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Agrobiodiversity in organic small-scale coffee farms in Chirinos district, Peru.

Master ‘s Thesis

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Declaration

I, Kelly Marilin Delgado Rivera, hereby declare that this thesis, submitted in partial fulfilment of requirements for the MSc. Degree at the Faculty of Tropical AgriSciences of the Czech University of Life Sciences Prague, is wholly own my work unless otherwise referenced or acknowledged.

In Prague: 27-04-2018

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Kelly Marilin Delgado Rivera

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Abstract

Most of the Peruvian coffee producers are small farmers, located throughout the eastern and western slopes of the Andes. Coffee plantations are traditionally associated with shrubs, timber tree species, fruit trees, including grasses and flowers, among others, allowing the farmers to diversify their income, provide a favorable microclimate, maintaining the biodiversity and ecosystems. The aims of the thesis was to access the diversity of useful plant species associated by smallholders in organic and conventional (no-organic) coffee plantations, in Chirinos district, northern of Peru.

Data were collected during August to September 2016, coffee farmers were (face to face) interviewed into their own farms. Through the survey were document the useful plant species associated in coffee plantations. According to the farmer were listed the preference plant species, reporting the local name, plant part use, main use, specific uses and management practices. Plant part use were classified by their main uses, also according to their growth habit. The obtained information was complement with informal conversations and direct observation in the farm.

The total number of species encountered were 66, belonging to 31 botanical families. The associated plant species diversity with coffee plantations demonstrated provide agroforestry services as also benefits for coffee growers as; food, environmental, fuel, animal food and medicine. The most representative were from the family; Fabaceae, Malvaceae, Apiaceae, Euphorbiaceae and Solanaceae. Conventional and organic Farmers had preference for food and environmental use category. The most representative useful species were *Inga chartacea* Poepp., Cf, *Musa x paradisiaca* L., *Zea mays* L., *Manihot esculenta* Crantz and *Cordia alliadora*. Coffee agroforestry systems in Chirinos maintained diverse plant species, coincided with another studies, which concluded that these agroforestry systems in tropics can play an important role in biodiversity conservation in human-dominated landscapes.

Key words: Agroforestry, agroecology, coffee, ethnobotany, Peru.

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INEI	Instituto nacional de estadística e informática
MINAGRI	Ministerio de Agricultura y Riego
JAS	Japanese Agricultural Standards
OCIA	Natureland and the Organic Crop Improvement Association
IFOAM	International Federation of Organic Agriculture Movements
FAO	Food and Agriculture Organization of Unit Nations
Fundes	Fundación para el Desarrollo Económico Social
UV	Use value
FC	Frequency of citation
PPV	Plant part value

1. Introduction

Agriculture is a major livelihood for millions of people in the world. At the same time the agricultural intensification is one of the major causes of deforestation, loss of biodiversity and ecosystem services (Foley et al. 2005)

Agroforestry systems have the potential to be productive while conserving a portion of the biodiversity that occurs in natural ecosystems (Garrity 2004). In many tropical landscapes agroforestry systems are the major ecosystem that resemble natural forest and are consider as a tool for biodiversity conservation. (Schroth et al. 2004).

Coffee, *Coffea arabica* L. (Rubiaceae) is important crop in countries identified as megadiverse (Mittermeier et al 1998). It is also one of the world's most important agricultural commodities and provides economic support for 20 to 25 million people (Schroth et al. 2004). There are several advantages in growing coffee in agroforestry system in comparison with intensive monocultures. For example, it has been shown that coffee under agroforestry systems, provide refuge or shelter for many animal species (Moguel & Toledo 1999) and sustaining ecosystems services such as water storage, coffee flower pollination and pest control (Perfecto et al. 2004; Klein et al. 2003) and can maintain soil fertility for longer periods of time (Siebert 2002).

Another benefit associated with shaded coffee systems are the important forest goods for the smallholders such as fruits, firewood and local construction material and are even a source of medicinal materials (Rice 2008). Smallholders maintain their coffee plantations as a source of income, and new strategies of integration allow them to improve their potential to satisfy basic human needs: food, security and health especially in times of low coffee prices or low coffee productivity.

The increasing coffee management intensity is result of the increase demand of coffee in the market (consumers). It has been conducted to many farmers in many parts of the world to convert their shaded coffee systems into unshaded or shade monoculture for increase in short term their yield. However, at the same time, it has been seen as an excellent opportunity for many conservationists which take in advance the impact of coffee agroforestry system on biodiversity conservation and have developed certifiers programs for help to conserve diverse in shade in coffee plantations in many parts of Latin America (Ambinakudige & Sathish 2008).

The purpose of this study was to access the useful plant species diversity associated in organic and conventional (no-organic) small-scale coffee farms in Chirinos District, Peru. Interviews were conducted to document the importance of these plant species on coffee farms and in coffee growers' livelihood. As also document farmers preference of these plant species and their respective management practices.

1.2 Coffee in agroforestry systems

1.2.1 Agroforestry systems

The term 'agroforestry' was first used in 1970 to describe the integration of trees and agricultural crops. Although the term and its definition are recent, it refers to a set of old practices. According to Nair (1993), these traditional land-use systems that combine trees with agricultural crops on the same piece of land have been practiced for thousands of years, and they have been important elements in tropical and temperate agricultural landscapes.

The scientific definition of agroforestry should stress two characteristics common to all forms of agroforestry and separate them from other forms of land use: 1) the deliberate growing of woody perennials on the same unit of land as agricultural crops and or animals, either in some form of spatial mixture or sequence, and 2) there must be significant ecological and economic interaction between the woody and non-woody components.

Lundgren and Raintree (1982) defined agroforestry as 'a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between the different components.

Agroforestry has demonstrated to be crucial to smallholder farmers and rural people in many developing countries because many native tree species can enhance their food supply, provide a variety of products such as fiber, medicinal products, oils, and gums, which play a critical role in meeting the basic needs (FAO 2015 & Nair 1993).

The implementation of different trees on farms increase the plant genetic diversity, at the same time plays an important role in the global carbon cycle, which are storage in the roots, above- ground biomass. The ability of the root system to improve soil organic matter is a crucial factor in low-input agricultural systems with low productivity levels. The ecological contributions of agroforestry systems are reflected in the conservation and restore of nutrients in the surface, as the nitrogen, the potential for minimize the soil erosion and nutrient leaching as also the capacity for maintain vegetative cover. Trees in agroforestry systems influence in water cycle, by increasing rain, retaining water in the soil, transpiration, reducing runoff and increasing filtration, avoiding surface runoff, agroforestry systems efficiently recycle nutrients in the soil that would otherwise be lost through leaching, thereby making a more closed nutrient cycle (Prada 2014 & Bharati et al.

2002). Are also considered for have a positive effect on the conservation of biodiversity specially in deforested or fragmented lands providing habitats and food for many animal species including birds, insects and other wildlife, thereby facilitating the relation between animal, seeds and pollen. (Prada 2014)

1.2.2 Traditional coffee systems

Traditionally management plantations are characterized for grow under a structurally and floristically diverse canopy of shade trees. (Perfecto et al 2005) Coffee produced on agroforestry farms is broadly referred to as "shade-grown coffee." However, not all shade-grown coffee is the same, neither their management practices. The extent of shade coverage in agroforestry systems varies, from densely shaded systems resembling mature forests to more lightly shaded systems with only one or two varieties of shade trees. (Jezzer & Verweij 2015)

Based on structural complexity, and management practices, traditionally coffee production systems in Ethiopia are categorized into four groups: Forest coffee, semi-managed forest coffee, coffee garden and plantation coffee system. The first three coffee production systems have been practices for centuries by small farmers and therefore are considered as one of the oldest 'traditional coffee systems (Gole et al 2001), which are mainly planted under shade of native trees.

In forest coffee system, this *C. arabica* occurs spontaneously underground of Afromontane rainforest at 1000-2000 m.a.s.l. (Schmitt et al 2009). The floristic composition, diversity and structure presented in this system is close to the natural forest and present different forest strata, which are emergent stratum > 30 m tall, middle tree stratum 15-30 m tall and shrubs layer 2-15 m tall (Gole 2001). The only intervention that can occurs in these systems are the clearing to allow movement in the forest during harvesting time (Gole et al. 2001). The coffee plants occurred in semi-management forest coffee, is the result from the modified structure of forest coffee system, where the number of large canopy trees were thinning in order to enhance more potential for coffee berries. The change occurred in this type of system is highly significant in the lower height classes representing for shrubs, and small trees which are cleared for avoid competition with coffee plants. (Schimitt et al 2008) the main management problem reported in these systems is the repeated removal of young shade trees, shrubs climbers (Senbeta & Denicsh 2006)

Coffee garden plantation, these system account almost half of the coffee plantation in Ethiopia. Here the semi forest coffee systems are converted into coffee garden plantation, with intensive management practices weeding two or three times per year, fertilizing with farmyard manure and crop residue. Where farmers significantly have reduced the diversity and density of non-coffee plant species, and planted service trees for shade and fruits as (mango, avocado) *Ensete ventricosum*, *Acacia abyssinica*, *Albizia gummifera Croton macrostachyus*, among anothers. The density of shade trees is usually low, varying 30-60 trees per hectare. Farmers from south and southwestern parts of the country have diversified their low-density coffee plants, intercropping it with several other crops such as sorghum, beans, sweet potato, chat (*Catha edulis*) and (*Ensete ventricosum*) which is an important Ethiopian staple food (Gole et al 2001). Plantation coffee production system accounts about 5% of the total coffee production in Ethiopia. In this type of system are private companies and some well managed smallholders coffee farms where the coffee plants are well management with adequate agricultural practices as; spacing, proper mulching, seedlings, weeding, shade regulation. The shade trees found here are old forest stands or planted.

The traditionally coffee system in Latin America are not much different from the Ethiopian. Because it has been also traditionally planted under the shade of primary forest. With the difference that in Latin America a great part of the primary forest has been partial clearing by slash and burn technique, after underground is eliminated and only few trees are left to provide shade and incomes (fruit, firewood, timber, etc) (Benito 2010). In the first years of establishment or when the coffee plants are renewed, the coffee plants are intercropped with cash crops (corn, beans and tomatoes) and perennials crops as cassava and museaceas (Arcila et al. 2007)

According to the typology develop by Moguel and Toledo (1999), can be distinguished five basic types of coffee production systems, which vary according to the type of shade and canopy. Although this typology was developed for coffee plantations in Mexico, it has been used as a frame of reference by researchers in other Latin American countries (Guhl 2009).

Traditional rustic systems, coffee is planted into understory the canopy of the rainforest, maintaining a shade level between 71-100%. Some characteristics of this system are the low use or no use of agrochemicals and minimum agricultural practices (just some pruning and shrub removal from the low-canopy). Most native canopy species and palms are preserved as part of the system, for commercial or traditional use (Villavicencio 2010). This system has a minimal impact on the ecosystem and even has shown in certain cases increase of biodiversity (Moguel and Toledo 1999).

Traditional shade polyculture is a shade system that involves a greater intensity management of understory plants with 41-71% of shade. In these system coffees grown alongside numerous useful woody and herbaceous plant species, forming a sophisticated system also known as coffee garden due to the variety of arboreal and the diversity of native and domesticated plant species. This association are done with the purpose to reduce production costs increase revenues through the incomes of tree products (fruit, medicine and raw materials), (Lopez et al 2007). Commercial polyculture are characterized by the removal of a large proportion of the existence original forest canopy and the introduction of a set of some commercial species providing appropriate shade for the coffee plants, normally in this type of system the coffee grown under the shade of leguminous species which add nitrogen to the soil or have some commercial value (Moguel 1999 , Julca et al.2010) Between these species can be mentioned *Inga* spp, *Cedrela odorata*, *Erythrina* spp, *Catilla elastic*, among others fruit trees as citrus, mango, among other cash crops. The shade cover presented in this system is 31-40% (Moguel & Toledo 1999). With the gradual intensification of the coffee plantations, the traditional shade coffee tends to be a shade monoculture eliminating fruit trees, tubers and another intercropping. Only are maintained some musaceae and Leguminosae (species of *Inga*), as exclusively and predominant shade. The use of agrochemical products is an obligatory practice, because it is oriented to obtain high yields.

