

Characterization and role of Amazonian fruit crops in family farms in the provinces of Sucumbíos and Orellana (Ecuador)

Caracterización y rol de los frutales amazónicos en fincas familiares en las provincias de Sucumbíos y Orellana (Ecuador)

Yadira Beatriz Vargas-Tierras,¹ Julia Karina Prado-Beltrán,² José Rogelio Nicolalde-Cruz,³ Fernando Casanoves,⁴ Elias de Melo Virginio-Filho,⁵ William Fernando Viera-Arroyo^{6*}

¹ Responsible of Programa de Fruticultura, Instituto Nacional de Investigaciones Agropecuarias (Iniap). La Joya de los Sachas, Ecuador. Email: yadira.vargas@iniap.gob.ec. orcid.org/0000-0002-1429-8122

² Research lecturer, Universidad Técnica del Norte, Facultad de Ingeniería Agropecuaria. Ibarra, Ecuador. Email: jkprado@utn.edu.ec. orcid.org/0000-0001-8836-3559

³ Administrator of the farm Palora, Instituto Nacional de Investigaciones Agropecuarias (Iniap). Palora, Ecuador. Email: jose.nicolalde@iniap.gob.ec. orcid.org/0000-0003-1342-9749

⁴ Agroforestry Specialist, Centro Agronómico Tropical de Investigación y Enseñanza (Catie). Turrialba, Costa Rica. Email: eliasdem@catie.ac.cr. orcid.org/0000-0003-2063-0010

⁵ Biostatistics Unit Director, Centro Agronómico Tropical de Investigación y Enseñanza (Catie). Turrialba, Costa Rica. Email: casanoves@catie.ac.cr. orcid.org/0000-0001-8765-9382

⁶ Responsible of the Programa Nacional de Fruticultura, Instituto Nacional de Investigaciones Agropecuarias (Iniap). Tumbaco, Ecuador. Email: william.viera@iniap.gob.ec. orcid.org/0000-0003-4472-4126

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* Corresponding author. Avenida Eloy Alfaro N.º 30-350 y Amazonas. Quito, Ecuador.

Abstract

Fruit crops in the northern Ecuadorian Amazon region are part of the crop diversity found in a production system called "chakra" that is known as a traditional and diverse agroforestry system. The aim of this study was to characterize the Amazonian fruits crops present in production farms with cacao (*Theobroma cacao*), coffee (*Coffea canephora*) and silvopastoral systems located in the provinces of Orellana and Sucumbíos. The information was obtained through targeted surveys and direct observations in the field. The results indicated that in the two provinces, producers establish from 1 to 19 fruit crop species in their plots, being the farms of less than 10 hectares the most diverse. In most farms, the predominant fruit crops in these production

systems are avocado (*Persea americana*), citrus (*Citrus* spp.), coconut (*Cocos nucifera*), ice-cream-bean (*Inga edulis*), papaya (*Carica papaya*), peach palm (*Bactris gasipaes*) and pineapple (*Ananas comosus*). These crops are associated with cacao, coffee, monocultures, silvopastoral systems, or dispersed outside these systems. On the other hand, other species have been introduced and are considered as fruit crops with market potential, namely, fig (*Ficus carica*), grapefruit (*Citrus x paradisi*), passion fruit (*Passiflora edulis*) and star gooseberry (*Phyllanthus acidus*). Fruit crop production is mainly destined for self-consumption and animal feed; however, the surplus is sold to generate an economic income.

Keywords: biodiversity, *Coffea canephora*, Ecuadorian Amazon, silvopastoral systems, *Theobroma cacao*

Resumen

En la región norte de la Amazonía ecuatoriana, los frutales hacen parte de la diversidad de cultivos que se encuentran en los sistemas de producción denominados *chakra*, que constituye un sistema agroforestal tradicional y diverso. El objetivo de este estudio fue caracterizar los frutales amazónicos presentes en las fincas productoras de cacao (*Theobroma cacao*), café (*Coffea canephora*) y con sistemas silvopastoriles, ubicadas en las provincias de Orellana y Sucumbíos. La información se basó en encuestas dirigidas y en la observación directa en el campo. Los resultados indicaron que, en las dos provincias, los productores establecen entre 1 y 19 especies de frutales en sus parcelas, y que las fincas de menos de 10 hectáreas son las más diversas. En la mayoría de ellas, los frutales predominantes

en los sistemas de producción son aguacate (*Persea americana*), cítricos (*Citrus* spp.), coco (*Cocos nucifera*), chontaduro (*Bactris gasipaes*), guaba (*Inga edulis*), papaya (*Carica papaya*) y piña (*Ananas comosus*). Estos cultivos están asociados con café, cacao, sistemas silvopastoriles, monocultivos, o dispersos fuera de estos sistemas. Por otro lado, se han introducido especies consideradas frutales con potencial de mercado, entre las que se encontraron grosella (*Phyllanthus acidus*), higo (*Ficus carica*), maracuyá (*Passiflora edulis*) y pomelo (*Citrus x paradisi*). En su mayoría, la producción de los frutales está destinada al autoconsumo y la alimentación de los animales de la finca; sin embargo, el excedente se vende, para generar un ingreso económico.

Palabras clave: Amazonía ecuatoriana, biodiversidad, *Coffea canephora*, sistemas silvopascícolas, *Theobroma cacao*

Introduction

In the tropics, the Amazonian forests are the largest and most diverse (Pitman et al., 2001). Moreover, the Amazon provides the world with essential environmental services such as the maintenance of biodiversity and the water cycle, and carbon storage (Ojea, Martin, & Chiabai, 2012).

