Agroforestry Systems, vol. 96, 2022, pp. 491-503.

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Agroforest Syst (2022) 96:491–503
https://doi.org/10.1007/s10457-021-00692-w

Traditional agroforestry systems: a methodological proposal for its analysis, intervention, and development

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Received: 21 January 2021 / Accepted: 17 September 2021 / Published online: 29 September 2021

Abstract Agroforestry is an interdisciplinary science that allows the sustainable use of the land and promotes a holistic management of its components, such as trees, crops, and animals. In the last 40 years, when merging the producers' traditional knowledge and the scientific advances on sustainability, these systems have demonstrated to be sustainable. Traditional agroforestry systems (TAS) are contemporary to the discovery of agriculture while agroforestry was established as a science in the second half of the last century. As in any other science, agroforestry research applies the scientific method and for the process of intervention and development of agroforestry systems there are several proposals, for example, one is the Design and Diagnosis (D&D) method. The main objective of this research is to find the method to diagnose of the TAS which allows the necessary intervention for sustainable development. For this purpose, studies were carried out in 12 farming communities located in the Sierra de Huautla, Morelos, Mexico, by using the Theory of Comparative Agriculture described by Cochet, adjusted to the methodology used by Apollin and Eberhart in 1999, for the diagnosis and analysis of production systems in rural areas. As result, the methodology highlights the importance and complexity of TAS and the need to address them with a system approach, as well as the perspective and vision of TAS users in the holistic improvement of their production system.

Keywords Ethno-agroforestry · Comparative agriculture · Diagnosis and design · Sustainable agriculture

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10457-021-00692-w.

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Introduction

On a global scale, society faces two major problems: hunger and poverty. Paradoxically, while food imports are increasing, food dependency in poor countries is also increasing. Therefore, it is urgent to take measures to modify the forms of production, transformation, distribution, and consumption of food, to satisfy the growing demand for food in the world market (Boff 2003). Due to the irrational use of agricultural technologies for productivity, promoted by government policies and adopted by producers in many countries, mostly located in tropical and subtropical regions, natural resources, necessary to promote forestry and agricultural development, are suffering accelerated deterioration (Alonso 2011). Thus, during the twentieth century, changes occurred in the global agri-food system, radically altering the pre-existing relationship between farmers and nature (Toledo and Barrera 2008). The existence of TAS dates to the beginnings of agriculture and continues to the present day. However, recognition of Agroforestry as a scientific discipline is recent (Nair 1993, 2012). Agroforestry research applies the scientific method, and for the intervention process the Design and Diagnosis (D&D) method (ICFRAF 1993).

Ethno-agroforestry requires an emerging research approach for the study of traditional agroforestry systems (practices, components, and interactions), which have been designed, established, developed, and managed by indigenous peasant communities. Thus, the scientific research field of agroforestry is in continuous theoretical-methodological development (Moreno et al. 2014).

In this new research approach, the family production unit (FPU) is used as the experimental unit, as established by the Inter-American Institute for Agricultural Cooperation (IICA 2016). It considers family farming as the form of social production that, primarily, uses labor from among family members and, occasionally, salaried labor, with little use of agricultural inputs; likewise, it considers that production is for self-consumption and, occasionally, it is sold. This type of agriculture exercises real control over the minimum endowment of means of production, including land (Almada and Barril 2006). Thus, the study of FPUs is complex, since they are diverse and present a dynamic reality, based on the interest of each FPU according to the different levels of access to the factors of production (land, labor, and capital). Thus, the evolution of each type of UFPs is defined by the set of ecological, technical, social, and economic factors and by the interconnection between them (García 1999).

Ozelame et al. (2002), proposes a new way of studying agriculture through systems theory as an instrument for understanding the complexity of each way of farming. The systems approach helps to perceive the historical transformations and geographical differentiation of the various types of agricultural production. According to Dufumier (1996), the fundamental element for understanding the type of land exploitation at the FPU level is the concept of production system, defined as the combination (in time and space) of available resources, labor force and means of production (land and capital) for agricultural, livestock and forestry production, since, in general, the FPU operates under different environmental and socioeconomic conditions. The differences between FPUs have to do with the conditions of access to and ownership of land, natural resources, available information, public services, markets, and financial resources, such as credit, knowledge, and available labor (Silva and Basso 2005).

Given the need to analyze the rural reality in its totality before any intervention and, in view of the corresponding methodological gab, the present study aims to analyze the TAS by applying the agrarian diagnosis methodology, which leads to the construction of forms of intervention and sustainable development of the FPU. The objective is to generate proposals for intervention and development of TAS, adequate to the needs, conditions, and aspirations of the FPU. The objective is to generate proposals for intervention and development of the TAS, appropriate to the needs, conditions, and aspirations of the FPU. The referent of this research is traditional knowledge, the object of study is family farming, and the approach is the Agroforestry Production System.