1.2.3 Full sun coffee systems

These systems are also called ‘modern’ or ‘technified’ systems, which grown as monoculture with no trees cover at all and the coffee bushes are exposed to direct sunlight. At the beginning of 90s’ in Latin America farmers were encouraged to replace traditional shade grown coffee with full sun cultivation in order to increase the yield of their coffee, using high levels of external inputs as fertilizers and pesticides. Nowadays approximately 1.1 million hectares are converted from agroforests to lightly shaded or full sun coffee systems (Rice & Lean 1999).

The increasing number of unshaded monoculture coffee systems in Latin America has resulted in environmental problems. Borbor et al. (2006) reported a great accumulation of N and P from synthetic fertilizers, in Guayas River basin of Ecuador. Where the ecosystem has experienced a negative consequence as the eutrophication. A serious issue that also affected the Lake Atilian in Guatemala, forming in the recent years toxic algae blooms.

The elimination of trees in coffee systems, make the coffee plants more susceptible to pest and diseases, (Damatta 2004). Required more labor intensive than shade counterparts, due to the greater frequency and time spend per activity of pruning, thinning and weeds remove (Alvez et al 2016). This systems reduce habitat extent and quality for native fauna. Mendez (2010) suggests that reducing plantation complexity could decrease mammalian diversity by 43%. Presenting also strong reduction of soil microorganism, birds, mammals, insects, amphibians and reptiles (Rice 1999, Moguel & Toledo 1999). Moreover, sun coffee plants age more rapidly than shade grown, and must be replaced more often, remain productive for only one-third to one-half as long as comparable with shaded plantations (Perfecto et al. 2008 & Damatta 2004).

However, are some studies that recommend the removal of trees up to certain level for the continued coffee productivity. Baggio et al. (1997) show that there is no difference between moderate shade and full sun

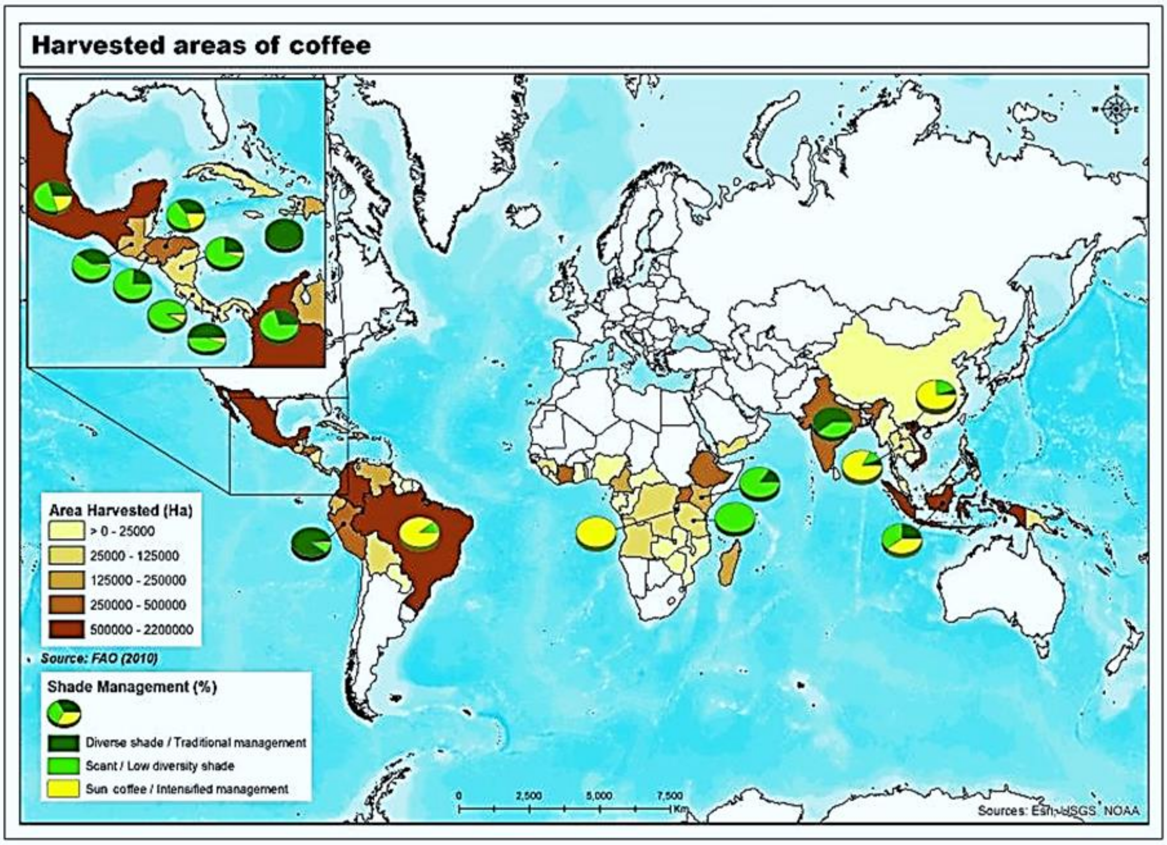

Figure 1. Percentage of cultivated coffee area managed under different technology or shade level.

1.3 Agrobiodiversity in coffee systems

Biodiversity refers to the total sum of different animals, plants and organisms living on Earth (Nair 1993) necessary to sustain functions of the agro-ecosystem. Biodiversity also includes species and genetic diversity, as well as variety in the habitats and ecosystems where they live. Agrobiodiversity encompasses interactions between genetic resources (plants, animals and micro-organisms), management systems and practices used by farmers and herders, who have abundant knowledge of biodiversity management and maintenance. In a general sense, agrobiodiversity is the set of all organisms related to food and agricultural production with importance for human development, including food security, nutrition and livelihood improvement (Shen et al. 2010).

In an effort to protect the vulnerability of the current agrobiodiversity, have been elaborated strategies for conserve genetic resources, these are: *ex situ* conservation in genebanks and *in situ* conservation of ecosystems carried out in protected areas and reserves. Studies have shown that shade coffee plantations act as a shelter for biodiversity, shade coffee grown in areas that coincide with high biodiversity levels and where livelihoods depend on the forest and its services. Many researchers in Mexican coffee farms documented an extensive biodiversity levels and affirm the urgency to conserve and promote these agroforestry systems.

Coffee land in Peru is established in one the zones that represent high levels of biodiversity and endemism, however, at the present, hundreds of hectares have been deforested for socio-economic reasons, bringing various species to extinction, without registration and with no knowledge of their real potential (Peña & Pariente 2015).

1.3.1 Vegetative diversity in coffee farms

As in most tropical countries, Peruvian coffee has been cultivated partly in original forests and partly where farmers have diversified with other plant species, motivated by the hope of increasing their income and improving their livelihood. Many studies have demonstrated the important dependence of livelihood on shade tree products, such as firewood, timber and fruit (Mendez et al. 2007) Tree shades protect coffee plants from destruction by hailstorms and winds, acting as a physical barrier, and they also contribute to the creation of an ambient micro-climate that is well-suited for the growth and development of coffee bushes (Mekonnen et al 2015).

A very common and dominant species of shade tree in Latin America is the genus *Inga* sp., as mentioned above which is the most preferred shade specie for monoculture and traditional shade coffee systems; 15 subspecies of *Inga* accounted for 47% of the shade trees found in Guatemalan coffee plantations (Anacafe 2008), and a similar situation was found in many coffee systems in Peru, where the farmers also use the shade of *Inga* sp. (Julca et al. 2010). This species has desirable characteristics for shade, nitrogen fixation, pruning tolerance, non-deciduousness, and fruit (Beer et al. 1998). However, the injudicious choice of this shade species genus *Inga* can act as an alternative host for nematodes, such as the coffee berry borer *Hypothenemus hampei* (Julca et al 2010). Ecosystem services provided by shaded systems are higher than their conventional unshaded counterparts. This provides important direct and indirect benefits for small-scale coffee farmers essential for their food security. The level of tree intensification in coffee farms depends on the environmental conditions, for example, in areas where rainfall is limited and dry seasons are long, shade trees may have adverse effects due to severe competition with the coffee for the available soil moisture. That is why in Brazil and Kenya, most coffee is grown without shade (Vander 2005). The coffee variety is another factor that must be considered for these systems. Robusta coffee has a more developed root system and is more vigorous than Arabica (Damatta et al. 2007), and hence the competition for nutrients between coffee plants and shade trees would be higher in areas that grow Robusta.

It has been demonstrated that shade reduces and stabilizes soil and air temperature; it increases and preserves surface soil humidity and also reduces the direct light intensity reaching the coffee plant. Growing coffee under shade trees is essential not only for the sustenance of coffee plantations, it is also important for protecting the environment in ecologically fragile regions, it plays an interesting role in the conservation of diversity in species, it improves food security, nutrition and income for rural people

1.3.2 Fauna diversity in coffee farms

Mixed crops with an abundance of shade tree species are better than sun-grown coffee or other types of tree-less agroforestry in providing food and shelter for fauna (Gallina et al. 1996).

A varied spectrum of bird diversity was found in Mexican coffee systems, with higher diversity in traditional shade coffee fields than in commercial polycultures with few canopy species and in sun-grown monocultures (Moguel & Toledo 1999) A comparative analysis revealed that the avifauna reported in traditional coffee systems has a similar richness (136 species) to that of farms adjacent to forests. Apparently, coffee agroforests functioned as a new vegetation habitat where birds were attracted both by the coffee cherries and by several other types of food, including fruit, nectar and insects. Perfecto et al. (2004) observed that supporting a diverse bird community increased predation on caterpillars, thus reducing plant and coffee berry damage (Jezeer & Verweij 2015).

Another study have shown that butterfly diversity is sensitive to changes in vegetative structure diversity and microhabitat characteristics, such as temperature and moisture (Bobo et al. 2006). Expecting interaction between these two factors (system and habitat), forest butterflies were measured in the northern Peruvian Amazon; the research found significantly higher diversity in organically shade-grown coffee plantations than in shade and sun-intensified coffee systems (Jezeer & Verweij 2015).

Dover & Feber et al. (1996) described the importance of hedgerows in providing shelter and additional nectar sources for butterflies and birds, which also act as biological insect control and pollinators in arable habitats. Globally, reptiles and amphibians respond to human-dominated ecosystems, but their adaptation depends on the specific fauna, the biogeographical setting and the degree and type of ecosystem alteration. Their most favored microhabitats are under plant litter, bromeliads, cracks in tree bark and cavities in tree trunks, etc. (Murrieta et al. 2013). But a research in Costa Rica showed that human activity with water tends to create breading sites for amphibians, their study showed a higher abundance of reptiles and amphibians in coffee forests reserves near rivers than in the adjacent coffee plantations (Mendehal et al 2014).

When referring to fauna also can be included a singular domesticated species which are introduced as part of coffee production. This is the case of the coati or mishasho (*Nasua nasua*), which belongs to the family of *Procyonidae*, lives at 1,300–2,000 m.a.s.l. in the central and southern parts of the Peruvian Amazon, and is sometimes confused with a wild cat. This small mammal processes ingested coffee beans in its digestive system together with other aromatic fruits; the digestion process increases the organoleptic characteristics of the coffee beans, which are then collected, processed and sold as some of the highest quality coffee (Valencia 2016). But this natural practice of using the coati is not new; it reaches back to the seventeenth century in Indonesia, where coffee with similar characteristics was produced with the help of the kopi luwak (*Paradoxurus hermaphroditus)*. The red muntjac or barking deer (*Muntiacus muntjak*) is one of the oldest deer species found in southeast Asia, and it also creates a coffee with unusual flavor. However, like the coati and the kopi luwak, the deer is not bred domestically, so this type of coffee is very rare.