The Amazon region of Ecuador (ARE) represents 48 % of the national territory, and is populated by more than 700,000 inhabitants, of whom 30 % belong to indigenous ethnic groups. The provinces of Sucumbíos and Orellana are located in the northern part, Napo and Pastaza in the central area, and Morona Santiago and Zamora Chinchipe in the south.

Most of their soils show an infertility complex so they form fragile ecosystems, prone to degradation in the short term when the natural forest is replaced by unsustainable production systems (Valarezo, 2012). Biodiversity in the natural ecosystems of the Amazon region has a high potential for sustainable development, when different forest resources and crops used and maintained by producers are integrated.

The management of these resources must be oriented effectively and, according to the ecosystem conservation, with strategies and practices that allow the recovery and the conservation of soils and water resources, as well as the maintenance of their natural fertility and the balance between pests and natural enemies (Nieto & Caicedo, 2012).

The northern ARE covers an area of 496,846 ha that includes forests, mountains and *páramos*, 205, 541 ha of cultivated pastures and 74,809 ha of permanent crops, among others (Instituto Nacional de Estadísticas y Censos [INEC], 2009).

In relation to permanent crops, 15 % of the area is occupied by fruit trees, and the most representative species are citrus (*Citrus* spp.), peach palm (*Bactris gasipaes* Kunth) and other native fruit trees as arazá (*Eugenia stipitata* McVaugh), borojó (*Borojoa patinoi*

Cuatrec.), guava (*Psidium guajava* [L.] Kunze), cocona (*Solanum sessiliflorum* Dunal), copoazú (*Theobroma grandiflorum* Willd. ex Spreng.), asaí (*Euterpe precatoria* Mart.), camu camu (*Myrciaria dubia* [HBK] McVaugh) and tampoi (*Baccaurea macrocarpa* [Miq.] Müll.Arg.) (Grijalva & Sist, 2009).

In this region, fruit trees are found in a traditional and diverse agroforestry and production system called *chakra*. Fruit trees are part of its biodiversity and are considered promising for their great nutritional potential, having suitable features to become sustainable crops, since they can be used in ecosystems conservation and restoration. This is especially true as part of the agroforestry systems in the Amazon, are established in association with other agricultural and forestry crops in a more orderly manner (González, 2013). Native communities implement *chakras* that are then replicated by colonists in the area; these have the purpose of satisfying nutritional needs and generating income through their commercialization (Jadán, 2012).

Álvarez (2012) registered 67 fruit trees species in *chakras* in the province of Zamora Chinchipe, identifying and characterizing 31 species with productive and nutritional potential in the same area. It is important to mention that several of fruit crops that were characterized are currently being exported within the subsector "Non-traditional fruits and other fruit trees", as processed fruits. Among these we find arazá, borojó and guava, which are sent abroad as jam and cereal bars.

On the other hand, there are fruit trees that have an enormous potential as achotillo or rambutan (*Nephelium lappaceum* L.), caimito (*Chrysophyllum cainito* L.), starfruit (*Averrhoa carambola* L.), cherimoya (*Annona cherimola* Mill.), peach palm (*B. gasipaes*), cherry plum (*Prunus cerasifera* Ehrh.), breadfruit (*Artocarpus altilis* [Parkinson] Fosberg), and guaba or guama (*Inga edulis* Mart.). Additionally, we also find soursop (*Annona muricata* L.), key lime (*Citrus x aurantifolia* [Christm.] Swingle), mandarin orange (*Citrus reticulata* Blanco), Malay rose apple (*Eugenia malaccensis* L.) and zapote (*Matisia cordata* Bonpl.).

Their potential lies in their antioxidant capacity (Clement et al., 2004, Contreras, Calderón, Guerra, & García, 2011, Correa, Ortiz, Larrahondo, Sánchez, & Pachón, 2012, Figueroa, Tamayo, González, Moreno, & Vargas, 2011, González, 2013, Mertz et al., 2009, Rojas & Narváez, 2009, Serrano, Umaña, & Sáenz, 2011, Vargas, Rivera, & Narváez, 2005, Vit, Santiago, & Pérez-Pérez, 2014), and in their contents of proteins, carbohydrates, fiber, calcium, iron and important vitamins for nutrition (Arango & Quijano, 1977, Vargas, 2003).

For this reason, Programa de Fruticultura del Instituto Nacional de Investigaciones Agropecuarias [Fruit Production Program of the National Institute of Agricultural Research] (Iniap) has identified the need to establish the potential fruit crops have in the northern region of the Ecuadorian Amazon. In 1990, the collection of Amazonian and exotic fruit trees was established as part of the germplasm maintained by Iniap in the province of Orellana, which covers an approximate area of 6 hectares, with ca. 80 species and 182 ecotypes.

The characterization of some materials shows that their nutritional composition, antioxidant properties and agronomic characteristics represent a potential to promote these crops as fresh or processed fruit, and increase local and regional markets (Grijalva & Sist, 2009; Ruiz, 2003).

In this sense, the aim of this study was to characterize and quantify the fruit trees grown in different production systems found in farms of producing families in the provinces of Orellana and Sucumbíos, Ecuador.

Materials and methods

The study was conducted in the northern region of the Ecuadorian Amazon, which includes the provinces of Sucumbíos and Orellana. The average temperature is 23 °C, with rainfall patterns of 3,500 mm per year. These high precipitation levels are correlated with the relative humidity data of 89% found in this region (Nieto & Caicedo, 2012).