Methodology

The Sierra de Huautla Biosphere Reserve is in the southern part of the state of Morelos, Mexico, and is bordered to the south by the states of Guerrero and Puebla. It covers an area of approximately 59,031 ha, with altitudinal levels ranging from 700 to 2200 m above sea level (Fig. 1). The coordinates are 18° 20’ to 18° 35’ north latitude and 98° 51’ to 99° 24’ west longitude (Dorado et al. 2005). The dominant climate is Aw0 (w) (i’) g, the driest of the sub-humid climates, with rainfall in summer and less than 5% precipitation in winter; the average annual precipitation is 900 mm, the average annual temperature is 25 °C, with annual oscillations of average monthly temperatures between 5 and 7 °C (García 2004). The predominant soils are the Haplic Feozems and Luvic Feozems; where Chromic Luvisols, and Lithosols are more abundant,

Fig. 1 Geographic location of the Sierra de Huautla, Morelos, Mexico. Elaborated by Patricia Ruiz García and Jesús David Gómez Díaz

presenting a lithic phase, with a rocky bed between 10 and 20 cm deep (INIFAP 1995). Land use is given by semi-extensive cattle activity of bovine cattle and seasonal agriculture with annual crops linked to the feeding of the cattle (INEGI 2001; Uribe et al. 2015). The dominant vegetation is the low deciduous forest (Miranda and Hernández 1963) which is characterized by the presence of trees of 4 to 10 m in height. The dominant plant families are Fabaceae, Euphorbiaceous, Burseraceae and Bombacaceae (Rzedowski 2006), and the representative tree species in the agroforestry livestock systems of the Sierra de Huautla are: *Bursera bipinnata*, *Amphipterygium adstringens*, *Crescentia alata*, *Acacia cochliacantha*, *Randia echinocarpa*, *Guazuma ulmifolia*, *Gliricidia sepium*, Haematxylum brasiletto, *Vitex pyramidata*, *Lonchocarpus rugosus*, *Mimosa benthamii*, *Lysiloma acapulcense*, *Lysiloma divaricatum*, *Conzattia multiflora*, *Bursera simaruba*, *Opuntia* spp., *Ceiba parvifolia*, *Eysenhardtia polystachia*, *Ipomoea arborescens*, *Malpighia mexicana*, *Pitecellobum dulce*, *Bursera aloexylon*, *Jacaratia mexicana*, *Stemmadenia pubescens* (Dorado et al. 2005; Burgos 2016).

The research methodology "Agrarian Diagnosis" was developed by schools of thought of some agronomy universities in France. This methodological proposal has been enriched with diverse experiences of rural diagnosis and analysis carried out in Latin America and Mexico. The agrarian diagnosis on based on the Agrarian Systems theory developed by Mazoyer and collaborators of the Institute National Agronomique Paris-Grignon—INA/PG, France (FAO 1999). This methodology is based on several information gathering tools: (1) conducting transects and landscape readings with the support of producers to inquire about the biophysical conditions of the study area; (2) recording observations made by participants in the study area for a given time; (3) conducting historical interviews with former producers in the area; (4) conducting technical–economic interviews with those responsible for the FPU; (6) developing typologies of producers; and (5) sharing preliminary results with those responsible for the FPU. The interviews were carried out on field trips according to what was proposed by Mesa (1996). These work tools highlight the importance of observation and knowledge of local actors, since the interviews contain open and semi-open questions to capture the farmer's logic in which the respondent is free to answer the proposed questions, favoring fluent speech (Guzmán and Alonso 2007).

With the pertinent modifications, the Theory of Comparative Agriculture (Cochet 2016) and the agrarian diagnosis methodology of Apollin and Eberhart (1999) were used for the study of TAS in 12 peasant communities established in the Sierra de Huautla, Morelos, Mexico. Based on the analysis of the collected data, proposals for intervention and development of the TAS were elaborated. Out of 3,351 FPU established in 31 communities of the Sierra de Huautla (INEGI, 2007), 1,380 FPU were studied. The communities under study was Ajuchitlán, Huautla, Quilamula, San José de Pala, Ixtlilco el Grande, Ixtlilco el Chico, El Limón de Cuauchichinola, Los Sauces, La Tigra, El Zapote, Tilzapotla, and Los Tanques.

To obtain information on the study area, secondary data was collected from books, journals, projects, previous studies, articles, guides, web pages, maps, media, and databases. In addition, physiographic, relief, hydrological, geological, edaphic, climatic, land use and vegetation maps were analyzed, as well as some socioeconomic aspects of the populations studied. Fieldwork was carried out using the following tools: (1) direct observation through field visits; (2) opinions with producers; (3) semi-structured interviews and surveys; and (4) community workshops to socialize information. The interview was open-ended, in which the interviewee was free to answer the questions (Guzmán and Alonso 2007) and was conducted on the plot of each informant according to Jiménez (1995). The reconstruction of the history of the peasant communities was done using the methodology proposed by Brun (2005) with the assumption that the current socio-economic situation of these communities has its roots in its history.

