https://doi.org/10.32854/agrop.v13i11.1811

The Coffee Agroforestry System in Mexico

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ABSTRACT

Objective: To identify the current coffee knowledge as agroforestry systems, with emphasis on Mexico.

Design/Methodology/Scope: A search for documentary information was performed on the Internet based on Google®, with the keywords "agroforestry and coffee plantations" and "coffee systems in Mexico".

Results: 88 documents were found; 91% of publications were in Spanish, 40% were from Colombia, 24% from Mexico, 7% from Costa Rica and the remaining 29% of other countries.

Study Limitations/Implications: This topic is studied in several institutions, although it does not constitute a systematized study line.

Findings/Conclusions: Most research works are centered on the importance of the coffee agroforestry system as provider of environmental services, among which the carbon and water intake, biodiversity reserve and erosion buffering stand out.

Keywords: coffee industry, water capture, *Coffea arabica*, carbon sequestration, environmental services.

INTRODUCTION

The word agroforestry is associated to silviculture, although it refers more commonly to an agroforestry system (SAF). This production focus has been used worldwide and is as ancient as agriculture itself. Nevertheless, barely in the 1970s, the first formal research on agroforestry was obtained. It tried to clarify the concept of agroforestry and differentiate it from other production systems (CONAFOR-UACH, 2013; Farfán, 2014). Agroforestry or an agroforestry system comprise those systems where there is a combination of arboreous species with shrubby or herbaceous species generally grown. This term is wide; it includes from the simple presence of some trees in combination with vegetation crops or cereals, to complex systems with multiple species in several strata (FAO, 1999). According to Farfán (2012), agroforestry objectives are: diversifying production, improve migration agriculture, increase organic soil matter levels, set atmospheric nitrogen, recycle nutrients, modify microclimate and optimize the system's productivity always respecting the concept of sustainable production. According to Noscue (2014), agroforestry objectives may also be applied to the growing of coffee (*Coffea arabica* L.).

Agroproductividad: *Vol. 13, Núm. 11, noviembre. 2020. pp: 45-51.*
Recibido: *abril, 2020.* **Aceptado:** *octubre, 2020.*

Due to the elevated level of components that constitute them and the interaction dynamic between them, agroforestry systems with coffee (SAFC) may be catalogued as complex systems, as they comprise interconnected parts, the links of which generate information for the observer and, as a result of interactions, properties that may not be explained from properties of isolated or separate elements appear. In SAF, the interaction of their components generate an adequate microclimate, in particular in suboptimal areas for coffee-growing (Farfán, 2014). The SAFC is usually compared with a forest as a similar ecological value may be attained (Manson *et al*., 2008). Forests are recognized as important systems due to the environmental services that they provide, such as carbon storage and capture, oxygen production, scenic beauty, habitat for diverse animal species; also, forests are indirect providers of water supply for urban life, fauna, medicinal plants and, in general, major elements of wild life (CEDERSSA, 2011; Moraga *et al*., 2011).

According to Londoño *et al*. (2014) "state-of-the-art means studying a substantial portion of relevant literature and sources of information in an area and develops an understanding process that converges in a global and integrating vision and a communication of this result for others." Therefore, the objective of this work was to identify the current coffee-growing knowledge of coffee as agroforestry systems, with emphasis on Mexico.

METHODOLOGY

A search and review of literature was made on the Internet via Google®, for documents published between 1984 and 2017, that were obtained through keywords "agroforestry and coffee plantations" and "coffee agroforestry systems in Mexico." The central subject were agroforestry systems and coffee. The search threw documents with other subject that contained keywords, although there were not deemed to be of interest for our research. Each document was analyzed to know what, how, where and why studies have been performed in subjects that comprise the previously mentioned concepts.

RESULTS

A total of 88 documents in the form of technical note, books written in Spanish and English, scientific papers in Spanish and English, guidelines, monographs and theses were found. Documents were made in Puerto Rico, Nicaragua, Peru, Honduras, Colombia, Costa Rica, and other countries in Latin America, and even from institutional agreements by Mexico-Nicaragua-Bolivia-Spain-Italy. The greater number of studies published in Colombia by CENICAFÉ (*Centro Nacional de Investigaciones de Café*) stands out with 27 documents, followed by CATIE (*Centro Agronómico Tropical de Investigación y Enseñanza*) of Costa Rica. 20 documents related to agroforestry were found in Mexico, but only 11 were specific of coffee under the shade or SAFC (Table 1).

