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Article

Community land planning proposals with agroforestry approach in Xaltepuxtla, Puebla

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Abstract

In this research they were generated proposals for reconversion of traditional production systems to sustainable systems ornamental Xaltepuxtla, Puebla, whose land is dedicated to the cultivation of ornamental plants at the expense of endemic trees and shrubs of the mountain mesophilic forest. The proposals for management actions and detonating change projects are based on the interest of the producers and the potential of the land units, aligning them with the attention needs indicated by the Puebla government and federal agencies. The proposals consider enrichment of acahuales, production of native species such as ferns and reforestation with species of commercial interest, as well as production and use of orchids and bromeliads, production of bamboo, grapefruit, chinese pomegranate and avocado, for which the forms of land, inventories of organic carbon in the soil, forest floor and aerial biomass including herbaceous, shrubs and trees. In the unit that proposes the establishment of a tilapia production module, the areas favorable for the construction of ponds and the availability of running water were defined, to which the different parameters to the water were determined and found to be suitable for this purpose. For the establishment of a module for honey production with meliponas, the place with protection and shade for this purpose was located and, in the project, to improve a mushroom mushroom production module, the area for the construction of the shed was located.

Keywords: agroecological zoning, biophysical diagnosis, participatory mapping, productive reconversion.

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Introduction

The biophysical diagnosis within the community territorial planning (Cordón *et al*., 2008) allows to know the biotic, abiotic and physiographic elements that interrelate in a natural environment. It is an indispensable requirement to plan the management and sustainability of natural resources, in addition, it allows identifying the potentialities and limitations of its resources for the benefit of the inhabitants that inhabit the area. Prior to the biophysical diagnosis, according to the methodology of community territorial planning (CONAFOR, 2007) modified to be applied at the farm level, two stages must be developed: the participatory workshop and the identification of bioproductive systems to intervene (Valencia-Trejo, 2020).

Xaltepuxtla is a community of Nahua and Totonaco origin, whose land is dedicated to the cultivation of ornamental plants at the expense of endemic trees and shrubs of the mountain mesophilic forest (BMM). This is fragmented, degraded and with less wealth, there is looting of firewood, fungi and plants, contamination of water bodies, involvement by tuzas, mistletoe and bad management practices such as stubble burning, as well as the extraction of plants with a bank of soil.

The results of the participatory workshop indicated that the cultivation of traditional ornamental plants is no longer profitable, most of the owners are older adults, there is abandonment of plots and insufficient resources in the productive link (Valencia-Trejo, 2020). The biophysical characterization of the study area indicated that 49% of the area is dedicated to the production of ornamentals, 22% will be used for restoration with BMM species and 8% has potential for agroforestry technologies. Based on these studies, this research aimed to generate proposals for productive reconversion of traditional ornamental production systems to sustainable systems through the application of agroforestry technologies in Xaltepuxtla, Puebla.

Materials and methods

According to the zoning of the areas assigned by the producers to initiate the productive reconversion within their lands (Valencia-Trejo, 2020). Field trips of the areas to intervene were carried out to assess the quality of the water resource to evaluate its potential for the production of tilapia, of the plant species present for the production of native species and carbon inventory. Table 1 describes the type of sampling applied to each property, activities carried out and their location (Figure 1). For the Cuctenco Farm, water sampling was carried out at three sites. S1 (ground floor pond), S2 (cement floor pond), S3 (river, pond supply point), with three repetitions per site.

Table 1. Biophysical sampling of the properties.

Farm	Owner	Sampling/activity	Sampling unit (UM)
Xoxocotla	Eleuteria Salas Vazquéz	Carbon inventory	S1-1
			S1-2
Xoxocotla	Enrique Salas Eslaba	Carbon inventory	S2-1
			S2-2
Ocotitla	Jose Luis Gutiérrez Castelán	Sampling of orchids and bromeliads	

Farm	Owner	Sampling/activity	Sampling unit (UM)
Cucpanco	Jose Luis Gutiérrez Castelán	Geopositioning of the areas (mushroom and meliponas cultivation)	
Cuctenco	Froilán Salas Vázquez	Water	S1
			S2
			S3
La Hortencia-Calistemo	Constantino Salas Vázquez	Carbon inventory	S3

