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Farmer's knowledge and perception of the milpa system: case study from Sololá region, Guatemala

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Abstract:

Diversified agricultural systems are expected to be more sustainable, resilient and productive than monoculture. However traditional systems such as the milpa, an intercropping between maize, beans and squashes, are knowledge-intensive and were simplified over time. Interventions targeting the diversification of the milpa have to include farmers' agroecological knowledge. This study explores the importance of farming in the livelihood strategies of the households and their perceptions of the diversification of the milpa system.

During the project hosted by the association 'Vivamos Mejor Guatemala' semi-structured interviews were conducted with 24 farmers in two Mayan communities, exploring household's livelihood strategies, current farm production, milpa degree of diversification and farmers' knowledge and perceptions of diversified agricultural systems.

Results show that most households practice subsistence farming but rely on off-farm salary to purchase food, and most farmers diversify their agricultural production to sell on the market. However all households are interested to diversify their system, to generate an income or improve household food security, but lack of resources such as finances and land, remains a major constraint. Nonetheless the hosting project is promising as it will provide lacking resources such as seeds/seedlings, materials or knowledge.

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LIST OF ABBREVIATIONS

FVC: Food value chain

Ha: Hectares

NTX: products for non-traditional exports

SD: Standard deviation

WEP: Wild edible plant

"WE ARE MAIZE MEN, BECAUSE MAIZE IS IN ALL OUR LIFE: IN OUR BLOOD, IN OUR FLESH, IN OUR BONES, IN OUR CEREMONIES, IN OUR THIRST"
(TCHWINQEL IXIN: 20)

1 INTRODUCTION

Mesoamerica is an important center of origin for at least 14% of the most important plant species worldwide, such as maize, beans, chile peppers, avocado, vanilla, amaranth, squash and agave. It is recognized as one of the cradles of early civilization, where plants started to be domesticated, leading to the emergence of agriculture (Brush, et al., 2003; World Heritage Centre, n.d.). Indigenous species such as maize (*Zea mays L.*), beans (*Phaseolus spp.*) and squash (*Cucurbita spp.*) were primarily domesticated and integrated into an intercropping system known as milpa (Zizumbo-villarreal, 2010). This traditional way of producing maize is a cultural heritage that comes from the pre-Hispanic times and can also be implemented with many other species such fruit trees, wild edible plants and medicinal herbs (Altieri, et al., 2012; World Heritage Centre, n.d.). It is considered as the 'foundation of food security in many Latin American rural communities' due to its ecological and nutritional complementarities (Zizumbo-villarreal, 2010). Nevertheless, maize remains the most important crop of the milpa, even if closely linked with beans for its development, which promotes the sustainability of the system and the diversification of cultures based on maize. Behind the cultivation of the milpa are hiding indigenous knowledge, beliefs and rituals that associate nature and culture to ensure a good harvest as well as the preservation and reproduction of the species (World Heritage Centre, n.d.).

Guatemala is the second most densely populated country in Central America, with 60% of its inhabitants living in rural communities, and 74% of them are considered as poor (López-carr et al., 2012). Indeed 70% of rural households is engaged in farming, and more precisely 72% of the rural poor are engaged in farming (Janvry & Sadoulet, 2010). Moreover, a population growth of 2.4% was observed in 2011 in this country, and this associated with increased commercialization, high rate of urbanization and landlessness and changes in agricultural practices, highly impacted the welfare of households (Carletto, et al., 2010; Janvry & Sadoulet, 2010; López-carr et al., 2012). Guatemalan maize production represents about 4% of the agricultural GDP and maize cultivation represents 2/3 of the total cultivated land (World Heritage Centre, n.d.), but the country remains highly dependent on imports for few staple foods (Janvry & Sadoulet, 2010).

During the last decades, a shift has been observed in farmer strategies due to globalization, which resulted in a restructuration of the regional economy, an increase in international migration and an emergence of new global and regional players (Aguilar-støen & Hirsch, 2015; Carletto et al., 2010).

As a consequence, although most of the land and resources were used for agricultural activities, some have been reallocated for some exploitative activities such as hydropower development, biofuel plantations, and mineral and oil extraction. These activities competed with and have partly displaced agricultural activities mainly carried out by smallholder farmers (Aguilar-støen & Hirsch, 2015). In addition production of products for non-traditional exports (NTXs) such as cowpeas or broccoli also increased, in order to take advantage of the comparative lower labor costs, to allow poor farmers to enter the export sector (Carletto et al., 2010). However, constraints due to market imperfections resulted in an increased risk for poorer people to adopt these types of riskier export crops. Moreover, even if households increased their earnings, they neglected domestic production as an element of food security, which resulted in a lack of visible positive effects on nutrition, mainly because of other factors such as poor sanitation and inadequate health practices (Carletto et al., 2010; Janvry & Sadoulet, 2010).

In addition "Industrial or conventional" agriculture, with simplified agroecosystems that are highly dependent on a few improved high-yielding crop varieties and agrochemical inputs tremendously increased agricultural environmental costs (Segnon, et al., 2015). The abundant rainfall and high temperatures tend to stimulate competition from weeds, pest outbreaks and nutrient leaching, and this genetic homogeneity enhances the risk for pest invasions and the vulnerability towards extreme climate events (Altieri & Nicholls, 2004). Altieri and Nicholls (2004) also claim that decreasing plant diversity threatens tropical food production, and what has been observed in the early 1990s, was a drop in profitability, especially for low-resource farmers. The main reasons were the significant loss of biodiversity and associated traditional knowledge that communities share about it, a decline in soil quality, an increase in pest resistance and increased greenhouse gas emissions (Altieri & Nicholls, 2004; Carletto, et al. , 2010; Segnon et al., 2015). Researchers have emphasized the need for tropical agroecosystems to mimic the structure and function of natural systems, with closed nutrient cycling, resistance to pest invasion, vertical structure and biodiversity conservation. This type of complex farming system, are adapted to the tropical conditions, and scientists assert that only agricultural systems that are highly diversified, productive and efficient could face the challenge to feed the world (Altieri, et al., 2012; Altieri & Nicholls, 2004). Indeed high degree of plant diversity can decrease risk for farmers by stabilizing yields over the long term, especially after periods of extreme climatic events. A study conducted in Guatemala showed that plots using diversification practices such as intercropping or agroforestry suffered less from soil erosion and had more soil moisture, which resulted in less economic losses than their conventional neighbours. Moreover, it is emphasized that smallholder agroecological production, promoting biodiversity, plays a substantial role to food security (Altieri et al., 2012).

However, a study conducted in Ecuador underlined that even if Andean farmers manage a high diversity of crops, 75% of their products were sold on the market, in order for them to buy food, which resulted in rather unhealthy diets (Oyarzun, et al., 2013). Another study in Mexico studied the productivity of the milpa system, and when comparing a maize monoculture with the system milpa, results show that 1.73 ha of land are needed for the maize monoculture to produce as much food as 1 ha of milpa (Altieri et al., 2012). However, an another study in Mexico showed that the sustainability of the milpa is uncertain mainly due to the competition with off-farm employment and long-distance migration (Birol, et al., 2008).

In Guatemala, what is observed is that farmers rarely specialize in only NTXs and that they also keep on cultivating the milpa (Carletto et al., 2010). Isakson (2009) reported that farmers of this region are aware of the possible returns they could have from other forms of economic provisioning (i.e. wage labour, commodity productions, NTXs production, transnational migration). However 99% of the households kept doing the milpa, even if considered as an ‘economic loss’, because it provides a guarantee for family’s basic sustenance (Isakson, 2009).

The region of Sololá, Guatemala presents a great biodiversity that the indigenous Mayan communities preserve. The population of the region is recognized as vulnerable as most of them live under the poverty threshold and about 70% of the children under 5 years-old suffer from chronic malnutrition (Vargas Ricca, et al., 2015). However, the diversity of products coming from the milpa system can be rich and balanced, and provides diverse food crops from small areas (0.5 to 2 ha) (González, et al., n.d.). As a consequence, a better nutritional status of the household members can be achieved, compared with the diversity of products supplied by a maize monoculture system. Moreover, surplus food can be sold on the market, and increase households cash income (Centro de Investigación en Ciencias Agropecuarias, 2004). A diversified farming system could also promote and enhance ecosystems services, which increases systems’ productivity and resilience, which is relevant in situation of climate change (Segnon et al., 2015). Nonetheless, nowadays farmers suffer from a gap of knowledge concerning their ancestral practices regarding the milpa, including the diversification of the system, and a decrease of interest of people for traditional food, and the use and benefits of underutilized species is observed (Termote et al., 2012; Vinceti et al., 2013, Secaira, personal communication, November 30, 2016). A study conducted in the department of Sololá reported that 28% of the producers used maize monoculture, while the others used intercropping systems. However, 60% of the producers only include beans in their system, and 12% also intercropped other products such as squashes, broad beans, potatoes, cauliflower or peas (Cifuentes et al., 2014).

This study is part of a broader project hosted by the non-governmental organization “Asociación Vivamos Mejor Guatemala”, and this specific project aims to “Promote nutritional health at the household and community level, as a strategy to prevent chronic child undernutrition in 3 indigenous communities in the department of Sololá”. This three-year project adopts an integrated strategy to address different aspects of these families’ livelihoods. Firstly to improve and diversify the agricultural production by providing education and technical assistance regarding agroecological practices, soil conservation techniques, good practices to reduce post-harvest and storage losses of basic grains, implementation or improvement of ecological poultry management. In addition, education will also concern nutrition health and food properties, as well as hygiene practices and policies from the health government, in order to prevent diseases. The project follow a methodology called ”Mejoramiento de Vida”. It aims to empower women to be active actors in the development process, and encourage them to improve their living by making small changes. The process starts from the inside of a person, the self-esteem, to the outside, household, parcels, community, etc. One of the action plans is to propose to the household to diversify their milpa, in order to provide a wider range of products for their family (Secaira, personal communication, February 22, 2017). Using agroecology-based management strategies can build a more sustainable, resilient and productive agricultural systems as it aims to ensure long-term productivity by promoting biodiversity and the associated ecosystem services supporting food production and human well-being (Altieri & Nicholls, 2004; Schipanski et al., 2016). Increasing biodiversity widen the range of ecological processes and services provided by the system, as species richness represent an assemblage of species presenting distinct traits. Several species show to generally facilitate activities of other species, which in turns increase ecosystem process rates, and would provide positive effects due to complementary niche partitioning. Therefore when a system undergo a period of stress, a greater biodiversity increase the stability of functioning in ecosystems, and it is more likely that the system include tolerant species which can compensate for the species exterminated by the disturbance (Truchy, et al., 2015).However the traditional milpa management tend to be knowledge-intensive. Therefore adaptions might be necessary and have to include farmers’ agroecological and location-specific knowledge, elements of traditional agricultural knowledge and modern agricultural science (Altieri & Nicholls, 2004; Segnon et al., 2015). The project started in January 2017 and was at the first step of diagnosis of the current situation, and using some participative methods could be used in these communities. These methods are recognized as useful instruments to capture individuals’ perceptions about their living environment and to depict community participation and local reality. It eases the communication between people involved and the process of data collection, as it results from a dialogue between participants and researchers, and often lead to raise awareness and participation of the participants (Medeiros, et al., 2011).

Moreover, studies concerning land-use dynamics should always take into account the socio-environmental situation in the studied community in their diagnosis, in order to identify variables related to the environment and the personal perceptions (Medeiros et al., 2011). Therefore, a first step of the project should explore the importance of farming in the livelihood strategies of the households, as well as their perceptions of the milpa system in two Mayan communities in the Sololá region, and if its diversification could be achieved in their point of view.

2 PURPOSE OF THE STUDY

This research aims to explore livelihood strategies of households, the importance of the milpa in farm production and their knowledge and perceptions from a more diversified agroecosystem and assess their motivations to implement it, in two Mayan communities in the region of Sololá, Guatemala.

The different sub-objectives of this study in the communities of Chuitzanchaj and Pajomel are to:

- Explore current farmers production and livelihood strategies.
- Evaluate the current diversification of their milpa systems.
- Explore farmer's knowledge and perceptions of the diversified milpa system.
- Co-create farmer' own potential scenarios with more diversified milpa systems

From this, different hypotheses will be formulated:

- The dominant livelihood strategy to sustain the household depends on subsistence farming.
- Farmer's market orientation negatively influences the diversification of the milpa system.
- Many crops and trees could be implemented to diversify the current milpa system, while not being detrimental regarding farmer's objectives.
- The labour demand in highly-diversified milpa system is the major constraint for its adoption.

3 MATERIAL AND METHODS

3.1 STUDY AREA

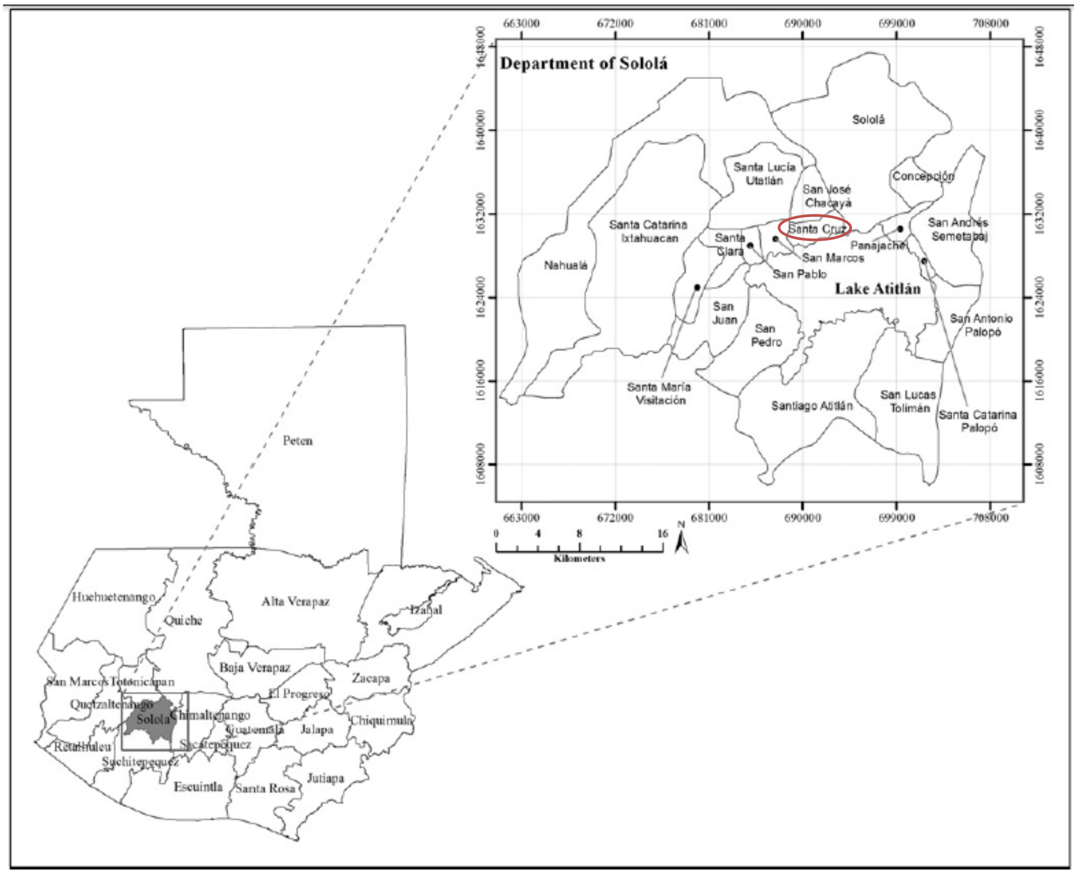


Figure 1: Map of Guatemala and the 19 municipalities in the region of Sololá. Case Studies: Pajomel and Chuitzanchaj are in the municipality of Santa Cruz (red circle) (Schmitt-harsh, 2013).