Another important research that show the importance of coffee systems as fauna habitat, done by Gallina et al (1996) where inside of traditionally management coffee plantations in Mexico were found a total of 24 non-flying mammalian species. Over 50% of the recorded species ate the coffee fruit as part of their diet, besides acting as insectivorous pest controllers and including small rodents in their diet as well.

1.4 Coffee production in Peru and land use

In Peru, coffee is grown throughout the eastern ranges of the Andes, which present the most favourable area for this type of crop due to the characteristics of the soil types, the climate conditions and the high precipitation. However, this area is now considered to be in the most critical condition because it contains the largest number of threatened ecosystems in the world, due to the human disturbance.

Coffee is cultivated in 210 rural districts of Peru, distributed in departments. San Martin, Cajamarca, Junín, Amazonas and Cuzco represent the principal growing regions, with 87.4% of the total production produced by small farmers, covering 383 973 hectares of the Peruvian territory (Peruvian Chamber of Coffee 2002, FAOSTAT 2017).

Plantations of this perennial crops are one of the most important forms of land use in tropical countries. It is very common find, that farmers systematically design their farm, diversifying many parts of their agricultural lands with generous components of perennial and annual crops to archive better land management.

For a productivity land use system requires a constantly deforestation of the natural vegetation, under the increase for supply quality or quantitative production (Walker & Oyama 1996). This have been a constant in the Amazon basin, where small farmers transform natural lands, leaving these, unproductive over time, producing land changes and increasing the vulnerability of the ecosystem, affecting also the livelihood of these rural farmers.

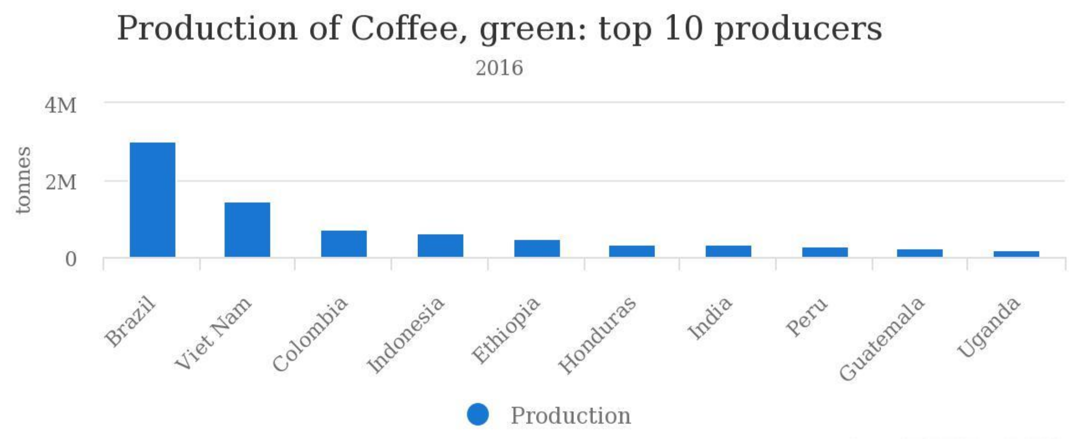

Figure 2. The ten main countries of coffee production. FAOSTAT 2016

1.4.1 Organic production

Organic agriculture uses tradition, innovation and science to benefit the environment and promote fair relationships and a good quality life for all involved (IFOAM 2015). These sustainable practices include the regular application of organic composted matter, ‘natural’ methods of disease and pest control, and good coverage of shade trees with diverse species, preserving and promoting diversity conservation and environmental stability. Although organic certification standards do not require the use of shade, most producers and certifiers see shade as essential for organic production. Coffee land production is considered organic only if it is recognized by an organization or certifier (Labrador & Altieri 2001). Organic coffee production is not synonymous with naturally fertilized land, it depends on technical recommendations under an organic conscience (Vander 2005).

Coffee certifiers maintain permanent partnerships with farmers, and through assembly meetings and the provision of technical assistance they help farmers acquire ecological methods for rejuvenating their plots, sustainable management practices on soil conservation, pruning, biological means of controlling pests and diseases, assistance in harvest and post-harvest, which is complemented by the empirical knowledge of the growers to jointly ensure a good quality of coffee production. High quality organic coffee products are a significant economic opportunity for the producers, they obtain benefits from a premium price through fair trade, which can in turn help reduce grower vulnerability to market fluctuations. However, although most producers said they were grateful for the small increase in income provided by the premium price, they still felt that it had not made a significant impact (Morris et al. 2005). Despite the lower yield in organic coffee farming, the requirement of greater labor management, and the increased time investment compared to conventional farms, organic coffee farming can provide other positive contributions due to environmental spillovers, such as biodiversity enrichment, enhanced coffee quality, or the extra provision of a variety of products, including fruits, firewood and timber (Perfecto et al. 2005, Masuda 2007).

Peruvian organic coffee production began in the 1990s through organizations created by Inka Cert S.A., (now called Bio Latina), which was the first organic certifier in the region (Armesto & Hernández 2006). This system is still developed mainly through the initiative and support of various cooperatives and private companies (Marquez 2015).

Before being certified and sold as organic, plantations must undergo a detoxification process or transition, which ranges from 2 to 3 years. This is one of the greatest effort realized by a coffee grower because during that period (detoxification process) they not receive any benefit from the certifier and must follow certain granted requirements (no use of chemical inputs, certain amount of cultivated trees and coffee plants, etc) (International

Coffee Organization 1994). This sustainable coffee production represents only a small fraction (0.5%) of the total global annual production of specialty coffees (Roncancio et al. 2012). Among the most recognized coffee certifiers are OCIA- Natureland and the Organic Crop Improvement Association in the United States, Naturland and Eco-OK in Europe, and JAS – Japanese Agricultural Standards in Japan (Calo &Wise 2005).

Peru, with some 90,000 certified organic hectares, is one of the world-leading exporters of organic coffee, together with the likes of Mexico, Brazil, Honduras, or Costa Rica. The considerable presence of organic coffee in Peru is attributed in a large part to the inability of smaller growers to pay for costly chemical fertilizers and pesticides (Gaspar 2017).

1.5 Coffee growers in Peru

For many years Peru's production was dominated by large haciendas (a Spanish colonial system), in which extensive agricultural lands belong only to one landowner. This latifundia system was ended in 1969 by an agrarian reform promoted by the local population. Nowadays, most of the plots are currently in the hands of the peasants who fought for the lands (Barriga 2009).

Small-scale farmers generally consist of a family unit that financially depends upon coffee, and they only allocate a small portion of their land to growing subsistence crops or to diversifying crop destined for self-consumption. This type of cultivation sustains about 155,500 families, most of them located on the slopes of the eastern Andes. In some sectors of Peru, coffee it is still considered marginal farming without capital investment by a part of the growers (Marquez et al. 2015). Farmers' living standards are very low and child labor is frequently present. The level of education is insufficient between these coffee growers, presenting a low literacy rate: 17% for men and 43% for women, with only 5% attaining higher education (MINAGRI 2016). In some sectors, farmers continue to use outdated and inadequate means of transport, such as pack animals (donkeys, mules, etc.) or vehicles in bad states of repair, to carry sacks of coffee beans (Palomino 2017).

The predominant coffee species is Arabica and the most frequently cultivated varieties are Typica, Bourbon, Pache Catimor, Caturras and other varieties. They are cultivated on small plots located in remote and flat areas in hilly regions, bordering the forest and far from urban centers (Jezeer & Verweij 2015, Bernhard 2002). According to a 2012 agrarian census, coffee producers have an average of 1 to 5 hectares with another 2.5

hectares under production (Fundes 2012), 30% belong to some type of organization and 20% export directly through their producer organizations (MINAGRI 2016).

Almost 80% of agricultural coffee lands still produce under a traditional system of rudimentary techniques inherited from their families' ancestors; this is a common feature in almost all Peruvian agriculture (Castro et al. 2004). Most agricultural coffee-growing is unpaid family labour. Wage-earning work is only provided in the harvest months, from March to August. During the rest of the year, farmers focus on other activities and prefer to cultivate other staple crops, while neglecting the requirements for maintaining acceptable coffee productivity (Castro et al. 2004). Moreover, farmers apply deforestation and south Andean practices to cultivate staple crops, causing erosion and degradation of the ecosystem.

Researches in rural economies assign an important trait to these families, namely, that apart from developing strategies that allow them a certain level of autonomy (diversification, livestock, textiles), they also join forces to obtain better income, access to market and capital equipment – through cooperatives, associations or private companies (Bacon 2005) – which help them reduce their vulnerability to the constant changes of the market. At the same time, these organizations provide them with support for the conservation of their product and the adoption of quality standards and teach farmers management coffee methods (Wollni & Zeller 2007).

Also, these organizations have contributed to a shift from illegal crops, like coca leaf production, to alternative crops, such as cocoa or coffee. This change has helped the small-scale farmers in the Peruvian jungle to increase and diversify their income in a legal and sustainable way while preserving the environment (Higuchi & Susumu 2011). However, some farmers still prefer to be independent of these types of associations, due to mistrust and bad experience from the corruption and government intervention in Peruvian cooperatives in the 1980s.

2. Objectives

The aim of the current study was to access the useful plant species diversity associated in organic and conventional small-scale coffee farms in Chirinos District, Peru.

Specific objectives:

- Describe the importance of these plant species on farms and in growers' livelihood.
- To document farmers' preference of these useful plant species and their respective management practices.
- Compare the diversity of these plants species maintained on organic and conventional coffee farms.

3. Methodology

3.1 Chirinos study site

Chirinos is one of seven districts of San Ignacio Province, located 83 km south of the provincial capital. Situated at 1,858 m.a.s.l. at the coordinates of 05°18’18’’ south, 78°54’00’’ west, between the eastern and western sides of the Andes, it covers a total land area of 351.9 square kilometers, with 34 villages registering approximately 13,525 inhabitants in total (INEI 2007).

Geographically, it is part of the ecosystem known as Rupa Rupa (400–1,000 m.a.s.l.) and Yunga, which contains a very humid premontane forest (above 1,000 m.a.s.l.). Yunga is covered by complex biological strata, dominated by trees between 10 and 35 m high, and the very high atmospheric humidity facilitates the presence of bromeliads, orchids, ferns and other epiphyte plants. This ecosystem hides countless animal species, birds, amphibians and insects (Tovar et al. 2012). The region had been reported as a transition zone between the typical low jungle and Andean jungle, (1,500–1,600 m.a.s.l.), which explains the presence of abundant endemism of fauna and flora, which give the landscape a variegated and singular appearance (Gentry 1982, Jorgensen & Ulloa 1994). The forest of Chirinos has two important drainage basins – Chinchipe River in the east, at the confluence of the Los Cuyes, Eriza, El Pindo rivers. The Tabaconas drainage basin in the west has as its tributaries the rivers of Santa Rosa and Tembla, both nascent from the high humid mountain range of Chinchiquilla (Peña & Pariente 2005).

The population is predominantly rural (81%, 11,582 inhabitants). It is dedicated to coffee production; the small farmers sell directly to stockholder representatives of independent coffee organizations.

On the other hand, while Chirinos is marked by considerable commercialization, with a high concentration of necessity goods and groceries, this type of commercial activity is usually informal. In the lower areas, the people living by the reservoirs in Tabaconas Valley cultivate rice, and this is the second most important agricultural crop of the district, followed by vegetables, such as cucumbers (*Cucumis sativus),* tomatoes (*Solanum lycoper*), spinach (*Spinacia oleracea*), or broccoli (*Brasica oleracea*; Adrianzen 2013).

The climate is varied, humid and cold in the highland, presenting strong winds and lower precipitation (13.8°C) from June to October, and relatively warm from November to April (18.6°C).