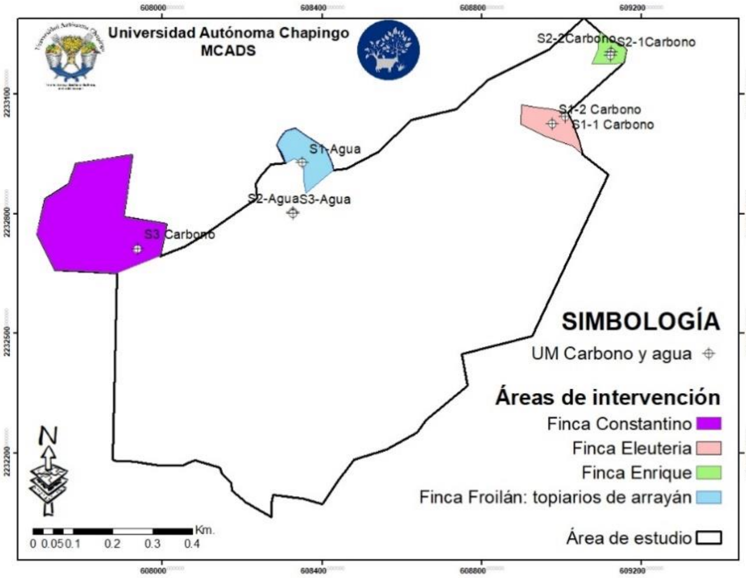

Figure 1. Units of biophysical sampling.

These samples were kept cold for the analysis of the chemical properties: pH, EC, total solids, P (Molybdate-Ammonium Vanadate method), K (flamometry), Ca, Mg, Fe, Mn, Cu, Zn (absorption atomic), S (turbidimetry), B (Azometin-H) according to the methodologies indicated by Álvarez-Sánchez and Marín-Campos (2015), turbidity (nephelometric) and biochemical oxygen demand (BOD_5) using the appliance method (Standards Mexican NMX-AA-028-SCFI-2001 and NMX-AA-038-SCFI-2001). In the Xoxocotla and Hortencia-Calistemo farms, the inventory of carbon reservoirs was carried out in accordance with the methodology proposed by the (IPCC, 2006; IPCC, 2007) in three components: a) live biomass of trees, shrubs and herbaceous; b) dead organic matter consisting of fallen branches and leaf leaf litter; and c) soil organic matter contained at depths of 0-6, 6-12, 12-18, 18-24 cm.

In order to reaffirm and obtain more information on the areas to intervene in each property, a semi-structured interview was conducted with each participating producer called the farm plan (Palma and Cruz, 2010), in which the general information of the farm was considered , age of the producer, vision, current situation, available labor, productive activities, limitations, opportunities, actions/projects to be followed and financing.

Results and discussion

Characteristics of the resources of the conversion areas

Based on the results of the participatory mapping of field trips and farm geo-positioning (Valencia-Trejo, 2020), the map of areas of productive reconversion and detonating change projects was generated (Figure 2).

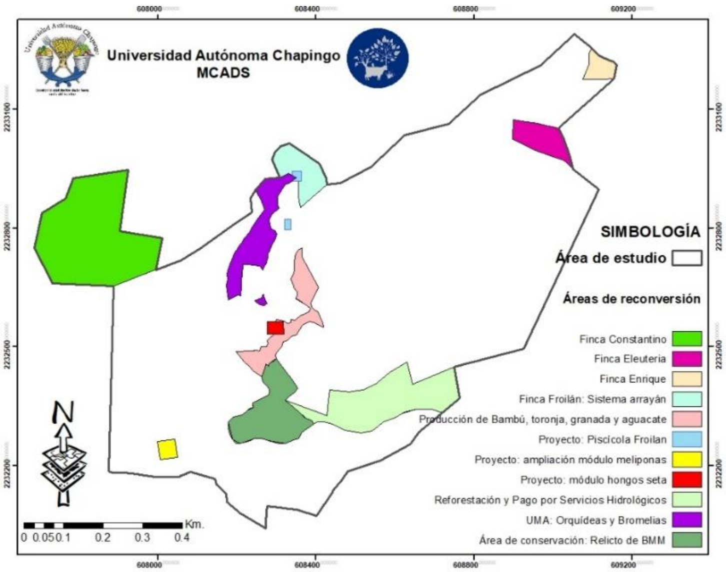

Figure 2. Map of conversion areas and detonation projects of change.