Guatemala is the northernmost of the Central American nations, with Mexico as neighbours in the north and west, and Belize, Honduras, and El Salvador on the east. Its population represented about 15 million persons in 2016, and is composed of about 40% by indigenous ethnic groups (Central Agency Institution, 2016).

Guatemala has the highest population growth rate of Central America. However, the population faces many difficulties for example infant, child, and maternal mortality, malnutrition and illiteracy, which is disproportionately affecting the indigenous population (Central Agency Institution, 2016).

The agricultural sector represents 13.6% of GDP and provides work to 31% of the labor force, with as key export crop: sugar, coffee, bananas, and vegetables (Central Agency Institution, 2016). However 23% of the population lives in extreme poverty and more than half of the population is below the national poverty line, and 71% of them living in rural areas (Central Agency Institution, 2016; Janvry & Sadoulet, 2010). On average 79% of the indigenous groups live below the poverty threshold, and

39.8% live in extreme poverty. In addition about half of the children under five years-old are chronically malnourished.

The area of study takes place in the Department of Sololá (see Figure 1), in the western highlands of Guatemala. The area of the department is characterized by heterogeneous topography, ranging between 628 to 3524 m above sea-level, and slopes from 0° to 75°. The climate is tropical with two principal season: a dry season from November until May and a rainy season in between May and October (Paricio, 2013). The averages of annual rainfall and temperature are about 2504 mm and 18-24°C, but wide variability is observed. The natural vegetation is mainly composed by broadleaf and coniferous forests (Schmitt-harsh, 2013). The watershed of Lake Atitlán is characterized by important amount of volcanic material highly permeable which, associated with the steepness of the area, increase the susceptibility for landslides (see Annex 1 and 2), torrential floods and the fall of rocks (Paricio, 2013). In times of high rainfalls the region is affected by extreme weather events such as hurricanes, storms and tropical depressions coming from the *Atlantic Ocean*, and their frequencies tends to increase these last years (Paricio, 2013).

The Department of Sololá is one of the poorest of the country, and about 96.2% of the population is indigenous Maya. The three Mayan communities involved in the project all live in the municipality of Santa Cruz la Laguna. Land tenure is mainly obtained by inheritance, or purchased or rented from other persons in the communities. However most of the communities in this area are governed by traditional community based Mayan authorities, and nowadays land tenure is under a combination of indigenous communal and municipal land tenure arrangements (Schmitt-harsh, 2013).

3.2 SELECTION OF HOUSEHOLDS

This study is part of a broader 3-years project which aims to improve the living of families in two communities (Chuitzanchaj and Pajomel) by proposing agriculture-oriented project to improve the access to food, and providing training concerning nutritional health and hygiene. Among these three communities 125 families were selected regarding the following criteria: families were motivated to participate in the 3-years project (project previously explained to them), families had pregnant and lactating woman at the start of the project, and/or had children under 5 years old. The 125 families would participate to workshops and receive technical support and education concerning agroecological practices, ecological poultry management, hygiene practices and nutritional health. A sub-sample of 24 households was randomly selected to also participate in this thesis study.

More participants in the project were from the community of Chuitzanchaj, with a ratio of 78 participants in Chuitzanchaj for 34 participants in Pajomel. This ratio was kept for the selection of the sub-sampled households, with 17 participants from Chuitzanchaj and 7 from Pajomel.

3.3 DIAGNOSIS OF THE CURRENT SYSTEM

- Sub-objective 1: Explore current farmers production and marketing strategies.

In a first step, household's livelihood strategies, current farm production and marketing strategies were explored for 24 households.

All persons interviewed were from the Kakchiquel indigenous group and were speaking Kakchiquel. They had difficulties to speak and understand Spanish, so a translator was involved in the interviews.

The first questionnaire started with closed questions regarding: family size and composition: number of persons in the household and sex, number of field cultivated and land property, and type of animals, numbers and purpose (see Annex 3).

In a second step, all cultivated fields owned or rented were reviewed, from 1 to 4 fields depending on the households. A combination of structured and semi-structured questions were asked concerning: the size of the field, types of crop cultivated, percentage of the field area occupied by the crop and percentage of the harvest dedicated for the household consumption or for the market. Field management was also investigated (i.e. inputs used, weed and residues management, rotations).

Species of trees were listed, their functions were discussed, and pictures representing different tree biomass were used to characterize each field (see Annex 4) (Félix, 2013). An aerial map of the village and the surroundings was presented to localise fields, and they were entered in Google Earth. The borders of the field were coloured depending of the Shannon diversity index, and Figure 2 and Annex 5 shows the colour code used, with the signification.

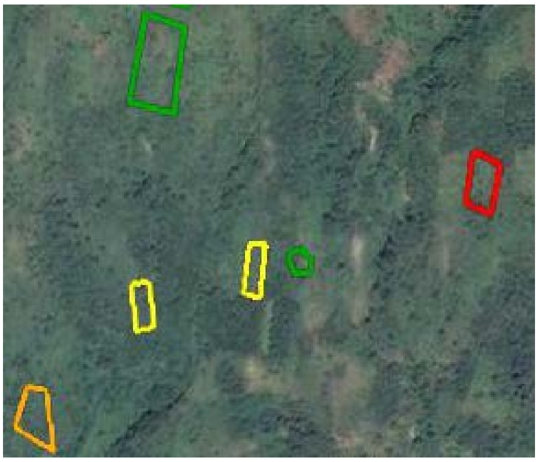


Figure 2: Example of map.

Sources of income were identified and weighted regarding the income they generated during one year, and periods during the year where households usually perceive anxiety and uncertainty over food access were identified.

3.4 DEGREE OF DIVERSIFICATION OF THE MILPA

- Sub-Objective 2: Evaluate the current diversification of their milpa systems.

Farm agrobiodiversity was assessed and the degree of diversification of each system was calculated using two indicators. The first one is the Margalef index (Equation (1)) that assesses the "richness" on-farm, by measuring the total farm area and identifying the number of different species of crops, herbs and trees on-farm.

In Equation (1), S is the number of species on-farm (herbs, crops and trees), and Ln(N) the natural logarithm of the farm area (m^2). The higher the Margalef index is, the more species are present on the farm, or the same amount of species is found on a smaller farm area.

$$DMg = \frac{S-1}{LnN} \qquad (1)$$

The second indicator is the Shannon index (Equation (2)) and assesses specifically the "evenness" of distribution of on-farm species (measured as a farm's frequency distribution). It was used only for crops and herbs, and trees when covering a significant area of the field. The area dedicated to each element was measured and the number of species on-farm identified.

In Equation (2), S equals the number of species on-farm and p_i is the area covered by the i-species divided by the total farm area (m^2). When H is very small only few species occupy a large areas of the determined farm (such as in the situation of a monoculture).

$$H = -\sum_{i=1}^{S}(p_i \ln p_i) \qquad (2)$$

3.5 PERCEPTIONS OF FARMERS REGARDING MILPA DIVERSIFICATION

- Sub-Objective 3: Explore farmer's knowledge and perceptions of the diversified milpa system.

Semi-structured interviews (Annex 6) were conducted to explore households' interest in the diversification of their system, their knowledge about the benefits of trees, vegetables and herbs, and their perceptions of a diversified system.

A participatory workshop was previously done with the selected 125 households. The members identified and listed crops and trees possibly grown in Chuitzanchaj and Pajomel, and identified the most important species. Seven elements were selected and used to discuss its possible influence on their milpa, and which ones could be adopted in their system. The adoption of new crops was explored using two Likert scales and related to farmer perceptions.

Following the methodology of Michalscheck (2016), Table 1 shows an example where farmers were primarily asked which criteria are the most important to decide upon the incorporation of a new crop in their milpa. A first Likert scale ranked the importance of this aspect for them, with 0 being 'Not important' and 3 being 'Very important' (in blue). The six aspects in Table 1 were used as bases but it remained open to other important aspects for farmers.

Then questions concerned specific trees, crops or herbs from the participatory list (called elements) not currently present in the farmers milpa, and how much their incorporation could contribute to each aspects (in green). Only seven elements were discussed to save time, with 2 species of forest trees, 2 species of fruits trees, 2 species of vegetables and 1 species of herbs.

Seeking for homogeneity, 7 'head' elements were proposed as first plan (Annex 7) if they were not present in the milpa. However, if one element was already present, it was replaced by another element from the second list 'substitution'.

Then a second Likert scale evaluated the potential benefits/constraints to implement a specific crop in the current farming system. The households were grading every element from -10 (highly negative impact) to 10 (highly positive impact), and Annex 8 shows the 6 different scales with their meanings. Afterward it was multiplied (in red) with the importance of the aspect for the household (between 0 and 3), and finally summed to obtain a final score representing the potential for each crops to be incorporated.

Table 1: Assessment of farmers decision to adopt a crop.

Crop adoption	If you think of incorporating this new crop, how could change your system in terms of …						
	-10 very poor; -1 slightly negative; 0 neutral compared to the current system; +1 slightly positive; +10 excellent						
	Labour/Time demand	Food security	Income generation	Climate resilience	Soil fertility	Weed/pest suppression	Total
How important are these aspects for you: 0= not important 1 = low importance 2 = medium importance 3= very important	2 x	3 x	3 x	1 x	2 x	0 x	
Poplar	-1 (-2)	0 (0)	2 (6)	8 (8)	8 (16)	0 (0)	28
Oak	-2 (-4)	0 (0)	2 (6)	8 (8)	5 (10)	0 (0)	20
Carrots	-5 (-10)	6 (18)	6 (18)	4 (4)	3 (6)	0 (0)	36
…							…

3.6 CO-CREATION OF FARMER'S DIVERSIFIED MILPA

- Sub-Objective 4: Co-create farmer' own potential scenarios with more diversified milpa systems based on their decision-making for crop adoption.

The project aims to add 3 species of crops per system and integrate fruit/forest trees elements in the milpa. From Table 1 it was discussed the implementation of the three crops with the best final score, as well as the trade-offs and barriers encountered by the household, which provided an overview of the situation, and a mind map was designed.

In addition a SWOT analysis - acronym for ‘strengths, weaknesses, opportunities and threats’ - was framed to summarize internal and external as well as positive and negative factors concerning the diversification of their milpa. A SWOT analysis is a simple situational analysis tool to produce knowledge and help in the process of decision-making, and can be used to appreciate the current situation and ease decision-making concerning strategies to adopt during the implementation of the project (Bohm, 2008).

4 RESULTS

4.1 DIAGNOSIS OF THE CURRENT SYSTEM

4.1.1 Household and farm characteristics

Household composition

Among the 24 households, the average number of persons per households was 5.7, with a maximum of 16 and a minimum of 3 persons per household. Due to the criteria of selection many households were couples recently married with a child in early infancy, therefore 25% of the households were composed of 3 members. However 42 % of the households had at least 6 members in their households because couples could have been married since many years, and last children were below 5 years-old.

Thirteen households reported to have sufficient food during the year. Period the most difficult for the 11 other households was during the rainy season when there were no off-farm activities, and they did not earn any income. Two households were maize sufficient and did not report periods of food shortage but most of them had maize for 6 to 8 months.

Farm characteristics

The average farm size was about 0.38 ha but varied widely in between farms, with a standard deviation (SD) of 0.22. The average size for the milpa was about 0.22 ha (SD = 0.10) and the sum of the other fields represented about 0.16 ha (SD = 0.15) but few households only had a milpa field. On average households cultivated 2.1 fields and Figure 3 shows the different fields reported by the households from Pajomel and Chuitzanchaj.

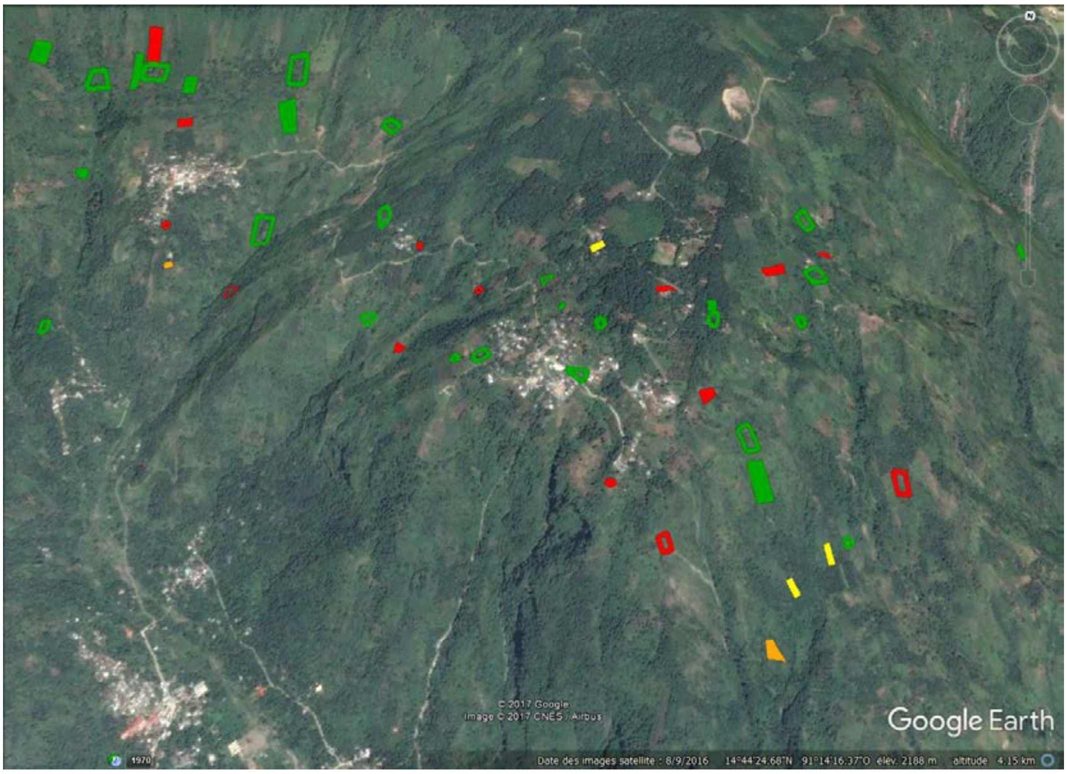


Figure 3: Map of the fields in Pajomel and Chuitzanchaj. Fields filled with colors represent milpa fields. In red and green are respectively fields with both milpa and farm Shannon index below and above the mean. In yellow are milpa having a milpa Shannon diversity index below the milpa mean, and a farm Shannon diversity index above the farm index. In orange is the contrary with milpa having a milpa Shannon diversity index above the milpa mean, and a farm Shannon diversity index below the farm index. See Annex 5.

In Figure 3 the milpa fields were very spread over the landscape, and for 8 households their milpa was the closest field to their household, even if it can remain far. Nine other households situated their milpa field further compared to others, because for instance closer fields were plantations that the households did not own, or fields smaller than the milpa.