The criteria for determining the typology of producers in three categories were: availability of land, number of cattle herds, combination of agricultural, livestock and forestry subsystems, level of intensification of their labor force, differentiated capital accumulation processes. Through the evaluation of these criteria, the socioeconomic analysis of the FPUs was carried out.

For the technical–economic characterization of the production systems, the methodology generated by Dufumier and Couto (2007) was used. For this purpose, the agronomic logic of the different agricultural, livestock and forestry subsystems was identified, according to the agroecological and socioeconomic context of each category of FPU. The following indicators were also determined: gross value added (GVA); net value added (NVA) and economic depreciation. To compare the different production systems, NVA was related to the area of cultivated, and to compare the degree of intensification of the production system. Likewise, NVA/MLU (net value added/man labor unit) was estimated to calculate the annual wealth created by the MLU, which represents the net daily productivity of the work performed. Likewise, the total family income (TFI) was estimated using the formula TFI = (NVA—Taxes—Interest—Wages—Rents + Subsidies), which represents the average annual remuneration that the family receives after paying social redistributions to the state including subsidies granted to the family nucleus by the government.

Since the TFI represents the family's capacity to cover essential economic needs and allows making the productive investments required for the renewal and modernization of the farm, it was necessary to incorporate the following concepts: economic replacement threshold assuming a low income level whereby the UPF can't ensure the renewal of the capital and the subsistence of the family in extreme poverty; Survival threshold with the minimum income that the FPU must obtain to ensure the subsistence of all family members.

The overall annual cost to cover the family's basic needs (food products, health, clothing, and education) was estimated as proposed by Devienne and Wybrecht (2003). The minimum welfare line (MWL) equivalent to the cost of the basic food basket in rural areas was determined in December 2017 considering the information provided by Jiménez (2017), which was estimated at $ 1066.58 MXN (One thousand sixty-six pesos 58/100 MXN) per month per family member. The basic welfare line (BWL) equivalent to the monthly cost of basic needs (food, clothing, health, and education) per person in rural areas estimated in December 2017 (Jiménez 2017) was 1930.78 pesos (MXN). An important part of the fieldwork was the presentation of results to the FPU managers, in order, to get their opinions and feedback. During these meetings, it was possible to analyze the prospects for agriculture in the study region and to highlight new lines of reflection for future actions.

The sample size was obtained using the saturation method proposed by Morse (1995). The average population per community was 115 FPUs, while the saturation point was 45 surveys, representing 39.13% of the existing FPUs. For data analysis, descriptive statistical tools were used to evaluate the variables that characterize the UPF.

Results

Landscape reading

By reading the landscape, three well-defined agroecological zones were identified in the communities under study (Fig. 2).

Silvopastoral system

The area where this agroforestry management system is developed has slopes of 30 to 55% and the cattle herd is managed extensively during the rainy season; in addition, firewood, fence posts and non-timber forest resources such as fruits, bark, or resins and seeds are extracted. In this agroforestry system there is no clear territorial arrangement of plant resource use, since it consists of the spontaneous growth of trees, and shrubs and herbaceous plants. The grazing activity occurs in the understory of the deciduous forest where cattle consume herbaceous plants, shrubs and foliage, and flowers and fruits of native trees. It is important to note that the management and use of forage resources in this silvopastoral system is the result of a strategy perfected over time by several generations of producers, where forest, forage and food resources are shared among producers on common land. The representative tree species of the silvopastoral system are: *Haematoxilum brasiletto*, *Conzattia multiflora*, *Lysiloma divaricata*, *Bursera bipinnata*, *Bursera simaruba*, *Mimosa benthamii*, *Guazuma ulmifolia*, *Gliricidia sepium*, *Lysiloma divaricatum*, *Opuntia* spp., *Ceiba parvifolia*, *Eysenhardtia polystachia*, *Crescentia*