In the study area, 37 farms were selected due to having research and validation plots with cacao

trees (*Theobroma cacao* L.), coffee (*Coffea canephora* Pierre ex A. Froehner) and silvopastoral systems, that were part of the project "Aporte a la construcción del desarrollo agroforestal sostenible en la Amazonía ecuatoriana (AFAM)" [Contribution to the construction of sustainable agroforestry development in the Ecuadorian Amazon]. The project was developed by Centro Agronómico Tropical de Investigación y Enseñanza [The Tropical Agricultural Research and Higher Education Center] (Catie) and Instituto Nacional de Investigaciones Agropecuarias (Iniap), and was carried out in ten parishes, five in the province of Orellana and five in the Sucumbíos.

The farms chosen had at least one fruit tree as a component of their production systems, as monocultures or in some type of association with cacao, coffee or pastures (Poaceae). Another selection criterion was the interest of farmers in learning new production technologies for fruit trees and associated crops (figure 1).

Data collection was carried out through structured surveys directed towards producers, obtaining information regarding the size of the farm, fruit tree associations with other crops, fruit trees diversity, age of the crops, agronomic management systems, yield and destination of production (commercialization).

To define the size of the farm, how it should be classified, and the size of the agricultural production units (APU), the Nieto and Caicedo classification (2012) system was used, i.e. farms of less than 10 ha; farms with 11 to 50 ha; farms with 51 to 100 ha; and farms with more than 100 ha.

The agrobiodiversity index (ADI) for fruit species was established according to the methodology proposed by Gravina and Leyva (2012) and Leyva and Lores (2012), which establishes a division by groups to calculate each subscript, as follows. 1) biodiversity for human consumption (forming, energetic and regulatory: IFER), 2) biodiversity for animal feed (forming: IFE), 3) biodiversity for soil (biomass: IAVA), and 4) complementary biodiversity (medicinal: ICOM).

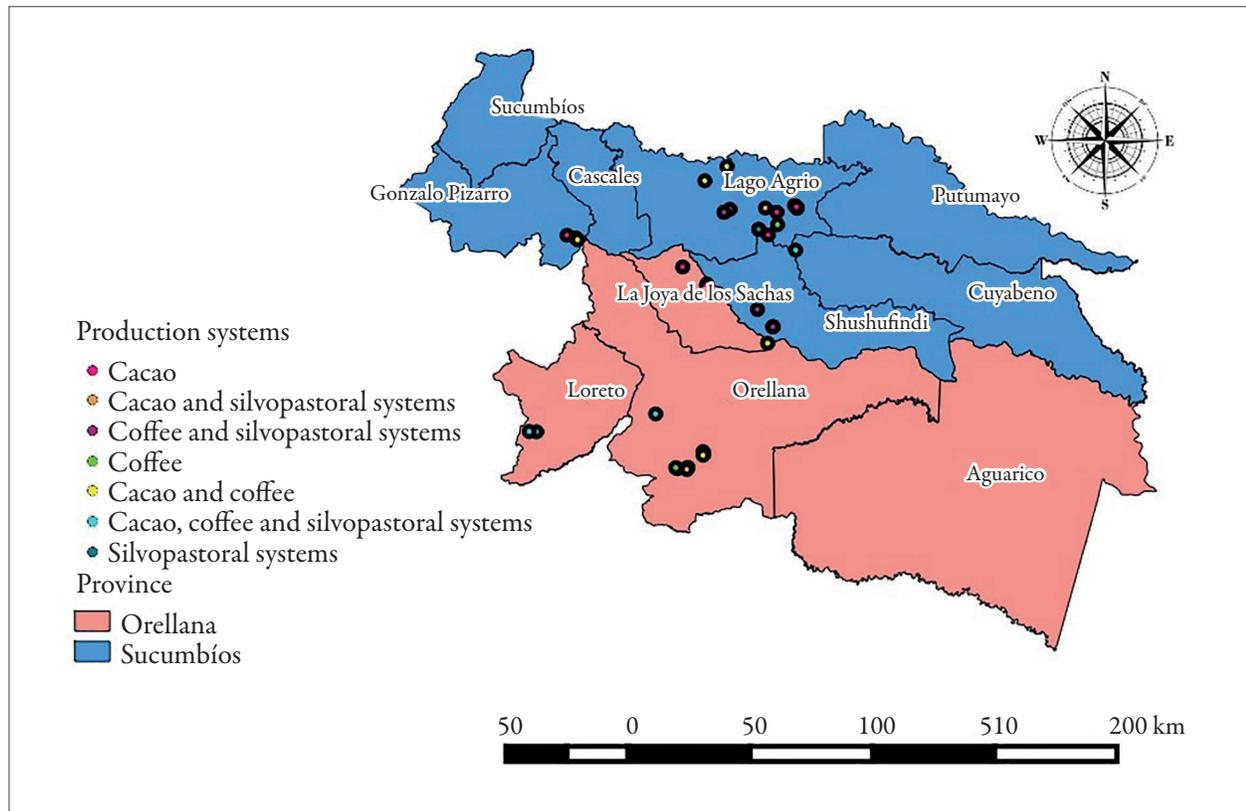


Figure 1. Location of farms producing cacao, coffee and silvopastoral systems, in the provinces of Sucumbíos and Orellana (Ecuador).

Source: Elaborated by the authors

The ADI was calculated using the following mathematical equation:

$$\frac{\sum_1^S Vi}{S_i (Vi.max)}$$

Where:

V_i : importance value of the species in a scale from 0 to 3

S_i : total number of components

An agroecosystem is considered efficient or sustainable when the ADI value is higher than 0.7. Furthermore, the association of fruit trees with other crops was also observed, such as cacao, coffee, pastures, dispersed, mixed with cacao and coffee, and pastures.

Regarding the definition of fruit tree management, questions were asked regarding the type of agronomic

management, the performance of activities such as weeding, pruning, application of manure and fertilizers, phytosanitary controls and thinning.