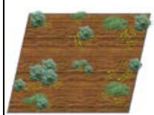
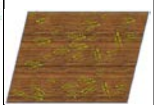
Out of the 24 households, 8 owned all their fields, 10 only rented and 8 rented and also owned fields, but only 2 of them rented their milpa and owned their other fields. Interestingly, Table 2 shows that land tenure status might not be influenced by the experience (number of years cultivating a milpa), as the averages were very close and varied widely among the sample. In addition the surface owned by the households is almost twice as large as the surface rented. A hypothesis could be that their rented land were used as additional land to grow different crops from the milpa. However standard deviations were very large, therefore no conclusions should be drawn without deeper discussion with the farmers.

Table 2: Number of years farmers sown their milpa and area cultivated by them depending on land tenure status.

	Experience (years)	Area (ha)
Owned	7.37 (SD = 5.93)	0.38 (SD = 0.22)
Rented	6.20 (SD = 7.95)	0.22 (SD = 0.10)
Owned and rented	8.33 (SD = 8.05)	

Table 3 shows that tree abundance in the milpa was rather heterogeneous with 5 households having a high tree density (number 1 and 2), 7 households with a medium tree abundance (number 3), and 14 households with few bushes (number 4) or without any trees in their fields (number 5). Interestingly, no households used trees as windbreaks around their field (number 6).

Table 3: Number of households having the different tree abundance.

Type of tree abundance in the milpa	1 	2 	3 	4 	5 	6 
Number of households	2	3	7	7	5	0

4.1.2 Farm management

Milpa management

In total there was 11 different types of fertilizers (Annex 9), and 5 of the 8 chemical fertilizers were used for the milpa. Nonetheless 19 households used the weeds to cover the soil and 3 buried them to bring organic matter to the soil. However 17 households burnt their residues and only 3 and 4 households respectively buried them or used it as cover. Finally most fields were steep with big problems of soil erosion and depletion of soil organic matter, and the area was very prone to landslides as shown in Annex 2. Only one household used dead fences in his milpa to prevent soil erosion and seven households earthed up the maize cane to prevent bending.

Crop composition

On average 2.6 types of crops were cultivated on their milpa field (SD = 1.1) and 3.4 (SD = 2.9) in other fields. More crops were cultivated in other fields as they could represent more than one field. On overall farms cultivated about 4.2 crops (SD = 2.6). However if tree species were taken into account, results increased to 4.3 species present in the milpa (SD = 1.7), 5.5 species in other fields (SD = 3.7) and 6.7 species on the farm (SD = 3.8) but there were lots of variations between households and fields. In total about 23 different species of crops were cultivated and about 16 different types of forest and fruit trees encountered in the different fields, the more common being: avocado, oak, poplar, cypress and pine tree.

Table 4 presents the different crops encountered in the milpa fields, and the number of households that were cultivating them. Table 5 presents the combination of crops found in the milpa fields, with the number of households that were intercropping them.

Table 4: Number of households having the different crops in their milpa field.

Crop	Number of households
Maize	24
Beans	19
Hierba Blanca (*Brassica cf. napus*)	4
Black nightshade	2
Fig leaf gourd	4
Chipilin (*Crotalaria longirostrata*)	4
Squash	1
Bledo	1
Chayote	1

Table 5: Number of households having the different associations of crops in their milpa field.

Crop association	Number of households
Maize – Beans	10
Maize	3
Maize – Beans – Chipilin (*Crotalaria longirostrata*)	3
Maize – Beans – Hierba Blanca	2
Maize – Fig leaf gourd	2
Maize – Beans - Hierba Blanca (*Brassica cf. napus*) - Black nightshade - Bledo – Fig leaf gourd	1
Maize – Beans – Hierba Blanca (*Brassica cf. napus*) – Black nightshade	1
Maize – Beans – Chayote – Chipilin (*Crotalaria longirostrata*)	1
Maize – Beans – Squash	1

The most important crop in the milpa was maize, and 19 households intercropped it with beans. Different herbs were also encountered, and some households reported that they grew by themselves, but others collected seeds and sow them to ensure the harvest for the next year. Only few vegetables were intercropped in the milpa, but the fig-leaf gourd was the most dominant as it was traditionally planted in the milpa in this area.

In other fields elements encountered were plantation of avocado or coffee, and few fruit trees were representing significant area in some fields such as bananas and peach. Many people with small area of arable land also grew maize (for grain or for leaves) and beans in their other field, but in general less herbs were found compared with the milpa, but 6 households only had one field of milpa.

The last three years 6 households had not done any changes, while 3 households sow their milpa for the first time this year. Four other households also started with a new field this year or two years ago so the changes over years could not be assessed. However 6 households decided/were able to implement a new crop in their milpa, but 2 households decided to simplify it, and 1 household removed their beans from the milpa but added fig-leaf gourd. Interestingly 2 households conscientiously applied rotation of vegetables in their field dedicated for vegetables, but not in the milpa.

4.1.3 Livelihood strategies

Distribution of sources of income

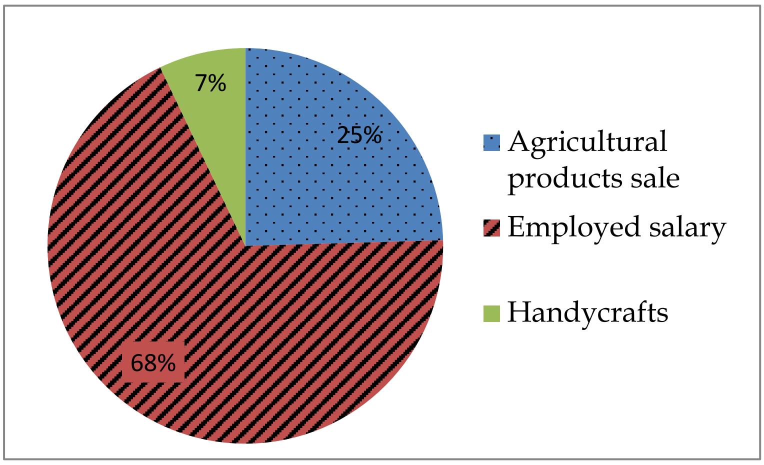


Figure 4: Percentage of households income from different sources.

Figure 4 represents the distribution of income and for the majority of the households the main source of income was the salary from off-farm activity. This impacted household food security as these jobs were seasonal and 11 households experienced food shortage during the rainy season (from May until November), when daily workers had difficulties to find work.

In our sample on average 1.08 persons/household worked as day labourer in another farm (SD = 0.9), but in 5 households no one had this type of agricultural job whereas in 1 household 4 persons worked as day labourer. On average 0.37 person/household was worker (SD = 0.6), with 15 households where nobody had a 'non-agricultural' job, and in 9 households 1 person was a worker. In addition, in 8 households 1 person made handicraft work as extra income (on average 0.32 person/household).

Product allocation

Farmers mainly cultivated to produce food for the household consumption. On average 80% of the total farm area was dedicated for the household consumption (SD = 0.2) and 14% for the market (SD = 0.2), representing about 0.3 ha (SD = 0.1) and 0.1 ha (SD = 0.1) respectively. Six percent of the area could be considered as 'non-productive' (SD = 0.1), as being composed by trees plantations not productive yet (seedlings of avocado and banana trees), or rented fields and the production of the trees cannot be used by the household.

Figure 5 shows important variations between households but it appears that the more people lived in the household, the more land was dedicated for the household consumption, but some large households had rather small farm size.

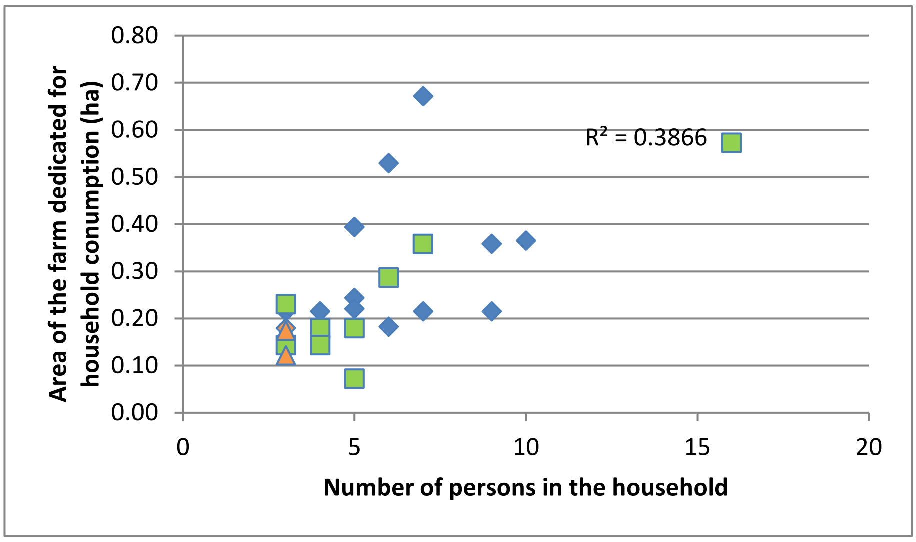


Figure 5: Area dedicated to household consumption depending on the number of members in the household. The green squares correspond to households only producing for household consumption and the orange triangles denote the market oriented households.

Ten households also kept 100% of their production only for the household consumption, and 3 of them reported feeling periods of food shortage. Two households were market oriented, and dedicated about as much land for consumption as other households with the same family size.

Figure 6 represents the total farm area dedicated for household consumption depending on the total farm area. Farms with dots situated above the red line dedicated more than the average size farm (about 0.38 ha) to their household consumption. However households number 32 and 265 reported to not have sufficient food at some period of the year.

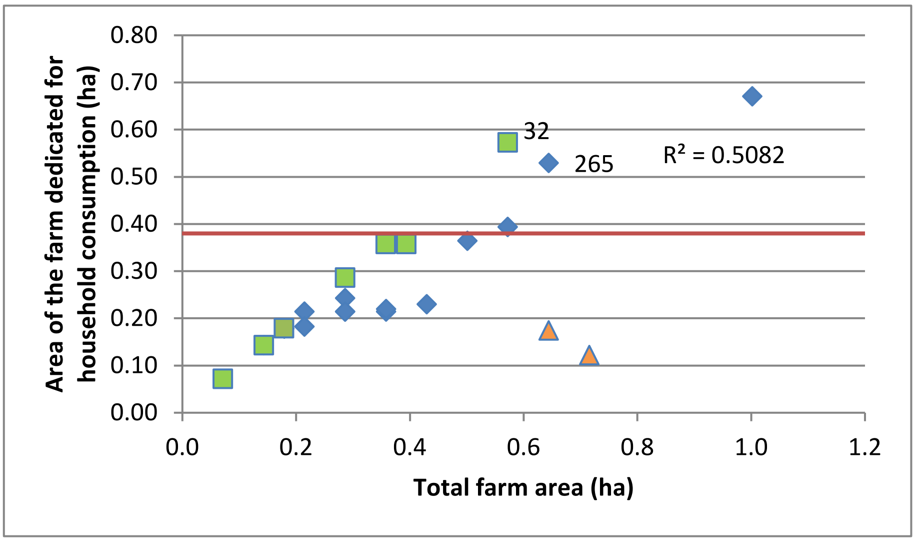


Figure 6: Area dedicated to household consumption depending on the total farm area. The green squares correspond to households only producing for household consumption and the orange triangles denote the market oriented households.

The average area dedicated for household consumption was about 0.3 ha (SD = 0.1). Only 8 households had an area dedicated for household consumption above this mean and 3 of them dedicated 100% of their production for their consumption (green dots).

Figure 7 shows the percentage of farm area dedicated for the consumption depending on the total farm area, and the larger the farm are, the lower the percentage of area dedicated to the consumption is. Therefore households might primarily search to provide acceptable quantity of food for the household and then decide to dedicate some land for the market. This implies that lack of land might be a major constraint for these households.

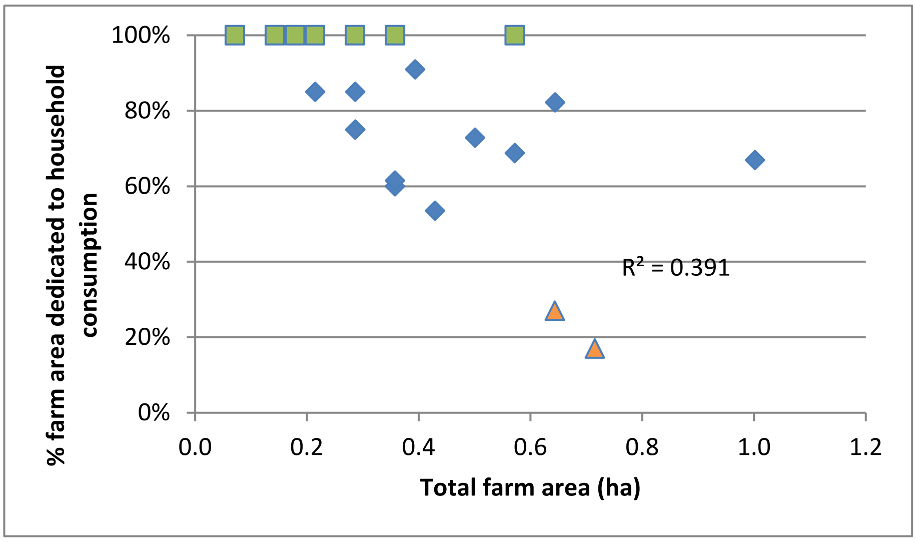


Figure 7: Percentage of area dedicated to household consumption depending on the total farm area. The green squares correspond to households only producing for household consumption and the orange triangles denote the market oriented households.

Area dedicated per persons

On average 1 person had 0.05 ha (SD = 0.02) of land dedicated for its consumption. The maximum was 0.10 ha/person and was from the only household with agricultural products sale (coffee, avocado and maize for leaves) as only source of income. They had enough food for the whole year by dedicating 67% of their land for their consumption. However, 2 households experienced periods of food shortage during the year whereas dedicating about 0.08 ha/person for consumption. Therefore the practices applied, the quality of the soil and other environmental and anthropologic factors should be more deeply explored.

Market strategies

Only 2 households dedicated more productive area for their market sale than for their household consumption (Figure 7). Their farm size was larger than the average but they dedicated for their consumption an area smaller than the mean area dedicated for the household. They sow their land only since 2 and 3 years and decided to be more market-oriented as they were already selling most of the beans produced from their milpa. In addition one of the two also had a coffee plantation and started a plantation of avocado of about 0.07 ha, both mainly to sell on the market.

Area dedicated for crops

Figure 8 shows for each crop encountered in the households, the mean area of 'productive' land (excluding non-productive plantations) dedicated for it in the households. Above the bars were the numbers of households whom grew the crops on their farm.

In general all products from the milpa were for the household, except the two market oriented households whom sold beans from their milpa. Otherwise, only two households sold a small part of the maize produced on their other fields (3 and 4% of the area).

Coffee plantation required the most space and the 3 households whom were growing it had on average about 0.2 ha dedicated to this crop in order to sell on the market. Second was maize mainly directed towards household consumption, then French beans but only cultivated by two households, and finally beans the second most important food for the household.

