and nutrients; and, 5) reduce burning to avoid nutrient losses through volatilization and leaching.

"It is recommended to avoid establishing species that are not native and consume large quantities of water, such as teak, tropical eucalyptus, African palm, etc. One of the native species that consume large amounts of water is the laurel, so it should not be established near the sources to be protected. In addition, it is recommended to establish species with superficial

roots in greater quantity or density, so the shade will be greater and the loss of water by evaporation will be lower" (Drouet *et al*, 2019).

"Diversification techniques is an economic and sustainable alternative that helps to increase the quality of life in rural areas. Each territory can be identified by the various products by establishing local development policies" (Perez *et al*, 2015).

A dynamic agroforestry system calculated for one hectare of cocoa cultivation and recommended by the UNOCACE Farm Plus Project (2020) to all its associated producers, consists of the following species:

Table 1 *Dynamic agroforestry system*

Species	Quantity / ha.	Planting distance (m.)
Cocoa	833	**4 x 3**
Fruit trees		**8 x 9**
Timber		**8 x 9**
Palms		**15 x 15**
Biomass (Guaba)	416	**6 x 4**
Musaceae	**833**	**4 x 3**

Source: Finca Plus Project, UNOCACE (2020).

"It is important to point out the species suitable for this cultivation system and the functions of each one, where three species alternatives can be mentioned for the provinces of Guayas, Esmeraldas and Sucumbíos " (Imán, 2019).

Table 2 *Native fruit and timber species used for the edges and interior of the cocoa agroforestry crop (Guayas, Los Ríos and Sucumbíos)*

Species	Fruit tree	Species	Forestry
Botanical Name	**Name Common**	**Botanical Name**	**Name Common**
Morinda citrifolia	Noni	*Ocotea acutifolia*	Jigua
Carica papaya	Papaya	*Persea schiedeana*	Aguacatillo
Alibertia patinoi	Borojó	*Swietenia macrophylla*	Mahogany
Eugenia stipitata	Araza	*Centrolobium ochroxylum*	Yellow
Mangifera indica	Handle	*Guaiacum officinale*	Guayacán
Anacardium occidentale	Marañon	*Cedrela odorata*	Cedar
Diospyros nigra	Black sapote	*Triplaris cumingiana Fisher and Meyer*	Fernán sanchez
Nephelium lappaceum	Achotillo		
Garcinia mangostana	Mongoose		
Annona cherimola	Custard Apple		
Pouteria sapota	Mamey		
Inga edulis	Guaba		
Chrysophyllum cainito	Caimito		
Syzygium jambos	Pomarrosa		
Artocarpus altilis	Frutepan		

Source: Mosquera (2021).

"In Ecuador there are several case studies of cocoa producers that determine that the practices of productive diversification compared to monocultures present several benefits in the economic, environmental, social and likewise for food sovereignty." (Carbo, 2018).
"Traditional and agro-diverse agriculture through the advance of the green revolution gave way to productive specialization oriented to the market. The productive techniques implemented in monoculture are not only related to the increased environmental impact of agriculture, but also to the loss of economic autonomy of small farmers; therefore, the results presented in economic and social terms of the diversification strategies used by small Ecuadorian cocoa farmers are analyzed. The results of the different case studies show that farmers who intercrop their cocoa plantations with other crops obtain better results in relation to monoculture. On the other hand, diversification favors the informal exchange of products and in turn the strengthening of social ties and affective networks" (Castillo *et al.* , 2018).
This study consists of characterizing the renewed agroforestry farms producing national cocoa (*Theobroma cacao, L.*), in the Yaguachi canton, in the "El Deseo" area with producers associated with UNOCACE, through a georeferencing of the various plant species, to help improve agroforestry systems through the productive diversification of small producers, and thus demonstrate the proper use of agroforestry systems found in each farm evaluated.

Materials and methods

The research was conducted in the Association of Agricultural Producers of El Deseo, "an organization made up of more than 60 families dedicated to agricultural activity, located at km 26 of the Yaguachi canton in the province of Guayas, 15 minutes from the city of Milagro, with its coordinates -S2° 12'6. 112" -W79° 37'39. 264" with an average altitude of 8 meters above sea level" (Icaza *et al.*, 2013). The method used to conduct the research was georeferenced coordinates, in addition to the global positioning system (GPS) in the different agricultural areas in which the KoBoCollect and GPS Status applications were used. Field activities included identifying the farms and the work site, training the researchers by UNOCACE technical staff, informing UNOCACE of the progress of the research and applying each of the phases with the KoBoCollect and GPS Status applications. Different types of applications were used to obtain the data for this study: 1) KoBoCollect application, which was installed and configured on a smart mobile device; 2) GPS Status, used for the georeferencing of the agroforestry systems; 3) tour of the perimeter of the farms to be evaluated, as recommended by the UNOCACE Farm Plus Project (2020), to obtain the total area; 4) with the