Water quality for the production of tilapia (*Oreochromis niloticus*)

The growth and reproduction of fish depends on the quality of the water, for this, it is necessary to maintain the physical-chemical conditions within the limits of tolerance for the species (Bautista and Ruiz, 2011). Quality is determined by temperature, oxygen, pH and transparency (Saavedra, 2003). The recommended physicochemical parameters are shown in Table 2.

Table 2. Recommended physicochemical parameters for tilapia culture.

Parameters	Optimum	Limits
Temperature	24 ºC-29 ºC	<22 < 32 ºC
Dissolved oxygen	<5 mg L^{-1}	>3 mg L^{-1}
pH	7.5	<6.5 - ≤ 8.5
CO_2	<30 mg L^{-1}	<50 mg L^{-1}
Ammonium	0.1 mg L^{-1}	<0.1 mg L^{-1}
Nitrites	4.6 mg L^{-1}	<5 mg L^{-1}
Salinity	0.024 mg L^{-1}	
Turbidity	25 UNT	<30 UNT

Parameters	Optimum	Limits
	Rank	
Total alkalinity	50-150 mg L^{-1}	
Total hardness	80-110 mg L^{-1}	
Calcium	60-120 mg L^{-1}	
Nitrates	1.5-2.0 mg L^{-1}	
Iron	0.05-0.2 mg L^{-1}	
Phosphates	0.15-0.2 mg L^{-1}	
Hydrogen sulfide	0.01 mg L^{-1}	

Source: Saavedra, 2003; SAGARPA, 2012. UNT= nephelometric turbidity units.

The analysis of water in the farm showed an optimum pH, without salt problem, the electrical conductivity is low, the total soluble solids (SST) for site 1 and 3 are of excellent water quality, exception class, site 2 it presents good quality, surface waters with low suspended solids content, generally natural conditions, favors the conservation of aquatic communities and unrestricted agricultural irrigation. Biochemical oxygen demand (BOD_5) is an indispensable parameter to determine the state or quality of water in rivers, lakes, lagoons or effluents. This indicates uncontaminated water of excellent quality at sites 1 and 2. In the case of site 3 the water quality is good, surface waters with low biodegradable organic matter content. Turbidity is in the optimal range at all sites, less than 25 UNT.

According to the WHO hardness classification, the three sites are in the range of 0-60 mg L^{-1} calcium carbonate, classified as soft water; low calcium and magnesium content (OMS, 2006) with optimal range of hardness for fish culture (20 to 350 mg L^{-1} $CaCO_3$, (Meyer, 2004) at site 2. For site 1, the Liming of the pond (Arboleda, 2006). No heavy metal contamination, zinc, manganese and copper were found in traces at all sites; however, the iron at site 1 has values greater than recommended (Table 3). To solve this limitation, it will be necessary to filter the water through zeolite (Petkova, 2013).

Table 3. Average values of the physical-chemical analysis of water variables.

Site	pH	EC	SST	DBO5	Turbidity	P-PO4	K	Ca	Mg	$CaCO_3$	S-SO4	Fe
		(µS cm^{-1})	(ppm)	(mg O_2 L^{-1})	(UNT)	(mg L^{-1})						
S1	6.53	13.28	5.9	2.63	11	2.94	0.3	0.96	0.34	3.8	0	0.37
s	0.03	0.31	0.15	0.44	0	0	0.02	0.01	0	0.02	0	0.02
S2	7.02	58.97	29.4	2.23	2	2.94	0.6	7.2	0.74	21.88	0	0.04
s	0.06	0.81	0.72	0.25	0	0.00	0.01	0.52	0	0.48	0	0.01
S3	6.8	13.74	7.1	3.12	11	1.47	0.33	0.97	0.3	3.7	2.83	0.09
s	0.06	0.07	0.15	0.18	0	0	0.01	0.02	0	0.07	0.58	0.01