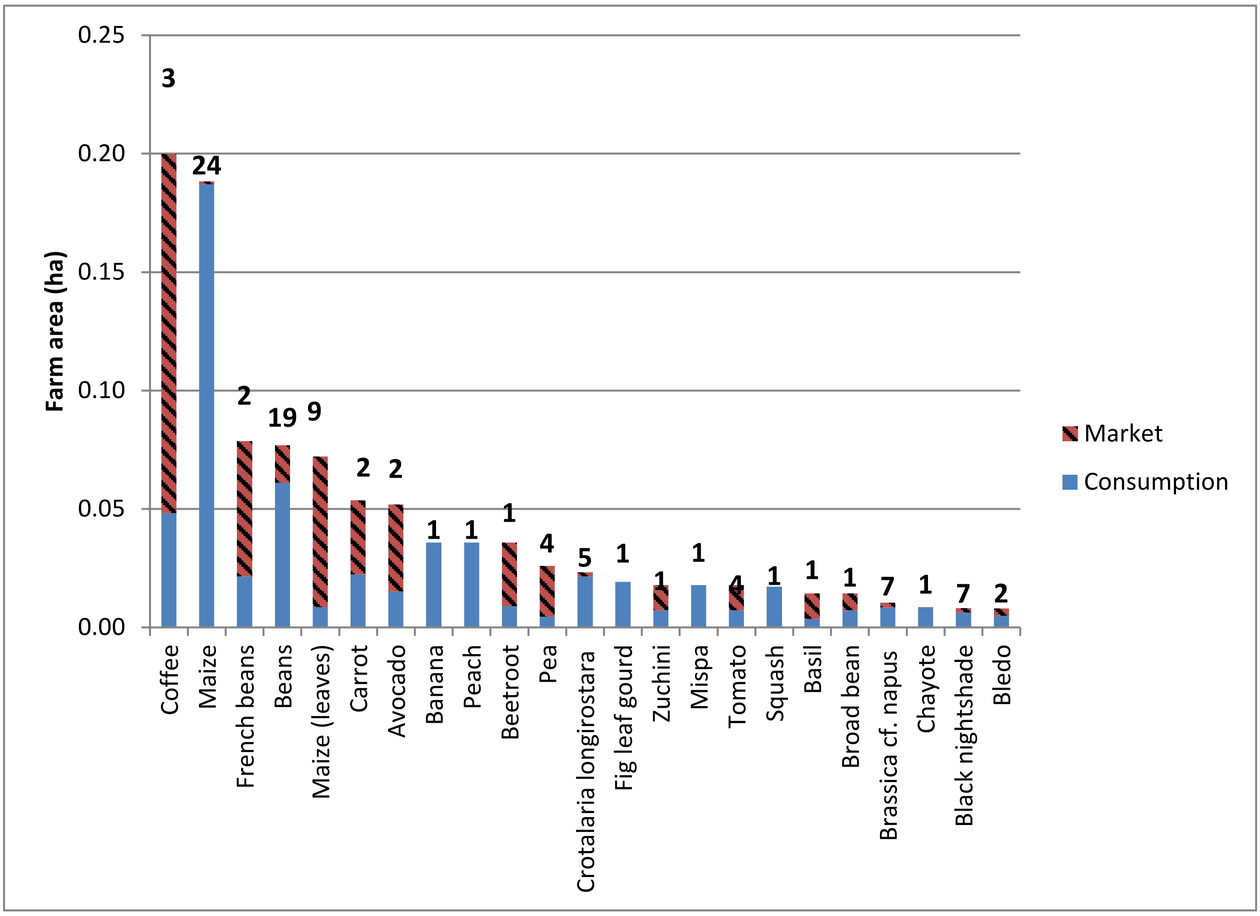


Figure 8: Average farm area dedicated for crops per households and area distribution between market (red) and consumption (blue). Numbers above bars represent number of households cultivating the crop.

4.2 DEGREE OF DIVERSIFICATION OF THE MILPA

4.2.1 Participatory list versus field reality

During a participatory workshop with the 125 families part of the project, a list of trees, vegetables and herbs cultivated and present in the area were reported to know species possibly found/grown.

Twenty-nine trees have been reported, including 14 fruit trees, as well as 21 types of vegetables and 10 types of herbs. In grey are crops/trees from the list found in the fields of the households, and only 7 forest trees out of 15 in the list were reported in the field of our group of 25 households. In addition only 3 fruit trees out of 14, 7 vegetables out of 22 and 5 herbs out of 10 are grown in the fields of our sample.

However some crops found in the field were not present in the list reported by the families, such as coffee tree or fig-leaf gourd and Annex 10 presents all the products encountered.

Table 6: List of crops/trees from farmers present in Chuitzanchaj and Pajomel.

Number	Forest trees	Fruit trees	Vegetables	Herbs
1	Bambu	Orange	Carrot	Basil
2	'*Palo de Pito*'	Red mombin	cucumber	'Chipilin'
3	Poplar	Granadilla	Cabbage	'Xupi'
4	'Guachipilin'	Banana	Beetroot	'Bledo'
5	Cypress	Anona	Zuchini	Black nightshade
6	Oak	Peach	Salad	Spinach
7	'Chocon'	Dragon fruit	Potatoes	'Hierba blanca'
8	Pine	Apple	'Miltomate'	Chard
9	'Sauco'	Lemon	Chayote	Mint
10	'Chilca'	Strawberries	Tomato	Chayote sprout
11	'Chali'	Medlar	Onion	
12	'Canac'	Plum	Squash	
13	'Roble'	'Matasano'	Corn cob	
14	'Cacho de Venado'	Avocado	Turnip	
15			Pea	
16			French beans	
17			Cauliflower	
18			Chilli pepper	
19			Broccoli	
20			Radish	
21			Broad bean	

4.2.2 Agrobiodiversity index

Margalef index

The mean farm Margalef index was 0.70 (SD = 0.45), the mean milpa Margalef index was 0.44 (SD = 0.23) and there was a great variability observed in our sample.

One household had a milpa Margalef index higher than the one for the overall farm, as the milpa was rather diverse, whereas his second field was a monoculture of maize, but it increased the farm area and therefore decreased the Margalef index of the farm.

Interestingly owned fields showed a higher Margalef index that was equal to 0.71 (SD = 0.35) than hired fields with their index equal to 0.52 (SD = 0.43). The variations within the sample remained wide but households whom rented fields could not choose the crops they wanted to grow, or to plant trees as the land did not belong to them. Another hypothesis was that the fields were considered as secondary, and therefore decided to not diversify.

Shannon diversity index

The mean Shannon diversity index for the farms was 0.89 (SD = 0.43), and 0.62 for the milpa (SD = 0.31), but 6 households only had 1 field of milpa to cultivate, and all of them had a Shannon diversity index below the mean.

Figure 3 shows that 9 households had a farm and milpa Shannon diversity index above the means (in green), but 8 households were below the milpa and farm means (in red). In addition, 3 households had a milpa Shannon diversity index below the milpa mean, but the overall farm had a Shannon diversity index above the farm mean (in yellow), and these milpa fields were situated the furthest for each households. On the contrary for 2 households the Shannon diversity index of their milpa field was above the milpa mean, but the overall farm Shannon diversity index was below the farm mean (in orange), and there was no explanation concerning the distance. There was no relation between the distance village-field and the Shannon diversity index, as some fields far from the household had a Shannon diversity higher than the mean, and some fields closed to the village had an index lower than the mean.

Agrobiodiversity overview

Figure 9 shows that there was a great variability of Margalef index, but households with low Margalef index were more likely to also have a low Shannon diversity index.

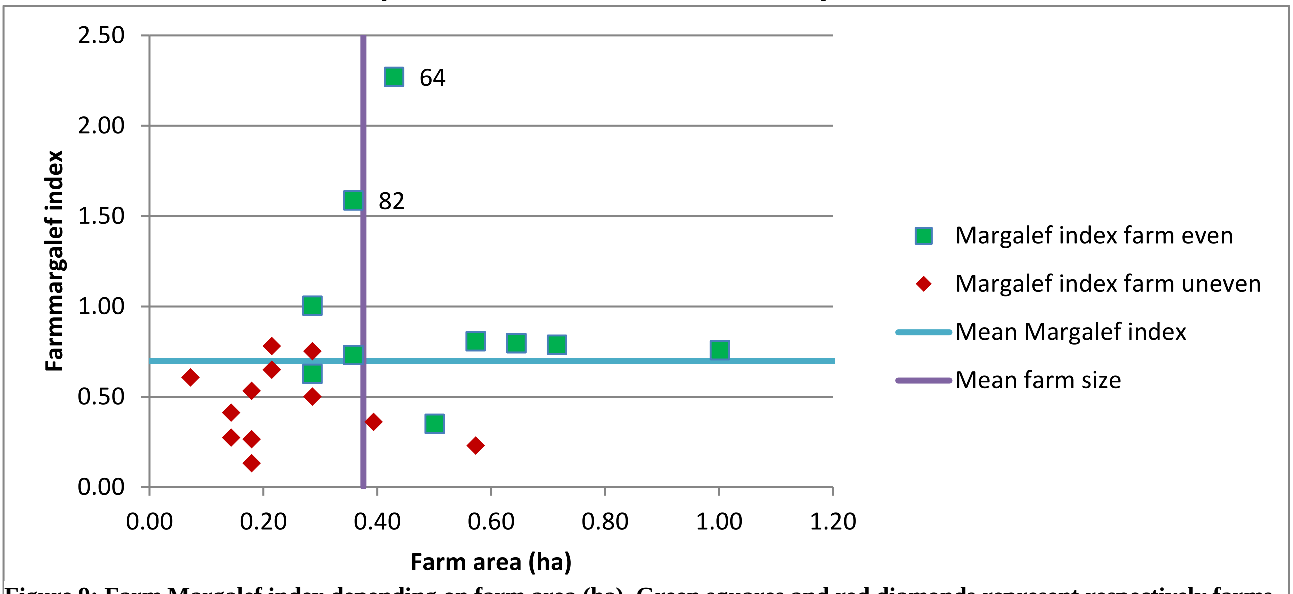


Figure 9: Farm Margalef index depending on farm area (ha). Green squares and red diamonds represent respectively farms having a Shannon diversity index superior and inferior to the average farm Shannon diversity index.

Figure 10 shows the Margalef and Shannon diversity index depending on the farm area, and farms with highest area seemed to have highest species richness and to be evener than smallest farms. This is also observed in the bottom-left quadrant of Figure 9.

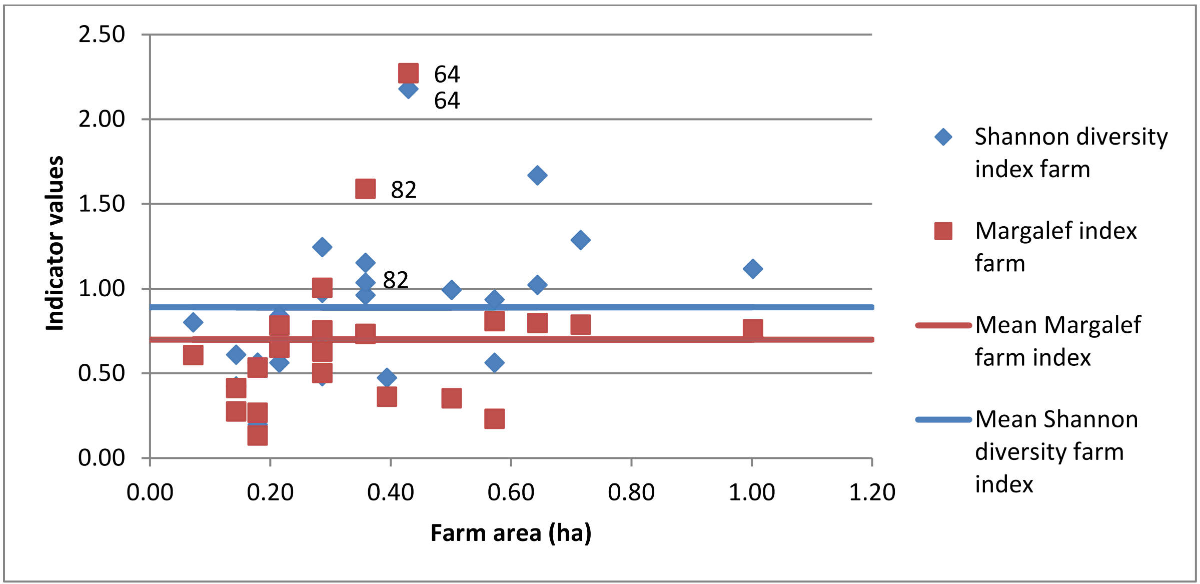


Figure 10: Farm Margalef (red squares) and Shannon diversity (blue diamonds) indexes depending on farm area (ha).

However, households number 82 and 64 had farm size around the average, but showed the highest species richness (respectively 20 and 14 species) and the crop distribution was rather even.

In addition Figure 11 shows the farm Margalef index depending on the farm area dedicated for the market. Most of the farms dedicating products for the market had a Margalef index higher than the mean, and showed a rather even crop distribution. On the contrary households dedicating all their land for their consumption (area dedicated for the market equals 0) had a rather poor species richness and crop distribution.

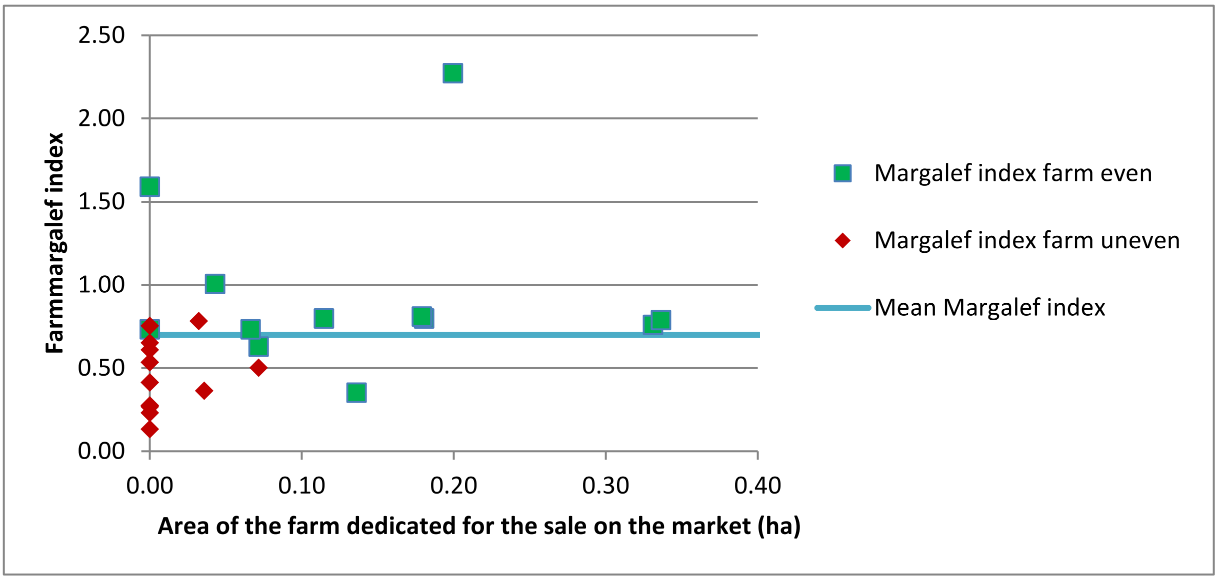


Figure 11: Farm Margalef index depending on the area of farm dedicated for the market (ha). Green squares and red diamonds represent respectively farms having a Shannon diversity index superior and inferior to the average farm Shannon diversity index.