On the other hand, the questions about the destination of the production were classified as for self-consumption, for animal feed, losses in the field (not harvested), lack of tree production, sale on farm or intermediaries on farm, or transportation for market sale.

Results were analyzed through descriptive statistics, showing means and standard error by species, farm and province. An analysis of variance was carried out using general and mixed linear models (Di Rienzo, Macchiavelli, & Casanoves, 2011). Differences between treatment means were estimated with the protected Fisher's LSD (least significant difference) test with a level of significance of 5 %.

In turn, categorical data were analyzed through contingency tables (chi-square statistic, maximum likelihood) and multivariate analysis using multiple correspondences. All these analyzes were carried out using the statistical package InfoStat, version 2015 (Di Rienzo et al., 2015).

Results and discussion

Farm size

With regards to the classification and size of the APUs, Nieto and Caicedo (2012) indicate that in the Ecuadorian Amazon the size has been categorized according to different farm surface ranges. In Orellana 62 % of these have an area between 11 and 50 hectares, compared to 46 % in Sucumbíos.

In second place, there are farms with less than 10 ha, which correspond to 23 % in Orellana and 38 % in Sucumbíos. Farms with extensions between 51 and 100 ha are those that register a lower percentage in both provinces, i.e. 15 % in Orellana and 17 % in Sucumbíos. No fruit producers were found with extensions larger than 100 ha.

The results of our research agree with what was found by Nieto and Caicedo (2012) in their study about the size of the APU in the Ecuadorian Amazon region, in which they point out that more than half of the farms (54 %) are in the range of 11 to 50 ha.

Similarly, Bravo et al. (2015) found that in the provinces of Napo and Pastaza, 53 % of the APU that carry out agroecological practices and cultivate different crops, have extensions between 21 and 50 ha, 17 % with a less than 21 ha, and a low percentage of productive units with areas of less than 10 ha.

Results show that in the province of Orellana, farms of less than 10 ha and from 51 to 100 ha have, on average, the highest fruit species diversity. It should

be noted that in those farms of less than 10 ha, between 8 and 19 species of fruit trees have been established, among which the most common are avocado (*Persea americana* Mill.), coconut (*Cocos nucifera* L.), guaba (*Inga edulis*) and lemon (*Citrus x aurantium* L.).

On the other hand, this differs from what was registered in the farms from 51 to 100 ha, in which the plots show a diversity between 12 and 16 species per farm, and the most frequent fruit trees are cherimoya, coconut, lemon, orange (*Citrus x sinensis* [L.] Osbeck), papaya (*Carica papaya* L.), pineapple (*Ananas comosus* [L.] Merr.) and zapote. In those with extensions of 11 to 50 ha, we found the lowest average number of fruit species, i.e. between 1 and 16 per farm, and the most common are orange and achotillo.

On the other hand, in Sucumbíos, within the three APU categories, the average diversity per farm was similar. In farms of less than 10 ha, between 8 and 10 species of fruit trees are observed, and orange is the most frequent species cultivated. In category two, producers have in their plots, from 1 to 14 species, and in this case, the most common crops were avocado and orange. Finally, in farms of 51 to 100 ha, the species established vary from 5 to 16 per plot, and the most frequent fruits were arazá, lemon and orange.

Species diversity

Our study indicates that the northern region of the Amazon shows a high diversity of fruit trees. Results showed that there are 41 species in the farms selected the same ones that are associated to different types of production systems. Fruit trees found in a higher number of farms are orange (76 %), coconut (73 %), guaba or guama (59 %), avocado (54 %), papaya (51 %), lemon (49 %), pineapple (41 %) and peach palm (35 %) (table 1).

Table 1. Number of individuals and frequency per fruit species in production farms in the provinces of Orellana and Sucumbíos, Ecuadorian Amazon

Common name	Scientific name	Botanical family	N.° of individuals	Frequency
Achotillo or rambutan	<i>Nephelium lappaceum</i>	Sapindaceae	104	10
Avocado	<i>Persea americana</i>	Lauraceae	89	20
Arazá	<i>Eugenia stipitata</i>	Myrtaceae	29	6
Badea	<i>Passiflora quadrangularis</i>	Passifloraceae	10	1
Borojó	<i>Borojoa patinoi</i>	Rubiaceae	14	4
Caimito	<i>Chrysophyllum cainito</i>	Sapotaceae	68	9
Starfruit	<i>Averrhoa carambola</i>	Oxalidaceae	5	2
Cherry plum	<i>Prunus cerasifera</i>	Rosaceae	4	1
Coconut	<i>Cocos nucifera</i>	Arecaceae	213	27
Cherimoya	<i>Annona cherimola</i>	Annonaceae	76	11
Peach palm	<i>Bactris gasipaes</i>	Arecaceae	375	13
Jackfruit	<i>Artocarpus heterophyllus</i>	Moraceae	2	2
Breadfruit	<i>Artocarpus altilis</i>	Moraceae	36	5
Guaba or guama	<i>Inga edulis</i>	Fabaceae	332	22
Guava	<i>Psidium guajava</i>	Myrtaceae	790	8
Soursop	<i>Annona muricata</i>	Annonaceae	60	12
Wild granadilla	<i>Passiflora incarnata</i>	Passifloraceae	20	1
Star gooseberry	<i>Phyllanthus acidus</i>	Phyllanthaceae	1	1
Fig	<i>Ficus carica</i>	Moraceae	1	1
Hobo	<i>Spondias mombin</i>	Anacardiaceae	7	4
Key lime	<i>Citrus x aurantifolia</i>	Rutaceae	16	4
Lemon	<i>Citrus x aurantium</i>	Rutaceae	651	18
Mandarin orange	<i>Citrus reticulata</i>	Rutaceae	36	8
Maracuyá	<i>Passiflora edulis</i>	Passifloraceae	2	1
Marañón	<i>Anacardium occidentale</i>	Anacardiaceae	5	2