SST= suspended solids, ≤ 25 excellent water quality, exception class (SEMARNAT, 2012). SST $25 < SST \leq 75$ good quality, surface water with low suspended solids content, generally natural conditions. It favors the conservation of aquatic communities and unrestricted agricultural irrigation (SEMARNAT, 2012). $DBO_5 \leq 3$ excellent, uncontaminated water quality (SEMARNAT, 2012); $3 < DBO_5 \leq 6$ good water quality, surface water with low biodegradable organic matter content (SEMARNAT, 2012). UNT= nephelometric turbidity units. s= standard deviation.

Carbon warehouses

Table 4 shows the carbon present in mulch, woody, leaf litter and herbaceous areas of the land destined for the enrichment of acahuales and reproduction of native species, as productive reconversion projects. The site (S3) Acahual la Hortencia-Calistemo Farm presented 0.88 Mg ha^{-1} C in leaf litter and 9.25 Mg ha^{-1} C in mulch. The site (S2-1) Acahual 1 Xoxocotla Farm with 1.82 Mg ha C in leaf litter and 1.65 Mg ha^{-1} in mulch.

Table 4. Carbon in forest floor: mulch, dry woody, leaf litter and aerial herbaceous biomass.

UM	Component	Weight (g)	Biomass (Mg ha^{-1})	C (%)	Reference	Carbon (Mg ha^{-1})
S2-1	Mulch	588.13	5.88	28	(Gómez *et al*., 2012)	1.65
S2-1	Woody	121.84	1.22	50	(Gómez, 2008)	0.61
S2-1	Leaf litter	454.42	4.54	40	(Gómez, 2008)	1.82
S2-1	Herbaceous	29.22	0.29	40	(De la Cruz-Osorio, 2015)	0.12
S3	Mulch	3302.69	33.03	28	(Gómez *et al*., 2012)	9.25
S3	Leaf litter	219.75	2.20	40	(Gómez, 2008)	0.88
S3	Woody	192.03	1.92	50	(Gómez, 2008)	0.96

S2-1= acahual Farm Xoxocotla-Enrique; S3= Acahual Farm Hortencia-Calistemo.

The study of carbon warehouses conducted by Ruiz (2016) in traditional ornamental cultivation systems and a BMM relic in Xaltepuxtla, in the BMM system estimated leaf litter carbon content of 0.63 Mg ha^{-1} and 1.09 Mg ha^{-1} in mulch. These results indicate that it took 20 years of rest from the land to allow the resilience of carbon sites. It should be noted, S3 of the Hortencia-Calistemo Farm with a high accumulation of mulch (9.25 Mg ha^{-1}), is because the dominant tree species are pines and oaks which provide a large amount of leaf leaf litter (ocochal) for its large carbon sequestration capacity. This high mulch value is congruent with that reported by Rodríguez-Laguna (2009) quantified at 9.88 Mg ha^{-1} in pine-oak forests. Mulch is one of the main stores of carbon and mineral elements in the soil of some ecosystems (Vogt *et al*., 1986) is a key indicator of the flow of energy and circulation of nutrients within the ecosystem.

Carbon reservoirs in trees at site S2-1= Acahual Xoxocotla-Enrique Farm have 6.64 Mg ha^{-1} of carbon (Table 5) while at Site 3 (S3= Acahual Hortencia-Calistemo Farm) the carbon was of 143.95 Mg ha-1 of carbon (Table 6). The difference is explained by the characteristics of the acahual, while in the S2-1 site the species are young with a D (normal diameter with bark) less than 20 cm, even D smaller than 10 cm predominates, unlike the site S3 where there are species such as the ocote (*Pinus* sp.) with D of 30 cm. Acahuales have an important carbon capture and reservoir potential, in relation to primary vegetation in less time; therefore, if they continue to maintain advanced stages of succession, they can be a stable vegetation alternative that generates environmental carbon capture and biodiversity services (García-Domínguez *et al*., 2018).

Table 5. Carbon from living biomass (trees) site S2-1= Acahual Farm Xoxocotla-Enrique.