4.3 PERCEPTIONS OF FARMERS REGARDING MILPA DIVERSIFICATION

Every household was interested to diversify their system but 10 households simplified it in comparison with their parents, 6 households reported to use exactly the same crops as them, and only 1 household grew more products than them. In addition, 4 households reported that their parents had a better harvest than them in the same fields, and one household observed a change in the climate, which associated with problems of soil fertility, questions the productivity of the land in this area. However 2 households reported that the harvest is better since they use fertilizers.

Figure 12 shows the number of households mentioning the different services provided by trees when asking: 'Which are all the benefits a tree can provide to you ?'.

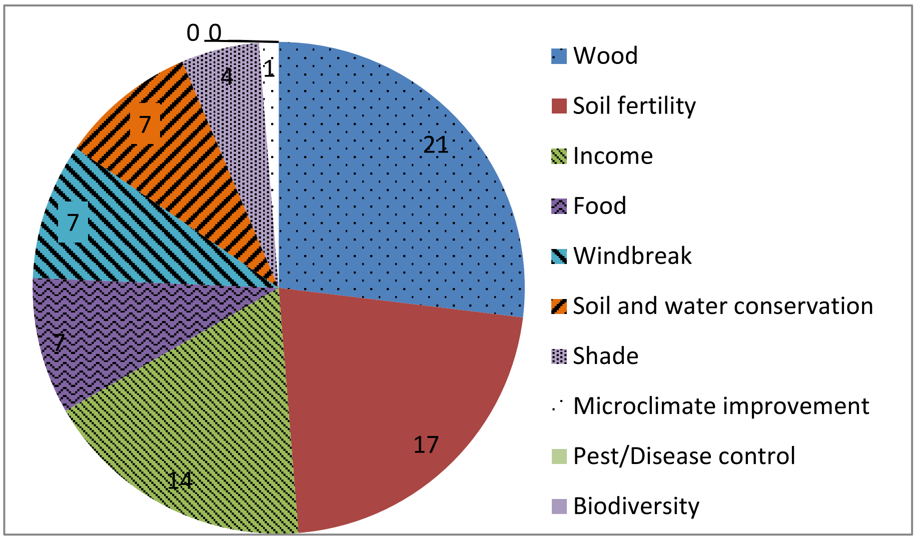


Figure 12: Number of households perceiving services from trees.

All households recognized that trees provide services, and the most mentionned were the provision of wood, the positive effect on soil fertility and the generation of income. However, no household discussed services regarding improving farm biodiversity, pests and diseases control, and only 1 household approached microclimate improvement, while few households discussed the potential for water conservation.

The same questions were asked for vegetables and trees.

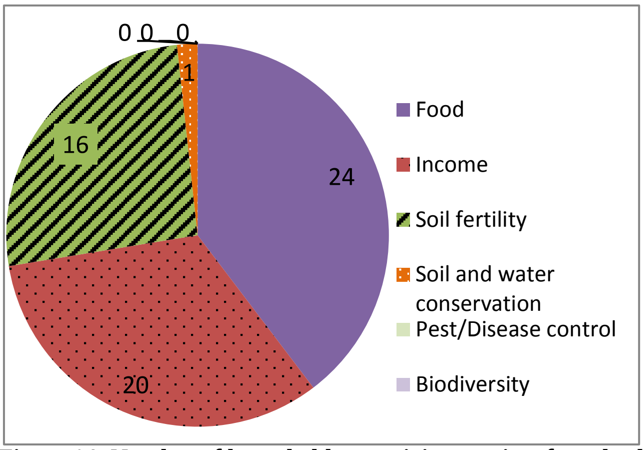


Figure 14: Number of households perceiving services from herbs.

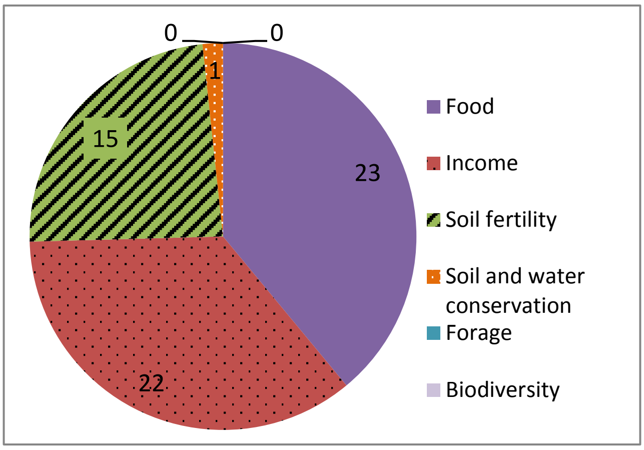


Figure 13: Number of households perceiving services from vegetables.

Figures 13 and 14 shows that results for herbs and vegetables were rather similar, and the provision of food and income generation were the two more mentioned services, followed by the improvement of soil fertility. Once again none of the households acknowledged the impact on biodiversity, and only one household (compared to 6 above) mentioned the benefits on soil and water conservation.

In a second step it was asked in two different questions 'Which are all the benefits/limits from diversifying your system ?', and Figure 15 and 16 respectively show the number of households mentioning the different benefits/limits.

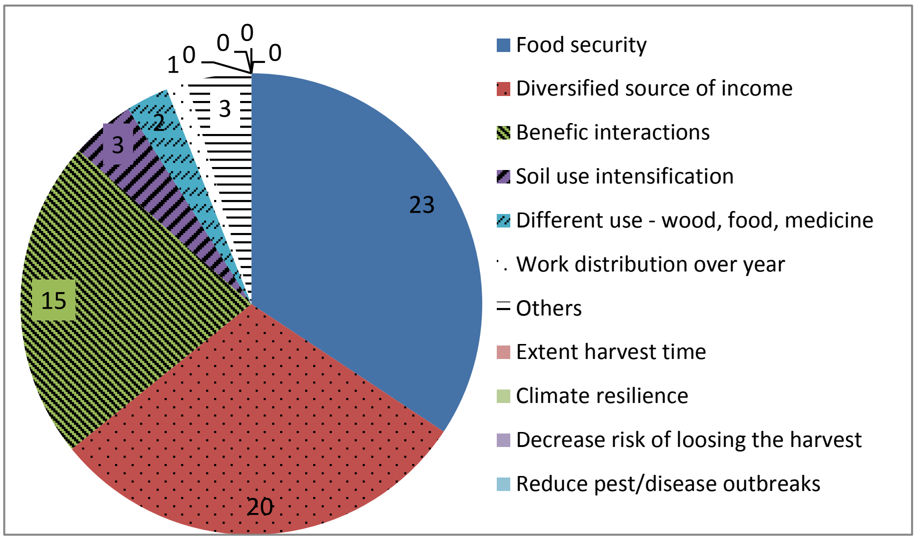


Figure 15: Number of households perceiving benefits from the diversification of their system.

Out of 24 households, 23 were interested to improve the household food security, 20 were looking for diverse sources of income, and 15 discussed the useful interactions between elements, especially the addition of soil organic matter. Three households also diversified their system to optimize their land-use, and the category 'others' mainly concerned soil conservation. None of the households mentioned the other benefits mentioned in Figure 15.

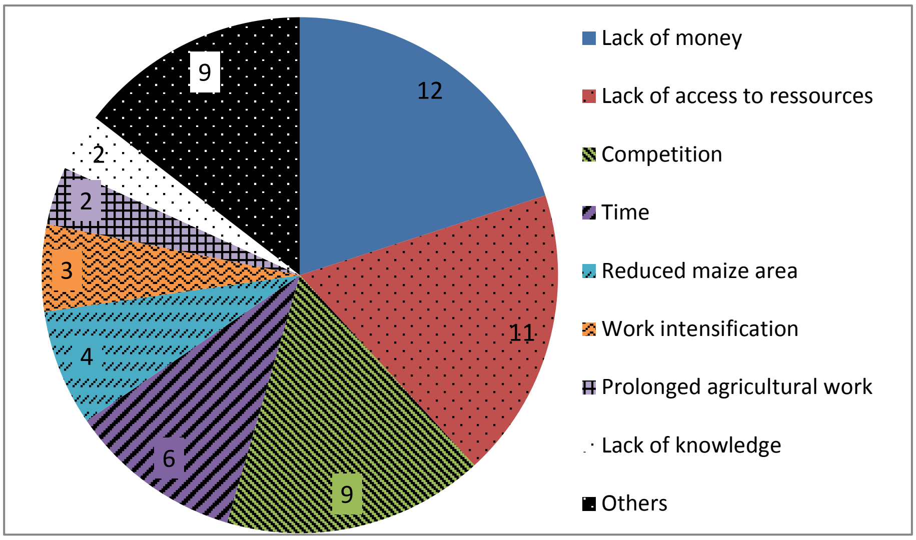


Figure 16: Number of households perceiving limitations to the diversification of their system.

The main limits mentioned were the lack of money and resources, the increased the competition for resources, and that it was more time-demanding. The types of limits in 'others' were the lack of water in and land to cultivate.

Criteria for crop adoption

Figure 17 presents the mean scores attributed by each households on the different criteria to take into account when adopting a new element.

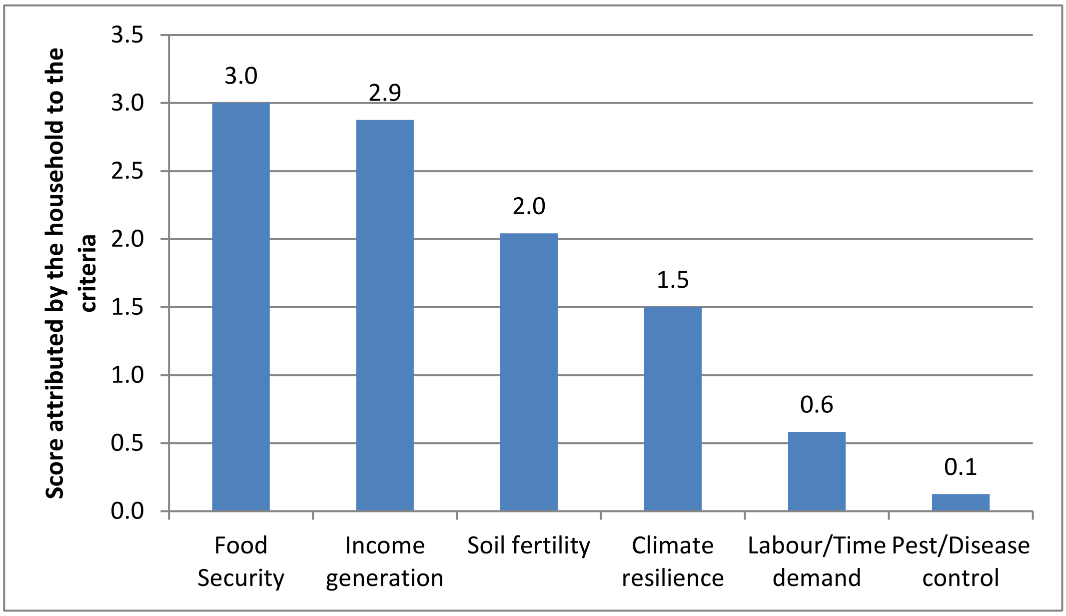


Figure 17: Households important aspects for crop adoption.

The potential of an individual crop to improve food security and income generation were the most important criteria for households to decide on the adoption of a new crop. It was followed by the provision of a good amendment to improve soil fertility and increase field productivity as well as improving field microclimate to buffer temperature and moisture variations. Interestingly the demand for labour and time by crops did not seem to be a key criteria. In addition, most farmers had no knowledge regarding control of pests and diseases so it could not be a criteria to take into account. Only one household proposed the provision of wood as other criteria, and rated it with a 3 ('very important').

A list of 7 'head' crops/trees composed by: poplar, oak, peach, avocado, carrots, tomato and chipilin (*Crotalaria longirostara*) was proposed at the first time, by default. However if one of these was already present in a milpa, another product from the same category (forest trees, fruit trees, vegetables or herbs) replaced it (see Annex 7).

Vegetables and peach tree were rare in the milpa, whereas poplar, oak and avocado trees were more widespread, therefore cypress or pine tree were proposed in replacement. The chipilin (*Crotalaria longirostara*) was already present in 6 milpas so spinach or black nightshade was proposed.

Indeed the category of forest trees was not interesting for the households as they did not provide food, whereas it was the most important aspect to adopt a crop for these households. On the contrary fruit trees and vegetables interested the households, especially to improve their diet, while generating income and improve soil fertility.

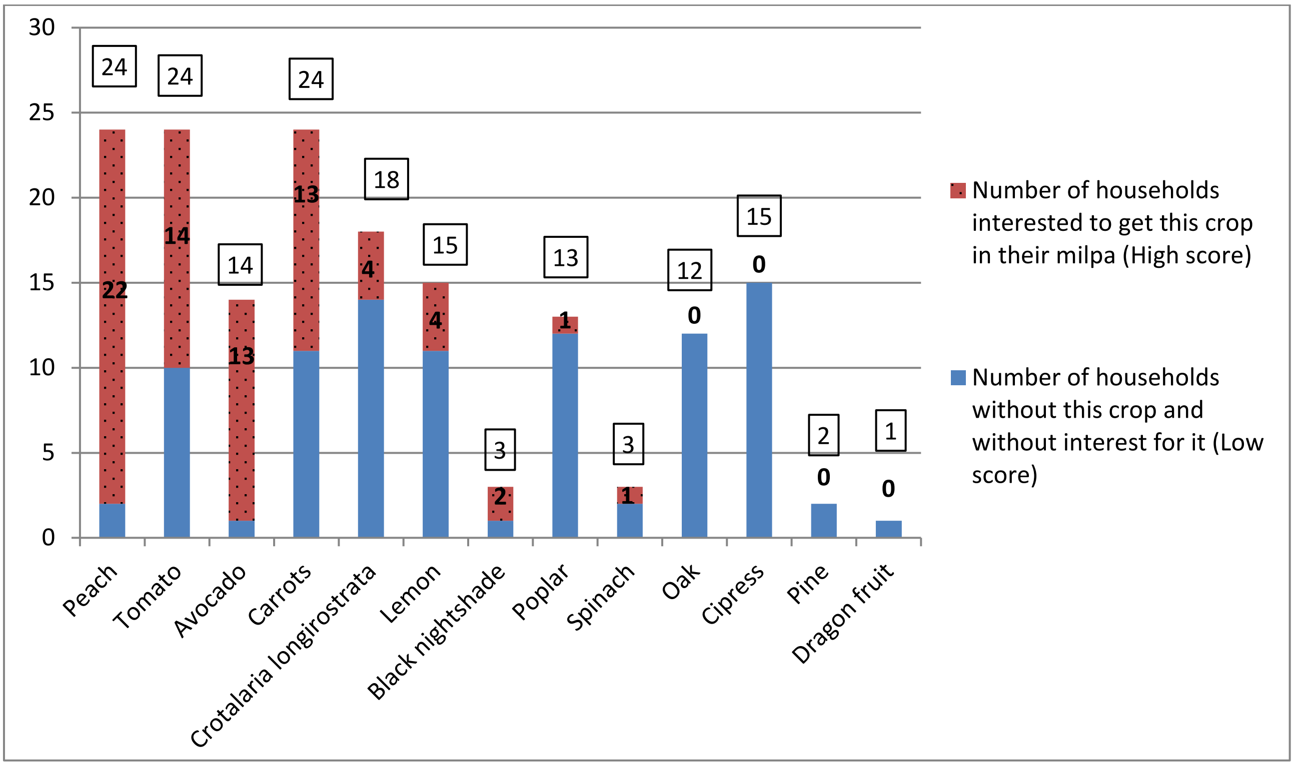


Figure 18: Number of households without the crop in the milpa (framed number) and how many of them consider the crop as interesting (red) or that did not rated the crop high enough to be considered as interesting.

