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UNIVERSIDAD AUTÓNOMA DE SAN LUIS POTOSÍ

FACULTADES DE CIENCIAS QUÍMICAS, INGENIERÍA Y MEDICINA

PROGRAMAS MULTIDISCIPLINARIOS DE POSGRADO EN CIENCIAS AMBIENTALES

AND

TH KÖLN - UNIVERSITY OF APPLIED SCIENCES

INSTITUTE FOR TECHNOLOGY AND RESOURCES MANAGEMENT IN THE TROPICS AND SUBTROPICS

THE CONTRIBUTION OF AGRICULTURAL BIODIVERSITY TO FOOD SECURITY IN AN INDIGENOUS COMMUNITY IN THE HUASTECA POTOSINA, MEXICO

THESIS TO OBTAIN THE DEGREE OF

MAESTRÍA EN CIENCIAS AMBIENTALES

DEGREE AWARDED BY UNIVERSIDAD AUTÓNOMA DE SAN LUIS POTOSÍ

AND

MASTER OF SCIENCE

NATURAL RESOURCES MANAGEMENT AND DEVELOPMENT

DEGREE AWARDED BY TH KÖLN – UNIVERSITY OF APPLIED SCIENCES

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COLOGNE, GERMANY 08/09/2019

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LA MAESTRÍA EN CIENCIAS AMBIENTALES RECIBE APOYO A TRAVÉS DEL PROGRAMA NACIONAL DE POSGRADOS (PNPC - CONACYT)

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Erklärung / *Declaración*

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Abstract

While global food production greatly exceeds dietary energy demand, undernutrition remains, and diets largely fail to ensure the health of the population. Agricultural biodiversity is crucial for the world's food security, but genetic diversity has been degraded. In Mexico, the dietary transition towards processed foods has contributed to malnutrition and a rise of diet-related chronic diseases. Mexico's indigenous people are conserving and creating valuable plant genetic resources in their swidden *milpas* and traditional agroforestry systems but remain the country's most vulnerable population group. The Teenek (or Huastec), an indigenous group that habitat the Huasteca Potosina, a region in north-eastern Mexico cultivate a high diversity of edible plants in their home gardens (*solar*), *milpas*, and agroforestry systems (*te'lom*, or *finca*). However, migration has been leading to the abandonment of traditional farming in the region.

The objective of this study was to analyse if the managed agricultural biodiversity of the different traditional land use systems contributes to the food security of the farming households in the community of Jol Mom. Food availability and access were investigated. In total, 40 households were surveyed. Dietary patterns were identified through principal component analysis. Informal interviews, semi-structured interviews and participant observation allowed to account for the people's own perceptions and provided additional insights. Findings showed that traditional Teenek farming systems are the source of a variety of nutritious foods and resulted to be the most important provider of fruits and vegetables. The average production diversity was 34 out of 56 crops, farmers cultivating more than one or two farming systems showed an increase of four and 11 produced species respectively. Production diversity was strongly correlated with food variety in a household's diet, with an increment of one per 0.85 produced crop. Two main diverging dietary patterns were revealed, a westernized diet relying largely on purchased foods, to which the younger generation was more inclined, and a traditional diet characterized by a high consumption of cultivated products, mostly observed in the older households.

In conclusion, farming households in Jol Mom profit from the agricultural diversity of their production systems, either through the consumption of nutritious foods or by the sale of agricultural products. However, a tendency towards nutrient-poor diets was observed. Increasing agricultural diversity and consumption of locally produced foods might help to fight this trend but would require a valorisation of traditional foods and an appreciation of the contribution of indigenous people's traditional agriculture to food security.

Keywords Traditional Teenek agriculture • food security • agrobiodiversity • dietary patterns

Resumen

Si bien la producción mundial de alimentos excede en gran medida la demanda de energía alimentaria, la desnutrición permanece y las dietas no garantizan la salud de la población. La biodiversidad agrícola es crucial para la seguridad alimentaria del mundo, pero la diversidad genética se ha degradado. En México, la transición alimentaria hacia los alimentos procesados ha contribuido a la malnutrición y al aumento de las enfermedades crónicas relacionadas con la dieta. Los pueblos indígenas de México conservan y crean valiosos recursos fitogenéticos en sus *milpas* y sistemas agroforestales tradicionales pero siguen siendo el grupo de población más vulnerable del país. Los Teenek (o Huastecos), un grupo indígena que habita la Huasteca potosina, una región en el noreste de México, cultivan una gran diversidad de plantas comestibles en sus huertos familiares (*solar*), *milpas* y sistemas agroforestales (*te'lom* o *finca*). Sin embargo, la migración ha llevado al abandono de la agricultura tradicional en la región.

El objetivo de este estudio fue analizar si la biodiversidad agrícola que se maneja en los diferentes sistemas de producción tradicionales contribuye a la seguridad alimentaria de los hogares campesinos en la comunidad de Jol Mom. La investigación se centró en la disponibilidad y el acceso a los alimentos. Fueron encuestados en total 40 hogares. Se identificaron patrones dietéticos a través del análisis de componentes principales. Las entrevistas informales, las entrevistas semiestructuradas y la observación participante permitieron dar cuenta de las percepciones de las personas y proporcionaron información adicional. Los resultados mostraron que los sistemas agrícolas tradicionales Teenek son la fuente de una variedad de alimentos nutritivos, y resultaron ser el proveedor más importante de frutas y verduras. La diversidad de producción promedio fue de 34 de 56 cultivos, los agricultores que cultivaron más de uno o dos sistemas agrícolas mostraron un aumento de cuatro y 11 especies producidas, respectivamente. La diversidad de producción se correlacionó fuertemente con la variedad de alimentos en la dieta de un hogar, con un incremento de uno por 0.85 cultivo producido. Se revelaron dos patrones dietéticos divergentes principales, una dieta occidentalizada que depende en gran medida de los alimentos comprados, a los que las generaciones más jóvenes estaban más inclinadas, y una dieta tradicional caracterizada por un alto consumo de productos cultivados, observada principalmente en los hogares de mayor edad.

En conclusión, los hogares campesinos en Jol Mom se benefician de la diversidad agrícola de sus sistemas de producción, ya sea mediante el consumo de alimentos nutritivos o mediante la venta de productos agrícolas. Sin embargo, se observó una tendencia hacia las dietas pobres en nutrientes. El aumento de la diversidad agrícola y el consumo de alimentos de producción local podría ayudar a combatir esta tendencia, pero requeriría una valorización de los alimentos tradicionales y una apreciación de la contribución de la agricultura tradicional de los pueblos indígenas a la seguridad alimentaria.

Palabras clave Agricultura tradicional teenek • seguridad alimentaria • agrobiodiversidad • patrones alimenticios

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1 Introduction

For decades, researchers assumed that population growth was a main cause of food insecurity and the intensification of agriculture a necessary means to fight it (Chappell & LaValle, 2011). But in spite of the considerable population growth since the mid-20th century, production today has reached an average availability of over 2,800 calories per person per day worldwide, which represents an increase of 24 % over the last fifty years and is above the recommended daily intake of around 2,200 calories (Chappell *et al.*, 2011). Still, 11 % of the world's population is chronically undernourished and diet-related disease is responsible for 20 % of premature mortality, a result from both undernourishment and obesity (IPBES, 2019; Sibhatu & Qaim, 2017). In many low and middle-income countries, urbanization and income growths, among others, have led to a 'nutrition transition', with a high consumption of processed food and beverages high in saturated fats, salt and sugars (Popkin, 1993; Popkin *et al.*, 2013; Townsend *et al.*, 2016), while an increased consumption of fish, fruit, nuts and vegetables are recommended for an improved health (IPBES, 2019).

At the same time, today's agriculture accounts for a quarter of anthropogenic greenhouse gases, and is leading to deforestation and land degradation (IAASTD, 2009; IPCC, 2014). The latest report from the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) is drawing a worrisome picture for the state and future of the planet's biodiversity but also highlights that indigenous people and local communities have been the safeguards of it (IPBES, 2019). It states that "feeding humanity and enhancing the conservation and sustainable use of nature are complementary and closely interdependent goals" (IPBES, 2019, p. 8). But the loss of local varieties and breeds of domesticated plants and animals is ongoing. "This loss of diversity, including genetic diversity, poses a serious risk to global food security by undermining the resilience of many agricultural systems to threats such as pests, pathogens and climate change" (IPBES, 2019, p. 3). The IPBES (2019) affirms that the trend is the result of land use change, knowledge loss, market preferences and large-scale trade, while "the lands of indigenous peoples and local communities, including farmers, pastoralists and herders, are often important areas for in situ conservation of the remaining varieties and breeds" (IPBES, 2019, p. 15).

Mexico is a megadiverse country, occupying fifth place in terms of species richness and combining this high biodiversity with high cultural richness, being home to approximately 56 indigenous ethnic groups which have occupied the area for 12 000 to 14 000 years (Casas *et al.*, 2007; Mapes & Basurto, 2016). Mexico has been recognized as one of the six or seven centres of agricultural origin, and from a list of the 126 currently most important species of the world, around 10 % have been domesticated in Mexico (Perales Rivera & Aguirre Rivera, 2008). The domestication of traditionally and currently important crop species such as squash (*Cucurbita pepo*), maize (*Zea mays*) and beans (*Phaseolus vulgaris*) have been dated to 10 000, 6300 and 2300 years ago (Perales Rivera *et al.*, 2008). The country is home of 7461 registered useful plant species, 2168 of which are edible (Mapes *et al.*, 2016).

The indigenous people of Mexico, whose ancestors were the creators of named agricultural biodiversity, are Mexico's most marginalized population group. The stark contrast of 4 % of non-indigenous men in rural areas living in extreme poverty to 45 % of indigenous women in the same situation (CONEVAL, 2017 as cited in FAO, 2019) shows the severity of the situation. Similarly, the rural population and indigenous people in particular are the population groups most affected by food insecurity, 35 % and 42 % respectively are facing moderate to severe food insecurity (Mundo-Rosas *et al.*, 2013).

The task of rescuing Mexico's rich indigenous and traditional ecological knowledge and conserving the plant genetic resources which continue to be created/generated in indigenous people's farming systems, while trying to improve their food security with food aid programmes appears in some way paradoxical, but this is the reality in a context where discrimination and social exclusion lead to disadvantages (CONEVAL, 2018), and where neoliberal politics have made the sale of traditional crops such as maize unprofitable, undermining peasants' means of existence (Keleman, 2010).

The Teenek (or Huastec), indigenous people of Mayan origin, live in the eastern slope of the Sierra Madre Oriental in northeastern Mexico, a humid sub-tropical region called the Huasteca (Alcorn, 1984b). While in large parts of the region sugarcane fields, extensive livestock or cash cropping with orange, lychee or other fruit tree plantations are common, the hilliest areas where named industrialized agriculture is impossible are still covered with secondary forest and a patchy mosaic of *milpa* plots often cultivated in steep and rocky slopes. When taking a closer look, different stages of successive regrowth of fallow land are visible, but the coffee plants and fruit trees which are part of agroforestry systems are often hidden by canopy. These zones are the ones where most of the Huasteca's indigenous population is concentrated (Kelly *et al.*, 2010), among others of Teenek origin, such as the community of Jol Mom. It is located between the mountains in the municipality of Aquismón in the state of San Luis Potosí and still relies on swidden *milpa* cultivation and agroforestry systems (*te'lom*), complemented by products from the home gardens (*solar*), among other occupations, for subsistence. A study on the agrobiodiversity of the *milpa* fields from Jol Mom's farmers revealed a high inter- and intraspecific edible plant diversity (Heindorf *et al.*, in print).

While rich in resources and traditional agricultural knowledge, the Jol Mom community, as with many of the surrounding indigenous communities, is characterized by its "very high" degree of marginalization (SEDESOL, 2013). Young people prefer to migrate to the cities, and temporal migration for wage labor is common due to the to the small returns which can be achieved with the sale of the harvest from the *milpas*.

The marginalized position of the indigenous communities which contrasts with their rich knowledge about the use of natural resources and the abundance of their agricultural plots was the starting point of the presented research. The motivation was to find out if the by the study from Heindorf *et al.* (in print) detected agricultural biodiversity in the Teenek farming systems contributes to food security in Jol Mom. Questions arose, such as: How do households in Jol Mom provide food? Do people consume products from their fields? Is food sufficient? Are diets healthy? And are households which still manage all three traditional Teenek farming systems (*solar*, *milpa* and *finca*) more food secure than households which have abandoned one or several production systems?

In the form of summarized research questions:

- Do the traditional Teenek farming systems contribute to the availability of foods and the access to nutritious foods in Jol Mom?
- How are dietary patterns in Jol Mom linked to the management of traditional Teenek farming systems and their associated agrobiodiversity?

1.1 Objectives

The objective of the research is to evidence if the agricultural biodiversity of the traditional Teenek farming systems contributes to food security in the community of Jol Mom. The specific objectives are:

1. Evaluate the availability of and the access to nutritious foods in the community of Jol Mom.
2. Examine the relationship between the management of agrobiodiversity in traditional Teenek farming systems, food security and diet in the community of Jol Mom.

1.2 Justification

In the face of the global environmental crisis sustainable alternatives to the industrialized food production system are sought. While some 30 years ago relating the environmental crisis to the capitalist model of resources appropriation was still the task of some critical voices (see Brundtland, 1987), the link between an economy focused on economic growth and the current environmental degradation has today found its way into global assessment reports (see IPBES, 2019). The paradigm shift to a sustainable economic model has been discussed considerably, but local conditions based on an unchanged economic system often do not allow the implementation of the new paradigm at a local level. In Mexico, traditional agriculture, despite its recognition as an *in situ* reservoir of plant genetic resources, remains discounted as unprofitable and unviable, and is not recognized as equivalent with the higher yielding conventional agriculture. Other benefits beyond returns, for example that traditional and indigenous food systems rely on a rich knowledge system which allows for a benefit from the interrelation of food, medicine and health, associating food with cultural identity and social well-being, are often overlooked (Johns & Eyzaguirre, 2006). Yet, "ensuring the adaptive capacity of food production incorporates measures that conserve the diversity of genes, varieties, cultivars, breeds, landraces and species which also contribute to diversified, healthy and culturally-relevant nutrition" (IPBES, 2019, p. 30). Mexico, with more than two third of its adult population overweight or obese and a rising prevalence of diet-related noncommunicable diseases, while 13 % of the children under five suffer from chronic undernutrition (FAO, 2019a), might be able to profit and learn from its peasant and indigenous people's food and knowledge systems.

But first of all, "it is essential to have a good understanding of the amount of biodiversity that is available within a given food system and how it can serve nutrition, health and agriculture. Only then can biodiversity be incorporated (and mainstreamed) into policies and programmes, in order to guide consumers, producers, manufacturers, policymakers and others in the identification and promotion of a healthy, nutritious, safe and sustainable diet and food supply." (FAO & Bioversity International, 2017, p. 3)

The present study aims at understanding the potential of Teenek traditional farming systems to contribute to food security and healthy diets of the people who are managing the agricultural biodiversity associated with the production systems.

From a research point of view, an investigation in the Jol Mom community is promising because sampling and analysis of livelihoods in Jol Mom is facilitated by the fact that several variables are static. Firstly, the community is of entirely Teenek ethnicity; secondly, although with varying degrees, agriculture is practiced by almost all households; and thirdly, the community is not involved in larger scale cash cropping. The household characteristics of the people in Jol Mom can be identified in many communities of the Huasteca Potosina, but in most communities the number of households still engaging in traditional agriculture as the main subsistence/income strategy is marginal, and food generation is therefore more detached from agricultural production, which would make the assessment of the relationship between agricultural biodiversity and food security, which the study is based on, harder.

Also in literature authors have called for research on how agrobiodiversity or wild biodiversity contribute to the overall quality of diets, beyond single nutrient intake, stressing the urge to address malnutrition, including obesity and chronic nutrition-related diseases (Powell *et al.*, 2015).

Similarly, the Commission on Genetic Resources for Food and Agriculture (CGRFA) "recognize that more data on composition and intake, for example on wild and underutilized species and animal breeds, are needed to determine the importance of food biodiversity in food security and nutrition. The Guidelines highlight the need for more research and more practice in the integration of biodiversity into dietary assessment (FAO, CGRFA 2016)" (FAO *et al.*, 2017, p. 2).

Finally, despite the rich agroecological setting and reservoir of plant genetic resources (Alcorn, 1984b; Heindorf *et al.*, in print), little research has so far been conducted on Teenek food systems and the relation between diets and agricultural production.

1.3 Scope and structure of the presented work

At the centre of this research is the commonly eaten food in Jol Mom, *i.e.* the people's diet, with a focus on products which are (also) cultivated in the farming systems of Jol Mom. Consequently, the method which most focus was laid on is the Food Frequency Questionnaire, which served to provide information on the frequency of consumption of each food, as well as basic information on agricultural biodiversity in the form of a count of species cultivated from the same list, and the source from where people acquire the food. Another quantitative method was the survey on household characteristics, including questions on food security, although open-ended questions were also included. Apart from that, a lot of valuable information was provided from qualitative methods, above all from the informal interviews with the respondents, giving insight into the people's own perception on food and diets and their livelihoods, and was rounded up by impressions and insights obtained from participant observation and semi-structured interviews.