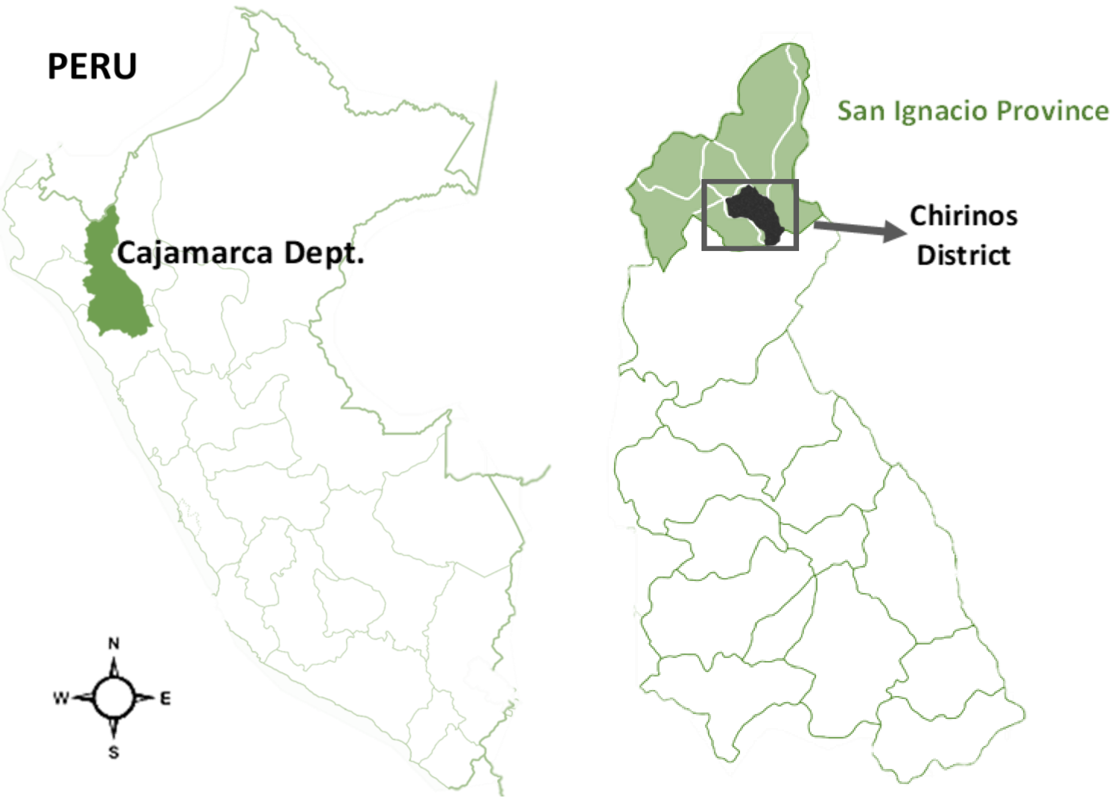

Figure 3. Map of Chirinos District where the study was conducted.

3.2 Data collection

Data were collected during the period of August and September 2016. The study was conducted at 20 small scale organic coffee farmers all dedicated to grow coffee as their main agricultural and economic activity, members of the coffee cooperatives Sol& Café and La Prosperidad de Chirinos and 18 coffee farmers, whom does not belong to any organic certificated program.

Each coffee farmer selected from the cooperatives lists was searched out and notified in their respective villages one week or at least three days before the interview. Visits were conducted in the company and with the help of a technical assistant representing the cooperative. The farmers were informed of the purpose of the visit, allowing the time and day of the survey to be coordinated. They were also asked if they knew of other coffee growers in the area who did not belong to any cooperative, providing the author with information for further interviews.

All the interviews were performed face to face with the farm owners in their coffee plantations. First, socio-economic data was documented (age, livelihood, region-ethnicity, amount of family members), followed by farm information (size, structure, history, reasons for this type of activity, how long under coffee system, types of inputs, coffee varieties and time planted, type of tree, seed acquisition, etc.) and complemented with informal conversation. Continual ethnobotanical data, species plants associated with the coffee farm, genetic material acquisition, shade management and harvesting time; the most important plants were listed, farmers named the plants based on their compatibility with coffee, their main uses, the plant part(s) used, in what way it is used, the cultivated variety, the plant products' commercialization. The main uses identified by the farmers were classified into these categories; medicine, material, food (including beverages), fuel, environment, and animal food. The same plant could fall into the same category. Plants were also classified according to their growth habit.

subsequently, in company of the cooperative technician a randomly selected plot in the farm were delimitated using GPSMAP64s, one rectangle sized 20 by 50 m counting 50 m horizontally and 20 m vertically along slope, this sampling plot was established on a minimum sampling area, which was demonstrated be the most appropriated for this kind of mountainous terrain (Palomino 1999). Within each plot in the coffee farm, all plants mentioned as useful were identified by the technician and/or with help of the farm owner.

Also, direct observation in the sample plot was cross-checked with the information obtained from the interviews. For further identification, photographs were taken of plant samples obtained during the fieldwork, collected as voucher specimens, pressed in between newspaper and card stocks and sent to Herbario Regional de Ucayali, Instituto Veterinario de Investigaciones Tropicales y de Altura, Universidad Nacional Mayor de San Marcos, Pucallpa, Peru. To Dr Mirella Clavo Peralta to carry out the taxonomic determination of the specimens.

3.3 Data analysis

All data information was firstly fed into the Microsoft excel spreadsheets. Farmers were categorized into two types of coffee production organic and conventional. Each plant was categorized, according to; common name, growth habitat, management status, plant part use, main use category, specific use and commercialized.

The total number of main uses reported were grouped into the following categories: Medicine, firewood, materials, food, environmental. Then, all the information was quantitatively evaluated and analysed.

To examine the relationship between categorical variables for organic and conventional, chi-square test was used, with the purpose to obtain probability – p-value, which was compared to selected significance level of 0.05.

3.3.1 Frequency of Citation (FC)

Frequency of citation was used to determinate the importance and incidence of citation for each specific specie, the calculation**,** consists in a very simple sum of informants that mention the use of the plant species (Albertin & Nair 2004). The highest number indicated the most frequently mentioned.

3.3.2 Category use value

For calculate the use value of each category (medicine, materials, food, fuelwood, environmental). Consist in a simple sum of all known uses for each species. Uses refer to use-categories (medicine, materials, food, fuelwood, environmental), not to specific use (Prance et al. 1987)

$$\boldsymbol{UV} = \sum_{i}^{n} \frac{Value}{use\ category\ (i)}$$

3.3.3 Species use value

To demonstrate the relative importance of plants known locally. The usefulness of each plant species s was assessed according to the simplified formula of Phillips and Gentry (1993):

$$UV = \frac{\sum U}{n}$$

Where; U equals the number of uses mentioned by each informant for a given species and N is the total number of informants. The species Use Value where the most frequently cited plant species will obtain a high UV.

3.3.4 Plant part use value

for report the use value of each plant part were use the followed formula:

$$PPV = \sum RU\ (plant\ part)/(\sum RU)$$

It is a simple division between the total reported uses for each plant part and the total number of reported uses for given a plant. (Höffman & Gallaher, 2007). Use report (It is a simple record of a single record of a plant mentioned by an individual)

4. Results

4.1 Characteristics of the informants

All the interviews were coffee growers, owners of the farms. Were observed characteristics for organic farmers belong to cooperatives that distinguish them from conventional farmers; they were more involved in many another aspects related to the coffee management. Had knowledge about the importance of biodiversity conservation, awareness of the climate change and the importance of agricultural responsibilities for a sustainable production. The time and cares dedicated, to the organic coffee farms were also a visible distinguish characteristics, more control of organic waste and no presence of domestic animals on the farms. Organic farmers considered the coffee production an activity that demand a great part of their time, in contrast with conventional farms, they could dedicate to another activity or had another independent economic income as small grocery in the village. However, both type of farmers demonstrated that their most important final product will the coffee.

The age of the coffee plants were older in organic farms an average of 8 years old and 4 years old in conventional farms. Organic and conventional farmers registered preferences from the varieties of *Coffea arabica* L. as; caturra, bourbon and tipica. Coffee growers also registered differences in farm size, organic farmers had an average of 2 hectares and conventional farmers 1 hectare. The time of farm possession were also different; organic growers had been owners nearby 19 years the majority granted by inheritance and conventional nearby 15 years obtained by inheritance or bought.

4.2 Species composition

A total 66 plant species were reported for this study, having a total of 51 different uses grouped into six categories. All record species belonging to 31 different families. The most commonly represented families included Fabaceae (n=9), Malvaceae (n=5), Apiaceae (n=4), Solanaceae (n=4), Euphorbiaceae (n=4), Solanaceae (n=4), Rutaceae (n=3), Lauraceae (n=3), among another 23 different families that registered not more than 2 species. A total of 23 species were common for both type of coffee systems, 19 species were found only in conventional and 24 species were found only in organic farms.

Eleven species were cited as having only one-use category, 26 as having two uses, 21 as having three uses and 8 as having more than three uses. A total of 23 species were recognized at voucher specimen, the remaining plant species were identified by the author using herbarium on-line of different universities of Peru.

4.2.1 Category of main use value

Food and environmental were the most representative use categories for both type of systems, organic and conventional (no-organic). Food category, were the highest reported, which were represented in total by 20 tree species, 2 herbaceous shrubs, 5 annual herbs, 4 biennial herbs, 7 perennial herbs, 2 shrubs and 2 vines.

Based on the number of use report, can be said that the most important species for food category were *Inga chartacea* Poepp. Cf (34 reports, 5.24%), *Manihot esculenta* Crantz (25 reports, 3.85%), *Musa x paradisiaca* L. (24 reports, 3.70%) and *Persea americana* Mill. (13 reports, 2%). Generally, all the fruits trees were eaten fresh as snack food, dessert fruit or as beverage or prepared as jams.

All these species were only for household consume. Another species that were also include in this category, with low reports, but in some cases could generate some small economic income from the surplus of the fruits, these were, *Pouteria lucuma* (Ruiz&Pav.*)* Kuntze, *Theobroma cacao* L., *Mangifera indica* L, *Carica papaya* L., and *Cirtus* sp.
Musa x paradisiaca L., together with important staple food as *Manihot esculenta* Crantz., *Arracacia xanthorrhiza* (6 reports, 0.92%) and *Colocasia Esculenta (*L.*)* (5 reports, 0.77%) among, another lower reported species as (*Lactuca sativa*, *Beta vulgaris* and *Coriandrum sativum*) represented to be an important food species, which are presented all year. At the same time these species are used for feed domestic animals (cavies, poultry, pigs and domestic birds). *Zea mays* L., also represent to be an important animal food source, used mainly as fodder for cavies and poultry. Furthermore, this specie registered a singular characteristic, for one conventional coffee farmer; *Zea mays* L., were planted on coffee farm, to provide food to the migrate parrots, and thus prevent that coffee beans being eaten by these birds.

The category of environmental was represented in total by 42 species. Environmental use category as in food use category were mainly represented by *Inga chartacea* Poepp. Cf (33 reports, 5.08%). *Inga* sp, also was registered as one of the highest cited and the preferred in the coffee farms, in the southern of Peru (Julca 2010). Have desirable characteristics, helps to retain nutrients in the topsoil, improve the microclimate, the leaf litter protect the surface and controls weeds (Lawerence 1993). *Musa x paradisiaca* L. had (23 reports, 3.54%), was the second most important specie for this category, intercropped with the coffee plants for provide temporal and the major specie that provide material from the leaves for thatching.