4.4 FARMER'S OPPORTUNITIES AND CONSTRAINTS TOWARDS MILPA DIVERSIFICATION

After identifying the three most interesting crops/trees for the household, their implementation in their milpa fields was discussed. Figure 19 shows the different constraints and opportunities that the households encountered.

Problems of lack of resources are represented in blue and show to be the main problem encountered by the households. Indeed lack of money was an underlying barrier for the households, as they could not purchase the material and seeds necessary for the implementation of new crops in their fields. In addition most of the milpa did not have access to irrigation and it only rained about six months in one year. Maize is a suitable plant in this environment but not vegetables or trees which need water during the dry season.

Moreover some households were concerned that it would be time-demanding and that they would have to hire employees. They also argued that they did not have enough space to sow new crops in their milpa if they wanted to keep harvesting the same amount of maize. The most recurrent solution proposed was to rent a new field, but it was financially difficult, and no trees could have been planted on rented field. In addition some milpas were situated far from the household and products could be stolen. However some households reported to have space in another field, sometimes closer, where they would prefer to grow additional crops. Moreover some households did not know the management of these new crops (i.e. sowing time, pest and disease control) and did not feel empowered enough to cultivate them.

However the implementation of this 3-years project could offer opportunities to the households by providing seedlings and seeds from the association tree nursery, trainings concerning diversified home garden, water and soil conservation techniques and education concerning ecological services.

From the previous discussions with the households the following SWOT analysis was done to investigate internal and external as well as positive and negative factors concerning the diversification of their milpa.

The main strength of the diversification of the milpa was the motivation that the households had to be part in the project and their interest to provide more nutritious food to their household. However they lacked crucial resources to diversify their system, such as water or sufficient land. Lack of financial resource was a major obstacle as the households were very dependent on off-farm salary to buy food, seeds and other materials. In addition the great importance that households gave to maize hampered their willingness to adopt other crops as they wanted to keep the same harvest. Moreover this project focused on the production of food for the household consumption, but households mainly diversified their production to sell on the market.

However there was a great biodiversity present in this area, with many native crops more resistant and adapted to the local environment which could grow efficiently in this luxuriant tropical environment. The tree nursery plays a key role in this project as the workers grow native forest and fruit trees, and vegetables in order for the participants to benefit from it. However most of the fields remained very prone to soil and water erosion due to the steepness and the heavy rains. In addition due to climate change the planification of the agricultural work regarding weather events became more unstable and inaccurate, which jeopardised their harvest.

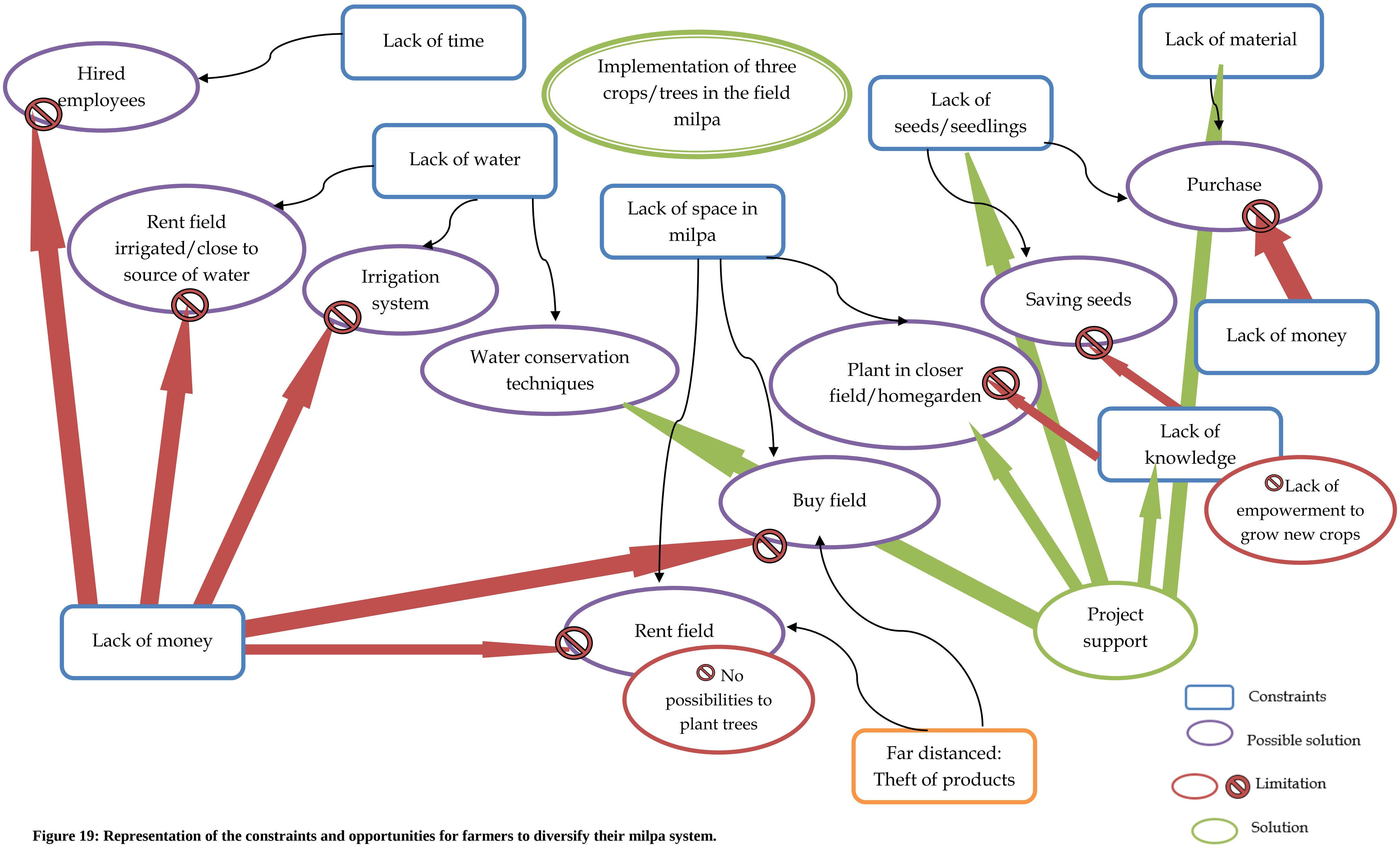


Figure 19: Representation of the constraints and opportunities for farmers to diversify their milpa system.

5 DISCUSSION

5.1 Subsistence farming

Twenty-two households out of 24 were subsistence-oriented farmers, dedicating most of their area for household consumption, and consuming at least all the production from their milpa. However their main source of income is the salary earned from off-farm activities and periods of food shortage are experienced when households do not receive a stable income. This rejects the hypothesis that subsistence farming was the dominant livelihood strategy to sustain the households.

Isakson (2009) described how equally dependent peasants are upon subsistence-oriented agriculture and wage labour and other forms of market income in Guatemala. He highlighted the complementarity between necessary off-farm income, and the milpa securing 'the foundations of the Guatemalan diet' (Isakson, 2009). He also identified that self-sufficient peasant were often exceptions as most households do not own sufficient landholdings, partly due to the complicated episode of decolonization (see Annex 11), and that pushed them to participate in off-farm activities. In our study the only household without any off-farm income also has the largest farm size (1.0 ha) and area dedicated for household consumption (0.7 ha), the highest area dedicated for one person consumption (0.10 ha) and notably does not report problem of food security.

5.2 Market influence on diversification

Interestingly farms dedicating significant area for the market had a Margalef and Shannon index above the mean, unlike the ones dedicating total farm area for household consumption, which rejects our hypothesis that farmers market oriented tend to have less diverse agricultural production than subsistence farmers.

Another study in Ecuador also found that most of the households were diversifying their production and sold about 70% of their production on the market in order to purchase food. They assessed farm agrobiodiversity and found a higher Margalef index mean of 2.0 and 1.55 for the Shannon diversity index, compared respectively with 0.71 and 0.89 in our study (Oyarzun et al., 2013).

Indeed the milpa did not show a great diversity, and a previous study in the same department reported more households intercropping maize and beans with 59% of the household growing it compared with about 42% in our sample, and maize monoculture reached 28% of the household, compared with about 12.5% in our sample. The average milpa size was equal, even if great variabilities were observed in our sample (Cifuentes et al., 2014).

5.3 Farmers interest

The 24 households showed a vivid interest regarding the diversification of their milpa, and producing more diverse products align with their objectives: ensuring household food security, generating additional sources of income and benefiting from interactions between the different elements (i.e. soil fertilisation, water conservation). This supports the hypothesis that many components could be implemented to diversify the current milpa system, while not being detrimental regarding farmer's objectives.

Indeed a study conducted by Segnon, et al. (2015) in Benin showed similarities as most households choosed crop diversification as a food security strategy, and improve soil fertility with crop rotation, therefore enhance field productivity. However in the study in Benin, at least one community was more knowledgeable regarding ecosystem services provided by agroforestry system (Segnon et al., 2015).

5.4 LIMITATIONS FROM FARMERS

Labour and time demand was not a key aspect as most households argued that every plant required time, and that they were willing to dedicate if it could have a positive effect on their household consumption or income. Farmers main constraint was the limited resources they had, which rejects the hypothesis that labour demand in highly-diversified milpa system was the major constraint. Access to materials such as irrigation systems, seeds or land was difficult which hampers field productivity and threatens their food security.

Maize and beans seeds were mainly saved and/or exchanged within families or village, like in two other studies conducted in the same region (Cifuentes et al., 2014; Keene, et al., 2014). However most of the farmers had to purchase vegetable seeds on the market, but their cost were preventing them, and this was also mentioned by Keene et al. (2014), as well as price volatility and loss of seed varieties.

As mentioned above, lack of land was a major problem and the study conducted by Keene et al. (2014) asked the amount of land needed to support a family, and most of them required about 1/3 more land than the average farm size in our sample (Keene et al., 2014). Moreover a study in Mexico reported that subsistence farmer had on average 0.46 ha, more than the double amount of land in our sample, in order to intercropped maize with other basic grains, native plants, vegetables and forest species (World Heritage Centre, n.d.).

5.5 FOOD ACCESS AND GLOBALIZATION

Previous results emphasized the ambiguous relationship between the households and the market environment. Access to market is important for the households' food security. However a study from Sibhatu et al. (2015) identified that, the type of products available in the outlets can lead to an unhealthy dietary diversification and threaten the health of the diet (Sibhatu et al., 2015). From our observations in the communities we identified two types of food-value chains (FVCs) coexisting. The first one is mainly represented by farmers selling parts of their agricultural production to other families or directly on the local market, and can provide nutritious food such as fruits and vegetables. The second FVC concerns the products found in proximity outlets, especially represented by calorie-dense processed/packaged foods such as carbohydrated drinks, chips, sweets, cakes, that are low in interesting micronutrients (Gómez & Ricketts, 2013).

Nonetheless some mothers desire to produce sufficient and diverse food to not purchase on the local market as they are concerned about food safety, farmers practices (chemicals spread) and the origin of the water used (recurrent problems of water contaminations. In addition many households eat nutritious native herbs (i.e. *Crotalaria longirostrata*) especially in times of food shortage. However other nutritious native crops such as chia or amaranth were not cultivated, and this disinterest for native and underutilised species was explained because of the preference for new imported processed food (Keene et al., 2014; Ebert, 2014) and because they were not interesting marketable products (Oyarzun et al., 2013).

However the production from the milpa remains an important component of the food environment of the households, as a great percentage of growers of NTXs reverted to grow the milpa (Isakson, 2009). For farmers the milpa is 'not reduced to the market value of the output' but also bring other types of values associated to this system and culture (Isakson, 2009). Indeed milpa cultivation is also a rational use of household resources, as women have very few opportunities to make off-farm income. Moreover most households have unsuitable land to grow NTXs so growing well-adapted species in the milpa makes it a senseful use of the land (Isakson, 2009).

5.6 Recommendations and integration of the project

The major recommendation would be to provide sufficient and diverse food all-year long, and focus on the production for home consumption (Janvry and Sadoulet, 2010), by improving soil fertility and increasing farm efficiency (Carozza et al., 2007; Pope et al., 2015; World Heritage Centre, n.d.).

Incorporating trees in agricultural systems such as windbreaks or agroforestry systems showed to increase soil organic matter, reduce nutrient leaching, improve water management through soil conservation and land restoration, and build a more stable, productive, and resilient system, while being suitable in steep fields (Pope et al., 2015; Haggar, et al., 2015). Moreover implementing homegardens composed by multi-purposes trees/shrubs would intensify the use of vacant spaces around the house (Alam, et al., 2010). Trees provide products such as food or wood highly valuable for the households, as well as ecological services such as pest and disease control and carbon sequestration. Agroforestry in milpa system is investigated in Guatemala and Mexico as a promising innovation (World Heritage Centre, n.d.).

Moreover studies showed that modern varieties do not meet farmers needs and are not always adapted to the location (Isakson, 2009; World Heritage Centre, n.d.), and there is a deep culture of diversity management through selective breeding and seed exchange in Guatemala (Isakson, 2009). Re actualising vegetable seeds saving from native crops could be a promising innovation for the households, and would emancipate them from seed companies and price volatility while reinforcing the flow of new varieties (Isakson, 2009).

Notably, the project of 'Vivamos Mejor' embraces a very holistic approach which targets the above mentioned limitations and follow the above mentioned recommendations by bypassing problems of financial resources and providing theoretical knowledge, seeds/seedlings, practical workshops and technical assistance. For instance the 'Asociación Vivamos Mejor Guatemala' developed a training centre in Chuitzanchaj called CEDRACC (Educational Center for Rural Development and Adaptation to Climate Change), which is briefly described in Annex 12.

5.7 Study Limitations

A limitation is the small number of surveys conducted (n=24) which only represents about 19% of the overall sample of the project. Therefore it is difficult to make strong conclusions especially due to the wide variability among our sample. In addition, all household were speaking 'Kaqchiquel' (local language), so the help of a translator was needed. Adding this intermediary between the researcher and the interviewee could induce biases in the answers of the interviewees. Moreover the survey was relying on self-reported metrics and few imprecisions could occur. Concerning the distribution of the different sources of income, it was only represented in percentage of yearly income but it would have been interesting to investigate it in the currency (quetzal guatemalteco) in order to make comparisons with the price of resources such as seeds or fertilisers, and make a better picture of the real profit made by farmers.