The work is divided into a theoretical part, an empirical part and a third section in which the highlights and the relevance of the obtained results are discussed. After the introductory section, the second chapter of this work will provide an overview of the concepts this work is based on and whose understanding is essential for the reading of the results of this study. At the same time, the author's interpretation and use of the concepts is explained. The third chapter is dedicated to the relevant literature which has been published in relation to the research topic. The setting of the case study is introduced in the fourth chapter, providing relevant information about the study region and describing the traditional Teenek agriculture which is the background of this study. The fifth chapter then presents the methodological approach assumed in this research, and the methods which were used to collect and analyse data. Afterwards, the results are presented, divided in two sections according to each research objective. Results and limitations of the investigations are discussed in the seventh chapter, before drawing final conclusions and describing outlooks for future investigation.

2 Theoretical framework

In this section the concepts of food security and agricultural biodiversity will be introduced. Furthermore, the concepts around smallholder agriculture and farming systems will be explained, as this is the contextual setting of the target population subject of the presented research.

2.1 Food security – definition, measurement and related concepts

The concept of food security evolved in the mid-1970 at a time of global food crisis, and focused on the availability and to some degree the price stability of basic foodstuff on the international and national level (FAO, 2003). Within the following 25 years, the concept was steadily modified first through the recognition of the importance of access to food by vulnerable people and the balance between demand and supply, then including aspects of food composition and food preferences and therefore drawing attention to context specificity. In 1996, at the World Food Summit, it was agreed upon that "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (World Food Summit, 1996). This definition was only slightly refined in 2001 to include social access on top of physical and economic access (FAO, 2001, 2003). Food insecurity, the absence of one or several of these conditions, can be classified in different stages between chronic (long-term), and transitory (short-term) (FAO, 2008). Seasonal food insecurity falls between the two, and describes a cyclical pattern of inadequate food supply, often resulting from variability in climate, cropping patterns, diseases and work opportunities or demand (FAO, 2008). Nutrition security includes care, health and hygiene practices in addition to the requirements of food security and is therefore a broader term than food security (Jones *et al.*, 2013). Hunger is a form of food deprivation, and defined by the FAO as an "uncomfortable or painful sensation caused by insufficient food energy consumption" (FAO, 2008), and in the latest report on the state of Food Security and Nutrition in the world the term is used as synonymous with chronic undernourishment (FAO *et al.*, 2018). When habitual food consumption is below a certain threshold which signals the dietary energy required for an active and healthy life, the individual is undernourished (FAO *et al.*, 2018). Undernutrition is a result of undernourishment, and "poor absorption and/or poor biological use of nutrients consumed" (FAO *et al.*, 2018; Jones *et al.*, 2013). Malnutrition on the other hand can result from either deficiencies, excesses or imbalances of macro- and/or micronutrients. Furthermore, malnutrition can also be caused by non-food factors related to the environment, to health services or care practices for children (FAO, 2008).

Food security encompasses four dimensions that must be fulfilled simultaneously:

1. The physical **availability** of food must be guaranteed, which is determined by food production, stock levels, net trade, transportation and wild foods.
2. The economic and physical **access** to food can be influenced by incomes, expenditure, market and prices of foods.

3. Food **utilization** depends upon feeding practices, food preparation, dietary diversity and the distribution of food within the household, which combined with good care can ensure sufficient energy and nutrient intake by the individuals.
4. The **stability** of the other three dimensions over time must be ensured and might be at risk in cases of adverse weather conditions, political instability, or economic factors and can lead to food insecurity (FAO, 2008; FAO *et al.*, 2018).

The dimensions are of hierarchical character, the availability of food is necessary for food access, but not sufficient, just as access to foods is necessary for adequate food utilization, but not a sufficient condition (Webb *et al.*, 2006). The scheme from Leroy *et al.* (2015) shows the dimensions, the levels of measurement of each dimension, and the different components of food security which can be analysed (Figure 1). The outcomes of the fulfilment of the dimensions find expression in the nutritional status, the physical well-being, and in cognitive and affective consequences of the people.

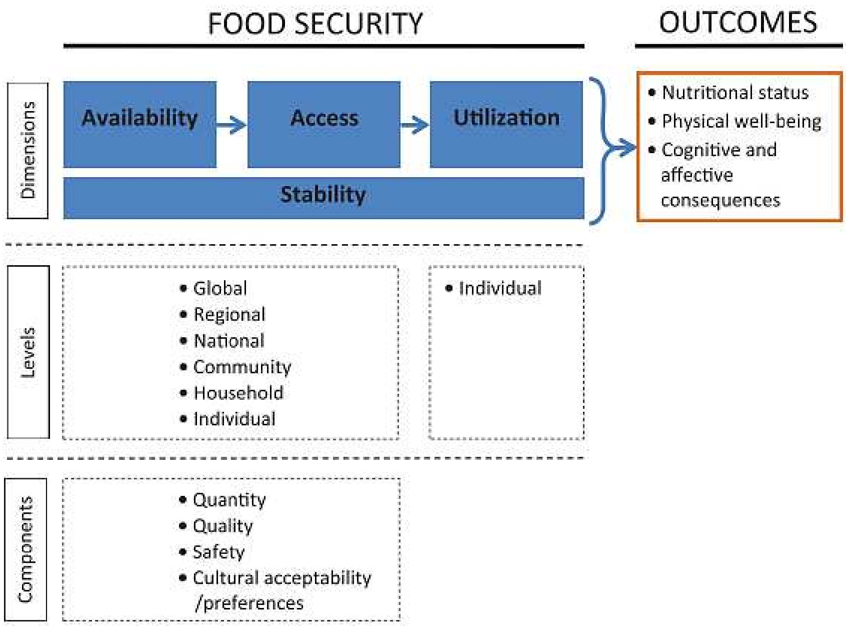


Figure 1: Food security dimensions, its measurement levels and components. Source: (Leroy *et al.*, 2015)

Rethinking of the measurement of food security took place after Amartya Sen's "Poverty and Famines" laid bare that people are food insecure not because of the unavailability of foods on the market but because their access to food is constrained (Maxwell & Smith, 1992; Webb *et al.*, 2006). The focus was put on improving the measurement of the 'access' dimension of food security, but "with only varying degrees of success", as Webb *et al.* (2006) put it. "Proxy measures are commonly used, be they centered on agricultural productivity and food storage or on children's nutritional status. Yet, each of these proxies is only a partial, usually indirect, measure of what is a larger, multifaceted phenomenon. Similarly, the relationship between caloric (or other nutrient) sufficiency and household food security has been shown to be unpredictable across a range of circumstances. Indeed, a recent international meeting on the measurement and assessment of food deprivation concluded that no 'perfect single measure that captures *all aspects* of food insecurity' had yet been found" (Webb *et al.*, 2006).

Unlike the availability of foods or the nutritional status of individuals, a failure of the access dimension of food security is difficult to determine. Often, deprivation is expressed by reallocation of resources, disinvestment of assets, a reduction of food intake or the taking of higher risks to obtain income (Webb *et al.*, 2006). As a consequence, measures of access failures started to capture household behaviours that are known to reflect increased food stresses (Webb *et al.*, 2006), which is the base of the experience-based food insecurity indicator. The Household Food Security Survey Module (HFSSM) was the first indicator of this sort, developed by the US Department of Agriculture, and after its success it was adapted for different contexts, *e.g.* for the Escala Latinoamericana y Caribeña de Seguridad Alimentaria (ELCSA) (Leroy *et al.*, 2015). Another way to evaluate food insecurity is to assess the measures households take to mitigate the consequences of food shortages. The Coping Strategy Index (CSI) used for this purpose is proposed as a methodology which can be adapted to the local context (Leroy *et al.*, 2015). Finally, a third group of food access indicators are the dietary diversity scores. Dietary diversity has been recognized as a key element of diet quality, as with increasing variety of foods consumed the intake of essential nutrients increases, and some have been designed specifically to measure food security, on the individual and on household level. They rely on a count of foods or food groups consumed over a certain recall period (Leroy *et al.*, 2015). While originally designed for measuring both quantity and quality of foods, the HDDS and the FCS have not been validated for predicting adequate quality (micronutrient adequacy), partly because they include food groups that contribute mostly to energy (*e.g.* oils, sugars). Leroy *et al.* (2015) provide an overview of the most commonly used food security indicators which have a low respondent burden and are suitable in large surveys (Table 1). They criticize that, althoughpart of the concept of food security, there are no validated indicators which account for the components of safety and the cultural acceptability of foods (Leroy *et al.*, 2015). Furthermore, attention must be paid when comparing the results of assessed indicators in different contexts. For example, an increase of a dietary diversity score will have different effects on micronutrient adequacy in a context where dietary diversity is generally high compared to a context where it is low. "It is critically important to ensure the right balance between reaching equivalence and maintaining local relevance" (Leroy *et al.*, 2015). More context-specific tools for assessing food security include, for example, the experience-based access indicator 'Months of Adequate Household Food Provisioning' (MAHFP) (Swindale & Bilinsky, 2010). Mostly used in rural context, it indicates the months in which food shortage has been or not been experienced. Furthermore, and especially interesting when assessing diversity within single food groups, *e.g.* as a link to agrobiodiversity (Keding *et al.*, 2012), a count of consumed food items, called Food Variety Score (FVS), has also been found to give a good assessment for the nutritional adequacy of the diet (Hatløy *et al.*, 1998; Torheim *et al.*, 2003).

Table 1: Most common and validated instruments used for measuring household (and individual) food access, information based on Leroy *et al.* (2015).

Type	Indicator	Design and validity	Level and context
Experience-based	Household Food Security Survey Module (HFSSM)	18 questions on behavior and attitudes that distinguish the degree of food insecurity experienced by households. Different recall periods, originally one year. Addresses quantity and quality	Household U.S. across contexts
	Escala Latinoamericana y Caribeña de Seguridad Alimentaria (ELCSA)	15 questions, design based on HFSSM. Addresses quantity and quality	Household Latin America across countries and contexts
	Household Food Insecurity and Access Scale (HFIAS)	Nine items that measure occurrence and frequency of domains associated with household food insecurity access. 30 days recall period. Indicates quantity and quality	Household Not appropriate for cross-country and context comparisons
	Household Hunger Scale (HHS)	Based on HFIAS last three items, indicating severe experiences of food shortage and hunger. 30 days recall period. Indicates quantity as a lack of food	Household Used for cross-country and context comparisons
Coping strategies	Coping Strategy Index (CSI) and reduced CSI	Identification of local coping strategies and design of a score. 7-day recall period	Household Context specific, not meant to be used for cross-country or context comparisons
Dietary diversity	Household Dietary Diversity Score (HDDS)	12 food groups: 2 staple foods (mostly quantity); eight micronutrient- rich food groups (quality and quantity); 3 energy-rich (and largely nutrient-poor) food groups (quantity). 24h recall period. Good for quantity, also used for quality but not validated	Household
	Infant and Young Child Dietary Diversity Score (IYCDDS)	Seven food groups: grains, roots, and tubers; legumes and nuts; dairy products; flesh foods; eggs; vitamin A–rich fruits and vegetables; other fruits and vegetables. 24 h recall period. Addresses quality, good for micronutrient density	Individual
	Women's and Individual Dietary Diversity (WDDS and IDDS) New: Minimum Dietary Diversity-Women (MDD-W)	WDDS and IDDS: 16 food groups, then aggregated into nine. MDD-W: ten food groups (grains, white roots and tubers, and plantains; pulses; nuts and seeds; dairy; meat, poultry and fish; eggs; dark green leafy vegetables; other vitamin A-rich fruits and vegetables; other vegetables; other fruits). 24 h recall period. Addresses quality, good for micronutrient adequacy	Individual
	Food Consumption Score (FCS)	Eight food groups, each with group-specific weight. 7-day recall period. Good for quantity, also used for quality but not validated	Household

While the FAO's definition of food security has evolved over the years, and measurement tools have been constantly improving, critics claim that the improvement of food security is often a simple policy goal, and aimed to be achieved without changing anything about the inequality in power that led to the food insecurity situation, patching up a broken system with entitlements (Patel, 2012), indifferent about the production conditions of the foods which merely serve to satisfy human needs (Barkin, 2016). These critiques, formulated by the international peasants' movement La Via Campesina, led to the counter concept of 'food sovereignty'. In contrast to food security, "the food sovereignty movement also advocates that people have sufficient access to food, but under the following conditions: (1) that food be produced through a diversified, farmer-based system; (2) that people have the right to determine the degree to which they would like to achieve food self-sufficiency and the ability to define terms of trade that are consistent with the sustainable use of natural resources and the health of local economies; and (3) that people not only have the right to sufficient calories, but also the ability to fulfil their nutritional needs with foods and practices that are culturally meaningful" (Isakson, 2009). The International Planning Committee for Food Sovereignty (IPC), which was formed in 2002, suggested four priority areas of food sovereignty, which are: the right to food; access to productive resources; mainstreaming of agroecological production; and trade and local markets. The declaration of Nyéléni stresses that food sovereignty means the primacy of people's and community's rights to food and food production, over trade concerns (World Forum for Food Sovereignty, 2007). Barkin (2016) highlights that "the operative difference between the two [food security and food sovereignty] is the emphasis on the conditions of production, the processes, and the impacts that this production has on the environment and on the people involved. By emphasizing process and impacts, the Food Sovereignty approach places its emphasis on the ways in which food systems promote a dynamic integration of communities with an all-inclusive concern for the relationship between producers, production, and the ecosystems within which they function." He argues consequently that the food sovereignty approach is not only a step towards fighting social inequality, but also for reaching environmental balance.

Another important concept in this context is the right to food, generally understood as the "right to feed oneself in dignity" and is an international human right many countries have committed to (FAO, 2019c). It is part of the International Covenant on Economic, Social and Cultural Rights (ICESCR). The Mexican constitution considers, since 2011, food security as a fundamental human right (Oxfam Mexico, 2013; Shamah-Levy *et al.*, 2017). Nevertheless, the normative frame is not sufficient, and the enforcement of this right will only be possible with an economic and political transformation from the system which is causing food insecurity in Mexico and the world (Oxfam Mexico, 2013).

In this work, the FAO's definition of food security and its dimensions is adapted, acknowledging its utility for measurement and comparison across studies. The focus is laid on the dimensions of food availability and food access and highlight some aspects of the stability dimension. Nevertheless, the political component of food security is also recognized – in line with the food sovereignty movement – and the work is seen as a contribution to the evidence of indigenous communities maintaining local food systems.

2.2 Agricultural biodiversity

The traditional Teenek poly-crop farming systems have been found to be the safeguards of a great variety of edible plants (Alcorn, 1984; Heindorf *et al.*, in print). While diverse on intra-varietal and species level, they also contribute to a landscape mosaic of the small *milpa* plots and agroforestry systems – diversity on landscape level. The concept of agricultural biodiversity is important for valuing their form of production and shall be introduced in the following section.

Agricultural biodiversity, also known as agrobiodiversity or the genetic resources for food and agriculture, is a sub-set of biodiversity. It is a result of natural selection processes combined with the effort of farmers, herders and fishers over millennia of selection and inventive developments (FAO & CBD, 1998). While several definitions exist, the FAO and the Secretariat of the Convention on Biological Diversity summarized in a technical workshop in 1998 that "agricultural biodiversity encompasses the variety and variability of animals, plants and micro-organisms which are necessary to sustain key functions of the agro-ecosystem, its structure and processes for, and in support of, food production and food security" (FAO *et al.*, 1998). It comprises:

- Harvested species such as crop varieties, livestock breeds, fish species and non-domesticated 'wild' resources;
- Non-harvested species present in the production system that support food provision;
- Non-harvested species in the wider environment that support functions of the food production ecosystem (FAO *et al.*, 1998).

While widely used as differentiation, there is no sharp line between wild vs. cultivated species, but rather a continuum from wild species under various degrees of human management and intervention through to domestication (Heywood, 1999; Perales Rivera *et al.*, 2008; Powell *et al.*, 2015). Not all species which have been used and managed have been domesticated, some are still collected in their natural environment, others were favoured or enriched in humanized environments, without being properly cultivated (Perales Rivera *et al.*, 2008).

The use of agricultural biodiversity, taking advantage of the variety and variability of plants, animals, landscapes, and soil organisms (Bioversity International, 2017) can take place on several levels, and in many forms. For example, certain species or plant cultivars might have desirable traits such as drought or salinity resistance. On a farm level, certain species planted together might create favourable micro-environments, or enhance resistance to diseases. Animals, crops and trees might lead to increased yields or pest management, lowering fertilizer or pesticide requirements. Furthermore, crop choices might increase food groups or contribute with particular nutritional and cooking qualities to healthy diets. Intercropping and crop rotations, such as those present in the ancient *milpa* system from Central America might combine crops that are nutritionally and environmentally complementary (Bioversity International, 2017). Diversity at a landscape level favours land usage mosaics creating beneficial synergies for water capture, pest control or habitat for local fauna; and production of different food groups throughout the year (Bioversity International, 2017).

Local species, breeds and varieties, in combination with local agroecological knowledge are key elements of sustainable, local food systems. They often include in formal research under-represented (neglected and underutilized) species which are not well known on a global scale (Bioversity International, 2017).

For the purposes of this research, a focus will be laid on the edible harvested part of agricultural biodiversity, and the study is limited to a subset of agrobiodiversity managed by Teenek households in Jol Mom, assessed with few exceptions on a species level.