Another representative specie for environmental category was *Erythrina berteroana* Urb, in total (13 reports, 2%) this species was also preferred by coffee farms, for improve the soil fertility, has high rates of biomass production, (Nair 1993), planted as a shade or in some cases as live fences, the two most notable characteristics attributed to the trees by the coffee farmers. Trees planted as live fences include native trees, registered with low individuals these were; *Cordia alliadora* , *Erythrina sp*. *Trema micrantha, Croton* sp*.,* and *Euphorbia cotinifolia L.,* also these species were cited with medicinal properties**,** in the case of *Croton sp.,* its sap is use to cure warts and ulcers, the latex of *Euphorbia cotinifolia* L have medicinal properties for calluses and constipation.

Fuel were obtained from the pruning of the trees, an activity that is realized at least twice per year at the beginning of the rainy season in March and after coffee harvest, (August-September). The pruning is done with the purpose to provide the required light to the coffee plants and improve the quality and productivity of the shade trees. During the year, larges or damage branches are cutting (maintaining pruning) to avoid some damage on coffee plants. And for this use category belong; *Inga chartacea* Poepp. Cf, *Erythrina berteroana* Urb, *Citrus aurantifolia* Swingle, between another trees with timber value as *Cordia alliadora* , Luehea *cymulosa Spruce* ex Benth. Cf, *Maclura tinctorial, Podocarpus sp.* Other specie with fuel purpose, that were not tree was the *Zea mays* L., which dry bracts of served as cooking fuel.

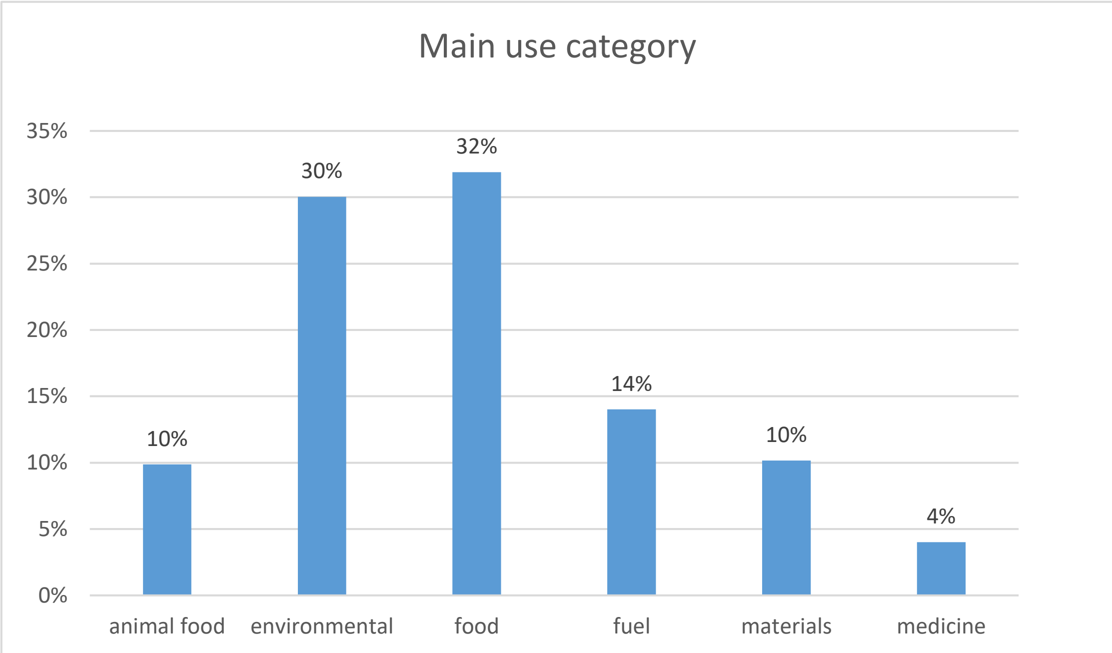

Figure 4. Total use categories of cultivated specie.

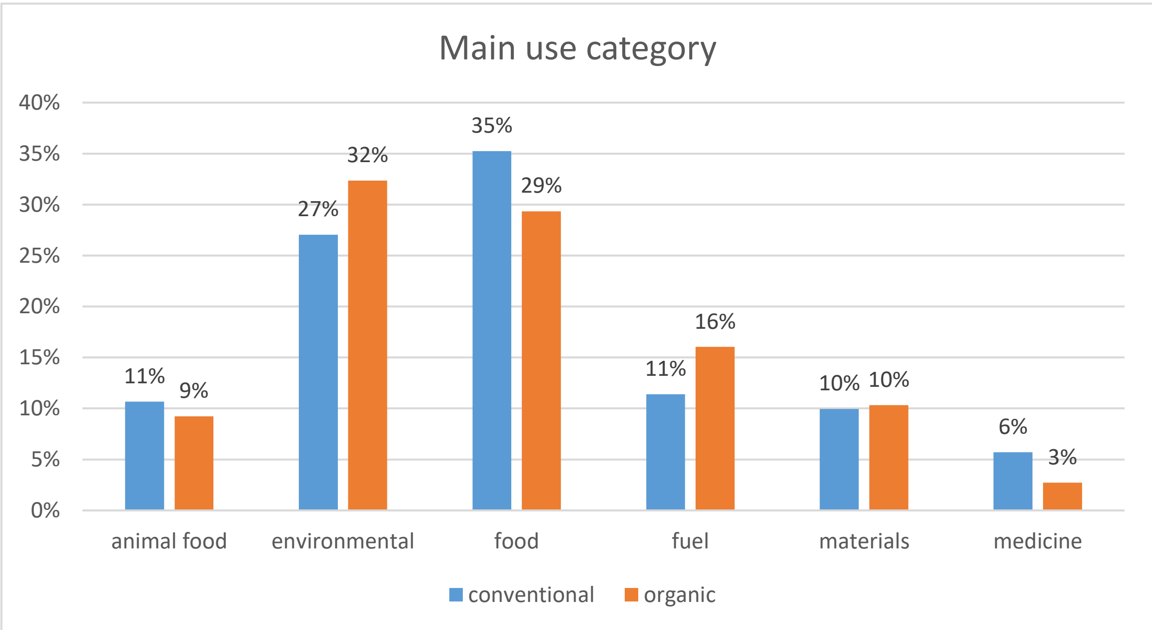

Figure 5. Comparison of use category of cultivated species in organic and conventional farms.

4.2.2 Plant life form

The dominant plant life form belongs to trees (40 species), perennial herb (8), shrub (5), annual herb (5), biennal herb (4), herbaceous shrub (2), vine(2). Trees species as mentioned above, were the most representative for enviromental, food and fuel category. All the 66 recorded plant species present use value, altrough only 23 species (16 trees, 3 perennial herbs, 2 shrubs, 1 annual herb and 1 herbaceous shrub) were similar for both type of farms.

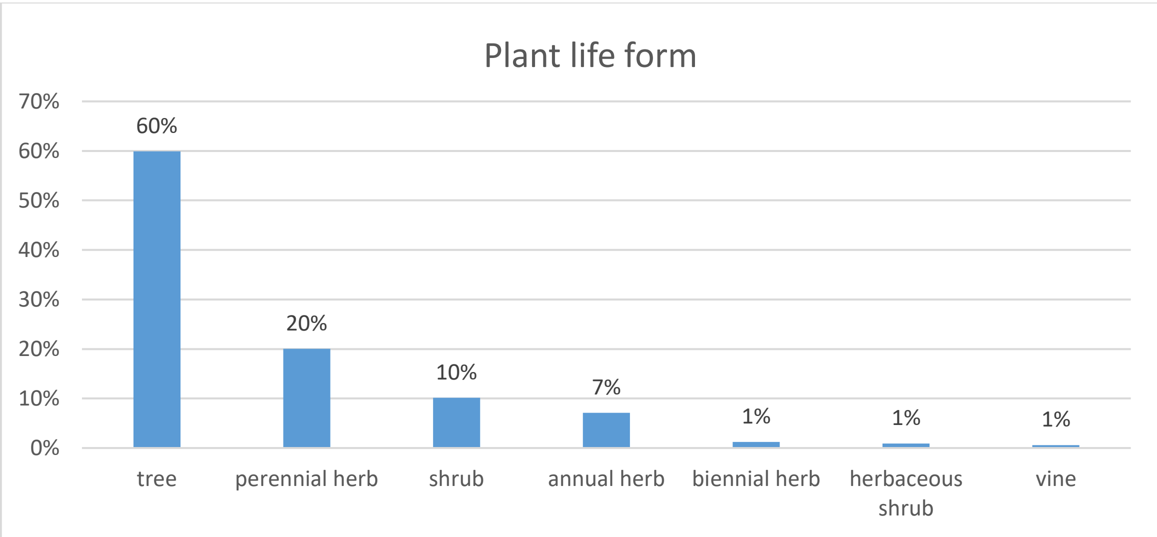

Figure 6. Percentage of total plant life form

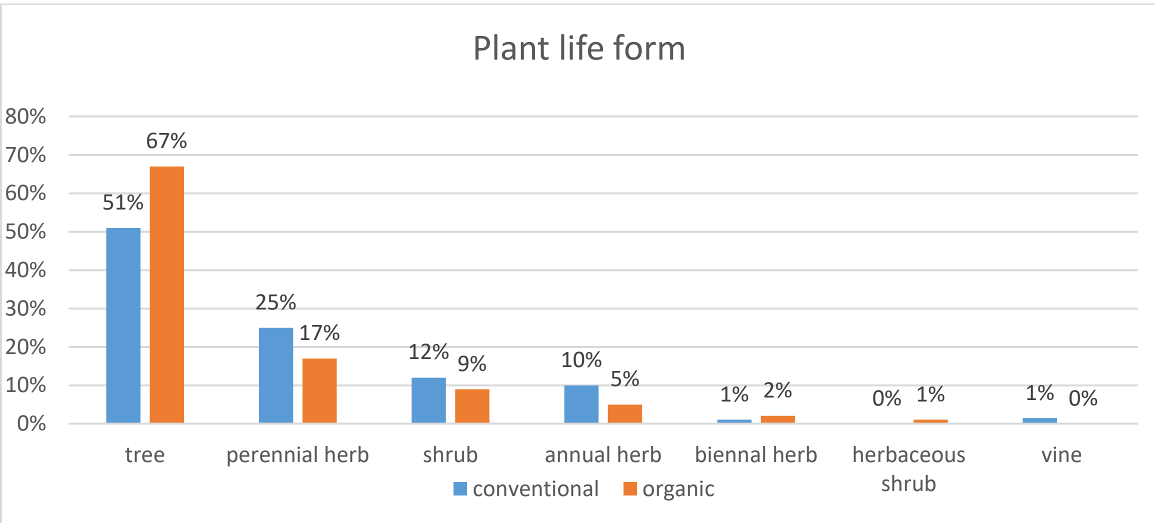

Figure 7. Comparison of plant life form.

From the graph below, can be see that organic has higher share of trees (67%) compared with conventional only (51%). On the other hand, conventional has higher share of annual herb (10%) and perennial herb (25%). Based on a Chi-square test, statistically significant at 5%. Obtained the followed results

Chi-square statistics:	29.561
p-value:	<0.001

Table 1. Chi-square test for plant life form

P-value < 0.001 is lower than 0.05. This means that the the plant life forms (tree, perennial herb, shrub and annual herb) will be depend on the type of farm.

4.3 Species use value

The graph (figure 8) show the 23-common species, for both type of coffee farms. The remaining species obtained lower index use value less than 0.16. The most representative specie use value was *Musa x paradisiaca* L, 'platano' with 90 citations, giving the highest specie use value (2.37). Among the most important plant parts are the fruits for food also for feed their animals, the whole plant provides environmental service as shade specially to the young coffee plants, their leaves also have material value. Conventional farms registered higher use value for this perennial herb (1.24).