In addition, the trees and herbs planted around the house were not taken into account in the Shannon or Margalef index, however sometimes it was composed by elements absent in the fields, which could have increased these indexes. Moreover the two diversity indexes provide results at the farm scale but not at the landscape scale. For instance one farm could have high values for both indexes, have many different fields spread over the landscape, and does not take into account the integration of this biodiversity in the surrounding landscape. Configurations of fields were not taken into account and sometimes can mislead results interpretation. It was also very difficult for the households to place their fields on the maps because they were from 2010 and most of the trees and elements used as landmarks were not present. In addition the landscape was rather hilly (see Annex 1) while represented plane on the map, and therefore difficult for the persons to appreciate the lengths and size of their fields. As a consequence in Chuitzanchaj, 2 households had one field each outside of the map and two other households could not situate one of their fields.

Finally it would have been interesting to integrate a study of seeds origins, genetic diversity and flows, and compare it communities, region and country, as this represents an important cultural part of their farming practices and is much documented.

6 CONCLUSION

A large proportion of the interviewed households (22 out of 24) were practicing mainly subsistence farming, reserved the production of their milpa exclusively for their household consumption, and 10 of them were not selling anything from their production. However the milpa alone did not sustain a family, so their main source of income was their employed salary, and households experiencing food shortage identified these difficult periods when they did not receive off-farm income.

Unexpectedly market orientation and sale of agricultural products were positively related with agrobiodiversity (crop richness and distribution) as most of the household were mainly diversifying their production in order to sell on the market. There is a positive relation between the agrobiodiversity and the area of the farm dedicated for the sale on the market, as well as with the total farm size,

The main criteria for farmers to implement new crops were to ensure household food security and to have an extra-income. All the households had a great interest to diversify their system in order to sell on the market and be more competitive, or to improve their nutritional health, or to secure the household diet and food safety.

The major constraint for farmers to diversify their system were the lack of resources and especially financial support. Most of them were willing to dedicate time and labour but constraints such as lack of land or water were strongly hampering them. However the members of the project already identified actions to tackle these problems while bypassing the lack of financial resources. They provide adapted and more sustainable solutions by providing seeds, materials and knowledge while empowering the families in order to improve their nutritional status.

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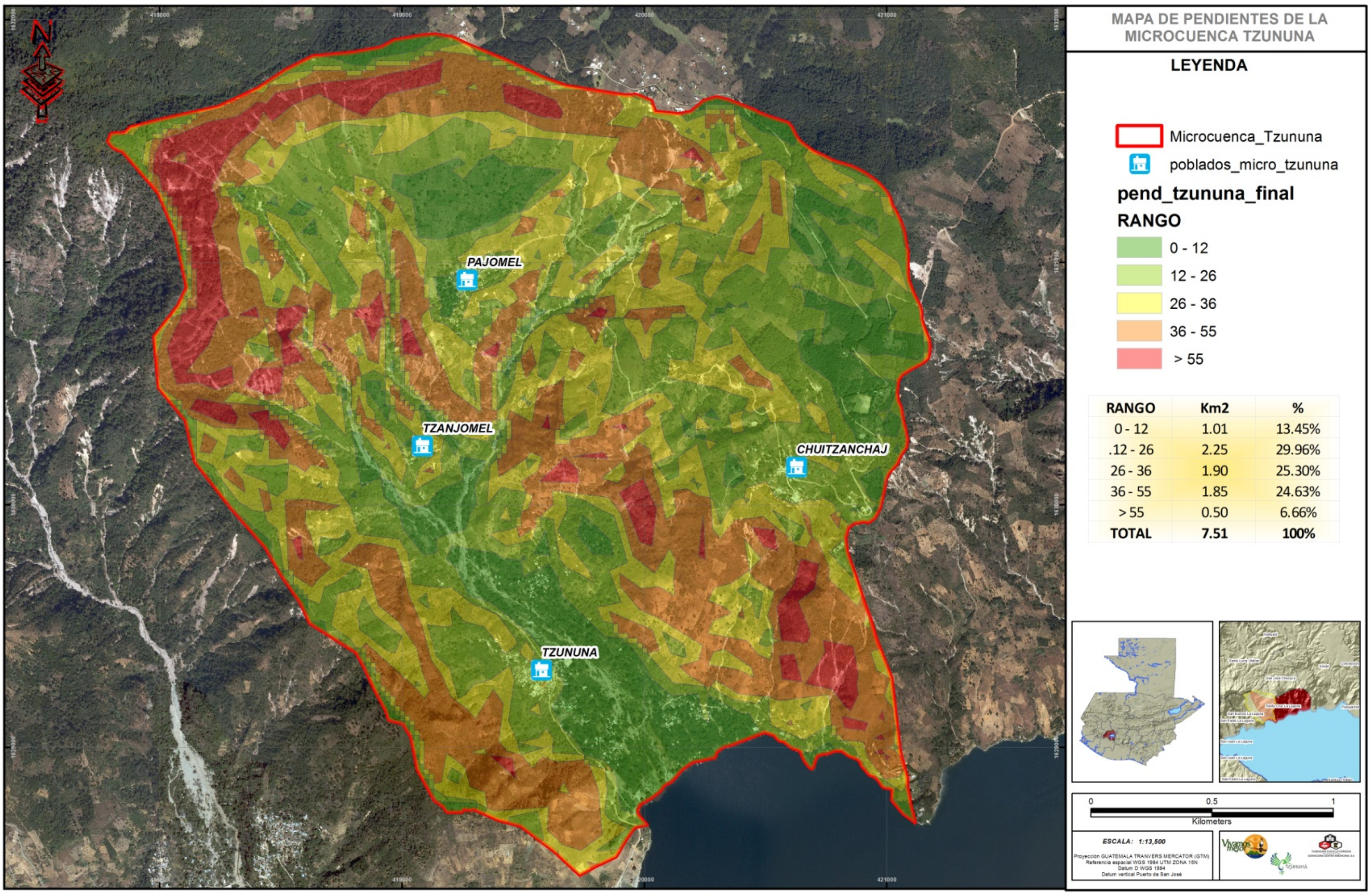
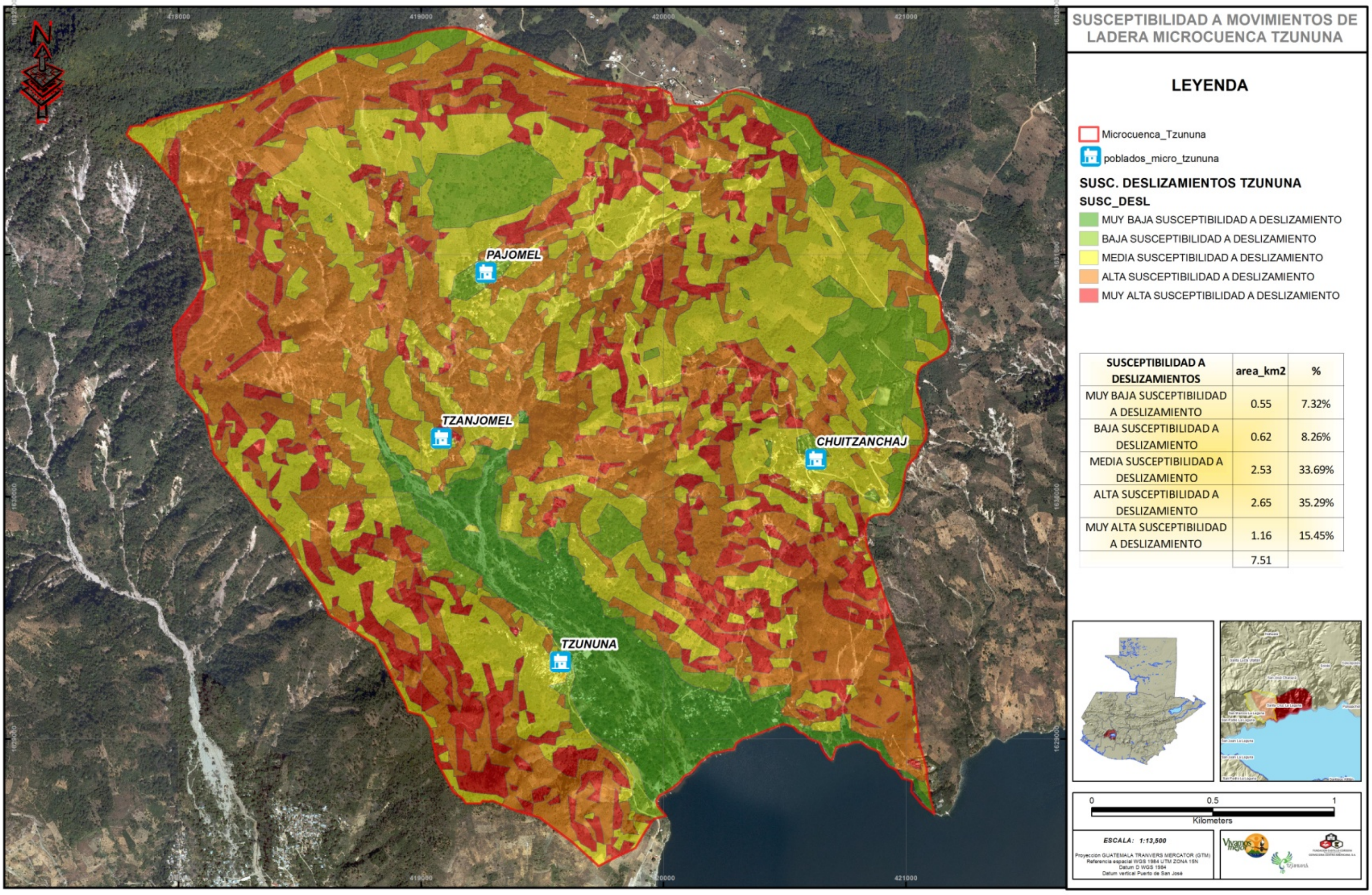
ANNEX 1: MAP OF THE SLOPES IN THE MICRO WATERSHED OF TZUNUNA



ANNEX 2: MAP OF THE SUSCEPTIBILITY TO LANDSLIDES IN THE MICRO WATERSHED OF TZUNUNA.



SUSCEPTIBILIDAD A DESLIZAMIENTOS	area_km2	%
MUY BAJA SUSCEPTIBILIDAD A DESLIZAMIENTO	0.55	7.32%
BAJA SUSCEPTIBILIDAD A DESLIZAMIENTO	0.62	8.26%
MEDIA SUSCEPTIBILIDAD A DESLIZAMIENTO	2.53	33.69%
ALTA SUSCEPTIBILIDAD A DESLIZAMIENTO	2.65	35.29%
MUY ALTA SUSCEPTIBILIDAD A DESLIZAMIENTO	1.16	15.45%
	7.51	

ANNEX 3: SURVEY HOUSEHOLD'S LIVELIHOOD STRATEGIES AND FARM PRODUCTION

#Boleta

Nombre informante

Nombre entrevistador

Fecha

Nombre personas en el hogar:

Municipalidad

* Mapa !

#Persona	Posicion en la familia	Sexo (F/M)	Edad	¿Tienes terreno propio ?	¿Tienes terreno alquilado ?
#					
#					
#					
#					
#					
#					
#					
#					
#					
#					
#					
#					
#					
#					
#					
#					

¿Qué tipo de animales tienes ?	¿Cuántos tiene actualmente?	¿Cuál es su proposito?

Milpa	Propio/alquilado ?		Municipalidad	
Cultivos (2017/2016):	%Superficie	%Hogar	% Mercado	% Ingreso

Practica de conservacion y de fertilidad del suelo:

Proposito de los àrboles en el sistema:

Listado de las 3-4 especies mas importante:

Practica de cultivo importanta por la milpa:

#Parcellas	2016/2015	2015/2014

Arbol abundancia:

#F	Propio/alquilado ?			Municipalidad		Practica de conservacion y de fertilidad del suelo:
Cultivos (2017/2016):		%Superficie	%Hogar	% Mercado	% Ingreso	

Proposito de los àrboles en el sistema:

Listado de las 3-4 especies mas importante:

Arbol abundancia:

¿ Nacio aqui ? ¿Tus padres viven aqui ?

¿Has hecho mayores cambios en la milpa desde tus padres ? Has visto mayores cambios en la milpa desde tus padres?

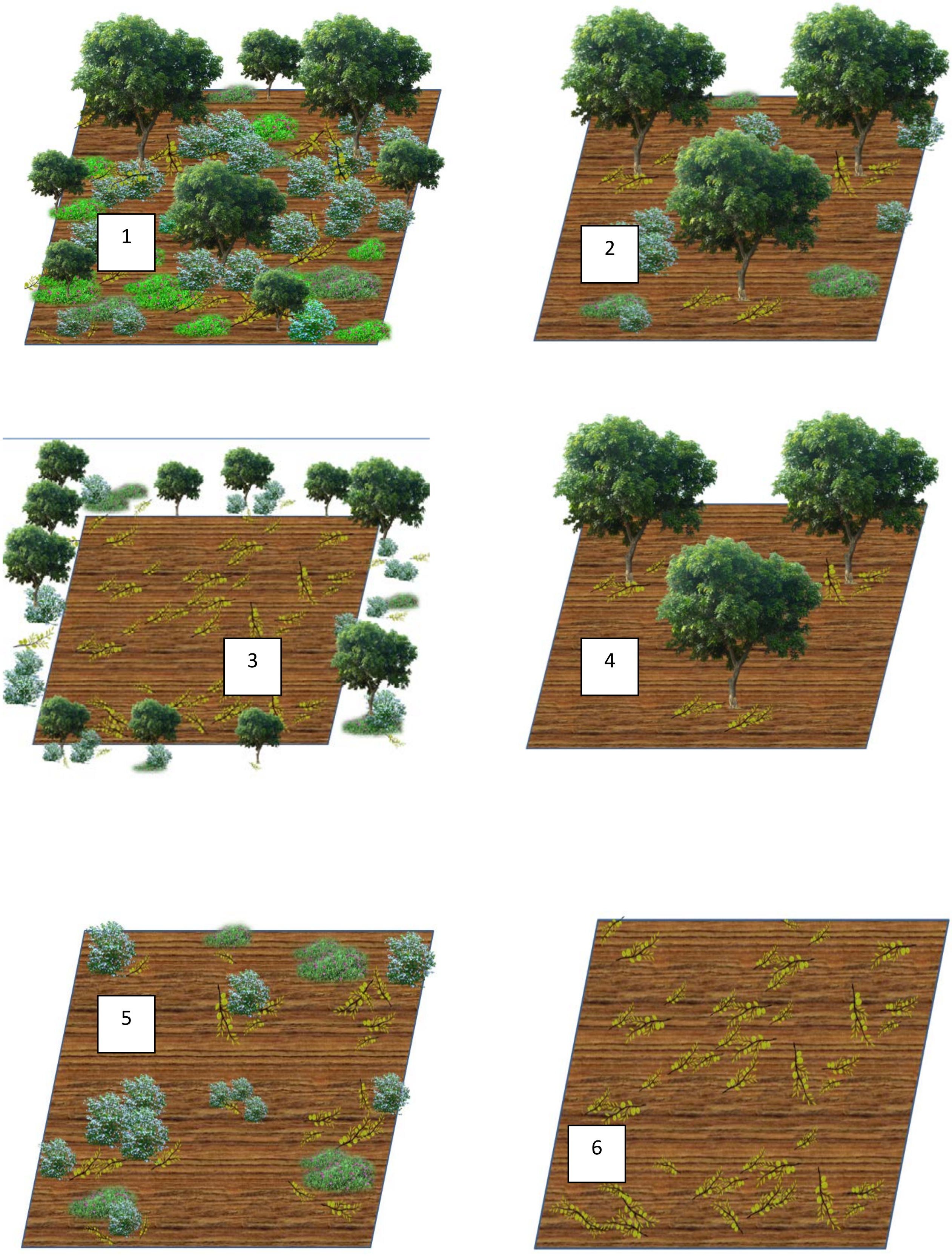
¿ Hay periodos durante el año cuando sientes que falta comida, o eque estes asustado de no tener suficiente comida para tu familia ?