2.3 Smallholder agriculture and farming systems

Smallholder farmers, also referred to as peasants (*campesinos*), are providing food for the world every day, and they are nowhere near to being a homogenous group of producers, engaging in different farming activities, living different realities, and pursuing different objectives. In the recently released resolution of the "United Nations declaration on the rights of peasants and other people working in rural areas", a peasant is defined as "any person who engages or who seeks to engage alone, or in association with others or as a community, in small-scale agricultural production for subsistence and/or for the market, and who relies significantly, though not necessarily exclusively, on family or household labour and other non-monetized ways of organizing labour, and who has a special dependency on and attachment to the land" (UN, 2018). Furthermore, the UN has just introduced the "UN Decade of Family Farming 2019-2028", aiming at valuing the important contribution of small-scale producers to food security in the world and improving their situation (FAO and IFAD, 2019).

Smallholder farmers can be distinguished according to their participation in markets, between 'net sellers', 'net buyers' and the 'self-sufficient' smallholders, *e.g.* referring to staple foods. "Other prices held constant, self-sufficient households are not affected by rising prices for staple foods, while net sellers gain. Of the three groups, net buyers are the most vulnerable to food-price shocks" (de Janvry & Sadoulet, 2011). In this way, subsistence agriculture can be – under certain conditions, *e.g.* resources availability and access for the farmers – a safety net to support existing policy responses to price instability in developing countries in order to deal with a food crisis in short and medium term (de Janvry *et al.*, 2011).

In the document "Agricultura familiar con potencial productivo en México" 'family subsistence agriculture' is defined as "oriented exclusively to self-consumption, with insufficient land and income available to guarantee economic reproduction, which induces them to resort to salaried work, rent part of the available area and depend to a large extent on government support" (FAO & SAGARPA, 2012), implying a dependency by the definition of the agricultural practice, and showing the peasants' often marginalized position in the countries' society.

Peasant agricultural practices are highly variable across the world. Farming systems, such as any systems, can be characterized by elements, their interrelationship, and the boundaries of the system (Doppler, 2000). Although sometimes a source of confusion, Doppler sees the different uses of the term 'farming system' as having potential, giving space for studying the topic from different angles and disciplines, such as agronomic or anthropological studies. Systems can be differentiated at different levels. The family systems (in the present study represented as the interviewed farmer households) are the households which take decisions according to their objectives and available resources. The farming systems are composed of family systems, and extend over several levels from family, village, to regional level (Doppler, 2000). A 'farming system' is a "population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate. Depending on the scale of the analysis, a farming system can encompass a few dozen or many millions of households" (Dixon *et al.*, 2001). Suprajacent levels are the village, composed of farming and non-farming families and institutions, and the rural systems. These systems have institutions and actors, social organizations, socio-cultural values and infra-structural constraints and potentials which are interrelated with other levels. The term agricultural systems is, according to Doppler (2000), broader and has a stronger focus on production and national market access, while decision-making at family or village level is neglected.

In this study three farming systems are distinguished – the home garden, the *milpa* and the coffee-based agroforestry system – even though they are simultaneously managed by Teenek families. Nevertheless, the aim is to highlight the differences between the families which have ceased from managing one or several of the systems and that each of the systems occur separately in very similar forms throughout Mesoamerica and in literature, which is why their distinction helps to compare results among studies, and also to provide a further understanding of (the) traditional Teenek farming system(s) (described in detail in section 4.3). Nevertheless, in order to acknowledge that the combination of the three systems is a trait of Teenek farming, the count of the systems is referred to as production systems, which are part of the integral traditional Teenek farming system.

3 State of the art

3.1 Linkages between agriculture, biodiversity, diet, and human health

Highlighting the contribution of ecosystems to the health and well-being of humans has become an emerging topic of interest in recent years facing the challenge to stop the global environmental crisis. "There is a bi-directional relationship between the environment and food. Human subjects depend on the goods and services provided by natural and managed ecosystems to meet their food needs. The production of food and its nutrient content are inextricably linked to the environment. Ecological interdependences are key factors for the dietary content of most living species we consume" (Allen *et al.*, 2014). Johns (2007, p. 832) warns that "In the face of economic and environmental changes, increased simplification of the diets of large numbers of people to a limited number of high-energy foods presents unprecedented obstacles to health. Cultural knowledge of the properties of plants erodes at the same time. Conservation of biodiversity and the knowledge of its use therefore preserves the adaptive lessons of the past and provides the necessary resources for present and future health."

Indigenous people have been recognized as key safeguards of biodiversity, and "the foods of indigenous peoples form part of rich knowledge systems [2]. They typically draw on indigenous resources, are based on local production, and are associated with the land and environments from which they are obtained. The merits of such concepts for guiding contemporary adaptation are testable in general terms, in the first instance in relation to scientific evidence for the health benefits of traditional food biodiversity, and second for their validity as a sociocultural basis for positive systems" (Johns & Sthapit, 2004, p.146). Traditional food systems provide evidence to the relationship between diet and health, such as the importance of fiber in African diets, of omega-3 fatty acids in Inuit and Mediterranean diets, or the antioxidants present in Asian diets (Johns & Sthapit, 2004). Also, a reliance on cereals, legumes and fruits and vegetables, of traditional food systems have a lower energy and higher fiber content than the modern trend and might reduce the risk of disease (Johns *et al.*, 2004).

The optimized diet includes both physiological and cultural factors according to Johns & Sthapit (2004), mediating the risk of disease as well as human well-being by embracing values and health favouring behaviour. Importantly, it links human and ecosystem health, and provides sustainable livelihoods (Figure 2).

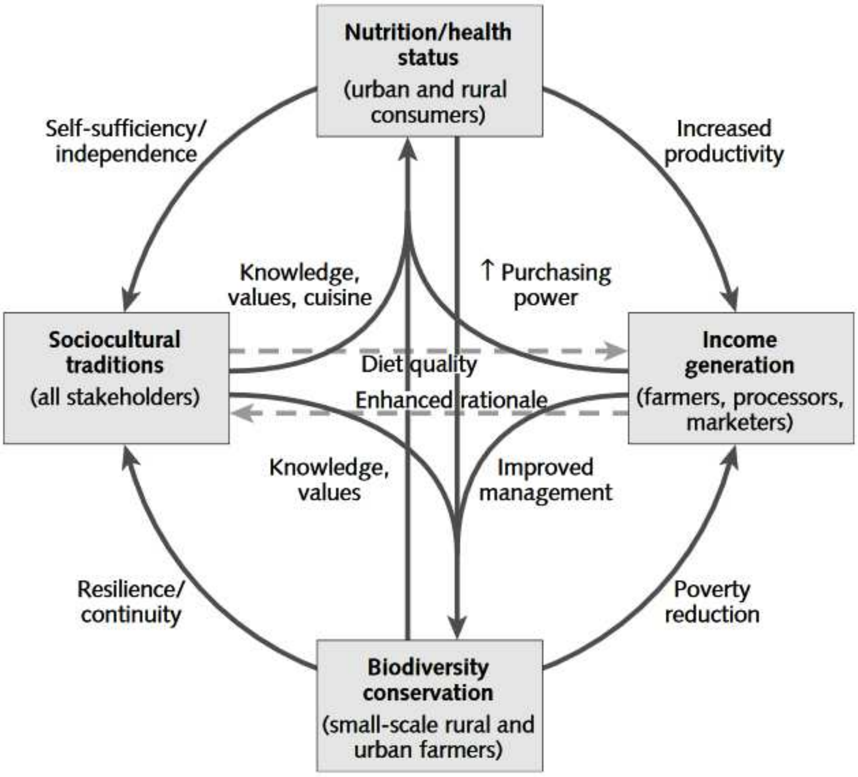


Figure 2: Model linking biodiversity conservation and human health and nutrition in developing countries. Source: (Johns & Sthapit, 2004, p.144)

3.1.1 Agrobiodiversity and dietary diversity

While the relationship between agricultural biodiversity, especially food biodiversity and nutrition might seem straightforward in the context of a rural population and diversification of small-farm production, and general above-mentioned links between environment and health are undebated, evidence trying to prove them is mixed (Johns, 2007). According to the aim of the study, literature was revised which analyses the contribution of edible, cultivated agricultural biodiversity to household food security in a rural context.

The most commonly used, systematic approach which was found is the analysis of correlations between production diversity and dietary diversity, an indicator for food access and diet quality. In the studies, agricultural biodiversity was mostly measured as a production diversity on specie's level (crop species richness), sometimes including livestock species, whereas dietary diversity indicators with different food group divisions and recall periods served to assess dietary quality or food access (Bioversity International, 2017; Jones, 2017a; Powell *et al.*, 2015; Sibhatu & Qaim, 2018). Fewer studies used additionally or alternatively metrics of nutritional status beyond diet diversity, or anthropometric data (Jones, 2017a; Powell *et al.*, 2015). Alternative or additional indicators used for agrobiodiversity assessment include crop varietal richness on subspecies level, crop species evenness indicators assessing the equality of distribution of crop species on farms, and the application of nutritional functional diversity indicators, as crop species which provide a specific combination of nutrients or a unique nutritional functional group to the agroecosystem (Jones, 2017a). It is important to highlight that a variety of methods has been employed and the cope of studies differs greatly, making comparison difficult (Jones, 2017a).

Studies can be sorted according to the different environments which can contain agricultural/food biodiversity (homegrown in different agroecosystems or aquaculture, from the wild, or from markets) or different pathways how agricultural biodiversity can contribute to food security (direct contribution to diets or indirect contribution by economic or environmental benefits). The latter is based on more complex relationships, and most reviews are based on how agro/food/crop (bio)diversity contributes to diets and nutrition. Nevertheless, some studies contrast other variables which might contribute to enhanced dietary quality other than agricultural biodiversity, such as market access and participation, and others include a gender focus as women's knowledge, social status, education and health have been identified as key factors for nutritional outcomes beyond individual level (Bioversity International, 2017). Furthermore, studies highlight that even though often wild and cultivated biodiversity is distinguished for assessment, there is a continuum of various degrees and types of human management through to domestication, equally as landscapes can have various degrees from non-agricultural to agricultural management, both providing wild and cultivated species (Powell *et al.*, 2015).

The association of production diversity and dietary diversity is found to be mostly positive, although the magnitude varies across the studies. Koppmair *et al.* (2017) and Sibhatu *et al.* (2015) only found a small positive relation between the two variables, with an increase of only 0.12 of number of food groups consumed when producing one additional crop or livestock species for the former and 0.9 % for the latter. Jones (2017) and Bellon *et al.* (2016) calculated that the relation was positive. Jones (2017b) says it was strong and of similar magnitude across all of the three agrobiodiversity indicators he took into account, undermining therefore the result with the diversity of indicators considered. Furthermore, he found agricultural biodiversity was also associated with greater energy intake per day and in greater protein, iron, vitamin A and zinc intake. Independently of the measured scale, authors find similar results for the strength of the relation of dietary diversity (DD) and production diversity (PD) when looking at different indicators. Jones (2017b) said the association was stronger when dietary diversity was low, similarly Sibhatu *et al.* (2015) found their estimated coefficient to be greater in Indonesia (DD 10.02, PD 1.72) and Malawi (DD 8.48, PD 4.8), where the on-farm diversity is low and smaller in the countries where production diversity is high anyway, like Kenya (DD 11.40, PD 7.82) and Ethiopia (DD 5.42, PD 10.19). Jones (2017b) found out that households had a higher probability to consume food from their own production when crop species richness (CSR) was high, purchased in change less diverse food and spent less money on food, in specific on vitamin A-rich fruits and vegetables. By contrast, for household with higher CSR less of the daily energy intake was covered by flesh foods than in households with lower CSR. Jones also found that household of little economic resources showed a stronger relation between agricultural biodiversity and household diet diversity than household of the highest wealth quintile, indicating that for the poorest part of the population, on-farm diversity is an important resource for a diverse diet.

Market access is overwhelmingly positively correlated with dietary diversity, but the measure are difficult to compare and might require methodological revision (Ickowitz *et al.*, 2019), as some authors use simple geographic distance measures as indicator (Luckett *et al.*, 2015; Sibhatu *et al.*, 2015). Other authors assessed how much of the food consumed has its origin in the market (Bellon *et al.*, 2016; Jones, 2017b; Sibhatu *et al.*, 2017). Jones (2017b) did not find a tendency indicating that agricultural biodiversity would lose importance with greater access to markets or commercial orientation of farms, which undermines predominance of subsistence agriculture in Malawi. He says that even households with greater market-orientation still consumed a similar proportion of self-grown crops.

Apart from the empirical findings on direct relationships between food biodiversity from markets and diets, markets can also drive food choices by defining "what is available, accessible, affordable and acceptable" (Bioversity International, 2017). Imports of homogeneous foods in Latin America and Asia are growing, which can be a risk for local producers of biodiverse foods, and consequently impact diet choices and composition (Bioversity International, 2017). Nevertheless, from a rural producer's perspective, market access has shown to be positively correlated with diet diversity. Apart from availability and access to markets, the affordability of healthy foods can influence food choices, and evidence from various countries shows that healthy diets are coupled with considerable costs (Bioversity International, 2017).

Off-farm income sources allow to purchase foods form the market and were in the study from Sibhatu *et al.* (2015) associated with higher dietary diversity scores, and of greater magnitude than production diversity. Also Keding *et al.* (2012) found women who had a business or service besides farming to have higher dietary diversity scores than women who were exclusively crop-farmers.

Authors also found that land tenure can play an important role in the relation of agricultural biodiversity and dietary diversity. Jones (2017b) observed that whereas for his study, household wealth and on-farm diversity showed no significant correlation, with greater size of the cultivated land increased on-farm diversity. For small farms, maize cultivation was prioritized to secure household consumption, which possibly kept these farms from incrementing their crop diversity. Bellon *et al.* (2016) state equally that with bigger land sizes, production diversity increased – which might be due to heterogeneous soils and topographies – and was independent from consumption decisions.

Bellon *et al.* (2016) condense their findings in a conceptual model which shows the interrelationship between the diversity scores while leaving the influencing factors open which vary for the specific context (Figure 3).

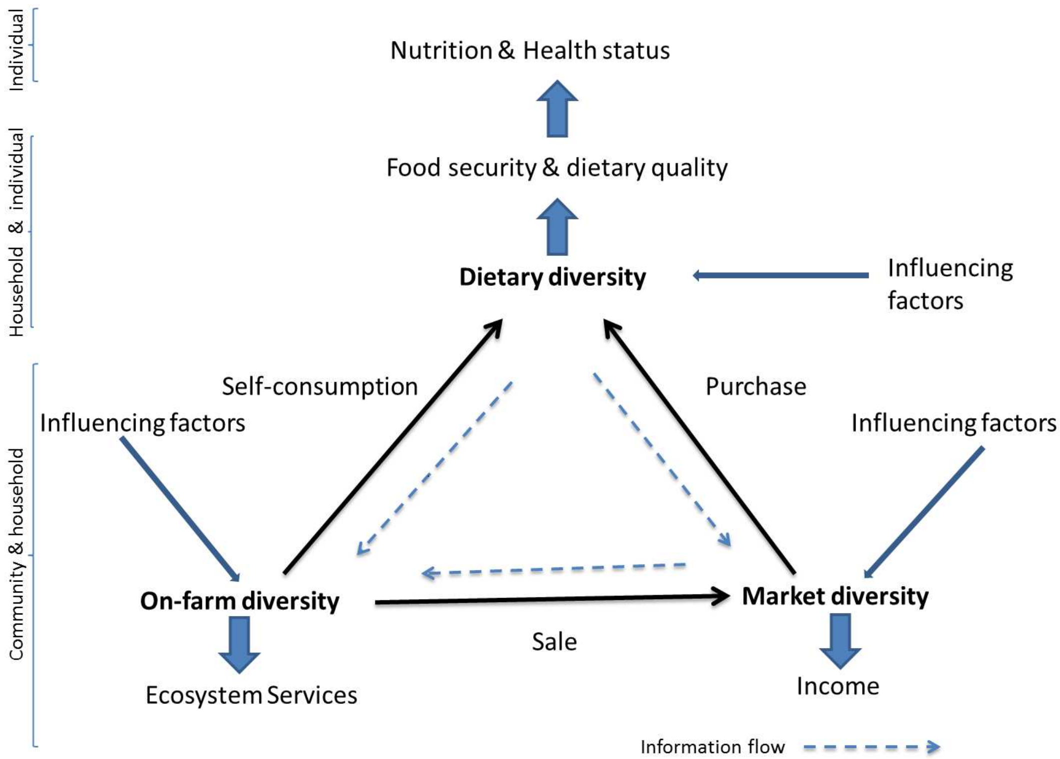


Figure 3: Relationships between on-farm diversity, dietary diversity and market diversity summarized in a conceptual model. Source: (Bellon *et al.*, 2016)

Powell *et al.* (2015) criticise that the studies relating diets, nutrition and agricultural biodiversity are often conducted with small sample sizes and without taking into account possible confounding factors. Authors state that apart of general insights which are missing to understand the relationship between agrobiodiversity, diet and nutrition, the impact of certain variables such as market access, farm size and wealth on this relationship need further research (Powell *et al.*, 2015), as well as taking into account how research design might contribute to the varying and little consistent outcomes, such as the methodologies used (Jones, 2017a; Powell *et al.*, 2015), or how seasonality and different agroecological conditions might influence the results (Powell *et al.*, 2015). They highlight that most studies are set in Africa and research is needed in understudied region such as Asia, Latin America and the Caribbean (Powell *et al.*, 2015).