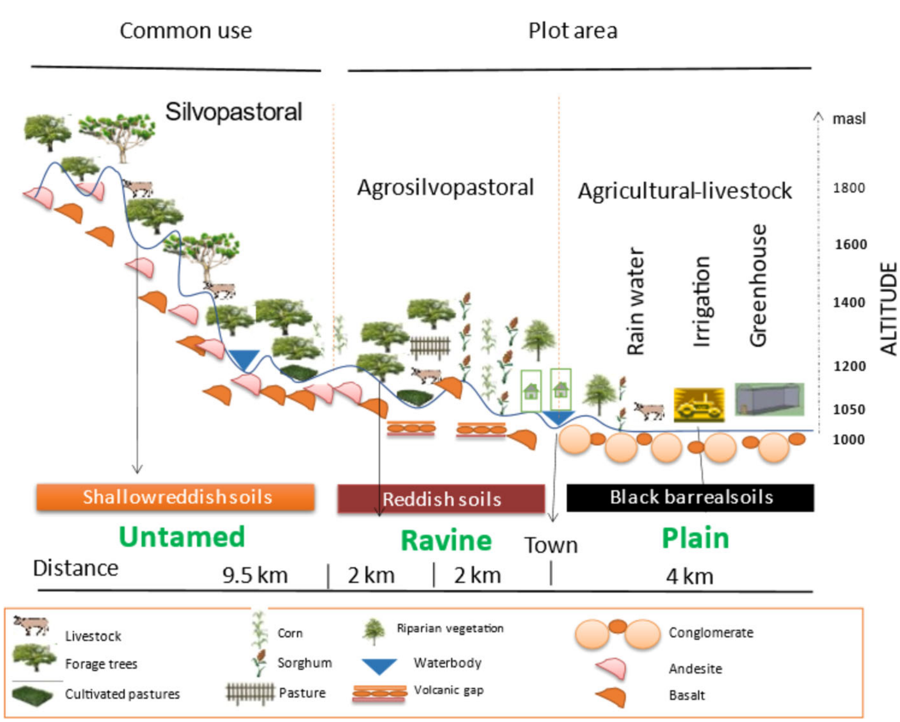

Fig. 2 Description of the topographic profile and traditional agroforestry systems in the Sierra de Huautla, Morelos, Mexico

alata, *Lysiloma acapulcense* and *Ipomoea arborescens*.

Agrosilvopastoral System

This agroforestry system is in the middle zone of the altitudinal profile where there is a topography with slopes of 15–30% and conditions are favorable for agriculture through the planting of corn (*Zea mays*), sorghum (*Sorghum vulgare*) and introduced grasses such as *Andropogon gayanus*. The tree species present are used for fodder, fruit, or medicinal purposes and for firewood and fence posts. The extraction of firewood for domestic use, fence posts and trees and shrubs for fodder use is important for the farm family and for the stability of the FPU. The agroforestry designs in this system are crops in alleys, trees dispersed in pastures and crops and live fences, where the selection characteristics of the trees are of multiples use and with a spatial distribution that allows the growth of pastures or some crops. The representative tree species of the Agrosilvopastoral System are *Acacia cochliacantha*, *Guazuma ulmifolia*, *Mimosa benthamii*, *Lysiloma divaricatum*, *Crescentia alata*, *Amphipterygium adstringens*, *Haematoxilum brasiletto*, *Gliricidia sepium*, *Pithecellobium dulce*, *Bursera aloexylon*, *Lysiloma acapulcense*, *Ipomoea arborescens*.

Agricultural-livestock system

This agroforestry system is in areas with gentle or flat slopes where the tree component is not the most important because the soil types have an average depth of 80 to 100 cm, which allows the planting and development of corn, sorghum and vegetable crops and the use of agricultural machinery. This system concentrates most of the agricultural production of corn, sorghum and vegetables in areas divided by fences of dead posts and live fences. For this reason, tree diversity is low. The main objective in this system is agricultural production, and the agroforestry technologies are live fences and trees at the edges of the plots with tree species such as: *Crescentia alata*, *Gliricidia sepium*, *Malpighia mexicana*, *Guzuma ulmifolia*, *Pithecellobium dulce*, *Bursera aloexylon*, *Jacaratia mexicana*, *Stemmadenia pubescens*, *Lonchocarpus rugosus* and *Vitex pyramidata.*

The first agroecological zone is located between 1400 and 1600 m above sea level (masl), where a silvopastoral system is used for livestock grazing with the native tree, shrub, and herbaceous vegetation. The second agroecological zone is located at altitudes between 1200 and 1400 masl, where the predominant agroforestry system uses woody and herbaceous species, annual crops, and animals mainly cattle. The third agroecological zone is located between 1000 and 1200 masl, where the agricultural-livestock production system is predominant with seasonal corn, sorghum, and beans (*Phaseolus vulgaris*) crops used to feed livestock during the dry season.

The analysis and systematization of the information made it possible to identify in the Sierra de Huautla the agroforestry livestock production systems whose main product is the sale of recently weaned calves with a live weight between 180 and 220 kg, and cull cows, with which the producer obtains cash income. On average, calves are sold at 200 kg at 8 months of age. However, when the market price is high, the producer does not milk the cow and the calf drinks all the milk produced by the cow, so calves are weaned at higher body weight and the producer earns more income from calf sales. Conversely, when calf prices are low, the producer milks the cows to produce fresh cheese and the calf may be weaned at less than 200 kg. Because cattle genotypes and pasture conditions are similar in the region, body weight and age of calves at sale are also similar in both the silvopastoral and agrosilvopastoral systems. The predominant type of cattle is Zebu (*Bos indicus*) crossbred with *Bos taurus*, mainly Brown Swiss.