¿Personas realizando actividades agrícolas como jornalero empleándo fuera del hogar? (Municipalidad)	¿% de ingreso ?	¿Personas realizando actividades no agrícolas como trabajador ? (Municipalidad)	¿Qué tipo de actividades ?	¿% de ingreso ?
#		#		
#		#		
#		#		
#		#		
#		#		
#		#		
#		#		
#		#		
#		#		

¿Personas fabricando objectos para vender? (Municipalidad)	¿Qué tipo de objectos vendeis ?	¿% de ingreso ?
#		
#		
#		
#		
#		
#		
#		

¿Otro tipo de ingreso ? (i.e. remesas, ayuda del gobierno ...)	¿% de ingreso ?

ANNEX 4: TREE BIOMASS CHARACTERISATION



Annex 5: Caption for interpretation of the maps.

Colour	Description Milpa	Description Fx	Interpretation
	Shannon diversity Milpa and Farm > Mean Shannon diversity Milpa or Farm	Shannon diversity Farm > Mean Shannon diversity Farm	The Milpa field and/or farm has an even crop distribution
	Shannon diversity Milpa and Farm < Mean Shannon diversity Milpa or Farm	Shannon diversity Farm < Mean Shannon diversity Farm	The Milpa field and/or farm has not an even crop distribution
	Shannon diversity Milpa < Mean Shannon diversity Milpa but Shannon diversity Farm > Mean Shannon diversity Farm		The Milpa field has not an even crop distribution but on overall the farm has an even crop distribution
	Shannon diversity Milpa > Mean Shannon diversity Milpa but Shannon diversity Farm < Mean Shannon diversity Farm		The Milpa field has an even crop distribution but on overall the farm has not an even crop distribution

ANNEX 6: SURVEY HOUSEHOLD'S INTEREST AND KNOWLEDGE ABOUT DIVERSIFIED SYSTEMS.

#Boleta Nombre informante
Nombre entrevistador
Fecha Nombre personas en el hogar:
Municipalidad

¿Hace cuántos años que tu siembra tu propio milpa ?

Ahora, los tipos de cultivos que tu tienes en tu sistema so (mira el cuestionario antes)

¿Tienes intéres en diversificar tu parcela ? ¿Porqué ?

¿Cuáles son los propósitos más importantes de los arboles en general?

Comida	Ingreso	Conservacion del suelo y agua	Biodiversidad
Leña	Mejorar microclimatico	Fertilidad del suelo	Control plagas/enfermedades

¿Cuáles son los propositos de las hierbas en general? (Ichäj) Ejemplo: chipilin, hierba blanca, hierba mora, bledo, amaranto

Comida	Ingreso	Control plagas/enfermedades	Forraje
Fertilidad del suelo	Biodiversidad	Conservacion del suelo y agua	

¿Cuáles son los mayores beneficios al diversificar tu sistema ?

Extender épocas de cosecha	Bajar el daño por plagas y enfermedades
Resistencia a riesgos climaticos.	Uso multiples - madera, leña, medicina
Seguridad alimentaria	Bajar riesgo de perder toda las cosechas
Interacciones benéficas entre las plantas (sombra, nutrie	Intensificar el uso del suelo
Tener diferentes fuentes de ingresos	Otras
Distribución del trabajo durante el año	

¿Cuáles séria lo mayores limites de diversificar tu sistema ?

Intensificación de trabajo	Falta de conocimientos	Otros
Competencia	Poco acceso a recursos (materiales/insumos)	
Reducción área de producción de maiz	Falta de dinero	
Prolongación del trabajo agrícola durante el añ	Tiempo	

¿Cuáles son los aspectos más importantes para adoptar un nuevo cultivo ?
(Comida, ingreso, resiliencia climatica, fertilidad del suelo, control de plagas y enfermedades, etc.)

Cultivo adopción	Si tu piensas introducir un nuevo cultivo, como va a cambiar tu sistema en terminos de ... -10 muy malo; -1 poquito negativo; 0 neutral ; +1 poquito positivo; +10 excelente									
	Trabajo/ tiempo necesid	Seguridad alimentaria	Generación de ingreso	Resiliencia Climática	Fertilidad del suelo	Plagas/Enfe rmedades				Total
Qué tan importante son estos aspectos para usted 0= no importante 1 = baja importancia 2 = importante 3= Muy importante										

Los 3 cultivos que tienen los mejores punteos son:

¿Piensa usted que podría sembrar estos tres cultivos en su parcela? Si/No y porqué ?

ANNEX 7: LIST OF ADDITIONAL ELEMENTS TO PROPOSE TO DIVERSIFY THE MILPA.

	Head element	***Substitution***
Forest trees	Poplar	Cypress
	Oak	Pine
Fruit trees	Peach	Lemon
	Avocado	Dragon fruit
Vegetables	Carrots	
	Tomato	
Herbs	'Chipilin' (*Crotalaria longirostrata*)	Spinach
		Black nightshade

ANNEX 8: INTERPRETATION OF THE SCALE SCORES.

Aspects	Phrase -10	Phrase 0	Phrase -10
Labour and time demand	“This crop is very time and labour demanding”	“This crop does not add any more time or labour ”	“This crop reduce a lot my time and labour”
Food security	“This crop improves greatly my diet”	“I do not eat this crop”	“This crop deteriorates my diet”
Income generation	“This crop provides a great income for my household”	“This crop does not provide me an income neither make me loose money”	“This crop makes me loose money”
Climate resilience	“This crop improves greatly the microclimate in my field”	“This crop does not impact the microclimate in my field”	“This crop deteriorates the microclimate in my field”
Soil fertility	“This crop improves greatly the soil fertility in my field”	“This crop does not impact the soil fertility in my field”	“This crop deteriorates the soil fertility in my field”
Weed and pest suppression	“This crop improves greatly the control of weed and pest in my field”	“This crop does not impact the control of weed and pest in my field”	“This crop jeopardises greatly the control of weed and pest in my field”

ANNEX 9: NUMBER OF HOUSEHOLDS USING FARMING PRACTICES FOR MILPA OR OTHER FIELDS (FX).

Fertilisation

	20-20-0	“Gallinaza”	15-15-15	Sulfato de amonio	Urea	“Yara”	Lombri-compost	Mixed fertilizers	Organic matter	Hydro-complex
Milpa	15	0	4	3	2	1	0	0	0	0
Fx	16	2	4	3	5	1	1	1	1	2

Weed management

	Machete	Mattock	Cover	Buried	Herbicide
Milpa	13	13	19	3	2
Fx	14	14	20	5	5

Residues management

	Burnt	Buried	Mulched	50% mulched/ 50% burnt
Milpa	17	3	3	1
Fx	17	4	7	1

ANNEX 10: LIST OF PRODUCTS ENCOUNTERED DURING OUR SURVEYS.

Name in Spanish	Name in English	Latin name
Aguacate	Avocado	*Persea americana*
Albahaca	Basil	*Ocimum basilicum*
Arveja	Pea	*Pisum sativum*
Avas	Broad beans	*Vicia faba*
Ayote	'Squash'	*Cucurbita argyrosperma*
Banano	Banana	*Musa spp.*
Bledo		Unknown
Café	Coffee	*Coffea arabica*
Camote	Sweet potato	*Ipomoea batatas*
Chilacayote	Fig-leaf gourd	*Cucurbita ficifolia*
Chipilin		*Crotalaria longirostrata*
Cyprés	Cypress	*Cupressus spp.*
Durazno	Peach	*Prunus persica*
Encino	Oak	*Quercus spp.*
Ejote	French beans	*Phaseolus vulgaris*
Eucalypto	Eucalyptus	*Eucalyptus spp.*
Frijol	Bean	*Phaseolus vulgaris*
Guachipilin		Unknown
Güicoy	Zucchini	*Cucurbita pepo*
Güisquil	Chayote	*Sechium edule*
Hierba blanca		*Brassica cf. napus var. napobrassica*
Hierba mora	Black nightsade	*Solanum nigrum*
Ilamo	Poplar	*Populus spp.*
Laurel	Laurel	*Cordia alliodora*
Maíz	Maize	*Zea mays*
Manzana	Apple	*Malus domestica*
Pino	Pine	*Pinus spp.*
Remolacha	Beetroot	*Beta vulgaris*
Tomate	Tomato	*Lycopersicon esculentum*
Yucca	Yucca	*Manihot esculenta*
Zanahoria	Carrot	*Daucus carota*

ANNEX 11: IMPACT OF THE EPISODE OF DECOLONIZATION IN GUATEMALA AND CONSEQUENCES ON AGRICULTURE.

Land scarcity remains a major constraint and relates to the complicated history of Guatemala. The country suffered from an important episode of colonization, where the colons appropriated the land belonging to the indigenous population. After the independence in 1821 the most powerful sectors, non-indigenous, legally received in heritage the ownership of the lands, which broadened the gap between the indigenous and non-indigenous population. After many decades of armed conflicts, especially between 1962 and 1996, the Peace Accords were proposed as solution and could have radically changed policies concerning land tenure in Guatemala. However the measures proposed concerning the redistribution of the land are not implemented, which results in an unequal distribution of the land where 2% of the farms own 67% of the arable land (usually rather plane and fertile) and 80% of the farms own in total 10% of the land, mainly very steep and not suitable for agriculture (Carrera, 2000).

As a consequence, farmers coped with the lack of land by converting of forest to agricultural land, reducing fallow period and using slash and burn practices also jeopardise soil fertility and food production by increasing soil erosion (Carozza et al., 2007; Pope et al., 2015). Carozza et al. (2007) pointed out that the introduction of maize cultivation associated with deforestation seems to be the most impactful agent towards soil erosion. Indeed the slash and burn practices in milpa cultivation in Mesoamerica was traditionally used, based on the principle that the soil would have a secondary vegetation growth to recover in between two periods of cultivation. However as land becomes more scarce, fallow period length decreases leading to land degradation (World Heritage Centre, n.d.). In addition the cultivation of the milpa in hillside areas (due to the land pressure) exacerbates problems of soil erosion, which decreases field productivity, drives people to deforest and convert more land to agriculture, and in return threatens their food security (Pope et al., 2015; World Heritage Centre, n.d.).

In addition in the 1980's neoliberal economic reforms were promoted by the US government, the World Bank and some Guatemalan elites, and were adopted in order to liberalize markets (Carey, 2009). Therefore many farmers adopted small-scale cultivation of NTXs instead of local and native products, as smallholder's farmers received loans with the condition to cultivate export crops (Carey, 2009; Carletto et al., 2010; Isakson, 2009, 2014; Janvry & Sadoulet, 2010). Therefore "in between 1985 and 2010, the quantity of land dedicated to non-traditional agricultural exports from Guatemala has increased by some 280 percent." (Isakson, 2014). It was supposedly a way to have more attractive products and reach an important growth in the agricultural sector by taking advantage of the comparative low labour costs (Carletto et al., 2010). However this led to a reallocation of the farm area from household consumption to market sale, and also increase the dependency towards agrochemical inputs leading to increased land degradation, decreased farm efficiency and threaten food security (Carey, 2009; Pope et al., 2015; Segnon et al., 2015). In addition prices on the global market dramatically declined due to additional producers entering into the export market and the important total volume of products exported (Carletto et al., 2010; Isakson, 2014). The importation of subsidized, cheap staple crops, competed with local products and pushed smallholders farmers out of the market, increasing their vulnerability (Isakson, 2014).

ANNEX 12: DESCRIPTION OF THE CEDRACC AND THEIR DIVERSIFIED MILPA PLOT.

The CEDRACC (Educational Center for Rural Development and Adaptation to Climate Change), promotes and trains individuals from the communities towards the topic of sustainable agriculture, climate change adaptation and risk management, food sovereignty and natural resources management. The centre is divided in different parts, and one of the major activities is the tree nursery which conserves, reproduces and promotes native species of forest and fruit trees, as well as vegetables. In addition they also propose the visit of demonstrative agroecological plots where are presented techniques such as terracing (agroecological garden), living fences (milpa field, see below) or their agroforestry systems using native biodiversity. Indeed below is presented the structure of their diversified milpa, with 13 different crops and 8 trees species. The Shannon diversity index of the milpa was about 1.77, which was above the households and milpa mean in our sample, respectively 0.89 and 0.62, and a Margalef index of about 3.04, compared with a mean of 0.70. Only 1 household had a Shannon diversity index superior, but had 3 fields (4.3 ha) in total, whereas the milpa of the CEDRACC had a surface of 0.07 ha. They are even above the indexes in the study from Oyarzun et al. (2013) whereas the average farm area was superior than the milpa field of the CEDRACC.

It is also in this center that households will receive education and support regarding soil conservation techniques, the provision of seeds and seedlings, workshops about seeds selection and solutions to reduce post-harvest losses. Households will also learn towards the implementation or improvement of the chicken management by visiting the chicken coop of the CEDRACC. Workshops concerning nutrition health and food properties, as well as hygiene rules and policies from the health government will be provided in the training centre. As observed the organization ‘Vivamos Mejor’ already built the problem tree and took actions adapted to the households needs.

Composition of the milpa field:

Number of crops: 13
Number of tree species: 8
Area (ha): 0.07
Soil conservation techniques: Living fences and integration of tree element.

Shannon diversity index: 1.766
Margalef index: 3.04

<table>
<tr><td colspan="12">Pilloy 3% of the milpa</td></tr>
<tr><td colspan="6">Maize
(5/8; 13.6% of the milpa)</td><td colspan="6">Beans
(3/8 = 8.1% of the milpa)</td></tr>
<tr><td colspan="12">Living fence: Chipilin (Crotalaria longirostara) 2.5% of the milpa</td></tr>
<tr><td colspan="6">Maize
(3/5; 13% of the milpa)</td><td colspan="6">Broad beans
(2/5; 8.7% of the milpa)</td></tr>
<tr><td colspan="4">Basil (1/3; 1% of the milpa)</td><td colspan="4">Rosemary (1/3; 1% milpa)</td><td colspan="4">Ixbut (1/3; 1% of the milpa)</td></tr>
<tr><td colspan="4">Maize
(5/10; 10.9% of the milpa)</td><td colspan="4">Beans
(3/10; 6.5% of the milpa)</td><td colspan="4">Potato
(2/10; 4.3% of the milpa)</td></tr>
<tr><td colspan="12">Pastocetaria 2.5% of the milpa</td></tr>
<tr><td colspan="3">Maize
(5/12; 9% of the milpa)</td><td colspan="3">Beans
(3/12; 5.4% of the milpa)</td><td colspan="3">Zuchini
(2/12; 3.6% of the milpa)</td><td colspan="3">Fig leaf gourd
(2/12; 3.6% of the milpa)</td></tr>
<tr><td colspan="12">Comfrey 2.5% of the milpa</td></tr>
</table>