(Continue on next page)

(Continuation of table 1)

Common name	Scientific name	Botanical family	N.° of individuals	Frequency
Orange	<i>Citrus x sinensis</i>	Rutaceae	448	28
Naranjilla or lulo	<i>Solanum quitoense</i>	Solanaceae	5	1
Noni	<i>Morinda citrifolia</i>	Rubiaceae	5	3
Papaya	<i>Carica papaya</i>	Caricaceae	260	19
Pineapple	<i>Ananas comosus</i>	Bromeliaceae	875	15
Pitahaya	<i>Selenicereus megalanthus</i>	Cactaceae	2	1
Malay rose apple	<i>Eugenia malaccensis</i>	Myrtaceae	20	4
Pomelo or grapefruit	<i>Citrus x paradisi</i>	Rutaceae	2	1
Grapefruit	<i>Citrus x paradisi</i>	Rutaceae	33	8
Uva de árbol	<i>Pourouma cecropiifolia</i>	Moraceae	61	12
Zapote	<i>Matisia cordata</i>	Bombacaceae	42	9

Source: Elaborated by the authors

The fruit species that were found in smaller numbers and frequency come from different altitudinal levels, such as star gooseberry (*Phyllanthus acidus* [L.] Skeels), fig (*Ficus carica* L.), passion fruit (*Passiflora edulis* Sims) and grapefruit (*Citrus x paradisi* Macfad.). In the case of citrus fruits, these have been introduced because they are considered agricultural products with a huge market potential (Rogg, 2000). Similarly, Ruiz (2003) points out that citrus fruits are present in most of the farms in the Amazon region.

Other less frequent fruit trees are achotillo, arazá, badea, borojó, caimito, carambola, plum, cherimoya, jackfruit, breadfruit, soursop, guava, wild granadilla, hobo, lime, mandarin orange, cashew, naranjilla, Noni, pitahaya, Malay rose apple, grapefruit, Amazon tree-grape and zapote.

Although they are found less frequently in farms, there are other crops that have been implemented

in the Ecuadorian Amazon, such as achotillo, arazá, borojó, guava, pineapple fruit and Amazon tree-grape, because farmers need to diversify their fruit production and commercialization. These have been prioritized by Iniap due to their excellent adaptation and domestication conditions, as well as their nutritional attributes and economic potential.

Conversely, naranjilla is a fruit that stands out due to its history and impact. Initially, it was introduced in the provinces of Pastaza and Morona Santiago, and has been expanding in Napo and Orellana. In the seventies and eighties it was established in monocultures, which in a short time caused high incidence of pests, causing an excessive use of pesticides and unsustainable production, which generated the need to focus the production systems towards a sustainable trend (Ruiz, 2003). In turn, pitahaya has become an economically important crop, since its fruit is widely marketed nationally and internationally.

Association of fruit trees with other crops

Regarding the presence and composition of fruit trees in production systems, we observed that these are mostly associated with cacao cultivation in 85 % of the farms in Orellana and in 67 % of the farms in Sucumbíos.

In the province of Orellana, fruit species are dispersed outside the systems in 62 % of the farms; 54 % of these have fruit species in monoculture; 46 % of the producers associate at least one of their fruit trees with coffee systems and pastures. Further, 15 % of the farms distribute at least one of their fruit trees in mixed cacao and coffee systems.

On the other hand, in Sucumbíos, 50 % of the farms have at least one fruit species as monoculture or dispersed outside the systems; 38 % associate their fruit trees with coffee crops; 25 % with pastures

and about 13 % of the producers establish at least one fruit species in mixed cacao and coffee systems.

The results of the analysis of contingency tables show that the species present in the farms assessed are associated with the production system ($P = 0.0179$). The highest number of fruit species are found in cacao or coffee crops, followed by fruit trees scattered on the farm.

Among the fruits associated with coffee or cacao, we found that the most common species were achotillo, avocado, peach palm, guaba, papaya, pineapple and zapote, unlike systems composed simultaneously of cacao and coffee crops, in which arazá predominates. Among the species located dispersed in the production systems and outside of these, we find *Annona* spp. (cherimoya and guanábana), caimito, citrus, coconut, breadfruit and Amazon tree-grape (analysis of correspondence, figure 2).