GPS Status and KoBoCollect application, opened on the smart cell phone, we proceeded to georeference all the agroforestry species such as: cocoa, fruit trees, timber trees, musaceae, biomass, species in regeneration present in each evaluated farm; 5) all the information obtained in the field was recorded using a form in KoBoCollect. For the georeferencing in the case of cocoa, it was necessary to stay completely close to the plant and take the GPS point. In addition, for every 10 cocoa plants a sample had to be taken and determine whether the plant was bifurcated or not, if it was bifurcated, a maximum of 3 bifurcations were taken, with the help of a tape measure, the circumference diameters of each bifurcation and the height of the plant were measured; 6) on a DBH (diameter at breast height) form, all the species located such as musaceae, palms, timber, fruit trees, biomass, together with the GPS point were recorded; 7) all the data were recorded on a form in KoBoCollect, to finish with all the georeferencing of the species of each farm and then proceed to process the information; and, 8) all the results of the field work were interpreted.

Result

For the execution of this research, a georeferencing of the renewed agroforestry farms, producers of national cocoa, which were installed in 2016 and 2017, was carried out; it was necessary to go through the study area in order to measure the total area of the lots. It was possible to obtain the necessary data, of which 12 farms were installed in 2016 and 3 farms in 2017, as shown in Table 3.

Table 3 *Agroforestry farms producing national cocoa (Theobroma cacao, L.) evaluated in El Deseo, Yaguachi canton, Guayas province.*

Year	SAF NO.	Name of Producer	Area (ha.)
2016	01	Manuel Feliciano Salazar Beltran	0,5674
		Jacinto Velásquez Lavayen	0,8878
		Roberto Edmundo Martínez Maridueña	0,5742
		Juan Jofre Guerrero Reyes	1,9675
	05	Welcome to Perfecta Guerrero Peñafiel	1,0652
	06	Emilio Faustino León Ruíz	0,5118
		Lady Del Rosario Malavé Velásquez	0,7212
	08	Leonso Leonidas Martinez Salazar	0,3927
		María Estela Guerrero Peñafiel	0,8341
		Nancy Mónica Mora Salazar	0,5621
		Urbano Humberto Ruíz Franco	0,7897
		Víctor Daniel Haro León	0,8559
		Actual area taken	**9,7296**

2017	Manuel Feliciano Salazar Beltran	0,5327
	Pedro Regalado Guerrero Reyes	0,8681
	Hobla León Suarez	0,7569
	Actual area taken	**2,1577**
	TOTAL AREA	**11,8873**

Source: Association "El Deseo".
Prepared by: Authors.

Figure 1 shows the installation of agroforestry systems, where in 2016, 12 renewed agroforestry farms producing national cocoa (*Theobroma cacao, L.)* were established; and, in 2017, 3 farms were installed, belonging to small producers of the "El Deseo" precinct.

It is possible to observe the extension of the farms installed in 2016 and 2017, which present certain variability in their surface range, oscillating from 0.3 to 2.0 hectares, which indicates that it corresponds to the category of small producers; and, according to Prócel & Ordoñez (2018), they say that a small producer is one who owns less than 5 ha.

Characterization of the agroforestry systems present in the farms evaluated.

The agroforestry systems evaluated in this study present variable results according to each individual, species and family that compose it; a count of species planted in each area in the evaluated farms has been made; in addition, according to sources recommended by the dynamic agroforestry system of the UNOCACE Farm Plus Project (2020), the calculation allowed making the relevant technical recommendations of the species that remain to be implemented in the evaluated farms of the small national cocoa producers of the "El Deseo" precinct associated with UNOCACE; this study agrees with the publication made by (Salvador *et al.* 2019), which states that the biological diversity of an agroforestry system can be measured both by the richness of species and by the homogeneity of their distribution.

Characterization of the agroforestry system (SAF) N°01

The Agroforestry System (SAF) N°01, has an extension of 0.5674 ha, which was installed in 2016, which according to data reflected in Table 4, 200 individuals belonging to 14 species have been determined, of which great floristic diversity can be determined; in this system the cocoa species (*Theobroma cacao, L.)* stands out as one of the most important crops that produces income to the peasant family economy; as a second crop of importance constitutes the barraganete and dominico banana (*Musa paradisiaca L.*), established in greater numbers than other species; and oak (*Quercus robur L.),* as one of the most important timber trees established on the farm; according to (Guiracocha *et al.*, 2001), agroforestry systems with

cocoa, coffee and banana have the potential to be a fundamental tool for maintaining biological diversity in their geographical environment.