Overview of SAF Agroforestry Systems

Agroforestry Systems (SAF) are quoted for their forms of use and handling of natural resources, in which wood species of trees and multiuse trees (fruit, timber, foraging or living fences) are used in a sustainable domain. Also, this is referred to due to agricultural crops and/or animals of financial value and ecological and economic interactions between components. These interactions may be simultaneous and directly (synchronic) of components in the land or with a temporary sequence (diachronic) with a chronological interaction, without being present at the same time in the same land unit. Also, these refer to the application of handling practices compatible with cultural practices of the local population (Nair, 1993; FAO, 1999; Farfán, 2014; Noscue, 2014; López, S/F).

SAFs have been developed as an option for the handling and preservation of natural resources of the tropic that are found within a rapid degradation process. With the introduction of trees to these ecosystems, a greater total yield may be obtained as the diversity is kept and sustainable use of resources is promoted or the degradation of the land and loss in biodiversity is avoided at least (Farfán, 2012). Villavicencio-Enríquez (2013) recommended performing the social-economic analysis on the handling of SAF, based on sustainability, the preservation of resources and their biodiversity; income and outcomes of the system in form of inputs and products are to be identified together with processes generated between them to determine the SAF functionality.

General Definition of the Coffee Agroforestry System

Farfán (2012) defines that coffee agroforestry system (SAFC) as the "set of handling practices where tree species in association with (sic) coffee or tree planting of farms; the objective of which is the handling and preservation

Table 1. Research works performed in Mexico on coffee agroforestry systems from 1999 to 2017.

Title	Author	Year	Type of Material
Definition of shade-grown coffee with biophysical criteria	Instituto de Ecología, A. C.	1999	Workshop Results Report
Handling of tree species for agroforestry systems in the Maya Tzotzil-Tetzal region in northern Chiapas	María Lorena Soto Pinto	2000	Project final report
Coffee Agroforestry Systems. Production of more than a beverage	Lissette Rodríguez Rubí	2001	Abstract
Analysis of the Tree Structure of the Rustican Agroforestry System of Coffee in San Miguel, Veracruz, Mexico	Luis Villavicencio-Enríquez & Juan I. Valdez-Hernández	2003	Scientific Paper
Agroforestry Experience for Carbon Capture in Indigenous Communities in Mexico	Lorena Soto-Pinto, Guillermo Jiménez-Ferrer, Adalberto Vargas Guillén, Ben de Jong Bergsma, Elsa Esquivel-Bazán	2005	Scientific Paper
Agroforestry Characterization in Traditional and Rural Coffee Systems in San Miguel, Veracruz, Mexico	Luis Villavicencio-Enríquez	2013	Scientific Paper
Timber Agroforestry System in Mexico	National Forest Commission and Universidad Autónoma Chapingo (CONAFOR-UACH)	2013	Literature Review
Tree Structure and Diversity in Agroforestry Systems of Coffee in the Atoyac Mountains, Veracruz	Luis E. García Mayoral, Juan I. Valdez Hernández, Mario Luna Cavazos and Rosalío López Morgado	2015	Scientific Paper
Innovation with pink cedar; (*Acrocarpus fraxinifolius*) as a coffee-growing agroecosystem in central Veracruz	Sergio Sánchez Hernández	2016	M.Sc. Dissertation
Characterization of the Shade-Grown Coffee Agroecosystem in the Copalita River Basin	María Estela García Alvarado; Gustavo Omar Díaz Zorrilla; Ernesto Castañeda Hidalgo; Salvador Lozano Trejo; María Isabel Pérez León	2017	Scientific Paper
Diversification of Traditional Shade of Coffee Plantations in Veracruz through Timber Species	Sergio Sánchez Hernández; Martín Alfonso Mendoza Briseño and Raúl Vidal García Hernández	2017	Scientific Paper

of land and water, the increase and maintenance of production to guarantee sustainability and the strengthening of the socioeconomic development of coffee-growing families." Also, the "tree planting" term is defined as the capacity to establish trees in the coffee-growing farm without using space destined to the establishment of crops and without affecting coffee production. Rodríguez (2001) quotes SAF in coffee defined as "a set of land utilization techniques that combine the use of forest trees with coffee seeding."

The use of trees as a shade in coffee plantations began as a growing practice by growers in Asia and Africa. Shading was chosen and lay down without further analysis, by using any species; the result thereof was disadvantageous for coffee growers and, as a consequence thereof, the practice lost legitimacy (Farfán, 2014). The natural adaptation of coffee to underwood of shade trees is a strong argument for agroforestry practices in coffee production. *Inga* genus species are shade trees of greater use for coffee and cocoa (*Theobroma cacao* L.) in Mesoamerica, except for Costa Rica where *Erythrina poepigiana* (Walp.) O. F. Cook, is the most abundant species in coffee agroforestry systems (SAFC) (Cannavo *et al.*, 2011). For Farfán (2012) a tree employed for coffee plantation shade has to gather the following characteristics: a) being a legume on account of its potential to fix atmospheric nitrogen; b) adapting well to coffee climate; c) being of rapid growth and long life; d) having abundant branches and good height; e) the conformation of its foliage should not interfere with the passage of the sun; f) developing deep roots; g) being timber and withstand winds; and h) being immune to plagues that may affect the coffee plant.