The second most important specie value was represented by *Inga chartacea* Poepp 'guaba'. Organic farmers reported higher use value (1.24) than conventional (0.87) as they have desirable characteristics on farms, the whole plant provide shading, obtaining fuelwood from the pruned branches and food from the fruit. *Zea mays* L., 'maiz' (0.95), was the second most important herb, (annual herb) and as in the case of *Musa x paradisiaca* L, 'platano', *Zea mayz* L., presented to have higher index use value for conventional farms (0.63). Together with *Manihot esculenta* Crantz (0.95) its tuber part represents an important staple food. Traditional coffee farms in Mexico also registered *Zea mays* L., as important food source. (Martínez 2007)

The high higher presence of *Colocasia esculenta (L.)* and *Ananas spp.*, in conventional farms, could be due in part, of the age of the coffee plants cultivated, because young coffee plants are intercropped with coffee plants, the first two or three years.

X*anthorrhiza*, 'raicacha' was also an important crop but organic farmers cited higher use value index (0.24)

Laurel, *cordia aliadora* was the first important timber species, for both type of farms, with use value; organic (0.37) and conventional (0.55), this specie is mainly planted as a barrier or as live fence, always trying to avoid the competitions with the coffee plants. In organic farms this tree specie has more agroforestry function, however in conventional farms, *cordia aliadora* registered more uses, obtaining materials for construction or tools, its leaves and seeds are use as condiment and for treat respiratory problems and even be sell as timber in times of scarcity.

Fruit trees as *Citrus aurantifolia* Swingle,'naranja' (0.68) and *Persea americana* Mill.,'palta' (0.71) recorded important use value for both coffee farms. Followed by *Erythrina berteroana*,'erythrina' (0.58), *Inga* sp2 'laricaro' (0.53) and *Solanum sp. Acnistus arborescens*, 'pico pico' (0.50) an important native shrub retained and intercropped on coffee farms (Morantes et al 2006).

Theobroma cacao L. 'cacao' was also presented in both farms, although with low use value (0.34) because of the low species. Were cases that organic farmers also cultivated cacao as also second main crop after coffee. Another characteristic (other agroforestry uses) attributed by farmers to *Theobroma cacao* L., together with *Citrus aurantifolia* Swingle 'naranja', 'lima' (0.26) and *Mangifera indica* L, 'mango' (0.32) were that these trees in some way improve the organoleptic characteristics (quality) of the coffee beans.

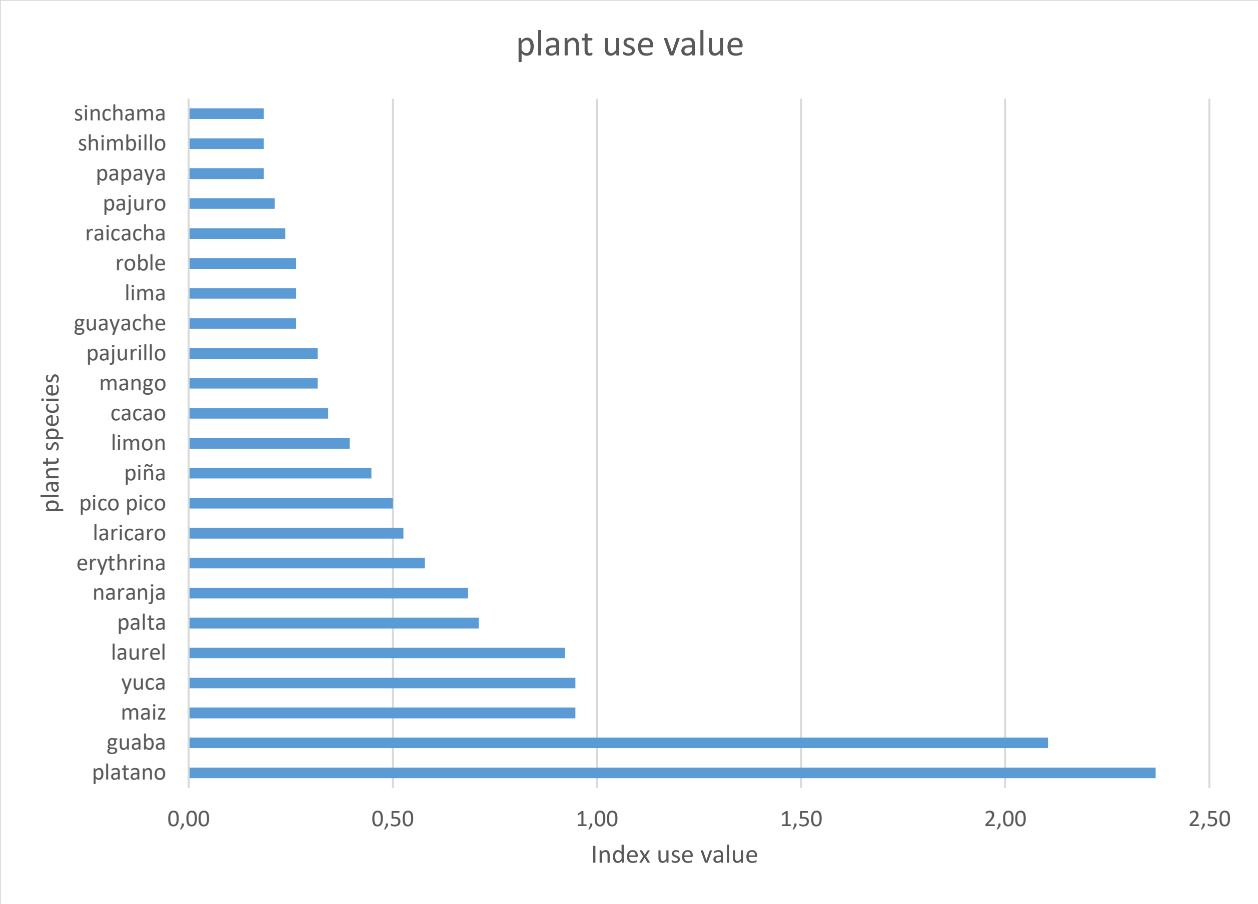

Figure 8. Use value of common species for both type of farms.

4.4 Plant part use value

4.4.1 Utilization of the plant parts

The followed figure 9. Shows the most commonly use plant part with the highest value more than 0.01 (1%). The remaining plant parts obtained a value less than 0.01, being lowest report plant parts. The whole plant of 36, followed by 2 perennial herbs, 1 herbaceous shrub, 1 shrub and 1 vine.

Whole plant, were the most representative plant part, mainly used for providing environmental services as shade, live fence and another agroforestry uses, this last referred by the farmers for the ability to provide organoleptic characteristics to the coffee beans. The second most commonly use part were the fruits of (12 tree and 2 vines, 1 shrub, 2 perennial herbs, 2 herbaceous shrubs and 3 annual herb). These fruits were mainly eaten fresh as snack food, as dessert fruits and in vegetable dishes, also used for treat coughs problems as in the case of *Citrus limon* (L.). The epicarp part of some fruits, were used for elaborate jams and beverage, even used for feed their domestic animals as cavies, poultry and pigs. Plant parts that were exclusively include in food category were aril, seed without testa, stem, tuber corm and fruit pulp. The aril part of the tree *Bixa Orellana* L., was use as condiment for the preparation of stews. The aril part the tree *Inga chartacea* Poepp.Cf., were consumed as snack food (raw). The softness and sweetness of the *Inga* arils, let them be known as ‘ice-cream bean’. Rich in vitamin A,B,C, and antioxidants. Seeds without testa of the *Theobroma cacao* L., were used to elaborate artisan chocolate beverage and its fruit pulp was eaten as dessert fruit as well as the pulp *of Mangifera indica* L. ‘mango’. The sugar or chancaca (a piece of solid sucrose) use instead of commercial sugar, the alcoholic (cañazo) and no alcoholic (chicha) beverage delivered from the stem of *Saccharum sp* is consider nowadays as a laborious artisan preparation, which could be registered only for one farmer, for his consume and sell. The tuber corm of the crop *Colocasia esculenta (L.)*, is considered an important staple food. The corms are peeled and boiled, then eaten as a complement in their meals or during the day in small quantities. Also consider as important staple food are the tubers of *Arracacia xanthorrhiza* and *Manihot esculenta* crantz., from which can prepare starches. The root, of *Daucus carota* L and *Beta vulgaris*, were cooked in soups, in vegetable dishes and as a root vegetable. In soups and in vegetable dishes are also include the leaf of biennial herbs. The leaves of *Cordia alliadora* is a condiment for special typical salt dishes and its infusion was used as a tonic and stimulant in cases of colds. With the pulverized seed can be obtained ointment to treat skin disorders. The leaves *Musa x paradisiaca* L., also were frequently use for the construction of temporary roof, the fresh leaves and bracts of *Zea mays L.*, were also frequently use as fodder for cavities and the dry bracts in some cases are materials for artisanal ornaments.

Branches of the trees and shrubs are pruned, after dry can serve as fuel mainly use for cooking, the branches of the timber species are well appreciated as fuelwood as also the trunk part (wood).

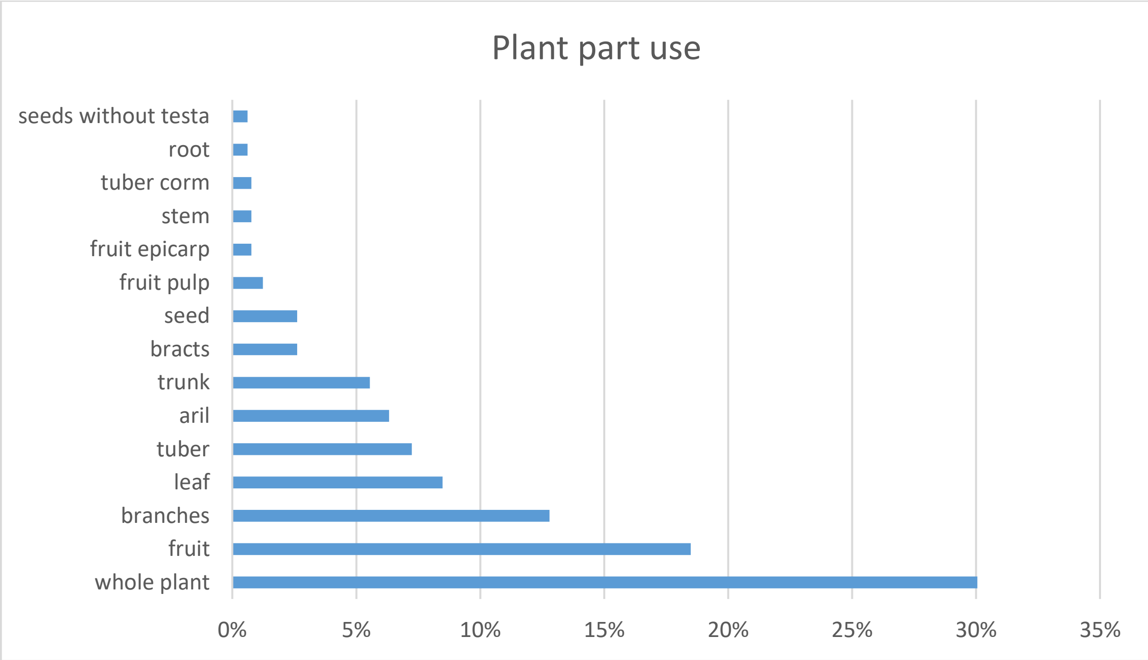

Figure 9. Percentage of the most representative plant part used.

Table 2. Summary of the collected information at organic and conventional farms.