Scientific name	Height (m)	D (cm)	Biomass (Ec. Y) (kg)	Biomass (Mg ha^{-1})	Carbon (Mg ha^{-1})
Heliocarpus appendiculatus Turcz.	13	11.46	57.19	1.43	0.71
Alnus acuminata Kunth.	16	18.46	191.75	4.79	2.4
Alnus acuminata Kunth.	12	13.05	79.62	1.99	1
Heliocarpus appendiculatus Turcz.	8	8.59	27.44	0.69	0.34
Alnus acuminata Kunth.	7	8.28	24.92	0.62	0.31
Ricinus communis L.	5	1.11	0.13	0	0
Rhamnus sp.	3	1.27	0.19	0	0
Ricinus communis L.	4	3.82	3.4	0.08	0.04
Alnus acuminata Kunth.	7	6.68	14.41	0.36	0.18
Ricinus communis L.	3	4.14	4.18	0.1	0.05
Clethra lanata M. Martens & Galeotti	10	7.96	22.53	0.56	0.28
Ricinus communis L.	8	1.27	0.19	0	0
Alnus acuminata Kunth.	15	12.73	74.78	1.87	0.93
Alnus acuminata Kunth.	9	8.91	30.12	0.75	0.38
Total				13.27	6.64

Estimated biomass: $Y=EXP\{-2.289+[2.649][LN(DN)]-[0.021][LN(DN)]^2\}$ (Brown, 1997). D= normal diameter with bark.

Table 6. Carbon of living biomass (trees) Site 3. S3= Acahual Farm Hortencia-Calistemo.

Scientific name	Height (m)	D (cm)	Biomass (Ec. Y) (kg)	Biomass (Mg ha^{-1})	Carbon (Mg ha^{-1})
Clethra lanata M.Martens & Galeotti	12	22.76	325.05	8.13	4.06
Clethra lanata M.Martens & Galeotti	10	24.51	391.68	9.79	4.9
Psidium guajava L.	6	18.94	204.53	5.11	2.56
Pinus sp.	30	92.31	10594.69	264.87	132.43
Total				287.9	143.95

Estimated biomass: $Y=EXP\{-2.289+[2.649][LN(DN)]-[0.021][LN(DN)]^2\}$ (Brown, 1997). D= normal diameter with bark.

Organic carbon in soils (COS)

In (Table 7) the COS of the Xoxocotla Farm is presented at sites S1-1 (cedrela systems in productive reconversion 1) and S1-2 (cedrela systems in productive reconversion 2); as well as in the acahuales (S2-1 and S2-2). The S1-1 site presented the highest value of COS at the depth of 0-26 cm (230.33 Mg ha^{-1}) at this site a lot of COS has been generated due to frequent pruning for the cultivation of cedrela, these results are consistent with the Ruiz (2016) carbon study in the Xaltepuxtla bioproductive systems for the mixed ornamental system that includes cedrela (243.24 Mg ha^{-1}) in the first 30 cm deep.

Table 7. Organic soil carbon (COS) in the Xoxocotla Farm.

UM	Depth	OM (%)	Da (g cm^{-3})	COS (Mg ha^{-1})	COS (Mg ha^{-1})
S1-1	0-6.5	9.38	0.66	40.27	
S1-1	6.5-13	11.22	0.86	62.7	
S1-1	13-19.5	9.21	0.99	59.24	
S1-1	19.5-26	10.72	0.98	68.12	230.3
S1-2	0-6	11.055	0.62	41.12	
S1-2	6-12	11.725	0.73	51.26	
S1-2	12-18	12.06	0.79	56.95	
S1-2	18-24	8.375	0.74	37.23	186.6
S2-1	0-6	11.055	0.59	39.39	
S2-1	6-12	11.89	0.67	47.92	
S2-1	12-18	10.854	0.84	54.89	
S2-1	18-24	11.055	0.84	55.88	198.1
S2-2	0-6	9.715	0.4	23.56	
S2-2	6-12	8.54	0.8	41.13	
S2-2	12-18	9.38	0.71	40.14	
S2-2	18-24	8.71	0.75	39.39	144.2

S1-1= 1 cedela system in productive reconversion Xoxocotla-Eleuteria Farm; S1-2= 2 cedela system in productive reconversion Xoxocotla-Eleuteria Farm; S2-1= acahual 1 Xoxocotla-Enrique Farm; S2-2= Acahual 2 Xoxocotla-Enrique Farm. Da= apparent density.