History of the rural environment

The dynamics and evolution of the FPU's agricultural activities and practices, which were recorded in interviews with the oldest producers in the region and through bibliographic consultation on agrarian history, made it possible to identify different production systems that followed one another over time (Fig. 3). The reconstruction of the agricultural history of the study region through the timeline identified the mechanisms of technical and social reproduction of the production systems. Thus, the periods of homogeneous functioning and the ruptures that signal the end of a mode of land exploitation and the recompositing of the landscape from the agro-ecological, technical,

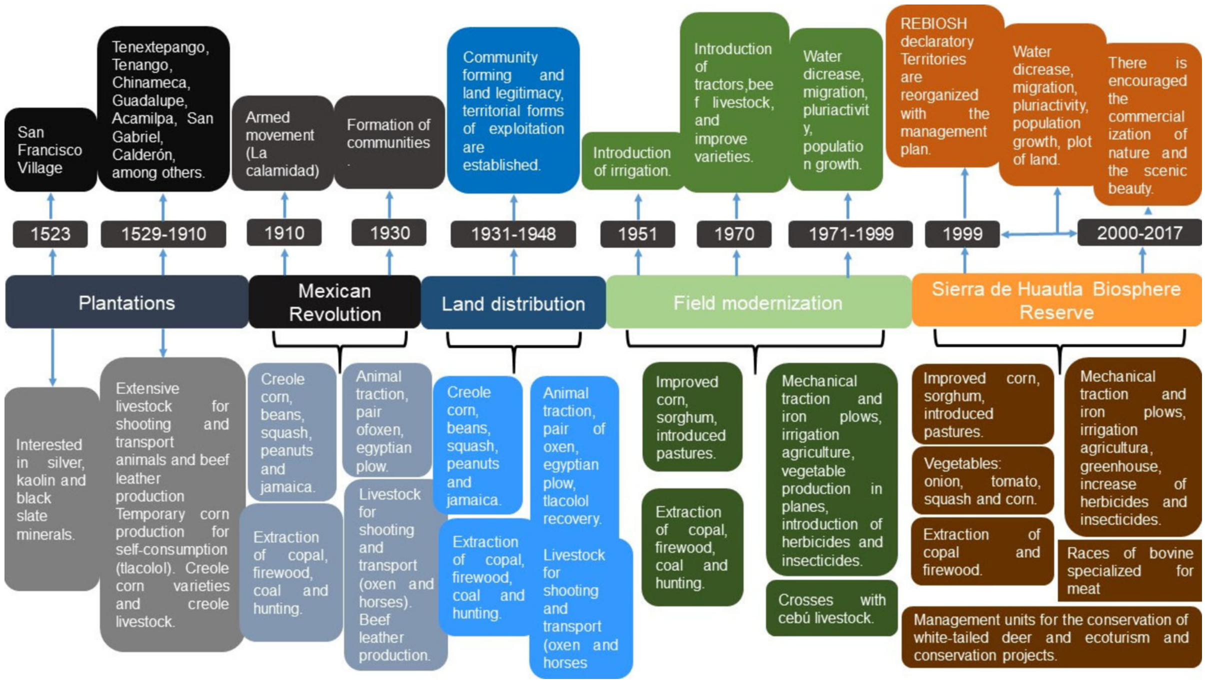

Fig. 3 Diagram of the agricultural history of the Sierra de Huautla, Morelos, Mexico

and socio-economic changes that resulted in the current agroforestry production systems were located. Historical periods that took place in the Sierra de Huautla region were the following: La Hacienda, Mexican Revolution, Agrarian Distribution, Modernization of the Countryside, and creation of the Sierra de Huautla Biosphere Reserve. The Agroforestry Livestock System has its origins in the colonial period when Spanish hacienda owners introduced cattle.

FPU typology

The analysis and systematization of the information showed that there is heterogeneity within each agroecological zone, and therefore the FPU typology was constructed. Based on the availability of land, the number of breeding cows, level of labor intensification and the differentiated capital accumulation process, three categories were identified. The socioeconomic characterization of each FPU category is presented in Table 1.

The analysis of the production systems and the typology of producers allowed us to develop the appropriate intervention strategies for each type of FPU (Table 2).