Examples of Studies Performed in SAFC in Mexico
Sánchez *et al.* (2017) studied the diversification of traditional shade of coffee plantations in Veracruz through timber species. Interviews documented the existence of timber utilization forms and the economic

inputs of tree species introduced in shade-grown coffee farms in central Veracruz. They visited farms to recognize the species and evidence the producer's knowledge on these species and the traditional and commercial growing of coffee. Producers prefer the Spanish cedar (*Cedrela odorata* L.) and encino (*Quercus oleoides* Schltdl. & Cham.), known locally as timber tezmol; at the same time, encino (*Quercus laurina* Bonpl.), pink cedar (*Acrocarpus fraxinifolius* Wight *et* Arn.), achiotillo (*Alchornea latifolia* Sw.) and ice cream bean (*Inga edulis* Mart.) as a shade for coffee trees.

In 2015, García and his collaborators characterized the structure and diversity of arboreous vegetation in three coffee agroforestry systems: rural, simple polyculture, complex polyculture and semi-deciduous of the Atoyac mountains, Veracruz. They sampled 917 individuals distributed in 90 taxa. Identified species identified were distributed in 32 families and 65 genera. The complex polyculture shows more richness in species than the rural system and simple polyculture. The most important species in the SAFC structure was *Cordia alliodora* Cham.; and, for the semi-deciduous forest were *Bursera simaruba* (L.) Sarg. and *Myriocarpa longypes* Liebm., with no significant statistics between it and the complex polyculture.

In order to perform an agroforestry characterization of the traditional coffee-growing system (STC) and the rural coffee system (SRC) in San Miguel, Amatlán de los Reyes, Veracruz, México, Villavicencio-Enríquez (2013) performed an inventory of canopy species as an experiment as well as obtaining information for the functional and socioeconomic analysis by means of interviews to community producers. STC considers a lower number of canopy species, which only meets the shade option for coffee, while the SRC employs the natural canopy of the tropical rainforest, which preserves a greater number of native species based on their structures, composition of species and use of canopy trees. Both systems obtain similar financial benefits, although the composition of canopy species and obtained products are different. The main economic product are timber trees, followed by coffee and palm trees *Chamaedorae tepejilote* Liebm. and *Chamaedorae elegans* Mart. The sale of forest and agricultural products gave 2.5 times as much financial gain for SRC than STC. Both production systems may be profitable when handled in a sustainable manner and with the sale of coffee and other organic-type products.

Soto-Pinto *et al*. (2005) studied the carbon capture in the northern zone, the border zone and the Chiapas jungle, where growers were involved in a project that began in 1994; by means of participative methodologies, they exchanged information with technicians in a process of mutual learning. They laid down agroforestry systems in individual lands, in agricultural areas susceptible of enriching with trees: shade-grown coffee, fallow corn systems, continuous use corn (without fallow), with silvopasture systems, diversified plantations and natural forest regeneration systems. They consider that the sale of environmental services is an activity complementary to productive activities for each family, as agroforestry systems allow greater income in the medium and short terms.

Villavicencio-Enríquez & Valdez-Hernández (2003) proposed analyzing the vegetation structure of the rural coffee agroforestry system (SAF) (*Coffea arabica* L., *Coffea canephora* Pierre ex A. Froehner) and comparing it with the semi-deciduous forest with little disturbance (SMSP), through the determination of importance value indexes and species diversity, and performing the taxonomic identification of all tree components. The prepared a species-area curve that consists in charting the number of vegetation species found for a sampling surface and they obtained the Jaccard coefficient (*Cj*), to know the floristic similarity between studied systems. They found a total of 81 tree species that belong to a native, secondary and exotic vegetations, of which 62 were present in the rural coffee SAF and 66 in the semi-deciduous forest. The Jaccard coefficient (*Cj*) for both studied systems was 0.58, which indicates a floristic similarity of 58% and 42% of different species between both systems. Diversity and equity values were greater in the SMSP system compared to the rural coffee SAF, which shows greater richness of species and a more equitable distribution in sampled jungle units.

DISCUSSION

Agroforestry may be deemed to be more than a single and finished technology. Although several finished systems have been conceived and tested, such technology may require an adjustment for particular situations. The flexibility that the agroforestry focus is one of its advantages. Agroforestry systems limit risks and increase agriculture sustainability, both at a small and big scale. Also, they may be deemed to be main parts of the agricultural system itself, as it contains other subsystems that define a way of life. In order to plan on the use of trees in agroforestry systems, it is necessary to have a considerable knowledge of its properties. Information desirable for each species includes its benefits, its adaptability to local conditions (weather, soil and stress), the size and shape of the canopy, root system and the suitability of several agroforestry practices (Martin *et al*., 2007). It is also recommended that the potential shown by each agroforestry plantation has to be foreseen as a shelter for the preservation of biodiversity, both in vegetables and animals. Although CEDERSSA (2011) reports that the contribution of 1% to the gross domestic product (PIB) from forest activity in Mexico has little significance, its presence in national life has great importance, as its spaces are environmental service suppliers.