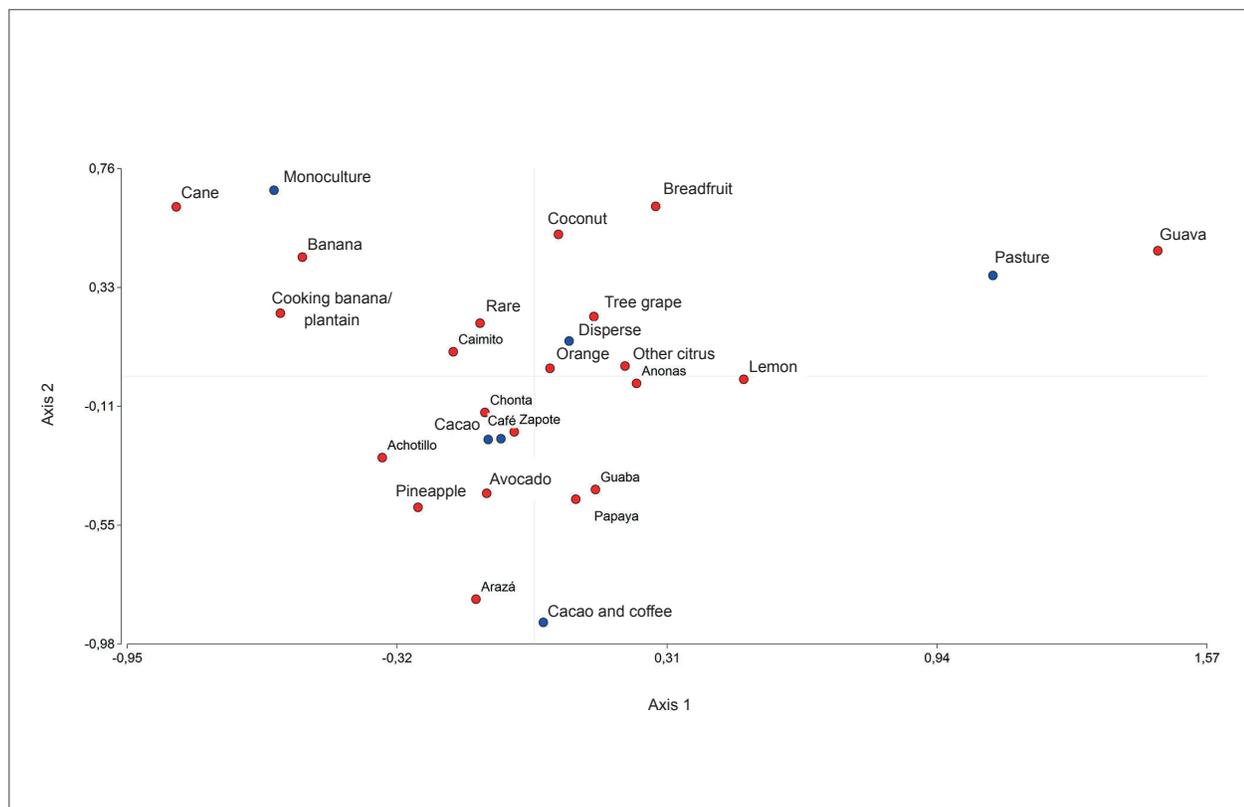


Figure 2. Biplot obtained through simple correspondence analysis of the fruit species associated with other production systems in the provinces of Orellana and Sucumbíos, in the Ecuadorian Amazon.

Source: Elaborated by the authors

Studies carried out by Virginio-Filho, Villanueva, Astorga, Caicedo and Paredes (2014) in the provinces of Orellana and Sucumbíos show that 70% of the farms that have coffee, also have timber trees, fruit trees and other crops associated to this crop. Regarding cacao cultivation, 67% of the area is associated and 33% has been left under full sun exposure. The same authors indicate that 43% of livestock farms with natural pastures are associated with timber and fruit trees, and that 56% of the area with improved pastures is associated to other crops.

In addition, Jadán (2012) states that in the province of Napo cacao cultivation is associated with native fruit trees that contribute to food security, such as avío (*Pouteria caimito*), white cacao (*Theobroma bicolor* Humb. & Bonpl.), caimito, cherimoya, peach palm, guaba, morete (*Mauritia flexuosa* L.f), and paso (*Gustavia macarenensis* Philipson: Lecythidaceae); furthermore, also the Amazon tree-grapes and fruit trees of commercial value, such as avocado, lime, lemon, mandarin orange and orange.

On the other hand, Ramírez (2005) points out that in the Ecuadorian Amazon coffee is associated with cherimoya, citrus fruits, guaba, various palms (*Bactris gasipaes*, *Iriartea deltoidea* Ruiz & Pav. (= *I. corneto*) and *Virola* spp.), and cacao. In coffee plantations you can also find avocado (Mancilla, 2012), guaba and orange (DaMatta & Rodríguez, 2007).

Other studies suggest that the fruit trees that producers mostly associate with coffee are achotillo, avocado, arazá, borjój, caimito, peach palm, coconut, breadfruit, guaba, soursop, jackfruit, lemon, mandarin orange, orange, pineapple, grapefruit, Amazon tree-grape and zapote; and cacao crop producers usually plant their cacao crop in association with borjój, soursop, orange, lemon and papaya (Virginio-Filho et al., 2014).

On the contrary, in the production systems in which monocultures are maintained, no type of fruit tree is found inside or outside the plots; meanwhile, in livestock production systems, guava is the most abundant species in pastures (figure 2).

This agrees with studies carried out by Valarezo (2012) in the southern region of the Ecuadorian Amazon, finding that guava is present in silvopastoral systems due to its multiple benefits, i.e. direct positive interactions, such as protection against climate inclemency, and the contribution of its edible phytomass. Moreover, mediated soil interactions, such as provision of nutrients, animal protection from the wind, excessive temperature and solar radiation, and can exert effects on forage growth and quality. Somarriba (1995) also mentions that guava can be used to transform unproductive pastures, because this fruit has an invasive potential that allows it to survive constant cattle trampling.

Agrobiodiversity index

The agrobiodiversity index showed a value of 0.52 (IFER: 0.77, IFE: 0.66, IAVA: 0.33 and ICOM: 0.33), which shows a degree of unsustainability of the agroecosystem, since an acceptable index corresponds to 0.7 (Gravina & Leyva, 2012).

In the specific analysis, we observed that the IFER showed the most favorable situation, by obtaining the closest value to achieve sustainability; furthermore, and on the other hand, deficiencies were observed in the IAVA and ICOM subscripts due to their low values. The IFER showed that there is a good fruit species diversity for human consumption. However, producers establish their fruit trees in their production systems without taking into account the number of species or diversity.

The indices obtained show the need to increase the agricultural biodiversity of fruit trees in an equitable way, based on classification groups, so that the agroecosystem is integral, functional and balanced, from an agricultural, ecological, economic and sociocultural point of view.