Category I. Decapitalized FPU with little equipment for agricultural and livestock production, with the use of pasture rent and sale of labor. The surface area of these FPUs is 10 to 15 ha distributed in 2 to 3 farms for the cultivation of corn (1 ha), beans (0.3 ha), sorghum (1 ha) and pasture (7.7 ha). Agricultural production is oriented towards self-consumption and backyard livestock raising is also practiced with minor species (poultry and pigs) for self-consumption or to save money. Crop residues are sold to those in charge of other UPFs that own livestock. These families supplement their income by extracting and collecting timber and non-timber products from grazing land. They receive subsidies from the government, as the production system does not allow them to meet their basic needs and they often must sell their labor power to survive. These UPF represent 40% of the communities studied in the Sierra de Huautla. In this category of producers, young people migrate to other cities in Mexico and to other countries in search of better employment opportunities.

Category II. Little-equipped FPU that grow corn and beans, have small herds of cattle that use the land for grazing, although some family members eventually sell their labor. The UPFs have land areas between

Table 1 Indicators of economic development of the Family Production Units (FPU) in the peasant communities of the Sierra de Huautla, Morelos, Mexico

Indicators per FPU	Category I	Category II	Category III
Number of FPU members	5	5	5
Man labor units (MLU)	3	3	3
Total land area (ha)	10 a 15	15–40	40+
Rented land (ha)	0	0	12
Gross product ($)	42,677.06	91,602.81	208,865.31
Intermediate consumption ($)	9421.99	39,329.41	86,629.50
Gross value added (GVA) ($)	33,255.07	52,273.40	122,235.81
Depreciation ($)	3214.70	5201.36	20,142.00
Net value added (NVA) ($)	30,040.37	47,072.04	102,093.81
Value of contracted wages ($)	0	0	10,500.00
Freight and rental costs ($)	3425.00	4675.00	6850.00
Land rental income ($)	8600.00	0	0
Cost of land rental ($)	0	0	8600.00
Government support income ($)	2,251.90	12,446.40	28,606.00
Total family income (TFI) ($)	37,467.27	54,843.44	104,749.81
Number of required wages	180	230	247
Value of the family wages ($)	208.15	238.45	424.09
Value of wages in the region	175.00	175.00	175.00
MWL per FPU member	1066.58	1066.58	1066.58
BWL per FPU member ($)	1930.80	1930.80	1930.80
Value of the annual wage in the region (220 days) ($)	38,500.00	38,500.00	38,500.00
MWL/FPU ($)	63,994.80	63,994.80	63,994.80
BWL per FPU ($)	115,848.00	115,848.00	115,848.00

MWL minimum welfare line, *BWL* basic welfare line; $ in MXN pesos

15 and 40 ha where they combine agricultural production with cattle and forestry with the sale of firewood and fence posts. On average, they cultivate 1.5 ha of corn and 1 ha of sorghum, which they use for self-consumption of grain and to feed their livestock with dry fodder during the dry season. The livestock sub-system is composed of cattle, equines, and backyard cattle. The equines are used in agricultural work as draft animals and the cattle herd is made up of 10 breeding cows. The families supplement their income by extracting and collecting timber and non-timber products from the grazing land. They also receive economic support from the government in the form of subsidies since the income from the production system does not cover the family's economic needs. These UFPs represent an average of 47% of the peasant communities studied.

Category III. Composed of well-equipped and capitalized FPUs that implement the agricultural, livestock and forestry production system and hire labor in the important crop activities as they have more than 40 ha of cropland. These FPUs combine agricultural, livestock and forestry activities, have the largest number of animals and the largest amount of goods produced. Cultivated areas can vary from 5 to 10 ha, either owned or rented. In addition, these FPUs grow improved pasture to feed livestock, grow corn (2 ha) for self-consumption and sorghum (3 ha) to feed livestock. They have a herd of up to 40 breeding cows and can rent more land for grazing during the dry season of the year. In addition, families in this category also receive government support in the form of subsidies. These UPFs carry out farming activities with family labor, although they often hire labor.

Table 2 Intervention proposals for the development of traditional agroforestry systems in the Sierra de Huautla, Morelos, Mexico

Agroforestry system	FPU category	Agroforestry technology	Agricuctural component	Animal component	Observations
Agrosilvopastoral	I	Living fences Trees scattered in crops	Corn, beans, castilla squash	The producer rents his land and sells the agricultural residues to category III FPUs	The selection of tree species depends on the collection activity to which the FPU is dedicated. The by-product from agricultural activity is sold to ranchers
Silvopastoral	I	Improved fallows	Induced pasture	The producer rents his land and sells the agricultural residues to category II and III FPUs	The tree species vary depending on the collection activity that the FPU is engaged in
Agrosilvopastoral	II	Living fences Trees scattered in crops	Yunta corn, sorghum, and beans	Mixed herd of dual-purpose cattle, sheep, goats and horses	The tree species vary depending on the collection activity to which the FPU is dedicated. Equines are your workforce
Silvopastoral	II	Improved fallows	Induced pasture	Livestock of dual-purpose cattle, sheep, goats and horses	The tree species vary depending on the collection activity to which the FPU is dedicated. Equines are your workforce
Agricultural livestock	III	Living fences Trees on boundaries	Corn, sorghum, vegetables, and greenhouses	Livestock of beef cattle	The FPUs do not want any agroforestry technology because it is an impediment to their mechanized crops and because they have little surface area with these characteristics. The by-product from agricultural activity is used to feed their livestock
Agrosilvopastoral	III	Scattered trees in paddocks Living fences Trees on boundaries	Corn, sorghum, induced pasture	Livestock of beef cattle	Capitalized ranchers who manage beef cattle and grow sorghum in contract farming. These FPU use energetic species to repair fences and forage to feed their livestock
Silvopastoral	III	Living fences Improved fallows	Induced pasture	Livestock of beef cattle	Capitalized ranchers who manage beef cattle and grow sorghum in contract farming These FPU use timber tree species to repair fences and forage to feed their livestock