Jones (2017a) in his review comes to the conclusion that impacts of agricultural diversification on health are largely unknown, and that research gaps need to be filled regarding the impacts on nutrition related diseases and deficiencies, as well as potential impacts on overweight and obesity (Jones, 2017a). In line with this, Powell *et al.* (2015) stress that for addressing all forms of malnutrition, insights are needed in how cultivated and wild biodiversity contribute to overall diet quality, instead of focussing on certain nutrients or food groups.

3.2 The situation of food security and nutrition in Mexico

Data for evidence of the state of Mexico's food security and nutrition is provided by national surveys. Since the 1950s national nutrition surveys have been conducted, with improving methodologies over the time. The latest published survey is the National Health and Nutrition Survey (ENSANUT) of 2016. Deprivation due to food access, an indicator aiming at capturing which part of the population faces difficulties in satisfying their food requirements (quantity, quality, and dietary diversity) due to insufficient income, has been measured since 2009 (Shamah-Levy *et al.*, 2017). It is part of the multidimensional measurement of poverty conducted by the National Council for the Evaluation of Social Development Policy (CONEVAL), using an adapted version of the experience-based Latin American and Caribbean Food Security Scale (ELCSA). The tool has been incorporated into the National Surveys on Household Incomes and Expenses (ENIGH) and is present in the ENSANUT survey from 2012 onwards (Shamah-Levy *et al.*, 2017).

In terms of food availability, on national level Mexico is not lacking dietary energy supply, reporting 3072 kcal daily dietary energy per capita in 2013 (FAO, 2019b), with cereals and tubers constituting nearly half of it (43.9 %), followed by sugar and sweeteners (15.4 %), then meats, and oils and fats (Shamah-Levy *et al.*, 2017).

On average, Mexican dedicate around one third of the households budget on foods, for lowest income households even half of the budget, while in better situated households it is around one quarter (ENIGH INEGI, 2015c, as cited in Shamah-Levy *et al.*, 2017).

Results from the latest National Health and Nutrition Survey (ENSANUT 2016) show that 85.3 % of the Mexican population regularly consume sugary drinks, 38 % processed snacks and 45.6 % sweet cereals. On the other hand, of the recommended food groups 42. 3 % consume regularly vegetables, 51.4 % fruits and 70 % legumes (ENSANUT MC, 2016). In average, dietary diversity was 6.5 food groups per day, with 4.2 recommended food groups and 2.3 not recommended food groups daily (ENSANUT MC, 2016).

Authors studying food insecurity in Mexico are based on the FAO's definition of food security and build their research on the nationally or internationally validated food security indicators, such as the Latin American and Caribbean food Security Scale (ELCSA).

Mundo-Rosas *et al.* (2013) studied food insecurity in Mexico using data from ENSANUT 2012 and a harmonized version for Mexico of the Latin American and Caribbean food Security Scale (ELCSA). They report that 41.6 % of the households suffered mild food insecurity, 17.7% moderate food insecurity and 10.5% severe food insecurity, in summary that 28.2% of Mexico's households suffered from moderate or severe food insecurity in 2012, struggling to provide sufficient food for the family. A total of one third of the households in rural areas and one quarter of the households in urban areas were categorized with moderate or severe food insecurity. 42.2% of households with at least one person of indigenous ethnicity were classified as moderate or severe food insecurity, identifying this social group as risk factor, despite the fact there are social programs directed to this population group. A strong correlation of socioeconomic status and food insecurity was found in the study. Severe food insecurity was associated with low height and weight among children. Households in moderate food insecurity were found to be consuming high-fat, sugary and low-micronutrient and fibre dense foods, which were perceived to be economically more accessible than other foods. These dietary patterns have been associated with health problems like low weight, anaemia, iron deficiency, overweight and obesity and chronic diseases related to inadequate nutrition. Furthermore, food insecurity has been related to psychological problems like depression diseases and anxiety in mothers and children. These consequences of food insecurity can be observed up to the national level, as nutrition-related diseases affect highly the costs of the public health sector. Mundo-Rosas *et al.* (2013) conclude that in order to improve the national situation, multi-sectorial, joint actions of agriculture, health, education, social development and community-intern are needed to form synergies that tackle the problems of food insecurity.

A study based on the National Household Income and Expenditure Survey (Encuesta Nacional de Ingreso y Gasto en los Hogares, ENIGH) 2008 using the Mexican Scale for Food Security (Escala Mexicana para la Seguridad Alimentaria, EMSA), a food insecurity scale based on the ELCSA, analysed the food purchase of household with children under five years according to their level of food insecurity. The study found that in total, 48 % of households were classified with food insecurity, of the population speaking an indigenous language it was 69.7 %. A higher educational level of the mother was associated with higher food security, and purchase of lower food variety was associated with food insecure households. (Vega-Macedo *et al.*, 2014) point out that a limitation of the presented study was taking food expenditures as variable, which does not represent the actual consumption.

The increase of dietary diversity, an indicator for dietary quality, has been set as a nutritional goal by the ENSANUT 2012. For 35 % of Mexican adults, dietary diversity is low, for 60 % medium (3-4 food groups, including cereals, milk products and legumes) and only 4.7 % of adults consume a diverse diet (5-7 food groups, including meats and eggs, fruits and vegetables, and vitamin A rich fruits and vegetables). For children between two and four, half consumes a medium diverse diet and one third a diverse diet, but among children with indigenous origin a quarter consumes only two food groups (Shamah Levy *et al.*, 2013, as cited in (FAO, 2019a)).

The energetic contribution of cereals and tubers to the overall diet has decreased by 11.1 % and the consumption of beans and other legumes halved in the last 40 years. At the same time, the contribution of fats and of meat doubled, and of eggs even tripled. While the consumption of fruits and vegetables remained stable, they constitute the group with lowest overall consumption.

"Dietary patterns of Mexicans have changed dramatically in the last four decades, which has negatively impacted the nutritional status of the people, increasing their vulnerability to noncommunicable diseases (NCDs). The food and nutritional transition (TAN) has been characterized by a decrease in the consumption of traditional foods, protectors of health such as beans and corn, and the increase in the availability and consequently the consumption of processed and highly processed foods with high energy density, high sodium content, saturated fats, sugars, colorings, preservatives, flavorings and stabilizers; in turn, the consumption of products of animal origin has increased." (translated from Spanish from (FAO, 2019a)). Mexico occupies the first place in the sale of processed food among Latin American countries, and the fourth worldwide according to data from 2013 ((FAO, 2019a) with data from FAO y OPS, 2017).

Mexico's declared main challenge are the high rates of overweight and obesity. An estimated 57 % of the Mexican population are overweight or obese (in 2016), adults are the most affected with 73 %. In urban areas, 35 % of the children in school age are overweight or obese, in rural areas 29 %. Furthermore, 13.6 % of Mexico's children under five suffer from chronic undernutrition, in rural areas even 21 % (FAO, 2019a). The named unbalanced dietary patterns which lead to overweight and obesity are also characterized by a lack of nutrient deficiencies, the 'hidden hunger', and it is known that the resulting undernutrition in the early ages of life leads to the predisposition of obesity in adulthood (FAO, 2019a).

Programs for the improvement of food and nutrition security include the by now finished National Crusade Against Hunger (Cruzada Nacional Contra El Hambre) which run from 2013 to 2018 under the government of Peña Nieto, implemented under the Ministry of Social Development (SEDESOL) with the aim to decrease poverty, undernutrition and food access deprivation by improving food supply, supplements and provision, and by improving the population's capacity to acquire food. It targeted 400 municipalities most affected by extreme poverty and food insecurity (Shamah-Levy *et al.*, 2017). While the National Crusade Against Hunger targets above all poverty-related undernutrition, overweight and obesity are currently more prevailing nutritional health problems, and in focus by the National Strategy for the Prevention of Obesity, Overweight and Diabetes, raising awareness and promoting healthy eating habits, and improving health care for respective diseases (Ibarrola-Rivas & Galicia, 2017; Secretaría de Salud, 2013). Furthermore, the Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA) implemented together with the FAO the Strategic Project for Food Security (PESA), which is directed at rural areas in extreme poverty improve infrastructure services and provision of goods (Ibarrola-Rivas *et al.*, 2017).

Food security governance in Mexico is criticised for lacking coordination between multiple governmental agencies (Agriculture, Health, Federal) which are involved in the topic, and the insufficient effectiveness of the implemented programmes (Gálvez, 2018; Ibarrola-Rivas *et al.*, 2017; Shamah-Levy *et al.*, 2017).

Authors discussing nutritional trends have related globalization and trade liberalization to the current rise of obesity and diet-related chronic diseases which are associated with energy-dense, poor-quality diets (Hawkes *et al.*, 2009). Barry Popkin first described the 'nutrition transition' as a worldwide observable trend toward a diet high in fat and processed foods while low in fibre, often termed 'Western diet'. Together with the demographic transition from rural into urban areas where a more sedentary lifestyle and a change in cultural and household structure goes in hand with altered consumption patterns and eating habits, the transition can lead to increases of degenerative diseases (Popkin, 1993). In this sense, while food insecurity and poverty rates have gone down, negative health outcomes have accompanied the nutrition transition in developing countries due to the double burden of undernutrition along with overweight and obesity (Popkin *et al.*, 2013), and the double burden of both communicable and non-communicable diseases.

In Mexico, these trends can be observed with the implementation of the North American Free Trade Agreement (NAFTA), which was signed in 1994 and which led to an explosion of the number of supermarkets, discounters and convenience stores in Mexico. With this, the sale of processed foods, such as soft drinks, snacks, baked goods and dairy products observed an increase of 5-10 % per year between 1995 and 2003 (Hawkes *et al.*, 2009). While stunting and undernutrition have decreased and indicators describing the socioeconomic status of the population have gone up, overweight, obesity and mortality rates from noncommunicable diseases have increased (Rivera *et al.*, 2009; Soto-Estrada *et al.*, 2018).

Epidemiological studies have shown changes in food consumption patterns at household level in Mexico and might contribute to the rising prevalence of nutrition-related chronic diseases. During a short time, the consumption of fats, refined sugars and soft drinks has risen, while a reduction in fruits and vegetable intake has been observed. Furthermore, Mexicans recreational and nonrecreational physical activity has gone down, while access to energy-dense, low-micronutrient and low-cost foods has increased (Flores *et al.*, 2010; Rivera *et al.*, 2002). Mexico is the number one seller of processed foods among the Latin American countries, and scoring fourth at global level (FAO, 2019a).

Multiple factors are involved in eating practices, and instead of the study of individual nutrients or food, a whole-diet approach such as the analysis of dietary patterns is now seen as required to study the relationships between nutrition and health, which accounts for the multidimensional nature of diets and diet-related diseases, ranging from nutrient intake and metabolism to food consumption behaviour and attitudes (Allen *et al.*, 2014; Hu, 2002). The analysis of dietary patterns with multivariate factor or cluster analysis has emerged as a whole-diet approach which has been successfully predicting disease risk or mortality (Hu, 2002) and applied relating dietary patterns with other cultural and economic determinants (Flores *et al.*, 2010).

With data from the nationally representative National Health and Nutrition Survey of 2006 (ENSANUT 2006) Flores *et al.* (2010) found three major dietary patterns among Mexican adults, in which the 'traditional' dietary pattern was related to a high coverage of dietary energy with maize foods, supplemented with beans; the 'foods and sweets' pattern was connected to alcohol, soft drinks, white bread and fast food, and the 'diverse' pattern consumed dairy, rice and pasta, meat and others foods. While scoring higher in the consumption of food groups of the dietary diversity score than the 'traditional' pattern, the latter two dietary patterns were associated with an increased risk of being overweight and obese, compared to the people who eat traditional Mexican food. Of the traditional dietary pattern, almost 60 % of the sample were indigenous and lived overwhelmingly in rural areas (Flores *et al.*, 2010).

In a study about overweight and obesity among Mexican school-age children which was based on ENSANUT 2006, five dietary patterns were differentiated: Rural dietary pattern (relying on tortilla and legumes), sweet cereal and corn dishes pattern (consuming sugary cereals, tortilla, and maize products), the diverse pattern (several food groups), western pattern (high consumption of sweetened beverages, fried snacks, industrial snack cakes, and sugary cereals), and the whole milk and sweet pattern (characterized by a high intake of whole milk and sweets) (Rodríguez-Ramírez *et al.*, 2011). The 'sweet cereal and corn dishes pattern' and the 'western pattern' were associated with overweight and obesity, while children with the rural dietary pattern consumed most fibre and had the lowest fat intake and showed least incidence of overweight and obesity.

Increased blood pressure and hypertension is another worrisome widely occurring health issue in the Mexican population (ENSANUT MC, 2016). Foods such as meat, processed meats, sweets and pastries, containing high contents of saturated fat, sodium and sugar, have been associated with (Monge *et al.*, 2018). Monge *et al.* (2018) investigated prevalence of these factors among the Mexican population. Eating habits were differentiated into a 'Prudent' pattern, with mostly fruits and vegetables; a 'Western' food consumption pattern, defined as including processed meats, fast foods, and red meat; and a 'Modern Mexican' dietary pattern which included traditional foods like corn tortillas and hot peppers together with unhealthy foods (*i.e.* sodas) and low intake of fruits. Both 'Western' and 'Modern Mexican' were directly associated with incident hypertension in Mexican women. Therefore, additionally to the 'Western' diet which has been associated with coronary heart disease, the undergoing nutrient transition to a 'Modern Mexican' diet is favouring hypertension (Monge *et al.*, 2018).

Ponce *et al.* (2014) evaluated dietary quality of Mexican adults taking data from ENSANUT 2006. Rural residents, those from southern Mexico and of the lowest socioeconomic status consumed a diet with lower risk of cardiovascular diseases, while participants of higher socioeconomic status showed an opposite trend. On the contrary, micronutrient adequacy and dietary diversity showed an inverse relation, with urban inhabitant, northern states and upper socio-economic status scoring highest. They conclude that consumption patterns of the Mexican population are not adequate and that regarding the epidemiological and nutritional transition in Mexico, above all for a diet with cardioprotective character should be accounted for in food and nutrition programmes.

In conclusion, food security in Mexico remains a problem even though food availability has increased. The double burden of malnutrition and noncommunicable diseases is linked to the nutrient transition Mexico is experiencing. The indigenous population is still among the most affected by stunting of children (Rivera *et al.*, 2009), and food insecurity. On the other hand, traditional Mexican dietary patterns score best when it comes to a diet with low risk of obesity and noncommunicable diseases, and large parts of the indigenous population seems to adhere to this dietary pattern (Flores *et al.*, 2010; García-Chávez *et al.*, 2018).

3.3 Traditional agriculture, *milpa* cultivation and food security in Mexico and Mesoamerica

Another set of authors is interested in reconciliating the food system and peasant agriculture in Mexico and Mesoamerica. These authors part from the idea that traditional peasant agricultural practices have been contributing the conservation of environmental and cultural capital, including the conservation of crop genetic resources in their farming systems. They are interested in the threats which are presented to the maintenance of these farming systems and investigate the nutritional contribution wild and cultivated biodiversity in and around these farming systems have to the peasant's diet and health. Most discussed farming systems in this context are agroforestry systems such as the biodiverse backyard and the often coffee-oriented 'cafetal' or '*finca*', and the Mesoamerican swidden *milpa* poly-cropping system based on the cultivation of maize intercropped with legumes, squash, chili, herbs, and other useful plants mainly destined for direct household consumption (Isakson, 2009). The threats to the maintenance of the farming systems and their agricultural biodiversity authors discuss are among others market integration by orientation towards cash-cropping, which often implies a conversion of land into monoculture, or alternative income sources by migrating to urban centres or engaging in wage labour opportunities in tourism or nearby industry. In this section, relevant studies from all Mesoamerica were included due to the common *milpa* cultivation practices and cultural overlaps the region presents. Because of the multidisciplinary character of the topic, a variety of methods have been employed by authors, ranging from monetary evaluations of foods and crops biodiversity indexes, food security and nutrition metrics and tools, and a great part implemented qualitative approaches or mixed methods.

The *milpa* is an ancient Maya agricultural system has been recognized as fundamental part of the Mesoamerican culture: Maize is the "stuff of life", the *milpa* a "sacred place", and even a "cultural script" (Bee, 2014; Isakson, 2009; Nigh & Diemont, 2013; Ponette-González, 2007; Quevedo Pérez *et al.*, 2017; Schmook *et al.*, 2013). Presumably, 'swidden' agriculture, also called 'shifting cultivation', 'slash-and-burn' is the oldest farming method of the Americas, an agroforestry systems "in which woody vegetation is regenerated after a period of annual cropping" (Nigh *et al.*, 2013, p. e45). In Mexico, the *milpa* has been defining dietary habits and has been a contributing to food self-sufficiency for the rural population (Bee, 2014; Nigh & Diemont, 2013; Ponette-González, 2007; Quevedo Pérez *et al.*, 2017). There are numerous works highlighting the valuable role of the *milpa* system for sustainable resources management and the agroecological movement in Mexico (Astier *et al.*, 2017; Nigh *et al.*, 2013; Toledo & Barrera-Bassols, 2017). It is a steady source of new maize varieties, and highly dynamic (Isakson, 2009). Traditionally, the fallow period in which secondary vegetation regenerated was about 15 to 40 years, but nowadays is often shortened (Bermeo *et al.*, 2014; Montagnini, 2006). The grade of market participation of crops produced in this system is highly variable, and often destined for home consumption. The primary function of the *milpa* is the provision of maize, which is of great importance for the preparation of many foods, headed by the Mesoamerican staple food tortilla.