Local name/scientifc name	**Family**	**Plant life form**	**Use categories**	**plant part use**	**specific use**	**Use vale**		**Frquency of citation**		**Specie reconized**
						organic	conventional	organic	conventional	
achiote *Bixa orellana* L.	Bixaceae	tree	F Fu Envir.	aril branches whole plant	condiment fuelwood shading	0,08	0,08	1	1	yes
algodon *Gossypium barbadense* L.	Malvaceae	shrub	Fu Mat	branches flower bud seed hairs	fuelwood paper substitutes	_	0,08		1	yes
apio *Apium sp.*	Apiaceae	perennial herb	F	stem	soups vegetable dishes	0,05	_	1	_	no
babaco *Carica sp.*	Caricaceae	herbaceous shrub	F Envir.	fruit whole plant	dessert fruit other animal food types shading	0,08	0,03	1	1	
balsa *Ochroma lagopus*	Malvaceae	tree	Fu Mat Envir.	branches trunk whole plant	fuelwood furnishing live fence shading	0,11	_	1	_	no
beterraga *Beta vulgaris*	Amaranthaceae	biennial herb	F	root	root vegetable	_	0,03	_	1	no
bituca *Colocasia Esculenta (L.)*	Araceae	perennial herb	F	tuber corm	staple food tuber vegetable	0,03	0,11	1	3	no
bolaina	Malvaceae	tree	Fu	branches	fuelwood	0,08	_	1	_	no

Guazuma crinita.			Mat	trunk	live fence					
			Envir.	whole plant	poles					
cacao	Malvaceae	tree	Fu	branches	fuelwood	0,26	0,08	3	1	yes
Theobroma cacao L.				fruit pulp	jams					
			F	fruit epicarp	beverage					
				seeds without testa						
camote	Convolvulaceae	perennial herb	A.F	tuber	other animal food types	0,05	_	1	–	no
Ipomea batatas.			F		staple food					
caña de azucar	Poaceae	perennial herb	F	stem	alcoholic beverage		0,08	–	1	no
Saccharum sp.					non-alcoholic beverage					
					sugar					
catagua	Euphorbiaceae	tree	Fu	branches	fuelwood	0,11	_	1	_	no
Hura crepitans.			Mat	trunk	furnishing					
			Envir.	whole plant	live fence					
					shading					
cedrillo	Meliaceae	tree	Mat	trunk	furnishing	0,05	_	1	_	no
Cabralea canjerana.			Envir.	whole plant	live fence					
cedro	Meliaceae	tree	Mat	trunk	timber	0,05	_	1	_	no
Cedrela odorata			Envir.	whole plant	live fence					
culantro	Apiaceae	annual herb	F	leaf	condiment	0,05	_	1		no
Coriandrum sativum.					vegetable dishes					
erythrina	Fabaceae	tree	Fu	branches	fuelwood	0,45	0,13	7	3	yes
Erythrina berteroana Urb.			Med	leaf	live fence					
				seed	nervous system					
			Envir.	whole plant	shading					

eucalipto	Myrtaceae	tree	Mat	trunk	construction	_	0,11	_	1	no
Eucaliptus saligna.			Med	leaf	coughs					
					throat					
			Fu	branches	fuelwood					
frejol	Fabaceae	annual herb	F	fruit	fodder	0,08	_	1	_	no
Phaseolus vulgaris.					soups					
					starches					
frejol chileno	Fabaceae	annual herb	F	fruit	soups	__	0,11	_	2	no
Phaseolus sp.					starches					
granadilla	Passifloraceae		F	fruit	dessert fruit	_	0,05		1	
					other					
					agroforestry					
Passiflora sp.			Envir.	whole plant	uses					
guaba	Fabaceae	tree	F	aril	fuelwood	1,24	0,87	20	15	yes
Inga chartacea Poepp.										
Cf.			Fu	branches	shading					
			Envir.	whole plant	snack food					
guaba castilla	Fabaceae	tree	F	aril	shading	_	0,05	_	1	yes
Inga sp1			Envir.	whole plant	snack food					
guayaba	Myrtaceae	tree	F	fruit	dessert fruit	0,05	0,05	1	1	yes
Psidium guajava L.										
Cf.			Envir.	whole plant	shading					
guayache	Myrsinaceae	tree	Fu	branches	Fuelwood	0,18	0,08	2	1	no
Myrsine Oligophyla			Mat	trunk	construction					
					beams					
					charcoal					
			Envir.	whole plant	shading					
hierba santa	Solanaceae	shrub	Med	leaf	hay fever	_	0,05	_	1	yes
Cestum microcalyx Francey					irritation					
huarapo		tree	Fu	branches	fuelwood	0,05	_	1	_	

unknown			Envir.	whole plant	shading					
chirimoya	Annonaceae	tree	F	fruit	dessert fruit		0,08	_	1	yes
Annona cherimolla Mill.			Envir.	whole plant	other agroforestry uses					
					shading					
choloque	Quillajaceae	tree	Fu	branches	fuelwood	0,05	_	1	_	no
Quillaja saponaria			Envir.	whole plant	live fence					
laricaro	Fabaceae	tree	F	aril	snack food	0,34	0,18	7	4	yes
Inga sp2.			fu	branches	fuelwood					
			Envir.	whole plant	shading					
latero	Podocarpaceae	tree	Fu	branches	fuelwood	__	0,08	_	2	no
Licaria trianda			Envir.	whole plant	shading					
laurel	Boraginaceae	tree	F	leaf	condiment	0,37	0,55	3	6	no
Cordia alliadora			Mat	trunk	construction					
					beams					
					carpentry					
					timber					
					tools					
			Med	seed	ointments					
					sinuses					
					throat					
			Fu	branches	fuelwood					
			Envir.	whole plant	live fence					
					shading					
lechuga	Asteraceae	biennial herb	F	leaf	vegetable dishes	_	0,03	–	1	no
Lactuca sativa.										
lima		tree		leaf	beverage	0,21	0,05	2	1	no
			F	fruit	dessert fruit					

			Fu	branches	fuelwood					
			Envir.	whole plant	other agroforestry uses shading					
limon *Citrus limon (L.).* Osbeck	Rutaceae	tree	Fu	branches	beverage fuelwood	0,16	0,24	2	3	yes
			F	fruit	external application					
			Med		coughs					
			Envir.	whole plant	other agroforestry uses shading					
llanten *Plantago linearis Kunth*	Plantaginaceae	perennial herb	Med	leaf	coughs irritation	_	0,05	_	1	no
lucuma		tree	F	fruit	dessert fruit	0,08	_	1		yes
*Pouteria lucuma (Ruiz&Pav.)*Kuntze.			Envir.	whole plant	other agroforestry uses shading					
maiz *Zea mays* L.	Poaceae	annual herb	Mat	bracts	crafts	0,32	0,63	2	5	no
			A.F	leaf	fodder					
			F	seed	sweet dish					
			mat	leaf	wrappers					
			Fu		fuelwood					
mandarina *Citrus sp.*	Rutaceae	tree	Fu	branches	fuelwood	0,16	_	2	_	no
			F	fruit	dessert fruit					

			Envir.	whole plant	other agroforestry uses					
					shading					
mango	Anacardiaceae	tree	Fu	branches	fuelwood	0,11	0,21	1	3	yes
Mangifera indica L.			F	fruit pulp	dessert fruit					
			Envir.	whole plant	other agroforestry uses					
					shading					
morero	Moraceae	tree	Mat	trunk	timber	0,05	_	1	_	no
Maclura tinctoria			Envir.	whole plant	shading					
naranja	Rutaceae	tree	Fu	branches	fuelwood	0,45	0,21	5	3	yes
Citrus aurantifolia Swingle.			F	fruit	beverage					
			Envir.	whole plant	other agroforestry uses					
					shading					
naranjilla	Solanaceae	herbaceous shrub	F	fruit	dessert fruit	0,05	_	1	–	no
Solanum quitoense			A.F		other animal food types					
pajurillo	Fabaceae	tree	Fu	branches	fuelwood	0,26	0,05	5	1	no
Erythrina sp.			Mat	trunk	construction					
					stakes					
pajuro	Fabaceae	tree	Fu	branches	fuelwood	0,21	_	2	_	no
Erytrina edulis.			F	seed	sweet dish					
			Mat	trunk	construction					
					live fence					
			Envir.	whole plant	shading					
palta	Lauraceae	tree	Fu	branches	fuelwood	0,50	0,21	8	5	yes

Persea americana Mill.			Envir.	whole plant	shading					
			A.F	fruit	other animal food types					
			F	fruit	vegetable dishes					
palta fuerte	Lauraceae	tree	Fu	branches	fuelwood	0,05	_	1	_	no
Persea s.			F	fruit	vegetable dishes					
pan de arbol	Moraceae	tree	Fu	branches	dessert fruit		0,08		1	yes
*Artocarpus altilis (Parkinson)*Fosberg.			F	fruit	fuelwood					
			Envir.	whole plant	shading					
papaya	Caricaceae	tree	F	fruit	dessert fruit	0,18	_	2	_	yes
Carica papaya L.					snack food					
			A.F	fruit epicarp	other animal food types					
			Envir.	whole plant	shading					
pico pico	Solanaceae	shrub	Fu	branches	fuelwood	0,24	0,26	5	6	yes
Solanum sp			F	fruit	snack food					
			Envir.	whole plant	shading					
pijiana	Unknown	tree	Envir.	whole plant	shading	_	0,03	_	1	no
unknown										
piña	Bromeliaceae	perennial herb	F	fruit	dessert fruit	0,18	0,26	2	3	no
Ananas spp.			Med	fruit	constipation					
			F	fruit epicarp	beverage					
			A.F		other animal food types					
			Mat	leaf	matting					
			Envir.	whole plant	other agroforestry uses					

piñon rojo *Euphorbia cotinifolia* L.	Euphorbiaceae	shrub	Med	latex	calluses	0,16	_	2	_	yes
					warts					
				leaf	constipation					
					drops					
			Envir.	whole plant	live fence					
piria	Lauraceae	tree	Fu	branches	fuelwood	0,05	_	1	_	no
Persea caerulea			Mat	trunk	furnishing					
platano	Musaceae	perennial herb	F	fruit	dessert fruit	1,13	1,24	12	14	yes
Musa x paradisiaca L.					other bird					
					other animal food types					
			Mat	leaf	thatch					
			Envir.	whole plant	shading					
raicacha *Arracacia xanthorrhiza*	Apiaceae	perennial herb	F	tuber	other animal food types	0,16	0,08	3	3	no
					staple food					
repollo	Brassicaceae	biennial herb	F	leaf	green vegetables	0,08	_	1	_	no
Brassica oleracea			A.F		other animal food types					
					soups					
roble	Malvaceae	tree	Fu	branches	fuelwood	0,26	_	3	_	yes
Luehea cymulosa Spruce ex Benth. Cf.			Mat	trunk	construction					
					furnishing					
					charcoal					
					timber					
			Envir.	whole plant	live fence					
					shading					
romerillo	Podocarpaceae	tree	Mat	trunk	timber	_	0,05	_	1	no

Podocarpus sp.			Envir.	whole plant	live fence					
sangre de grado	Euphorbiaceae	tree	Envir.	whole plant	live fence	_	0,11		1	yes
Croton sp.			Med	sap	shading					
					ulcers					
					warts					
shimbillo	Fabaceae	tree	Fu	branches	fuelwood	0,11	0,08	2	1	yes
Inga aff. nobilis Willd.			F	fruit	snack food					
			Envir.	whole plant	shading					
sinchama	Cannabaceae	tree	Fu	branches	fuelwood	0,18	_	1	_	no
Trema micrantha			Med	leaf	congestion					
			Mat	trunk	beams					
					furnishing					
					charcoal					
			Envir.	whole plant	live fence					
					shading					
tomate	Solanaceae	annual herb	F	fruit	vegetable dishes	_	0,03	–	1	no
Solanum lycopersicum										
wuan wuan		tree	Fu	branches	fuelwood	_	0,08	_	1	no
unknown			Mat	trunk	construction					
			Envir.	whole plant	live fence					
yuca	Euphorbiaceae	shrub	F	tuber	staple food	0,45	0,50	6	8	yes
Manihot esculenta Crantz.					starches					
					tuber					
					vegetable					
			A.F		other animal food types					
zanahoria	Apiaceae	biennial herb	F	root	other animal food types	0,08	_	1	–	no
Daucus carota L.					soups					

					vegetable dishes					
zapallo *Cucumis* sp	Cucurbitaceae	vine	F	fruit leaf	other animal food types sweet dish	_	0,05	–	1	yes

F=Food, Fu=Fuel, A.F= Animal food, Envir=Enviromental, Med=Medicinal, Mat=Material.