The combination of trees and crops is an association between different beings that coexist and commonly differ in economic yields. As for coffee plantations in agroforestry systems, the combination has to be made with trees of which lesser profits would be expected. Therefore, the introduction thereof in crops should no cause losses in productivity, no matter how valuable the environmental service is. The task is to know, identify and integrate forest and agronomic technologies both to silviculture and agriculture. For this, the knowledge of rural social traditions and the abilities in human relations should be supported (Farfán, 2014). If this is established under the shade of an adequate species and distance, coffee may produce the same as if it were under free exposure, depending on the variety of used clones. In productivity terms, there are contrasting results. Lymbaeck *et al*. (2001) found that the productivity average in organic coffee farms is 23% lower than the production of conventional farms. While Villarreal *et al*. (2002), state that the production average in organic production systems of the Mesa de los Santos farm in Santander, Colombia was 20% greater than the production of technical conventional farms.

Research performed by Farfán (2010) that compare organic coffee grown under the sun and organic under the shade in environmental conditions of Colombia indicate that it had a greater harvest in the first century under the handling under full sun; nevertheless, after the plantation cycle, the production is similar, except for seeding densities in the growing process. The handling of organic coffee under the shadow recommends the installation of densities greater than 4,000 plants ha^{-1}; also, it does not recommend growing coffee under full sun with organic handling. There are no sufficient studies that allow comparing results of other countries with Mexico or even perform comparisons between Mexican coffee regions and states. For this, in order to preserve biotic resources of the central Veracruz coffee region, it is necessary to assess the environmental impact of the entire removal in order to grow coffee at full solar exposure or to introduce yearly crops. The shades of traditional polycultures, in combination with banana, ice cream bean or citrus, contribute to maintaining soil fertility, as well as reducing erosion, supplying organic matter produced by litter and fixing atmospheric nitrogen. In the short term, the full sun coffee growth may produce satisfactory results for the economy; nevertheless, the suppression of the tree stratum in a fog zone, just like the central part of Veracruz, may have terrible consequences in the long run (Barradas & Fanjul, 1984) (Figure 1). In turn, Contreras & Osorio (2015) recognize that the coffee-growing regions in Veracruz were defined decades ago and, currently, the manner in which the coffee crisis modified this production zones is not known. Therefore, it is pertinent to analyze the evolution of coffee-growing regions and redefine those regions known for their new characteristics. Interdisciplinary studies supported by conceptual agroecology frameworks, social anthropology and rural sociology that help actors

Figure. 1. Example of current situation of land with the coffee agroforestry system in the municipality of Tlacotepec de Mejía, Veracruz, Mexico. November 2018.

involved in the production to identify and overcome challenges associated to the development of sustainable handling strategies in the agricultural sector are required.

There is little information related to functions, structure and benefits of the coffee-growing agroforestry system, reason why the performance of studies that reveal the influence of tree species used as a shade in coffee plantations is justified. Even when institutions that do research to this respect have international reputation, the information obtained in Colombia and Costa Rica, which also attains the first places in biodiversity shelter may not be compared. Tree species that exist in combination with coffee plants in some coffee-growing zones in the states of Chiapas and Veracruz in are known in studies performed by Colegio de Postgraduados, ECOSUR, Instituto de Ecología A. C., Colegio de Veracruz, Universidad Veracruzana, Universidad Nacional Autónoma de México and Universidad Autónoma Chapingo. What happens to other coffee-growing states in Mexico?

CONCLUSIONS

Forest specialists both in agronomy and agroecology recognize that polycultures, agroforestry and other diversification methods imitate the natural ecological processes and that the sustainability of complex agroecosystems is based on the ecological models that are followed by these production methods. It is recognized that, depending on variety, coffee has greater yields in monoculture or plantations without employing shade; although these systems are not favorable for the preservation of the environment and biota, as its modernization considers an indiscriminate use of agrochemicals. The employment of shade in the coffee-grown area has been documented and the biodiversity, absorption of water and nutritious contribution of trees in the coffee plantation, contribute with other products such as timber, wood or fruits, necessary for the agroecosystem's self-supply. It is suggested to do further research related to agroforestry systems in general with the coffee-growing agroforestry system in Mexico, as the information available is scarce, as even the contribution of the coffee agroforestry system to the Mexican coffee-growing industry is known.

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