Ibarrola-Rivas and Galicia (2017) point out in their research that the analysis of food security in Mexico requires an understanding of the specific cultural, socioeconomic and environmental context, and the integration of food production and consumption. A sustainable food production as well as a sustainable food consumption is essential to achieve a stable, resilient and sustainable food system. The authors plead for an exclusion of non-essential food items, such as salty snacks, sodas, or meat from the diet and for a low-input agricultural system which avoids the production of non-essential food items, as well as crops for biofuel production or drugs production.

Based on literature, they identified five dietary patterns in their study that illustrate the Mexican spectrum of food consumption patterns, called the 'poor rural', 'traditional Mexican *milpa*', 'transition urban', 'rich urban' and 'organic' diet, and related them to the demographic situation, the socioeconomic condition and the nutritional status of the population. While households of the "poor rural" diet might suffer undernutrition due to conditions of extreme poverty which can affect the diet, and migrate to urban areas to earn money or work in agriculture, the 'traditional Mexican *milpa*' diet in this context was assumed by the authors to be consumed by poor households but not extreme poverty, and with producers owning crop land, even though of small size (less than 1.5 ha). The diet is characterized as nutritious and healthy, based on the food crops maize, beans, squash and chili, which are produced in the *milpa* system, and an occasional consumption of other food items, among them animal food products. The other diets were attributed to urban low/middle to high class households. The authors come to the conclusion that the *milpa* production-consumption system is the most resilient one, as its agricultural production is associated with low risks, low production and consumption costs and low resources demand and it results in a healthy diet and the maintenance of a culturally important production system (Ibarrola-Rivas *et al.*, 2017).

García Urigüen (2012) explains in his book "La alimentación de los mexicanos" that the Mexican diet is product of the prehispanic inhabitants who millions of years ago succeeded in domesticating corn, beans and chili, and stimulated the development of agriculture and peasant lifestyle instead of nomadism. Around 600 BC, in the teotihuacan culture the diet consisted among others of corn, beans, squash, chili, amaranth, nopal, purslane, avocado, tomato and guaje, and fruits like tejocote, capulin, plum and white zapote, as well as aromatic herbs like epazote and oregano. Turkeys, hares, deer, dogs and rodents as well as birds and some fish provided sources of animal protein (García Urigüen, 2012). While at first the food systems of indigenous and Spanish population was separated, one based on corn and the other one on wheat, integration and fusion of both systems eventually led combinations of maize and beans with pork or chicken meat (García Urigüen, 2012).

The consumption of products grown in the *milpa* has been, as other elements of traditional diets such as *pulque*, associated with the indigenous and poor population. The picture of it as the diet of the poor has led to the belief that the diet leads to undernutrition, while the reason for the rural poor's food insecurity and bad nutritional status is often their marginalized position in society and the fact that farmers have little land available to dedicate to *milpa* production, as in many cases the orientation to cash-crops in form of monocultures occupies the largest part of their land, while the production of foods for home consumption is neglected, which can be a factor for a poor diet (Almaguer González *et al.*, 2016).

Falkowski *et al.* (2019) sum up the different reasonings from authors that lead to malnutrition of rural smallholders, also called 'the hungry farmer paradox' (Bacon *et al.*, 2014) in the Global South: The first one parts from the idea that low crop yields from traditional smallholder agroecosystems lead to rural poverty, as traditional management cannot match productive capacity of more intensive agriculture. This leads to a poverty trap driving environmental degradation due to extensive land cover conversion. The solution of this problem according to authors supporting this reasoning is to overcome the situation by intensification and maximization of yields, which includes reducing agrobiodiversity for focussing on cultivation of commercial cash crops, with fertilizers, pesticides and mechanized labour input (Falkowski *et al.*, 2019). The second viewpoint is that traditional agroecosystems are productive and culturally important and help conserve biodiversity because they do not rely upon external energy inputs. These authors "claim that hegemonic socioeconomic forces continue to marginalize indigenous peoples and poor rural smallholders, relegating them to farm infertile land prone to environmental degradation. According to this view, rather than empowering rural smallholders, intensifying agricultural production in these regions will force them to continuously add expensive external inputs, such as chemical fertilizers and pesticides, rather than rely upon traditional management strategies that would minimize crop losses and increase socioecological resilience (*e.g.*, diversification)" (Falkowski *et al.*, 2019, p. p.2).

Bacon (2014) in his study of Nicaraguan smallholders practicing rainfed agriculture found that food insecurity among rural smallholders is common, but mostly seasonal, lasting on average three months. Annual cycles of precipitation, inter annual dry periods and storms, crop prices fluctuations, and a low income generation from the cash crop coffee produced, were interrelated factors contributing to the 'hungry farmer paradox' (Bacon *et al.*, 2014; Falkowski *et al.*, 2019). "Smallholders often do not produce enough food to last their household the full year and/or sell a portion of their subsistence crops after the harvest, when market prices are low and cash demands are pressing, and then cannot afford to buy food during the subsequent lean months when crop prices are typically higher (Devereux *et al.*, 2008). The timing of income from off-farm employment, remittances, and cash crops can further affect the duration and intensity of the lean months" (Bacon *et al.*, 2014, p. 134). Bacon *et al.* (2014) furthermore find that households with more fruit trees reported fewer lean months.

Fernandez & Méndez (2018) did not find a significant correlation between farm diversity in coffee plots and dietary diversity, but the number of thin months and farm diversity were inversely correlated. Households in this study set in Chiapas, Southern Mexico, were producing on average 37 % of the food consumed, while purchasing 61 %. The most produced foods were those which are part of the traditional diet: corn, beans, wild leafy greens, coffee, eggs, and some fruits and vegetables (Fernandez *et al.*, 2018). Communities in more remote settings produced a higher percentage of their foods.

The *milpas* of the Lacandon Mayas in the study of Falkowski *et al.* (2019) were calculated to be able to meet nearly all of the nutritional requirements of the families. They conclude that "rather than be discounted as a cause of poverty for rural smallholders, traditional *milpa* management should be celebrated as a valuable land management system that sustains their livelihoods. The diversity of *milpas* may preclude industrial intensification in this agroecosystem, but it ensures resilience and adaptability in the face of environmental and economic uncertainty" (Falkowski *et al.*, 2019, p. 13).

Bee (2014) looks at how food security of farmers in Guanajuato, Mexico might be affected by climate change taking a gender perspective. The declaration 'if we do not eat tortillas, we do not live' demonstrates the worry women have to provide this maize for their families, suffering from price fluctuations of this staple food. Rural families suffer most from the fluctuation in the price of the food they eat the most, especially corn (Bee, 2014).

Bee (2014) found that regardless of whether women have legal rights over the land in question or not, in households women were primarily responsible for planting, weeding and harvesting. However, the results of this study also draw attention on the less obvious role that women play in the production and provision of food. Weeding the field, is essential for household food security because during the process, the women gather the quelites, in that study defined as edible wild plants that grow between the corn and bean and take them home for household provisioning. Bee argues that the role of quelites to supplement diets in times of deficit in food production is well documented by scholars, but most studies obscure the role of women in the supply of edible plants.

Daltabuit Godás & Ríos Torres (1992) investigated the dietary changes households were experiencing in the transition of subsistence agriculture to market economy in a community in Yucatan, Mexico. They found that households of low socioeconomic status had a higher intake of traditional foods than families with more economic resources. Furthermore, young migrants were having a radical change in their diet, with a consumption of more processed foods. They conclude that economic transition and migration lead a decline of subsistence-oriented agriculture, which in turn lead to a deterioration of diets.

Schmook *et al.* (2013) argue from their findings that out-migration and wage-labour did not deteriorate *milpa* production but were rather a medium to conserve it: "general external forces that have driven intensification and livelihood diversification in Calakmul have in fact contributed to this persistence of *milpa* cultivation. Off-farm work by other household members provides necessary cash income, which allows farmers to spend time on *milpa*. The 'double exposure' of households to climate changes and neoliberal policies (O'Brien and Leichenko 2000) has made farming more difficult. This situation also means that farmers are in a more economically marginal position, which, ironically, suggests that subsistence food production is all the more important to households" (Schmook *et al.*, 2013, p. p.104). To a similar conclusion comes Isakson (2009), arguing that peasants in Latin America continue to rely on returns from market activities to complement output from farming plots, as those are too small to reach self-sufficiency, while subsistence-oriented agriculture is necessary to complement the low wages of the labour market (Isakson, 2009).

But Isakson (2009) also criticizes that authors have analysed the effect of market integration on the conservation of agricultural biodiversity, but have failed to "distinguish among different forms of market provisioning" and "often fails to situate markets within their broader social contexts" (Isakson, 2009, p. 726). In his study about *milpa* peasants in the Guatemalan Highlands he focuses on understanding the reason why peasants continue making *milpa* and how market integration of the farmers might influence *milpa* cultivation. He finds that farmer's multiple engagements with the market economy rather complement than substitute the subsistence-oriented *milpa* farming.

Other authors are worried about the effect of the commoditization of food systems, defined by Dewey (1989) as the use of agricultural products for sale instead of home consumption, on the food security and in specific dietary outcomes of peasants. While advantageous on national level as a component of economic growth, its potential benefits are eroded by the inequitable use of foreign exchange, in which small-scale producers are used for the extraction of surplus value (Dewey, 1989). On the household level, the replacement of food with cash can have deteriorating effects on nutrition/dietary diversity, due to the low prices paid to producers during increased need for cash to purchase products, and the reduced decision-making power of women, as usually the male parts of the households are the ones in charge of money. Dewey (1989) found in several case studies in countries in Latin America, among them Mexico, that commoditization tended to have a negative nutritional impact in poor rural households, while households which were able to continue producing some food for home consumption were found to have a nutritional advantage. Dewey (1989) names two potential direct effects of commoditization of foods on diet. First, the substitution of purchased for traditional foods, and secondly changes in dietary diversity. The nutritional outcomes of these changes depend on the choice of which foods are purchased. In her study, Peruvian and Mexican peasants replaced home produced foods by purchased foods of inferior nutritional quality than the traditional diet. For example, the Mexican households reported a higher consumption of sugar, wheat flour products and rice, and a replacement of a native drink (*pozol*) made from ground corn and cocoa beans by soft drinks took place, as they represented a cheap alternative and was seen as drink of higher status among the population.

In the debate about the meaning and the reason for why farmers continue *milpa* cultivation in Mesoamerica despite adverse measures which have come with the rise of the neoliberal politics, and which have led to a situation in which *milpa* farming is largely unprofitable (Isakson, 2009), authors discuss whether subsistence-oriented farming of peasants should be seen as a manifestation of food sovereignty. Cultivation of maize via traditional methods in Mexico is discussed as a form of rejection of the unstable and exploitative alternatives the capitalist market economy offers (Isakson, 2009).

In conclusion, authors which have been focussing on traditional agricultural practices and food security in Mesoamerica find a tendency of deterioration from traditional diets to diets with including high intakes of processed foods during the transition from subsistence-oriented agriculture to cash cropping or wage-labour employment. Nevertheless, although reported in some studies, the new economic activities do not necessarily lead to an abandonment of *milpa* production, in some cases the income is even used as a mean to maintain the traditional farming systems. Still, a rising consumption of industrialized foods draws a worrisome picture. Authors draw also attention on the marginalized social position peasants are occupying in their counties, which involves discrimination for their sometimes indigenous origin, and places them at the bottommost position when taking up wage labour. Some of them therefore suggest a strengthening of the food sovereignty of communities, and a maintenance of the production of foods for household consumption in order to prevent a further deterioration of diets.

Concluding the literature review, authors are still in debate about the contribution of agricultural biodiversity on food security and dietary diversity in specific, which is also due to a lack of congruent methods which make comparison among studies difficult, and due to the lack of adequate methods to evaluate this relation more efficiently, which has been recognized by scholars. Furthermore, different tendencies according to the location of studies were detected. While studies set in sub-Saharan Africa are more worried about the direct relation of factors influencing dietary diversity or the nutritional status of households and individuals, studies in Latin America and specifically on peasant's agrobiodiversity management focus more on the underlying causes of nutritional changes of diets, relating them to the context of production and cultural change.

4 Introduction to the case study

4.1 The Huasteca Potosina study region

The Huasteca region is situated in the easternmost ranges of the Sierra Madre Oriental and the Gulf coastal plain, including parts of the states Veracruz, Hidalgo, and San Luis Potosí. Approximately one third of the area is situated in the state of San Luis Potosí, denominated Huasteca Potosina. A population of different ethnicities is living in this region, and it is concentrating 96 % of San Luis Potosí's indigenous population, mainly of origin Teenek, Nahua or Xi'ui (also named Pames). Whereas in the hills and mountains of the region the people are mostly of indigenous origin, in the plains a *mestizo* population prevails (Kelly *et al.*, 2010). Agricultural activity dominates the region, with wide extents of sugarcane and cattle in the plains, and secondary forest and temporal agriculture in the mountainous areas.

Agriculture has been practiced in the Huasteca by indigenous people since pre-Colombian times. Today, only little remnants of the original forests are present, and change of forest cover into productive land is ongoing (Hernández Cendejas, 2012; Peralta Rivero *et al.*, 2014). Land degradation and erosion of ecosystem services are a risk following the conversion of forests into agricultural land in the Huasteca region (Ribeiro Palacios *et al.*, 2012), additionally to the threat it presents for biodiversity conservation.

While a trend of forest cover loss due to extension of livestock or other land uses has been ongoing since 1753 in many parts of the Huasteca Potosina, the communities with high communal land tenure (which coincide with being mostly indigenous) have been classified by Hernández Cendejas (2012) as the ones with the most sustainable land use because they show low deforestation rates during high demographic growth, high population density and low per person land use. Geographically, they are located in the hills and mountains of the Huasteca of San Luis Potosí. The main uses in these areas are rain-fed agriculture based on shifting cultivation; and forest, which often includes managed forest for coffee production and other domesticated plants.

Scientific literature on Teenek and in general agriculture in the Huasteca include the works from Moreno-Calles *et al.* (2013) who look at strategies for maintenance, stressing the importance of the *te'lom* agroforestry system among other traditional agroforestry systems, and Hernández Cendejas *et al.* (2016) discuss the *te'lom* agroforestry system as an alternative to the deforestation in the Huasteca. Ponette-González (2007) dedicates an article on the economics of household coffee production, but also describes more broadly the reality of Teenek peasants. Mercado Ruvalcaba (1996) analyses the historic effects of the introduction of different crops and livestock such as cattle, sugarcane and coffee.

And of course there is to name the works from Janis B. Alcorn about the Teenek *te'lom* agroforestry system, her reflections about resources conservation and development policies in the context of Huastec-managed forests (Alcorn, 1981b, 1984a; Alcorn & Toledo, 1995) and ethnobotanical work

(Alcorn, 1981a). Most importantly, her work "Huastec Mayan ethnobotany" (Alcorn, 1984b), which made a detailed description of the Teenek farming systems presented in this work possible.

Furthermore, there are few but valuable works on edible plants and ethnobotany in the Huasteca, *e.g.* the work from Cilia López *et al.* (2015), who identified 54 edible plant species in an indigenous community in the Huasteca Potosina. They highlight the importance of these locally available and accessible plants whose consumption can have health benefits, and which are furthermore adapted to the local environment. Quevedo Pérez *et al.* (2017) investigate the complex relationship between the cultivation of maize and food, spiritual, mythical, religious and socio-economic aspects. Recently, there has been a study conducted by Claudia Heindorf *et al.* (in print) on the total edible plant diversity in the *milpas* of three Teenek communities in the Huasteca Potosina. In total, 191 edible plant types were found, including 140 farmer recognized variants and 51 species with no variants. A total of 84 species was found, which is higher than reported in other studies on *milpas* so far. The study shows that indigenous farming communities in general and Teenek traditional *milpa* systems in specific are key for *in situ* conservation of crop genetic diversity. One of the communities which were included in the study was the community of Jol Mom in Aquismón. The great variety of edible plants in a setting which is characterized by high poverty rates contributed to the motivation to conduct the present research and to take a closer look at how food provisioning works in this context, and which role the traditional Teenek farming systems play in it. Furthermore, the work from Heindorf *et al.* (in print) provided a list of edible plants which served as a base for the development of the crop list used in the presented research.

To the literature in the field of food security counts the study from Castañeda-Díaz de León *et al.* (2015), which analyse the availability of food in the indigenous community of Tocoy, in the municipality of San Antonio, in the Huasteca of San Luis Potosí. They find that the interviewed families are below the minimum wellbeing line, and that they produce little food variety. They report that products with high nutrient content are expensive in the community of Tocoy when compared to prices in urban centres, while nutrient-poor products such as sodas are cheaper. In the indigenous community of Cuatlamayán, results indicate the prevalence of under- as well as overnutrition among adolescents (Rodríguez Ramos *et al.*, 2013). Cilia López *et al.* (2015) write then about the nutrition transition in this community, due to the high consumption of industrialized products and the reported physiological patterns of body height and weight, all of which indicate that the diet of the reported population is inadequate. Ávila-Uribe *et al.* (1994) on the other hand show in their ethnobotanical study that in the ejido San Pedro de las Anonas, Teenek people complement their basic diet which consist of tortillas, beans, chili and coffee with diverse plants from their environment.