Fruit tree management

Results indicated that there is a relationship between the association system and the agronomic management in fruit trees ($p=0.0001$); we observed that fruit trees that are found in cacao, coffee, and mixed cocoa and coffee plots, receive some type of agronomic management.

Fruit tree species distributed outside the systems and those that are located as monocultures are exempt from management (figure 3). According to the results by farm, we observed that 89 % of these carry out

some type of management in at least one of the species under production. The most frequent activities are weeding, pruning, application of manure and fertilizers, phytosanitary control and thinning.

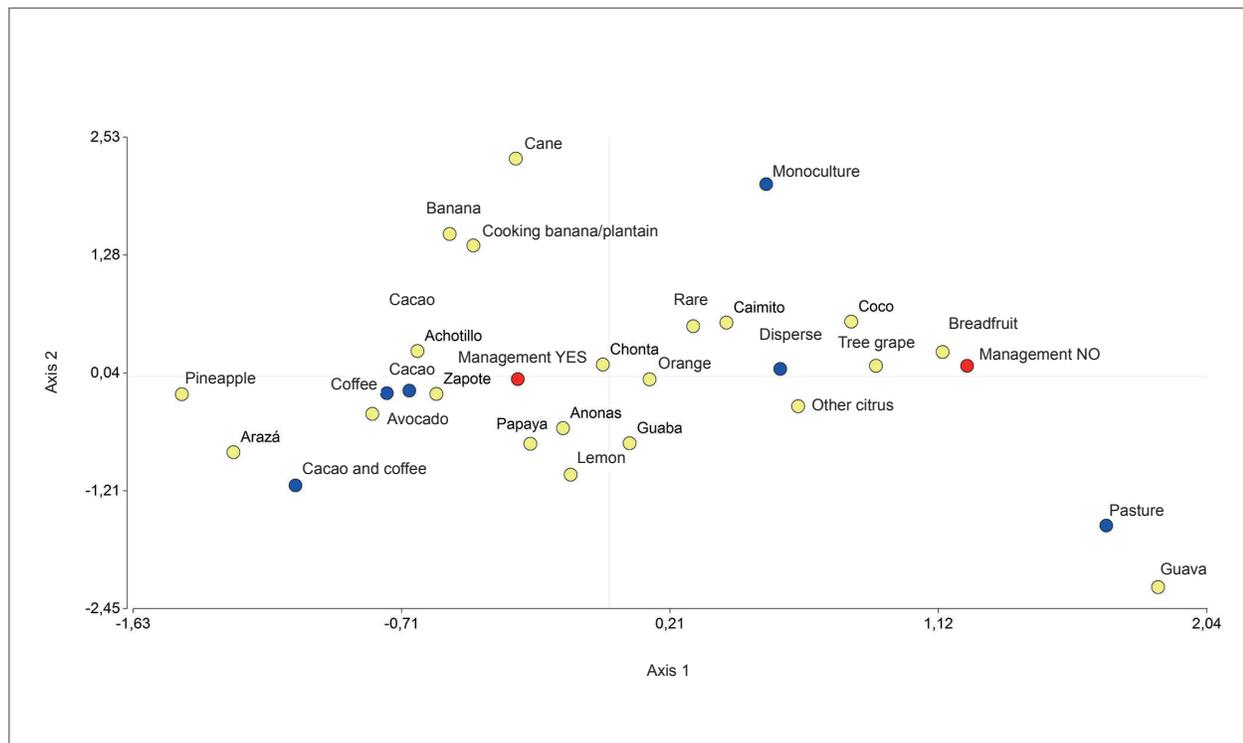


Figure 3. Biplot obtained by multiple correspondence analysis of the fruit species associated with other production systems, which receive or not agronomic management in the provinces of Orellana and Sucumbíos, in the Ecuadorian Amazon.

Source: Elaborated by the authors

Ruiz (2003) indicates that in the Amazon region, fruit trees are cultivated without carrying out cultural practices, usually on abandoned pastures or degraded areas. This does not agree with our results, because, in order to increase their production, producers are implementing some type of management practice in at least one fruit in their farm.

It should be noted that, in recent years, institutions have shown interest in improving production, so research was carried out on the propagation, management, harvest and postharvest of certain Amazonian fruit trees. Some of these are arazá, borojó and naranjilla (Cuéllar, Ariza, Anzola, & Restrepo, 2013; Jiménez, Díaz & Sotelo, 2014; Ochoa &

Ellis, 2002; Rincón & Garzón, 2012; Van Kanten & Beer, 2005), which indicates the importance of these species in the Amazon region.

Fruit tree age

In the northern area of the Amazon, there is a high variation in the age of fruit species. In Sucumbíos, the youngest individuals are found, i.e. 73 % have ages between 0 and 5 years, 11 % are between 6 and 10 years of age, 9 % between 11 and 20 years, and 7 % have ages over 20 years. Likewise, in Orellana, in 50 % of the species there are individuals with ages between 0 and 5 years, 29 % between 6 and 10 years, 19 % between 11 and 20 years of age, and only 2 % are over 20 years old.

In the species assessed, we found that the fruits achotillo, badea, carambola, coconut, jackfruit, passion fruit, pineapple and pitahaya are the species with the youngest individuals, i.e. with less than five years of age. Producers are introducing these types of fruit trees as they have a greater demand at the national and international levels for their larger size and flavor. Passion fruit, pineapple and pitahaya are exported within the subsector of "non-traditional fruits" to countries such as Germany, Canada, Chile, Colombia, Belgium, the Netherlands, Italy, Spain, United States of America and Russia, among others (Ruiz, 2003).