The COS in S2-1 at the depth of 0-26 cm was 198.08 Mg ha^{-1} and the S2-2 acahual was the lowest value (144.21 Mg ha^{-1}). Although these lands have remained at rest for twenty years, the variations in the COS with the depth in the first 26 cm are low (less than 3%), remaining in ranges 8.37 to 12.06% of soil organic matter (Figure 3a, 3b and Figure 3c and 3d). These variations can be associated with topoform and soil management within the bioproductive system. According to Ruiz (2016), topoforms with a slope equal to or greater than 15% and the use of hoes are determinants in soil deterioration and consequently in carbon loss.

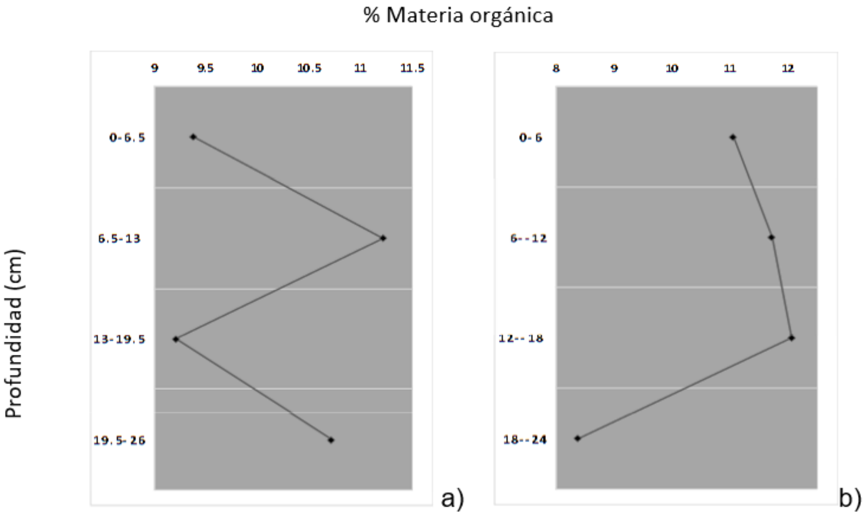

Figure 3. Distribution of the percentage of organic matter of the Farm (Xoxocotla-Eleuteria); a) S1-1; and b) S1-2.

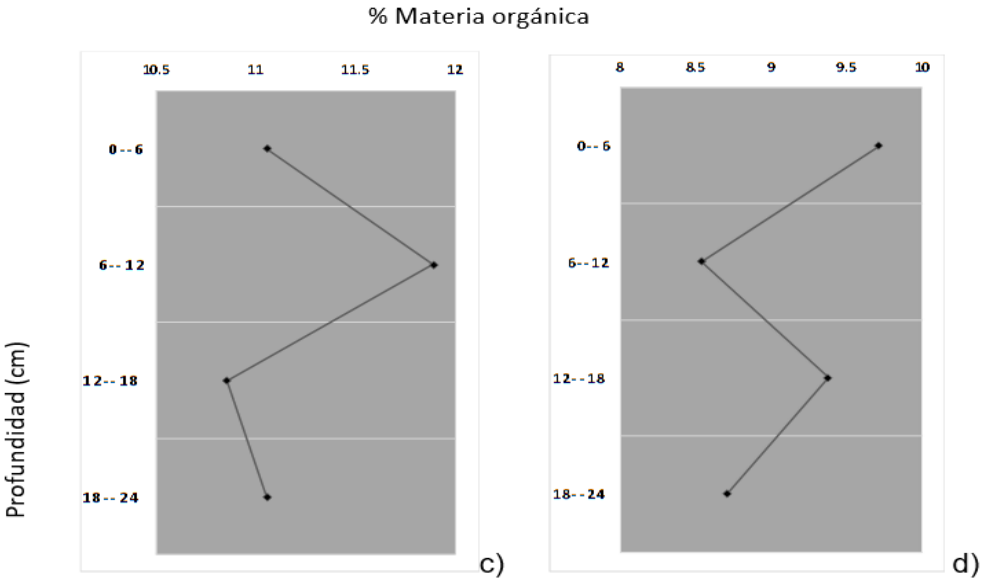

Figure 3. Distribution of the percentage of organic matter in the Farm (Xoxocotla-Enrique); c) S2-1; and d) S2-2.