Furthermore, there are numerous thesis written from students of the UASLP in San Luis Potosí and other universities, among others works on nutritional value of foods which form part of the traditional diet (Díaz Torres, 2017), strategies to improve nutrition (Rodríguez Ramos, 2015; Zúñiga Bañuelos, 2017), a tool for measuring food security in indigenous communities was designed (Martell González *et al.*, 2016), Teenek resources use for food provisioning was examined (Ortega Ortiz, 2002) and the a work on the meaning of plants, in terms of the value which is given by the local population, was analysed (Carabajal Esquivel, 2008).

4.2 Characteristics of the study site: The community of Jol Mom

The community of Jol Mom (or Xol Mom) with a population of 728 inhabitants in 2010 and 169 households (SEDESOL, 2013) forms part of the ejido Tampaxal and is situated at N 21° 32' 32'', W 99° 3' 4'' (GeoNames, n.d.) in the municipality of Aquismón. It lies at 600 m a.s.l. (INEGI, 2010a), with humid warm weather with rain all year (Af(m)(e)w'' according to Garcia, 2004), an average annual temperature of 24.6°C, and annual precipitation of 2478.3 mm (García, 2004). The months with highest precipitation are from May to September, while the driest months are November to March (Figure 4). The vegetation can be classified as semi-deciduous forests (INEGI Datos vectoriales Uso de Suelo y Vegetación serie VI), with rainfed agriculture as predominant land use (INEGI Datos vectoriales Uso de Suelo y Vegetación serie VI) over leptosols (INEGI Datos vectoriales edafológicos Serie II). It is located in a hilly area, agricultural plots are sometimes set on steep slopes (the average gradient in Jol Mom is 10°) and high occurrence of limestone rocks (average rockiness 56 %) (Heindorf *et al.*, in print) (Annex Figure 28). In the latest intercensal national population and housing survey of 2015, 28.1 % of the population of Aquismón was reported as living in extreme poverty (INEGI, 2016), and in 2010, 55.7 % of the population suffered from deprivation due to lack of access to food in the municipality (CONEVAL, 2010). In Aquismón, 88.6 % of the population is considered indigenous (INEGI, 2016), in Jol Mom the number is 95.2 % (INEGI, 2010a). No drinking water network or public drainage network is installed in Jol Mom (INEGI, 2010b), and the community is classified with "very high" degree of marginalization (SEDESOL, 2013). The main occupation in Jol Mom is agriculture.

Because of the high farmer recognized edible plant diversity, this community has been proposed as a priority site for the *in situ* conservation of plant genetic resources by Heindorf *et al.* (in print).

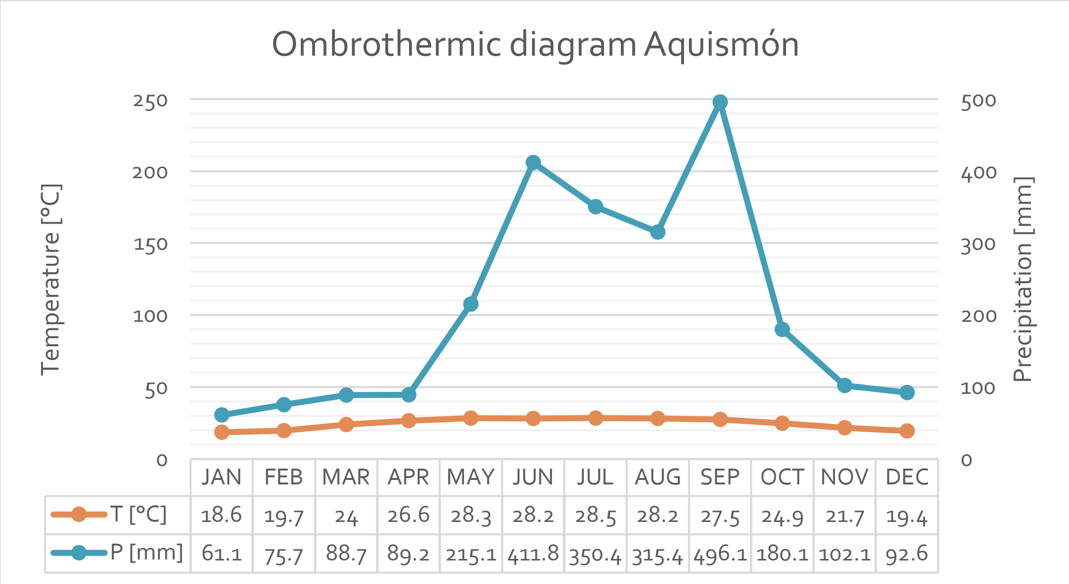


Figure 4: Ombrothermic diagram with average monthly temperature and precipitation in Aquismón, San Luis Potosí (station: Aquismón, 220 m a.s.l.). Plotted with data from Garcia (2004)

4.3 Traditional Teenek agriculture

The Huastec (or Teenek) people are Maya speakers and have been using resources from the Huasteca region in north-eastern Mexico for around 3000 years (Alcorn, 1981b). Various studies have high-lightened the valuable role of Teenek forest management for forest conservation (Alcorn, 1981b, 1984a; Hernández Cendejas, 2012; Hernández Cendejas *et al.*, 2016) and the importance of traditional ecological knowledge for sustainable resources management (Alcorn, 1984a). According to Altieri & Merrick (1987, p. 88), "traditional agroecosystems represent centuries of accumulated experience of interaction with the environment by farmers without access to scientific information, external inputs, capital, credit, and developed markets". The high plant diversity in their polyculture or agroforestry systems are a salient feature of traditional farming systems (Altieri *et al.*, 1987). In this study, 'traditional' is understood in the sense as it is used in topic-relevant literature (Altieri *et al.*, 1987; Altieri & Toledo, 2011; López-Forment, 2000) when referring to indigenous or ancient agricultural practices which main characteristics have been kept and are still exerted the same way.

Once present in the states of San Luis Potosí, Tamaulipas, Veracruz, and Hidalgo, today the Teenek population can still be found in southwestern San Luis Potosí and in northern Veracruz (Alcorn, 1981b). Subsistence agriculture, gathering, cash cropping, and wage labour are all part of Teenek subsistence (Alcorn, 1984b). Teenek defined spaces according to Alcorn (1984b) include the dooryards, pathways, sugarcane, henequen fields, swidden *milpa*, *k'kaalumlab* (garden), *eeleb* (home garden), *te'lom* (a place or group of many trees, different to the forest)), and in some cases additionally fields of certain cash crops. While the mestizo population also practices partly subsistence oriented shifting agriculture, Alcorn (1984b) describes the latter as being more cash crop oriented, most of their land is focusing on a single species such as cattle pasture, orange groves, or sugarcane plantations. Nevertheless, there are also regional differences between the Teenek land management decisions. Whereas in the foothills, Teenek dedicate parts of their available land to *milpa* cycled plots, another part to sugarcane and another part is forest, in the mountain communities coffee is more important, and more land is devoted to *te'lom* (managed forest) instead of sugarcane (Alcorn, 1984b). Teenek 'traditions', as Alcorn (1984b, p.56) puts it, "include elements introduced by their Spanish conquerors, by the Aztecs and Chichimecs who preceded the Spanish, and by modern North Americans – all woven into a fabric created in pre-Olmec times". Teenek produce staple foods such as maize, bean, manioc, and sweet potatoes, as well as fruits and vegetables in their swidden *milpas* and gardens.

The backyard, or home garden, in Spanish called '*solar*', 'patio', 'huerto familiar', is situated close to the house and highly variable in species composition and richness due to its variable size and management choice. Home gardens are common in tropical and sub-tropical world regions where subsistence land-use systems predominate. They are a multi-story combination of a variety of trees and crops, and sometimes domestic animals around homesteads (Kumar & Nair, 2004). Among with shifting cultivation, home gardens are said to be the oldest land use activity and evolved as a gradual intensification of cropping as a response to an increase in population and shortage of arable land. As home gardens mostly provide food for home-consumption and are not focused on a maximized productivity, they have lost some of their relevance with the growing importance of market economy (Kumar *et al.*, 2004). Nevertheless, environmental deterioration has demonstrated the importance of sustainable agricultural practices. Normally, no agrochemicals are used in home gardens and they conserve a great cultivar diversity (Kumar *et al.*, 2004). Production in home gardens is maintained almost continuously throughout the year, with a combination of crops with different production cycles, thus providing a continuous food supply (Fernandes & Nair, 1986). Furthermore, they lead to a diversified diet of the household members and are a significant source of minerals and nutrients (Kumar *et al.*, 2004).

The *milpa* is the central and historically embedded part of Teenek life and agriculture. Even though ceremonies, or religious activities are now participated in varying degrees by families, there are tales of a culture hero who planted the first *milpa*, and all stages of the *milpa* have certain rituals and stories (Alcorn, 1984b). The *milpa* is a resources management institution, and the Thipaak, the spirit of maize, is the organizer of the plant-human relationship (Alcorn, 1984b). Teenek agriculture is based on natural processes of the moist tropical environment to renew and protect the soil (Alcorn, 1984b). Preparation of agricultural sites starts with the slashing of the standing vegetation, followed by the burning of the debris to fertilize the soil, as this process is releasing nutrients bound up in the plant bodies into a usable form for the crops (Alcorn, 1984b). Furthermore, this phase of preparation is taken advantage of to collect and store firewood. Sometimes fallow land of vegetation with two to three years old successional communities is utilized, but ideally farmers use 8 to 15 years old sites, as regrowth is less dense and productivity of these sites is higher due to higher soil moisture, more ash produced, and the fire is hotter and therefore more effective in killing the seeds of herbaceous weeds and other not desired vegetation (Alcorn, 1984b). Nevertheless, due to higher population density fallow periods are said to have been reduced since the revolution (Alcorn, 1984b). The decision on the size of the plot is taken according to available land, but also the available workforce, the money to pay workers (while before, rather labour exchange was the usual practice), and the time investment. The seeds used are often a mix of seeds kept from the year before and seeds purchased in the local market (Alcorn, 1984b). In the lowland, *milpa* can be started at any time of the year, and with various cycles per year if desired. On the contrary, farmers in the mountainous areas plant only once a year between May and July. Maize (*Zea mays*) is planted in the start of the season. The timing and placement of secondary crops such as different types of beans, amaranth, sesame or chili varies but takes mostly place in the same period as the maize seeding or shortly after. Slashing back of vegetation is carried out four to six weeks after seeding. Maize is harvested in two stages. First, it is harvested as tender *elote*s (young ears) and in a second step as maize yellows, after full maturation and drying of the maize still in the field. Protecting maize from losses to birds and wild animals is time consuming in the first and latest stage of the *milpa*, sometimes temporary shelters are built in the field to guard during the night. While Alcorn (1984b) differences between the *k'aalumlab* (garden) and the *milpa* field, definitions of what is a *milpa* nowadays differ even between community members. Alcorn describes the *k'aalumlab* as a detour between a single season *milpa*'s end into fallow field, lasting around eight years before being abandoned. Essentially, other crops are grown in the same space after slashing back vegetation after the *milpa* cycle, but not burning it (Alcorn, 1984b).

The *te'lom* is a managed forest with different intensity of management. While it sometimes might appear 'undisturbed' forest, species composition and distribution is due to the long history of forest management of the Teenek people in the region (Alcorn, 1984b). The most important commercial product of the *te'lom* is coffee, which was introduced in the early 19th century into the region (Alcorn, 1984b), but over 300 plant species can be found in a *te'lom* plot (Alcorn, 1984a). The food from *te'loms* contributes important vitamins, minerals, fats, and protein to a tortilla-based diet, preventing nutritional deficiencies (Alcorn, 1984a). *Te'lom* sites can be intentionally located on steep slopes and ridges, or close to creeks, to prevent erosion and protect the quality of the water supply, and sometimes also offer a place for social recreation. *Te'loms* contain trees primarily, but their structure can be very heterogeneous (Alcorn, 1984a). The *te'lom* is low in labour requirements and is mostly managed as complementary to other agricultural systems. Management practices vary, weeding is only done rigorously in cases of commercial orientation and the removal of unwanted plants depends on the priorities in the different sections of the *te'lom*. Apart from food for the household, it provides fruits and leaves for the feeding of domestic livestock and is source of construction material and firewood. The *te'lom* includes a great diversity of species, and it is managed in a way that causes little disturbance of natural communities (Alcorn, 1984a). As Alcorn (1984b) observes, in some areas *te'lom* is referred to as 'cafetal' (coffee plantations), as this describes its main purpose. Undergrowth clearing, if practiced, is carried out usually once a year around July, when also transplantation of coffee bushes might take place (Alcorn, 1984b). Appropriate light conditions are created by removing some of the vegetation in the area where coffee is scattered, although canopy density varies highly among plots. Coffee harvest usually takes place in December or January. Coffee is either sold as fresh berries, as dried beans, or stored for own consumption (Alcorn, 1984b).

Finally, citing Alcorn (1984b, p.394), "Teenek swidden activities, (...) create a more diverse vegetational environment than would otherwise be available", decreasing risk by increasing the diversity of resources available with least labour investment.

In this research, and after conversations with local farmers, Alcorn's (1984) definition of the different Teenek production systems is adapted. In line with the mostly used terminology in Jol Mom, the '*solar*' is referred to when describing the backyard or home garden, and to '*finca*' when talking about the coffee-based agroforestry system, the *te'lom*. Today, some farmers prefer to grow other crops such as chili or squash or other vegetables instead of maize in their *milpas*, as it is said that growing maize does not offset the labour and money for its cultivation. For the use of this research, the *milpa* is defined as an intercropping and/or crop rotation system cultivated one to several years before being abandoned for fallow period, with mostly annual crops which might include maize or not. In total, the term 'traditional' is used to differentiate the farming methods which are subject of this research and present in Jol Mom from farming systems people of Teenek origin might have adapted additionally, which might include modernized farming methods.

5 Methodology

5.1 Methodological approach

Food security analysis both multi-disciplinary and multi-sectoral (Jones *et al.*, 2013), meaning that there are different approaches and disciplines which analyze food security, with different methodologies and viewpoints. As already mentioned in section 2.1, there is no single indicator for measuring food security. While standardized food access indicators have been a useful instrument to assess food insecurity on a large scale, they cannot consider the particularities and complexities of local contexts which might include alternative forms of food provisioning, or livelihoods which do not correspond to global trends. In the frame of an indigenous community with overwhelmingly traditional livelihoods it is considered that in order to understand the relationship between the traditional Teenek farming systems and the food security of Jol Mom the meanings and perspectives of the community need to be considered instead of applying a standardized tool. It was decided to apply a mixed-methods approach, which "represents a set of systematic, empirical and critical processes of research and involved the collection and analysis of quantitative and qualitative data, as well as their integration and joint discussion, to make inferences product of the information collected" (Hernández Sampieri, 2014, p. 534) The methods used were household surveys, informal interviews, interviews with key informants and participant observation. Hence, Figure 5 depicts the relationship between the objectives of this study and the methods which have been used.

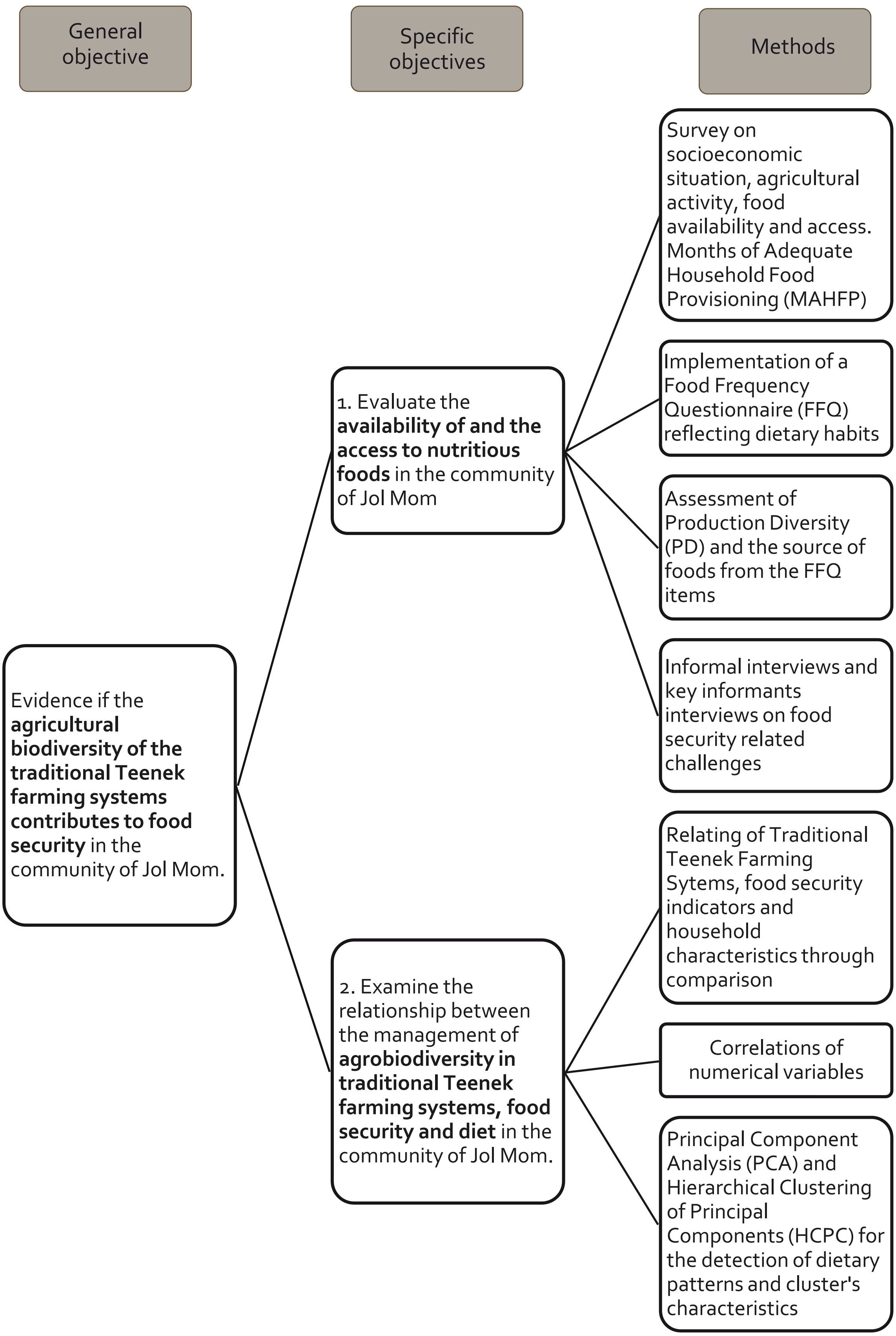


Figure 5: Methodological framework displaying how objectives are linked to methodological approaches and which methods were used for assessment and analysis.