These UPF represent an average of 13% of the peasant communities established in the Sierra de Huautla.

Discussion

The landscape reading identified the Livestock Agroforestry Production System (LAPS), which is based on the extensive use of available natural resources (soil, water, and vegetation) and is integrated by three Traditional Agroforestry Systems: (a) Silvopastoral System with livestock use of native herbaceous, shrub and tree vegetation. This agroforestry system involves the use of perennial woody species (trees and shrubs) and forages herbaceous species that interact with the animal component through an integrated management system; (b) Agrosilvopastoral system with woody and non-woody species, annual crops as well as animals, to produce food, medicinal plants, fodder, wood, and firewood. The most important crops being corn and sorghum, as well as small areas of induced pastures, and forest areas with native species of high importance value that are used to satisfy diverse economic, social and cultural needs of the peasant families; and (c) Agricultural-Livestock Production System with scattered trees, developing seasonal agricultural processes around the cultivation of corn and sorghum, which are of great importance for livestock feeding during the dry season when pastures are scarce in the region. These results are congruent with those reported by Apollin and Eberhart (1999), Burgos (2016) and by Uribe et al. (2015).

The information obtained in the field interviews showed that within each agroecological identified homogeneous zone, there are marked differences in the types of FPU, due to local variations in the agroecological environment and the socioeconomic differences that have historically existed among subsequent generations of farmers (Dufumier 1990). Therefore, the FPU typology established the differences between them, to form groups of FPU with common characteristics and needs. The research found three types of FPUs ranging from agriculture with hand tools and animal traction, to forms of production with elements derived from conventional agriculture with an advanced level of mechanization. FPU characteristics are like those reported by Dufumier (1996) and by Uribe et al. (2015).

The agricultural area of each production system was related to the degree of use of land and livestock resources. It is notorious that the use of labor force in all FPU categories is based on family labor, with no gender differences- In all cases the use of family labor is higher than hired labor. The FPUs in Category I do not have cattle and obtain lower incomes than those generated by the FPUs in Categories II and III which are holders of greater land area where they grow sorghum and produce cattle. Table 1 shows the different economic indicators of the FPU categories, where it is observed that the number of members per FPU is five and the number of man labor units is three, while the land area varies from 10 to more than 40 ha. Thus, the gross product depends on the factors of production (land, labor, and capital), as does the net annual income (NAI) and the income per unit of human labor.

The remuneration of labor invested in the different FPU activities by category is approximately \$208, \$238, and \$424 per day for the three categories, respectively, which represents labor productivity (Table 1). Thus, the total family income (TFI) of the different FPUs categories is directly dependent on plot size, labor intensification, presence and number of animals, and available technology. This information is like that reported by (Apollin and Eberhart 1999).

Figure 4 shows that the income of FPUs in categories I and II is not sufficient to reach the minimum welfare line (MWL), so the level of social reproduction is at risk. In contrast, for FPU in category III, income is higher than the MWL, so the productivity of workers' labor is sufficient to cover the family's needs, and there is still a surplus to expand its capacity for socioeconomic reproduction. When income and the replacement economic threshold were lower than the MWL, as happens in FPUs of categories I and II, it will not be possible to invest or develop and will not be able to satisfactorily replace the means of production, much less adequately remunerate family labor at market prices. Consequently, when there are better remunerated labor opportunities outside the FPU, peasant families will go out to sell their labor force (Apollin and Eberhart 1999; Uribe 2012; Uribe et al. 2015).

In FPU categories I and II, income was below the minimum welfare line and the social replacement threshold. However, these FPUs continue to exist because of selling their labor outside the FPU, which generates migration. This situation demonstrates that dual labor activity, resulting from the combination of agricultural activity and migration, can be a form of survival for these FPUs. However, this is not always the case for the new generations of the farming family, since small plots of land do not guarantee a promising future for the children, and they must migrate to other cities. Thus, in the medium or long term, the new members of the peasant families end up being expelled from the rural environment. Similar results to ours were previously found by Apollin and Eberhart (1999), Devienne and Wybrecht (2003), Brun (2005), and by Uribe (2012).