Table 4 *Agroforestry species identified in FFS N°01*

Plant species	Scientific name	Family	Quantity
Achiote	*Bixa orellana L.*	Bixaceae	
Cocoa	*Theobroma cacao L.*	Sterculiaceae	
Coffee	*Coffea arabica L.*	Rubiaceae	**1**
Caimito	*Chrysophylum cainito L.*	Sapotaceae	**1**
Guaba	*Inga edulis L.*	Fabaceae	
Guachapele	*Albizia guachapele L.*	Fabaceae	**1**
Mandarin lemon	*Citrus limonia L.*	Rutaceae	**1**
Handle	*Mangifera indica L.*	Anacardiaceae	
Niguito	*Muntingia calabura L.*	Flacourtiaceae	**1**
Pachaco	*Schizolobium parahybum*	Caesalpinaceae	
Banana barraganete	*Musa paradisiaca L.*	Musaceae	
Dominican plantain	*Musa paradisiaca L.*	Musaceae	
Oak	*Quercus robur L.*	Fogaceae	
Tamarindo	*Tamarindus indica L.*	Fabaceae	**1**
Total, plant species			

The items established in the SAF N°01, are catalogued as follows: cocoa *(Theobroma cacao L.)*; fruit trees such as caimito (*Chrysophylum cainito, L.)*, mandarin lime (*Citrus limonia L.)*, mango *(Mangifera indica L.)*, coffee *(Coffea arabica L.*), tamarind *(Tamarindus indica L.)*; timber species such as pachaco (*Schizolobium parahybum*), oak (*Quercus robur L.*), guachapele (*Albizia guachapele),* niguito *(Muntingia calabura L.)*; biomass such as achiote (*Bixa orellana L.)* and guaba *(Inga edulis L.);* musaceae such as banana barraganete and dominico (*Musa paradisiaca L.).);* and, it was identified that the farm does not have palm trees; therefore, the farmer must necessarily plant this species on his farm; a study that agrees with the publication by Guiracocha *et al. (*2001), where he states that the floristic structure of the FFS are usually determined by fruit trees; while Sanchez & Sanchez (2016) and (Caicedo et *al.* , 2019), indicate that the structure of the FFS are composed of timber and fruit trees; thus originating "more carbon in long periods of time". (Alegre, 2017).

Technical proposal for PAS N°01

Taking into account the recommendation of the UNOCACE Dynamic Agroforestry Systems Farm Plus Project (2020), the following table is proposed to optimize the number of

agroforestry species for this FFS, together with the species to be established on the farm analyzed.

Table 5 *Dynamic Agroforestry System recommended for PFS N°01*

Species	C. Established	C. Recommended	Missing Species
Cocoa		473	**334**
Fruit trees			
Timber			
Palms	0		
Biomass		236	**223**
Musaceae		**473**	**448**

Source: Finca Plus Project, UNOCACE (2020).
Prepared by: Authors.

The recommendation established for the SAF N°01, according to the calculated data presented in Table 5, the farmer should establish in its 0.5674 ha, 334 national cocoa plants of the national variety 800 and 801, 69 fruit trees (caimito, lemon, mandarin, mango, orange), 64 timber species (pachaco, oak, guachapele, niguito), 25 palm trees (coconut, chontilla), 223 guaba and achiote plants to recover the biomass; and 448 musaceous plants (banana barraganete, dominico and guineo seda), so that the agroforestry system is dynamic, generates stable income for the small producer, and is also environmentally friendly and compatible with the environment.

The same procedure should be assumed for the following FFS N° 02 - 15, considering the area (ha) of each farm and the number of plant species present in each agroforestry system, in order to optimize each farm and make it profitable for the small cocoa producer; since the biodiversity of the farm generates additional profits for the small producer and therefore the biodiverse forest sequesters carbon and regulates the planet's climate, which is sometimes invalidated by society. This same methodology and technology could be replicated on smallholder cocoa farms in both the coastal and Amazonian regions of Ecuador, where conventional inputs that degrade and pollute terrestrial and aquatic ecosystems are not used.

Conclusions

Between 2016 and 2017, 15 farms were installed, obtaining a result of 11.88 ha of dynamic agroforestry systems. Of all the farms evaluated, the extension ranges from 0.3 to 2.0 hectares,

which are located within the category of small producers. The purpose of the renovated dynamic PFS is to improve the vegetation cover of the soil, to enhance family income, improve the natural landscape and contribute to carbon recycling.

The main crops recorded on the 15 smallholder farms were classified as follows: cocoa *(Theobrama cacao L.)*, musaceae (Dominican plantain, guineo de seda and barraganete plantain), biomass (guaba and achiote), fruit trees (guanabana, papaya, achotillo, orange, mandarin, subtle lemon, mandarin lemon, grapefruit, guava, mamey colorado, mamey cartagena, breadfruit), timber (oak, guachapele, pachaco, melina, cedar, laurel, guayacán) and some palm trees (coconut, chontilla, African palm). The study revealed that there are several farms that do not comply with the dynamic agroforestry systems recommended by UNOCACE's Finca Plus Project (2020), and in most cases they need to be complemented with the items already evaluated and in one or two cases apply a thinning system, so that the agroforestry systems become profitable for the small producer, dynamic and environmentally sustainable.

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