Regarding countries that import these fruits, the "green" trend consumers show means that they look for products with sustainable production that do not come from monocultures. As indicated above, in the Amazon there is a high percentage of crops in association with other crops or production systems, that is to say that they comply with the aforementioned trend.

In the case of coconut, both the cultivated areas and the investment in the acquisition of machinery and technological equipment should be increased, so that all fruit components can be exploited to the maximum for export purposes, since currently only their juice is used.

Fruit tree performance

Fruit trees that show greater production in both provinces are arazá, caimito, guava, lemon, mandarin orange, orange and grapefruit. According to our study, arazá is found in mixed system with cacao and coffee, with production that exceed those reported by Ruiz (2003), i.e. with 53 to 128 fruits/plant (10.6 to 256 kg/plant) and fruits that weigh 200 g each.

Regarding caimito, in this study we found that its yield oscillates between 100 and 320 fruits/plant (19.29 to 61.71 kg/plant), productions are similar to those reported by Gonzales (2007) from 300 to 350 fruits/plant (57.86 to 67.50 kg/plant), and fruits have an average weight of 193 g. On the other

hand, guava production in pastures was 200 to 500 fruits/plant, i.e. lower than what has been reported by Gonzales (2007), which indicated that their trees produce from 30 to 40 kg/plant, with fruits with a weight of 50 g.

In general terms, the production of citrus fruits that were dispersed in the farms varies from 100 to 1,000 fruits/plant (5 to 100 kg/plant), with fruits of 100 g of weight. In the case of lemon and mandarin, production in Sucumbíos exceeded two and four times the production found in Orellana.

Conversely, orange production in Orellana exceeded twice the one found in Sucumbíos; meanwhile that of grapefruit was similar in both provinces. Vélez, Álvarez and Alvarado (2012) point out that the production of citrus fruits depends on several factors, including climatic conditions, irrigation, fertilization, age of the plants and pruning, among others.

Other fruit trees that were found in production systems in association with cacao or coffee and that showed low yields were avocado, peach palm, guaba, papaya and zapote. In the case of peach palm, the average production was 6 bunches/plant (84 kg/plant) in Orellana and 18 bunches/plant (252 kg/plant) in Sucumbíos. Gonzales (2007) indicates that in the Brazilian Amazon there are average yields of 8 bunches/plant (112 kg/plant).

In the farms evaluated, zapote plants produce 35 to 175 fruits/plant (25 to 127 kg/plant), unlike in Peru, where yields vary from 700 to 1,000 fruits/plant (500 to 725 kg/plant) (Flores, 1997). Likewise, authors found that guaba production ranged from 48 to 94 fruits/plant (23 to 44 kg/plant), in contrast to the Brazilian and Peruvian Amazon, where 300 fruits/plant (141 kg/plant) are harvested (Flores, 1997, Gonzales, 2007).

Finally, the results show that the production of papaya in the north of the Ecuadorian Amazon was 15 to 50 fruits/plant (5 to 18 kg/plant), while Gonzales (2007) states that in the Brazilian Amazon it is 20 to 60 fruits/plant (7 to 21 kg/plant).

Production destination

In our study we observed that producers who allocate at least one fruit tree for their self-consumption and animal feed on their farms range up to 85 % in Orellana and 100 % in Sucumbíos.

On the other hand, 85 % of the producers in Orellana and 71 % in Sucumbíos own fruit trees that do not produce, possibly because of their age (very young or long-lived, i.e. with more than 20 years of age), to the fact that some propagated species are of sexual origin, or because the plants were acquired in non-certified nurseries. In addition to the above mentioned, there are producers who introduce and plant materials from areas outside the study area, which are not suitable for cultivation in the Amazon region.

On the contrary, 39 % of the farms allocate the production of some fruit species for market sale. Fifty percent (50 %) of the producers in Sucumbíos sell most of their production to intermediaries on the farm (60 %), followed by 17 % who do it directly, 8 % sell it in local markets and 17 % to intermediaries in the market. Conversely, in Orellana we found that a single producer sells and delivers his fruit to intermediaries on farm.

Gonzales (2007) and Ruiz (2003) indicate that in the farms of the Amazon, the production of fruit trees is not only destined for food security as a self-consumption product, but also surpluses are used for fresh sale. On their farms, producers harvest fruit trees and sell them to intermediaries, or sell them in the markets of nearby cities.

That is, they have two options: to sell their fruits directly to the consumer or to intermediaries. The second option is the most common, receiving lower benefits, which has become an unprofitable activity. Gonzales (2007) states that it is possible that fruit sale in the Amazon is limited by the precarious distribution of profits, since families face markets that do not compensate the high transportation cost value.

Conclusions

In the northern Amazon region, there are approximately 41 fruit tree species, which farmers have established in their plots due to the need to diversify their production and increase their income. Species such as avocado, peach palm, coconut, guaba, lemon, orange, papaya and pineapple make up 50 % of the population of fruit trees found on farms. Citrus fruits constitute the most predominant species, since its presence was registered in 20 % of the farms sampled.

For most part, fruit trees are associated with cacao (68 %), coffee (76 %), and pastures (30 %). In these systems, producers cultivate achotillo, avocado, arazá, peach palm, citrus, guaba, papaya, pineapple and zapote, and because they are in association with other species, producers employ cultural practices that increase their yield.

A minimum percentage of producers commercializes fruit to obtain an additional economic income. Those that are mainly commercialized are peach palm, coconut, guaba, orange, papaya, pineapple and zapote. On the other hand, one of the fruits that is considered important, because of its export potential and because it generates high income, is pitahaya, but it was only found in 6 % of the farms.

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Disclaimers

The authors agree with the publication of this article, and declare that there are no conflicts of interest affecting the results of this study.

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