The Andosols, are the soils with the greatest capacity to store carbon due to the content of allophane that forms complexes with the organic matter protecting it from oxidation (Galicia *et al*., 2016), therefore, the values reported in Figure 3 are expected for this type of soil.

Management actions

The proposal of management actions and detonating change projects, although they derive from the interest of the producers and the potential of the farm for a given productive system, it is relevant to have financing for the achievement of technological intervention. The productive reconversions must be aligned with the attention needs indicated by the agricultural and livestock sector of the state, in this case the government of Puebla and federal agencies such as CONANP. Next, the management proposals by farm are discussed.

Xoxocotla and the Farms Hortencia-Calistemo

The market shortage and low profitability of ornamental production systems have forced producers to leave farmland at rest, becoming acahuales. Within its community support programs, CONANP subsidizes acahual enrichment projects based on restoration with timber species native to the BMM, which must have both the purpose of ecosystem restoration and multiple uses of interest to producers. For this area were included: *Alnus acuminata*, *Platanus mexicana*, *Heliocarpus appendiculatus*, *Fraxinus uhdei* and *Casimiroa edulis* in such a way that it is attractive as a management objective in the short, medium and long term (Arévalo, 2018). Other species that may be included are *Pinus pseudostrobus*, *Quercus* sp. and *Liquidambar styraciflua* L.

Among the enrichment of acahuales, technologies such as live fences, live barriers and the management of non-timber species are included, of economic interest such as the production of the native fungus *Entoloma avortibum* known as totolcozcatl (Mateo, 2018), reproduction of orchids, bromeliads and tree fern (*Cyathea salvinii*), species of great economic and ecological value. In the medium term, this restoration can aspire to the payment for environmental services sponsored by CONAFOR.

Production of native species

Through management units for wildlife conservation (UMAS) of tree fern (*Cyathea salvinii*), bromeliads and orchids. The producers of the Xoxocotla and Ocotitla farms considered these projects.

Extension of the meliponas module

Stingless bees (*Scaptotrigona mexicana*) in the Sierra Norte de Puebla have been exploited domestically to obtain their honey and wax (Ayala, 1999). The benefits that these bees provide as a stabilizing element of the ecological environment through the pollination of plant communities are invaluable.

Improvement and expansion of mushroom production module (*Pleurotus ostreatus*)

The group of producers mainly composed of medieros has already started with this project, however, the adaptation and expansion of the production module, inoculum production and the search for appropriate economic substrates require investment.

Tilapia production

While the availability and quality of water resource allows the fish activity, funding is indispensable. In 2019, these proposals were not supported by CONANP or by the state government, therefore, alternative projects must be kept in mind.

Delimitation of the area of alternative production

the following species with economic potential are recommended for the area: Bamboo (*Phyllostachys aurea*), grapefruit (*Citrus paradisi*), Granada (*Passiflora ligularis*) and creole avocado (*Persea* sp.). The conversion project proposals generated in early 2019 were managed by the UACh before the CONANP; however, there were no resources to finance these projects. Given this situation it is recommended to be attentive to the calls of SADER, SEMARNAT, CONANP, INPI to access resources. Financing management will be necessary through a civil donor association authorized by the Ford Foundation, Banamex Social Development, Root Capital and Peace Corps.

Conclusions

The proposals for productive reconversion of traditional ornamental production systems to sustainable systems for the benefit of the inhabitants and their natural resources must be based on biophysical conditions, vision of producers and intervention of researchers. Although, state and federal financing is essential for the implementation of these projects, the management capacity of the producers limits the areas of conversion to relatively small areas within the farm.

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