Since the FPUs will be the main protagonists of local development, they are the ones who will decide which innovations can be applied, considering their interests and their objectives, as well as their strategies. In summary, the contribution that this research makes to scientific knowledge is to analyze the perspectives of FPF through the agrarian diagnosis methodology to generate proposals for intervention

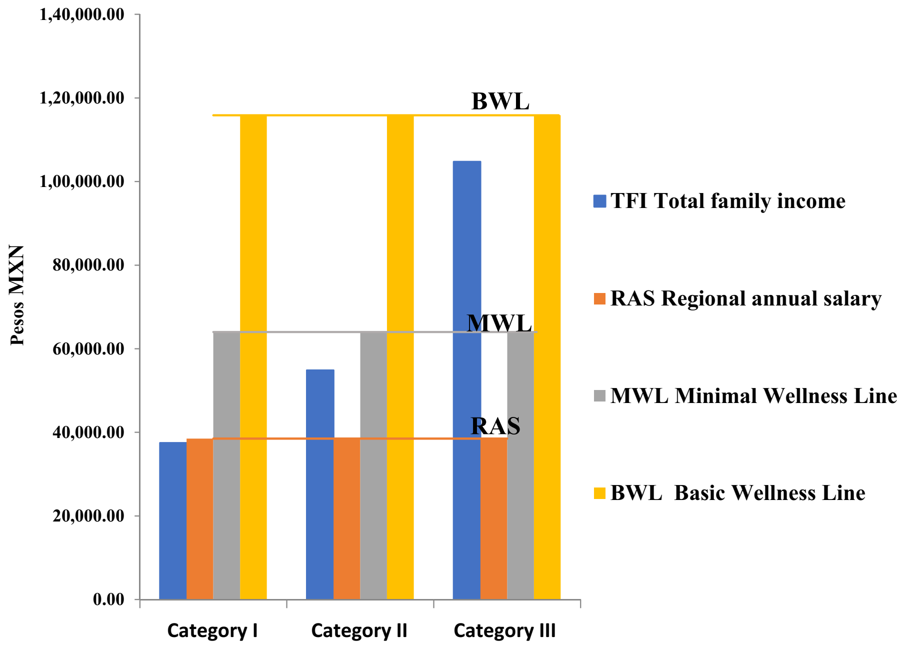

Fig. 4 Indicators of economic welfare of the Family Production Units (FPU) of the Sierra de Huautla, Morelos, Mexico

and development of traditional agroforestry systems, appropriate to the needs, conditions, and aspirations of producers, inducing an endogenous rural development.

Conclusions

In the peasant communities of the Sierra de Huautla, the biophysical and climatic conditions, defined by high slopes, shallow soils, dry season of more than six months with high temperatures, traditional agroforestry systems are developed as an option for agricultural production. In these traditional agroforestry systems, agricultural and forestry production are developed in function of cattle raising, so that cattle raising stimulates the other agricultural and livestock activities. The reconstruction of the agricultural history of the study region identified the technical and social reproduction of family production units, the succession and crisis of production systems. The chronological analysis of agricultural activities revealed periods of homogeneous functioning, as well as ruptures, signaling the end of a mode of exploitation and agroecological, technical and socioeconomic changes in current production systems. The differences and similarities of the family production units captured in the typology of producers are a function of the availability of natural resources, particularly land area, the intensification of the labor force and the use of technology. The family income of the production units depends directly on the size of the plot, the intensification of labor, the presence and quantity of animals and the available technology. Farming families located in categories I and II do not have sufficient income to reach the desired minimum welfare line, so their level of social reproduction is at risk and, despite this, they continue to exist by selling their labor force outside their production unit, which indicates migration. This double economic activity of the producers, resulting from migration and agricultural activity, is a relatively stable form of survival. However, in the medium term, the size of the plot of land is insufficient for the next generations, who will have to migrate for good, since, despite a certain capacity for resistance, the members of the new generations end up being expelled from the rural environment as agricultural producers. The diagnosis of family production units and their typology are essential prerequisites for generating development and agroforestry management proposals, based on the availability of productive resources, local knowledge of traditional knowledge and their cultural worldview. The diagnosis of family production units and their typology are essential prerequisites for generating development and agroforestry management proposals, based on the availability of productive resources, local knowledge of traditional knowledge and their cultural worldview. The Agrarian Diagnosis is a useful methodological tool for the development and management of traditional agroforestry systems.

Acknowledgements The authors thank the Consejo Nacional de Ciencia y Tecnología (CONACYT) for the scholarship granted to the first author and for funding this research.

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