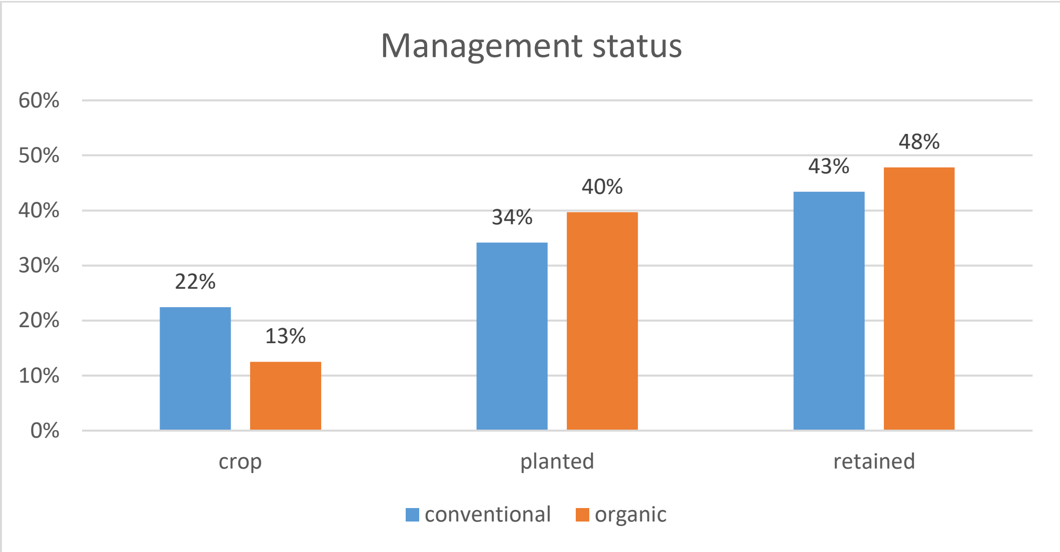

Figure 10. Comparison of management status of the recorded plant species.

Chi-square statistics:	11.308
p-value:	0.003504

Table 3. Chi-square test for management status

Crop is higher in conventional farms (22%), while management status of planted and are higher in both systems, but organic presented higher percentage values, with a test of Chi-square at 5% of significance. The obtained P-value (0.003), is lower than 0.05, thereby management status will depend on the type of farm system.

5. Discussion

The plant species diversity found in Chirinos's coffee agroforestry systems, were most representative by tree species, agreed with another similar studies performed in traditional coffee agroforestry.

Trees in tropical agroforestry systems are mainly use to provide shade, fruit, timber, fuel, medicine and fodder. Chirinos's coffee farmers also presented these uses, showing always efforts to associated trees and other plant species that could be firstly beneficial to the coffee plants. Farmers preference plant species, will be reflected in the increase of certain tree species in the management landspaces. For example, in Guatemala and Peru, fruit trees as *Citrus spp.*, *Mangifera indica, Musa* spp., and *Persea americana* were the most dominant tree species on coffee farms. Traditionally coffee systems in Mexico *inga* species presented dominance over another tree species. Some similar species were found in Chirinos farms, where the highest representative tree species, were; *Inga chartacea* poepp.Cf followed by *Persea Americana, Solanum* sp., *Inga* sp2., *Erythrina berteroana* Urb., *Cordia aliadora* and *Citrus aurantifolia* Swingle.

Perennial herb as *Musa x paradisiaca, Zea Mays* L., *and Manihot esculenta* Crantz were the most commonly source of food after fruit trees. These species are the most common in Latin America and households use them as basic food for their diet. Can be say that farmers in some way diversified their farms as strategy, coinciding with studies performed also in agroforestry system, where householders develop an effective strategy for ensuring food security.

Chirinos organic farms presented more trees species, while the average number of shrubs, perennial, biennial and annual herbs were similar for both systems. There is a tend that organic coffee agroecosystems management higher species than the conventional counterparts. However, it can contrast with Mendez (2010) where individually managed small farms that did not belong to the cooperatives supported higher levels of shade tree agrobiodiversity in coffee plantations than collectively managed organic cooperatives. The higher levels of agrobiodiversity in individual farms were the result of growers seeking to obtain a diversity of products (e.g., fruit, firewood and timber), whereas larger, collectively managed cooperatives concentrated on coffee production and did not prioritize product diversification (Mendez et al. 2009).

It indicates that species compositions on farms would appear to relate to different management and production objectives of the farmers independent of whether they are certified or not. So, the certifies would appear to be favored by those with more diverse shade systems (Haggar et al 2014).

This study revealed that both organic and conventional farms reported important uses for these diversity plant species, although can differ in the number of species and forms of uses. They are contributing to the persistence of traditional knowledge over these species. Nowadays that the vulnerability of tropical rainforest is increasing, due in part to the lack knowledge of the real value and potential that can support these ecosystems. Base on the results can be said that environmental use value was most important for organic farms, with highest number of trees, including native species, the influence of the organic associations on coffee growers was reflected in the shade management on the farm, for example; if the associated tree is good for shade, or for live fence, how and when must be pruned and reveled that no chemical inputs had been applied in the previous years, instead of that, they use the fermented coffee husk or the organic manure of the cooperatives. They expressed a clear idea to produce on long-term in a sustainable way. But it does not mean that conventional farmers had null knowledge on how management their farm, while is true that their final aim is high coffee yields, they also know about the consequences of the over exploitation on coffee lands. This study show, that conventional farms also reported importance for food and environmental uses as their counterparts. Plants species for medicine purpose were the lowest use category and index use value. In total seven species, among them are native species as *Eucaliptus saligna*, *Croton sp.*, *Cestum microcalyx* Francey and *Plantago linearis* Kunth., found in conventional farms. The low species and values of these plants species, may be due in part to the transformation of the lands into coffee farms. According to Stoffle et al. (1990) and Pieroni (2001), low values of plant species significance may also be associated with processes of losing traditional uses of plants. For instance, some plant species could have decreased their value due to generational changes of preferences, transformation of actual patterns of use, and probably the diminishing of traditional local knowledge (Guerrero et al. 2008). It should be mentioned that Chirinos-province supplied with many pharmacies. Thereby can tentatively said, that the low use value recorded in this study for these medicinal plant species and the current absence of conservative gathering might be due to a decrease in the use and knowledge, due maybe to the villager's preference to a faster or practical obtain of needed items. The use value is dynamic, changing through time in a human group or between sectors of a human group at a given time (Guerrero et al 2008).

These agroforestry systems can significate some important repertories of biological diversity. Tree species not only support farmers income, it has been demonstrated that, also maintain fauna diversity, by offering edible fruits, nectar and insects. Remarkable researches on shade coffee fields describe a great number of plant and fauna species, thus indicate that these agroforestry systems can play an important role for conservation and refuge of agrobiodiversity (Moguel 1999). And even more with projects that provide incentives for farmers to continue to conserve this agrobiodiversity with their perennial crops, which have been resulting with positive outcomes for household livelihoods and conservation.

Well management agroforestry systems as coffee or cacao, demonstrated potentials to deal with the climate change, through strategies that involve sustainable agriculture productivity, optimal use of natural resources and reducing as much possible the greenhouse gas emission. Currently are companies that are betting on tropical agroforestry system to buffer the increase of this global climatic problem.

6. Conclusion

The aim of this study was the assessment to plant species associated with organic and conventional small-scale coffee farms, in Chirinos. A total of 66 plant species were recorded. This study demonstrated that the amount of plants for each type of farm are different, organic farms reported more species than conventional. However, both type of farmers showed similar knowledge about useful plant species.

Conventional coffee farmers demonstrated preference for *Musa x paradisiaca* L., and organic for *Inga chartacea* Poepp. Cf. Both species were the highest reported for food and environmental category, which were the most representative categories.

As the majority of the recorded plant species were trees, these provide shade, live fences and other agroforestry use. This last use is referred specially to the genera citrus and aromatic fruit tress, farmers knowledge attributed characteristics to these species as good contributor to the quality of the coffees plants. An interesting issue that could require further research.

This study not registered strictly householder dependence on food incomes from farms, they dedicated to management coffee plantations as main socio-economic activity.

Chirinos coffee farms had preference on shade species that provide food, at the same time farmers diversifying their farms planting another crops that generate them some another food incomes apart than the fruit trees.

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List of Appendices

Appendix 1. Questionnaire research- Data about the informant

Name:
Gender:
Age/age range:
Occupation/livelihood:
Region:
District:
Community/village:
Ethnic group:
Member of the cooperative:
Organic coffee grower: Yes / No

1. Can you tell me about the history of your farm?

2. Do you grow coffee only in special plots ("*cafetales*") or also in other parts of the farm?

3a. *For organic farms*: When you have decided to grow organic coffee? And what was the reason?

3b. *For conventional farms*: Have you ever thought about to grow organic coffee? What was the reason?

4. Do you cultivate plants other than coffee on your farm? yes / no

5. Can you list all the plants (of all types: trees, shrubs, annual crops, herbs, lianas) which you cultivate or retain on your farm and please explain what kind of benefit do you have from each plant?

6. Can you show me mentioned plants on your farm?

7.Can you list most valuable woody plants (woody plants = trees, shrubs, lianas) associated with coffee? After mentioning the first 5 plants a line was draw and continue noting other plants if farmer mentions more than 5.

Appendix 2. Ethnobotanical information on useful plants cultivated or retained within coffee farms

Local name of the plant [1]	Growth habit of the plant [2]	Plant part(s) used	Main use [3]	Specific use [4]	Is this plant cultivated or retained in association with coffee? Yes / No	Do you cultivate more than one variety of this species? If yes - Can you tell me the variety name and how do you recognize it from other varieties?	How do you harvest the plant? [5]	When do you harvest the plant? [6]	Is the plant/plant products sold on the market? [7]	Herbarium voucher specimen collected?
1 Plant										
Plant 2										
Plant 3										

Notes on table

[1] You should distinguish if the plant name is in native language or Spanish language. In case the plant has several names note all of them. After filling the questionnaire ask each informant to show you all the plants mentioned "on site" and make the pictures of plants and also collect plant samples for herbarium reference collection. Do not forget to code (for example DEL 001, DEL 002 etc.) the pictures and plant samples and associate it with corresponding plants documented in the questionnaire.

[2] Growth habit types: TREE, SHRUB, ANNUAL CROP, HERB, LIANA. *Note*: You can ask but also you have to observe personally in the field.

[3] There can be different uses for different parts of the same plant. Categorize the main uses as follows: FOOD (including also beverages and food additives), FODDER (animal food), MEDICINE (including human and also veterinary), MATERIALS (e.g. construction wood, dyes, fibres, resins, essential oils….), FUEL (firewood, charcoal) , ENVIRONMENTAL (e.g. shading, soil improver, ornamental, fencing, erosion control), OTHER (all other uses which cannot be classified in previous categories).

[4] *Note*: ask informant to describe briefly how he practically uses the plant. This question can show us if the knowledge on plant is still practiced or not.

[5] Could be for example: "picked" (for the fruits), "felled" (for the trunk, …), "stripped from felled tree" (for bark,), etc.

[6] Could be for example: "year round", if not year round that ask informant to specify the season, for example January-March, …

[7] *Note*: if the response is YES, than go to the market and document the unit selling prices there.

Appendix 3. Coffee farms with *Inga Charctacea* Poepp. Cf.

Appendix 4. Coffee farms with *Musa x paradisiaca* L.

Appendix 5. Interview with a conventional farmer

Appendix 6. Interview with an organic farmer