Below an overview is given of what was done in this study to collect data, and how data (tool with which corresponding data were assessed in brackets) were analysed afterwards. In the following sections are presented in detail the methods which were used.

Data collection

A. **Food Frequency Questionnaire** (FFQ), **Production diversity assessment**, **Assessment of source of foods** (quantitative)

B. **Survey** with open ended and close ended questions on socio-economic situation, household composition, livelihood strategy (occupation and income generation), level of agricultural activity, food acquisition, availability and access, application of the Months of Adequate Household Food Provisioning (MAHFP) tool, farming motivation (qualitative and quantitative)

C. **Informal interviews** on perception about changes and challenges related to food security & **Semi-structured key informants interviews** (qualitative)

D. **Participant observation** of family life, and community dynamics.

Data analysis

1st objective:

- Description of categorical variables by absolute and relative frequencies, and of numerical variables by mean values and variance
    - Description of food consumption, production diversity, and means of food acquisition (FFQ) **(A)**
    - Description of food access and availability (FFQ, survey) **(A) (B)**
    - Description of socio-economic situation and household composition, and agricultural activity (survey) **(B)**
- Assessment of a Food Variety Score (FVS) and Production Diversity (PD) per household **(A)**
- Content analysis of food security and agriculture related challenges from key informants and informal interviews **(C)**
- Description of impressions from participant observation **(D)**

2nd objective:

- Comparison of population groups with different numbers of production systems **(A) (B)**

- Correlation matrix of numerical variables and bivariate regression between FVS and PD **(A) (B)**
- Conduction of a Principal Components Analysis (PCA) and Hierarchical Clustering of Principal Components (HCPC) with data of food consumption frequency **(A)**
- Characterization of clusters with numerical and categorical variables from survey **(A) (B)**

After three short exploratory visits in 2018 and 2019 in which contacts were established and first conversations and observations helped to get an overview of the local conditions and starting points for research, field work with the corresponding data collection was carried out in two successive visits between the 27th of March to the 11th of April, and the 15th to the 24th of April 2019.

5.2 Research design

5.2.1 Design of the household survey

For the identification of variables which might play into the food security status of the households, the socioeconomic situation was assessed in the survey (question 1-4, and 25-29, Annex Table 20). Questions furthermore targeted the level of agricultural activity and the number of farming systems in production as indicators of how intensely the traditional agricultural systems were managed, and if the household aimed at providing income through farming (question 5-15). In a third part, general consumption habits were addressed (question 16-18). The definition of the dimensions of food security was based on the definition by the Food and Agriculture Organization of the United Nations (FAO). Questions on food security were adapted from the Escala Latinoamericana y Caribeña de Seguridad Alimentaria (FAO, 2012), and included one question on food availability (question 20), and three questions on food access (question 19, 22, 23). The Months of Adequate Household Food Provisioning (MAHFP) tool was used to assess seasonal food security (Swindale *et al.*, 2010) (question 21-22). Open-ended questions on farming motivation (questions 30-35) aimed to identify how closely farming motivation and the conservation of agricultural biodiversity were linked to ensuring food security.

5.2.2 Design of the diet assessment instrument

A food frequency questionnaire (FFQ) was chosen to assess diets. The FFQ is a dietary assessment instrument considered by FAO and Bioversity International (2017) as having a high potential for adaptation to include biodiverse foods. A FFQ is a questionnaire which presents a list of foods from which the respondent is required to answer the frequency of consumption over a specified period of time (Cade *et al.*, 2002). Depending on its purpose and design, it can be used to assess foods or food groups, as well as for the purpose of assessing nutrient intakes (Cade *et al.*, 2002). It can be self-administered or conducted by the interviewer and contain an open or closed list of foods. The number of food items can vary widely, Cade *et al.* (2002) found a median of 79 foods in previous questionnaires. Qualitative or non-quantitative FFQ do not ask about the portion of the consumed food, whereas semi-quantitative questionnaires include standard portions, and quantitative exact measures of the consumed portion (FAO, 2018; Pérez Rodrigo *et al.*, 2015). In this study, a close-ended (once a preliminary study was conducted and the list was completed), interviewer-administered qualitative FFQ was applied on household level with a 12 months recall period (Annex Table 21), the reasons for this are outlined in the following paragraph.

Considering the farming and subsistence context, the time frame of 12 months was chosen to cover all seasons. Even though a longer time frame can reduce the accuracy of the responses, the consideration of all seasons was regarded as important for the assessment. The flexibility of the recall period is a characteristic of the FFQ, and was another reason why this method was chosen for assessment instead of a validated dietary diversity indicator, which generally cover recall periods from 24 hours to seven days, and require repeated application if seasonality is to be considered. As the aim of the study was to provide insight into food access, consumption patterns and dietary diversity on household level and not nutritional data, no assessment of the portions that were consumed was used. As literacy in this context was not a given for the whole population, the interviewer conducted the survey. The design of a closed questionnaire had the advantage of being able to compare data among households and calculate a dietary diversity score (see section 5.4.3).

In a preliminary Food Frequency Questionnaire, food items were compiled from literature on edible plants of Jol Mom (Heindorf *et al.*, in print) and the region (Cilia López, Aradillas, *et al.*, 2015), from previous works on diet and food frequency questionnaires (Rodríguez Ramos, 2015; Zúñiga Bañuelos, 2017) and from informal interviews with the local population. The food frequency questionnaire applied in the "Encuesta Nacional de Salud y Nutrición Medio Camino 2016" (Instituto Nacional de Salud Pública, 2016) was also consulted. A focus was laid on including items that were locally produced. The final version of the FFQ included 94 food items, 61 of which were also locally produced (without counting products of animal origin). A few species appear several times in the list, as different parts of the plant are consumed on a regular base, with different nutritional values and harvest periods. Foods which are locally produced are mostly accounted for on species level. In a few cases, distinction between species was not made, either because species characteristics were similar and therefore species were grouped together, or because differentiation of species was not possible.

With the same questionnaire, the source of the product (purchase, own production, others), and if it was cultivated by the household were assessed.

Figure 6 provides an overview on the methodological approach which was used designing the diet assessment instrument used in this study. It shows that food biodiversity can reach the consumer through two principle pathways: 1) via own production and gathered from the wild, and 2) purchase of wild or cultivated biodiversity (Bioversity International, 2017). Diets in Jol Mom are composed of both cultivated/collected and purchased foods. Therefore, the food frequency questionnaire (FFQ) is composed of both foods available through production in any of the three farming systems, *solar*, *milpa* and *finca* or *te´lom*, and foods available in local shops or markets, defined as either in the community of Jol Mom or the nearest market (Tampaxal, 30-40 minutes by foot). Wild foods were also accounted for where they played a major role in dietary habits.

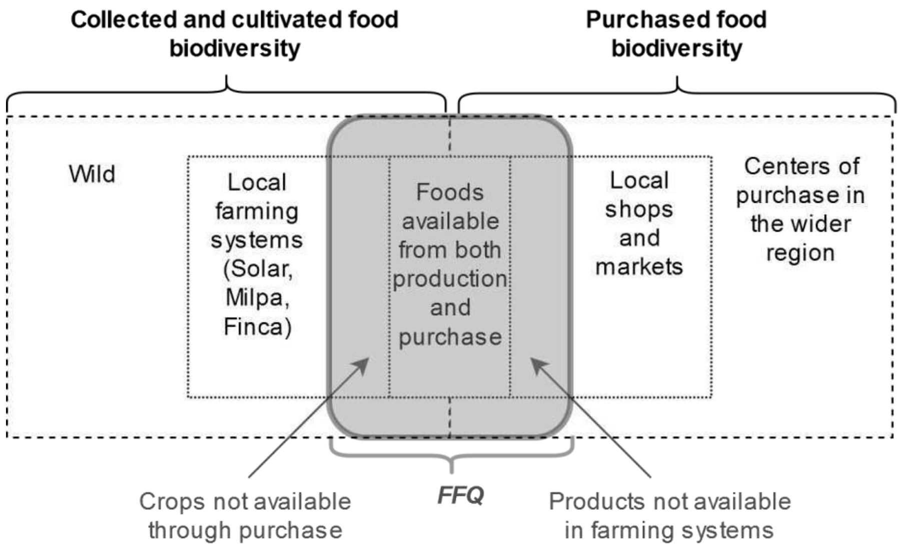


Figure 6: Methodological approach which was used in designing the list of foods for the FFQ.

5.2.3 Assessment of agricultural biodiversity

The question of whether the item was cultivated by the household aimed at addressing agricultural biodiversity, which in this study was assessed as production diversity from the items listed in the FFQ. From the final 86 items which were included in the analysis of the FFQ, 56 were defined as maximum crop diversity, including all items which had been identified as being cultivated by at least one farmer of the sample. Animal products were excluded from this count as their utility for food purposes can depend on a variety of variables, and production might extend over several years but not necessarily lead to consumption of the product. For example, pigs are commonly held but sometimes sold instead of eaten, or only eaten after several years, and therefore are not necessarily relevant for the assessment period of one year. Poultry might be held but used to produce eggs, therefore making assignment for counting difficult. Plant diversity was assessed for the most part on a species level, in some cases only the genus was counted. Items that included several species were counted as one under the common name. Common names, and their binomial name or genus were drawn from data from Heindorf *et al.* (in print) and can therefore be stated with a high certainty of correctness, as cited research was conducted in the same community. Scientific names were spelled according to www.theplantlist.org. The list of the cultivated items of the FFQ with binomial name or genus can be found in Table 2.

Table 2: The 56 crops from the FFQ list which are cultivated by sample population with their binominal name or genus and Spanish, English and Teenek common name (Based on Heindorf *et al.*, in print)

Scientific name	**Spanish ***	**English**	**Teenek ***
Allium longifolium (Kunth)	Cebollín	Spring onion	Xunnakat
Amaranthus hybridus L.	Quelite	Amaranth greens	Chidh
Ananas comosus (L.) Merr.	Piña	Pineapple	Chabcham
Annona reticulata L.	Anona (amarilla)	Custard apple	Pakdha' kukay
Arachis hypogaea L.	Cacahuate	Peanuts	Dhakl kakaw
Averrhoa carambola L.	Carambola/Garambolo	Carambola/Star fruit	Papayuelo
Cajanus cajan (L.) Millsp.	Lenteja de árbol	Pigeon pea	
Canavalia villosa Benth.	Flor de gallo	Flor de gallo	Koxol huiz
Capsicum annuum L.	Chile	Chilies	Its
Carica papaya L.	Papaya	Papaya	Utsun
Citrus aurantifolia (Christm.) Swingle	Limón agrio	Key lime/Mexican lime	Jili limón
Citrus medica L.	Lima dulce	Sweet lime	
Citrus reticulata Blanco	Mandarina	Mandarine	
Citrus sinensis (L.) Osbeck	Naranja	Orange	Lanáx
Cnidoscolus multilobus (Pax) I.M. Johnst.	Flor de ortiga/Mala mujer	Ortiga blossom	Wistil ak'
Coffea sp.	Café	Coffee	Kapé
Coriandrum sativum L.	Cilantro	Coriander	Kulantuj
Cucurbita moschata Duchesne	Calabaza	Pumpkin/Squash	K'alam
Cucurbita moschata Duchesne	Flor de calabaza	Squash blossom	Wits il k'alam
Cucurbita agyrosperma Duchesne	Semillas de calabaza	Pumpkin seeds	Dhuk'uk
Dysphania ambrosioides (L.) Mosyakin & Clemants	Epazote	Epazote	Tijtson
Eriobotrya japonica (Thunb.) Lindl.	Níspero/Nesfora	Loquat	Nesfora
Erythrina americana Mill.	Pemoche/Colorín	Coral tree/Colorines blossom	Jutuku
Inga vera Willd.	Chalahuite	Chalahuite	Dhubchik
Ipomoea batatas (L.) Lam.	Camote	Sweet potato	Idh
Ipomoea dumosa (Benth.) *L.O. Williams*	Suyo	Suyo	Dhuyu
Jaltomata procumbens (Cav.) J.L.Gentry	Ojo de guajolote	Procumbens/Creeping false holly	Wal palats
Litchi chinensis Sonn.	Lichi	Lychee	
Mangifera indica L.	Mango	Mango	
Manihot esculenta Crantz	Yuca	Cassava/Yucca/Manioc	T'inche'
Manilkara zapota (L.) P.Royen	Mamey	Sapota	Bolom it'adh
Mentha sp.	Hierba buena	Mint	Elwenax
Musa sp.	Plátano	Banana/Plantain	It'adh
Nopalea cochenillifera (L.) Salm-Dyck	Nopal	Nopal	Pak'ak'
Not specified	Hongos	Mushrooms	Mutsek
Passiflora aff. *edulis f. flavicarpa* O. Deg.	Maracuyá amarilla	Passion fruit	
Persea americana Mill.	Aguacate	Avocado	Uj

Scientific name	Spanish *	English	Teenek *
Phaseolus coccineus L.	Frijol coloní	Runner bean	Tsanak'w coloni
Phaseolus lunatus L.	Frijol wet	Lima/butter bean	Wet
Phaseolus vulgaris L.	Frijol mal te	Common climber bean	Dhakni tsanakw
Phaseolus vulgaris L.	Frijol pukul	Common bean	t'unu tsanakw
Portulaca oleracea L.	Verdolaga	Verdolaga/Purslane	Pits'ist wal
Prunus persica (L.) Batsch	Durazno	Peach	Tulaxnúj
Prunus serotina Ehrh. (among others)	Capulín	Capulin	
Psidium guajava L.	Guayaba	Guava	Bek
Rumex crispus L.	Lengua de vaca	Curly dock	Lek' ab pakax
Sechium edule (Jacq.) Sw.	Hoja de chayote	Chayote greens	Ak wal
Sechium edule (Jacq.) Sw.	Chayote	Chayote	Tsiw
Sesamum indicum L.	Ajonjolí	Sesame seeds	Dhakpen
Smilax aristolochiifolia Mill.	Ut'	Ut'	Ut'
Solanum lycopersicum var. *cerasiforme* (Dunal) D.M. Spooner, G.J. Anderson & R.K. Jansen	Tomate coyol	Cherry tomato	Tsakan tudhey
Spondias mombin L.	Jobo	Yellow mombin/Hog plum	K'inim
Tamarindus indica L. 1753	Tamarindo	Tamarind	
Vigna unguiculata (L.) Walp.	Frijol sarabanda	Cowpea	Lab tsanak'w
Xanthosoma sp. / *Xanthosoma sagittifolium (L.) Schott*	Luum	Tannia	Lúm
Zea mays L.	Maíz	Maize/Corn	Idhidh

** People in Jol Mom usually refer to the plants in Teenek and optionally in Spanish*

5.3 Data collection

A stratified random sampling was applied to select households for the sample population. A total of 47 households were interviewed, with 40 households included in the analysis, which corresponds to 23.7 % of the 169 households in Jol Mom. Seven surveys were excluded from the sample because of incomplete data, reasons for this were communicational issues because no translator was available, or because the interview could not be completed. The sample included households with all three traditional production systems (*solar*, *milpa*, *finca*), and households which only managed two or one of these production systems.

5.3.1 Survey conduction

The survey was conducted orally in Spanish, mostly with the individuals in their homes. Basic knowledge of the Spanish language of one of the household heads or the presence of a translator (which was either a Spanish speaking household member or another local person present in that moment) was therefore a prerequisite for the selection of households. Other selection criteria, also for deciding whether the male or female head of household was going to be interviewed, were the willingness of individuals to participate and their time-wise availability. Interviews lasted generally

40 to 60 minutes. In the start of the interview, a general explanation of the aim of the survey was provided.

For the part of the Food Frequency Questionnaire, the respondent was asked to answer questions about cultivation, consumption patterns and source of foods for the whole household during the last 12 months (instructions were adapted from the "Guidelines on assessing biodiverse foods in dietary intake surveys" from FAO and Bioversity International (2017)). The food items of the FFQ were named one by one by their local, Spanish name. In some cases, the more frequently used name in Teenek was used, or a translation of the Spanish name into Teenek was given if the item was not recognized. For each food the interviewee was asked to indicate the frequency of consumption during the last 12 months in the household. Frequency was assessed categorizing consumption into: never; less than once a month; once a month, every two weeks; once a week; two to six times a week; every day; and seasonally. The respondent was asked to indicate the source of food: purchased, own production/harvest/collected from wild; food was a gift or other means of acquisition. Ultimately, the individual was asked if the food had been cultivated or found in one of the household's farming systems. For the wild or spontaneously growing crops in the list (*Canavalia villosa*, *Cnidoscolus multilobus*, *Ipomoea dumosa*, *Jaltomata procumbens*, *Smilax aristolochiifolia*, and collected mushrooms), 'cultivated' was understood as accessible to the household, either growing in or close to the farming system, or in public spaces, *e.g.* along paths. It is acknowledged that if the item was growing in public spaces it is theoretically available to anybody, nevertheless availability does not necessarily lead to access (limited knowledge, time or other factors might restrict access). Any additional qualitative information which was provided on the food items was noted. After completing the list, the enumerator asked if any foods that had not been named had been consumed. As the FFQ after assessment was treated as a closed questionnaire, this information was assessed as a verification of completeness by the author, rather than information to include. This method was successful, as only very few households named foods outside of the food list, and in these cases the individuals said that these foods were not an essential part of the diet, and rarely consumed, confirming that they ought not to be included in the survey.

5.3.2 Collection of qualitative data

In some cases, after the application of the survey, an informal interview on the perception of challenges and observed changes on food security related topics was conducted, which generally took another 20 to 60 minutes. These conversational interviews were conducted only in cases in which individuals were disposed to provide further insights and explanations on the topic or related topics.

Apart from the informal interviews conducted with household heads, three structured interviews were conducted with key informants to assess seasonality of all the foods grown locally (interview N° 5, 6, and 7 in Table 3). Furthermore, three key informant interviews were conducted on the perception of challenges and changes related to food security (interview N° 1, 2, and 4), as well as a semi-structured interview with the representative of the ejido commissariat to get further insights into local issues (interview N° 3) and a semi- structured interview with an owner of a local shop in Jol Mom (interview N° 8).

Table 3: List of structured and semi-structured interviews that were conducted with medical staff in Tampaxal and with key informants in Jol Mom.

Interv. N°	Date	Position/Function	Purpose of interview
1	03/04/2019	Nurse in the local hospital 'Unidad medica rural Tampaxal N° 163'	Perception on challenges and changes related to food security
2	03/04/2019	Volunteer for health issues (Voluntaria de la salud) in the community of Jol Mom	Perception on challenges and changes related to food security
3	07/04/2019	Representative of Ejido Commissariat of Tampaxal	Perception on challenges and changes related to food security and land ownership in the Ejido
4	16/04/2019	Physician responsible of the local hospital 'Unidad médica rural Tampaxal N° 163'	Perception on challenges and changes related to food security
5	18/04/2019	Key informant in Jol Mom	Seasonality of foods
6	19/04/2019	Key informant in Jol Mom	Seasonality of foods
7	20/04/2019	Key informant in Jol Mom	Seasonality of foods
8	21/04/2019	Owner of local shop in Jol Mom	Perception of consumption patterns of local population

5.3.3 Participant observation

Participant observation was done during the period of field work in March and April 2019 by living with a local family and engaging in daily life of various participants, including the preparation of meals, visits of the agricultural plots and assisting in harvest, helping with the collection of firewood, and observation of everyday activities and family dynamics in the community of Jol Mom. By participating in local human life, as it is proposed by this method, it is possible to obtain direct access to "not only the physically observable environment but also its primary reality as humanly meaningful experiences, thoughts, feelings, and activities" (Jorgensen, 2015, p. 1). Therefore, the participation in the daily life of the inhabitants of this community during the fieldwork allowed to obtain information about the meanings and perspectives this community has over food production, traditional farming systems, and their diet, understanding these aspects as part of complex relations between the environment and culture. The data obtained through this method were collected in field notes, pictures and videos.

5.4 Data analysis

5.4.1 Survey data processing

Data from the survey was captured with Microsoft Excel 2016. Variables were codified using predominantly nominal categories (categorical variables, dichotomous and polytomous), and some variables were expressed in ordinal scales.

According to Swindale and Bilinsky (2010), the results from the Months of Adequate Household Food Provisioning (MAHFP) assessment ought to be evaluated by counting the number of months in which food had been named as being lacking, and creating a score which is comparable among households or studies. After applying the tool, however, it was considered that this evaluation of the tool was not appropriate for the context, as only 10 % of the households (see results section 6.1.3.4) had affirmed the question. Instead, data was analysed comparing the season in which households had indicated food provisioning challenges and the reason for it, therefore the data was used as information about seasonal variations of food security rather than an indicator for household food access.

Regarding the FFQ, in the cases in which a respondent named a consumption frequency as well as seasonal consumption, generally the consumption frequency was chosen to be plotted as it was considered as more accurately reflecting dietary consumption patterns. Exceptions were made for cases in which the respondent indicated a high frequency of consumption over a small seasonal period. In these cases, registering seasonal consumption was considered as best reflecting the dietary habit. Consumption categories were regrouped after revision, reducing from eight into six categories: never or almost never (never; less than once a month); once or twice a month (once a month; every two weeks); once a week; several times a week (two to six times a week); every day; and seasonally.

For analysis, the source of food was grouped into five categories: purchased; harvested; purchased and harvested; gift; not consumed. The category "gift" was used when respondents indicated that they were not used to buying the food, and also did not harvest it, but they still consume it. This is usually the case when a neighbour or relative often gives away certain products. 'Gift' was preferred as a term over using 'exchange' or 'barter', as according to an informant's understanding, the exchange of foods is not a common practice in the community.

After a revision of the consumption frequencies of items from the FFQ, for further analysis the list was reduced from 94 to 86 items, eliminating items which had been observed to not always have been identified by respondents, and eliminating foods which more than 70 % of the population had not consumed, as they were considered as possible noise producing factors for later analysis. The eliminated items were: calabaza pipián, zapote, jícama, papa del monte, pipán/piñon, manteca, piloncillo, café bomba.

5.4.2 Division in food groups

Food groups were assigned following the "Guidelines for measuring household and individual dietary diversity" (FAO, 2010). The division into separate groups was made accounting for observed dietary habits. For example, meats and fish form different groups according to the FAO document (2010). Nevertheless, in the community of Jol Mom, only tinned fish, if any, is consumed, which led to the decision that a separate group for fish would overvalue its importance for the diet. On the other hand, the group 'legumes, nuts and seeds' was separated into 'legumes' and 'nuts and seeds' following the same logic. Beans, an element of the 'legumes' groups, are an essential element of the Mexican diet (García Urigüen, 2012). Their crucial role as a source of protein, especially in animal-protein poor diets (Almaguer González *et al.*, 2016), justifies the decision to open a separate group for them.

The resulting 16 food groups were 1) cereals; 2) white roots and tubers; 3) vitamin A rich vegetables and tubers; 4) dark green leafy vegetables; 5) other vegetables; 6) vitamin A rich fruits; 7) other fruits; 8) legumes; 9) nuts and seeds; 10) milk products; 11) eggs; 12) meats and fish; 13) oils and fats; 14) snacks; 15) sweets; 16) spices and condiments. In Table 4 a list of all items from the FFQ with their respective food group is provided.

Even though several dietary diversity indicators consider often fewer food groups, detailed differentiation between food groups was considered as important, as especially foods from fruit or vegetable groups are considered as contributing to micronutrients intake and are therefore considered as crucial for dietary quality (ENSANUT MC, 2016; FAO, 2019a). Furthermore, this allowed us to account for different parts of plants, *e.g. Cucurbita moschata*, which is a central element of the farmers' diets. This method also allowed us to individually assess the contribution to dietary diversity of fruits, blossoms, and seeds of a single plant. A second example is *Sechium edule*, the fruit and leaves of which are both eaten regularly. Although there are more plants from which various parts are used, in the questionnaire the focus was laid on items that are consumed by a considerable part of the population on a regular base.

Table 4: The 86 food items from FFQ grouped according to food groups, the food group division used in the Principal Component Analysis, their common Spanish and English names, and indicating the edible part of the plant. For the PCA and HCPC analysis, for distinction food groups were market with '1' to indicate they are cultivated in Jol Mom and '2' when only available through purchase.

Food group	Food group for PCA and HCPC	Spanish	English	Edible part of the plant
1. Cereals	cereals1	Maíz	Maize/Corn	Seed
	cereals2	Arroz blanco	White rice	Seed
		Pan	Bread	Seed
		Pasta	Pasta	Seed
2. White roots and tubers	roots_tubers1	Yuca	Cassava/Yucca/ Manioc	Tuberous root
		Nopal	Nopal	Succulent stem
		Luum	Tannia	Starchy corms
	roots_tubers2	Papa	Potato	Stem tuber
3. Vitamin A rich vegetables and tubers	veg_vit_a1	Calabaza	Pumpkin/Squash	Fruit
		Camote	Sweet potato	Tuberous root
	veg_vit_a2	Zanahoria	Carrot	Tuberous root
4. Dark green leafy vegetables	veg_dark_green	Quelite	Amaranth greens	Leaves
		Suyo	Suyo	Leaves
		Hoja de chayote	Chayote greens	Leaves
		Lengua de vaca	Curly dock	Leaves
		Verdolaga	Verdolaga/Purslane	Leaves
5. Other vegetables	veg_others1	Chayote	Chayote	Fruit
		Chile	Chiles	Fruit
		Tomate coyol	Cherry tomato	Fruit
		Cebollín	Spring onion	Bulb and leaf sheaths
		Flor de calabaza	Squash blossom	Flower
		Hongos	Mushrooms	Stem and cap
		Pemoche/Colorín	Coral tree/colorines blossom	Flower
		Flor de ortiga/Mala mujer	Ortiga blossom	Flower
		Flor de gallo	Flor de gallo	Flower
		Ut'	Ut'	Young stem
	veg_others2	Tomate	Tomato	Fruit
		Cebolla	Onion	Bulb
6. Vitamin A rich fruits	fru_vit_a	Maracuyá	Passion fruit	Fruit
		Durazno	Peach	Fruit
		Mango	Mango	Fruit
		Papaya	Papaya	Fruit
7. Other fruits	fru_others1	Naranja	Orange	Fruit
		Mandarina	Mandarine	Fruit
		Guayaba	Guava	Fruit
		Plátano	Banana/Plantain	Fruit and starchy fruit
		Lima dulce	Citron	Fruit
		Limón	Key lime	Fruit
		Aguacate	Avocado	Fruit
		Lichi	Lychee	Fruit
		Anona (amarilla)	Custard apple	Fruit
		Carambola/Garambolo	Carambola/Star fruit	Fruit

Food group	Food group for PCA and HCPC	Spanish	English	Edible part of the plant
		Mamey/Chicozapote	Sapota	Fruit
		Chalahuite	Chalahuite	Fruit
		Níspero/Nesfora	Loquat	Fruit
		Capulín	Capulin	Fruit
		Jobo	Yellow mombin/Hog plum	Fruit
		Ojo de guajolote	Procumbens/Creeping false holly	Fruit
		Piña	Pineapple	Fruit
		Tamarindo	Tamarind	Fruit
	fru_others2	Melón	Muskmelon	Fruit
		Coco	Coconut	Fruit
		Sandía	Watermelon	Fruit
		Uva	Grape	Fruit
		Manzana	Apple	Fruit
		Fresa	Strawberry	Fruit
8. Legumes	legumes1	Frijol coloní (Ayocote)	Runner bean	Seed
		Frijol mal te (Frijol bayo o blanco)	Common/green bean	Seed
		Frijol pukul (Frijol negro)	Black turtle bean	Seed
		Frijol wet (pallar, garrofón, habones, judía de Lima)	Lima/butter bean	Seed
		Frijol sarabanda (Caupí, judía de careta, frijol de carita)	Cowpea	Seed
		Lenteja de árbol	Pigeon pea	Seed
	legumes2	Lenteja	Lentil	Seed
		Soya	Soy product	Seed
9. Nuts and seeds	nuts_seeds	Ajonjolí	Sesame seeds	Seed
		Semillas de calabaza	Pumpkin seeds	Seed
		Cacahuate	Peanuts	Seed
10. Meats and fish	meats_fish	Gallina, pollo	Chicken	
		Cerdo	Pork	
		Res	Beef	
		Embutidos	Sausage products	
		Pescado en lata	Canned fish	
11. Eggs	eggs	Huevos de gallina	Chicken eggs	
12. Milk and milk products	milk_prod	Leche	Milk	
		Queso	Cheese	
		Yogurt	Yogurt	
13. Oils and fats	oils	Aceite	Vegetable oil	
14. Sweets	sweets	Azúcar	Sugar	
		Galletas, pan dulce	Sweet biscuits, sweet bread	
		Refrescos	Soft drinks	
15. Savoury and fried snacks/ Processed foods	snacks	Frituras (sabritas, cuernos)	Fried snacks (sabritas, cuernos)	
		Sopa instantánea ‘Maruchan’	Instant soup ‘Maruchan’	
	spices	Café	Coffee	Seed
		Cilantro	Coriander	Leave

Food group	Food group for PCA and HCPC	Spanish	English	Edible part of the plant
16. Spices, condiments, beverages		Hierba buena	Mint	Leave
		Epazote	Epazote	Leave

5.4.3 Calculation of a Food Variety Score (FVS)

The Food Variety Score (FVS) is a dietary diversity score calculated by counting food items consumed across a determined time period (Hatløy *et al.*, 1998). Dietary diversity scores aim at evaluating food access and/or diet quality (Jones *et al.*, 2013). For the calculation of the Food Variety Score (FVS), food groups were divided into two categories adapted from ENSANUT MC (2016): 1) recommended, and 2) not recommended. The latter are food groups which are associated with an elevated risk of overweight, obesity and chronic diseases. The recommended food groups were 1) cereals; 2) white roots and tubers; 3) vitamin A rich vegetables and tubers; 4) dark green leafy vegetables; 5) other vegetables; 6) vitamin A rich fruits; 7) other fruits; 8) legumes; 9) nuts and seeds; 10) milk products; 11) eggs; 12) meats and fish; 13) oils and fats; 16) spices and condiments. Not recommended for regular consumption were 14) snacks; and 15) sweets. The list was therefore reduced from 86 to 81 items, as the items azúcar, galletas y pan dulce, refrescos, frituras (sabritas, cuernos), sopa instantánea 'Maruchan' did not form part of the score. The division into two principal categories also served well for the interpretation and discussion of the results.

The FVS was calculated by counting the foods whose consumption during the last year had been clearly affirmed (*i.e.* consumption frequency of "once or twice a month" or higher).

5.4.4 Analysis of seasonal data

Information from key informants on seasonality of crops was captured with Microsoft Excel 2016 and was used to create a calendar displaying the harvesting season for each crop. According to the respondent's definition and in line with the precipitation data (see ombrothermic diagram Figure 4), the rainy season was defined as the period between May and September.

5.4.5 Analysis of qualitative data

For the identification of perceived changes and challenges related to food security and agriculture in the community of Jol Mom, notes and quotes registered from informal interviews were grouped into thematical categories which corresponded to concepts used in this study (Annex Table 23). This permitted a systematic analysis of principal perceptions and was used to complement or sustain data obtained from the survey. Comments on food items which are part of the FFQ were registered and are displayed sorted by food item in Table 25 in the Annex.

The two key informant interviews with the medical staff from the hospital in Tampaxal and the key informant interview with the 'voluntaria de la salud' in Jol Mom were summarized and content was used for explaining the health-related challenges of food security in the region and in Jol Mom (Annex Table 24).

5.4.6 Descriptive statistics

Absolute and relative frequencies, as well as descriptive statistics were calculated using Microsoft Excel 2016.

5.4.7 Correlation and linear regression analysis

With Microsoft Excel 2016, a correlation matrix of the nominal variables from the survey questions was computed so to detect possible correlations between factors determining household characteristics. Regression models were used to predict the incidence of dietary diversity among households in Jol Mom (Bacon *et al.*, 2014). In the bivariate linear regression, the production diversity (PD) was set as the independent variable. In the given sample, this variable takes discrete values from 18 to 56.

5.4.8 Principal Component Analysis (PCA)

Multivariate analysis is used to display large datasets in reduced form and find patterns and new variables to describe a dataset. Principal Components Analysis (PCA) is a dimensionality-reduction ordination method. It is used to describe and summarize a dataset by reducing the number of variables while preserving as much information as possible (Husson *et al.*, 2011). For exploratory data analysis, PCA allows to find an underlying structure of the data without applying previous assumptions. Studies on diets have seen a shift from a focus on nutrients to food level, "with the driving force of this movement attributed to the accepted concept that people eat foods not nutrients" (Hearty and Gibney, 2008, p. 1), and with the consciousness that foods are more than the sum of their (known) nutrients (Johns, 2007). PCA is a factor analysis frequently used for identifying dietary patterns in a population (Hearty *et al.*, 2008). The base of analysis is a correlation matrix of the original food variables, and the output of new dietary and food pattern variables, and each individual is attributed a factor (or principal component (PC)) score for each of the derived factors (Hearty *et al.*, 2008).

In this study, PCA was performed to analyse the variability of consumption patterns between individuals and to see if there is a linear relationship between variables, summarizing the correlation matrix and looking for synthetic variables which permit the pooling of the consumption pattern of a household by a small number of variables.

For the implementation of the Principal Component Analysis (PCA) and the Hierarchical Clustering of Principle Components (HCPC), the package "FactoMineR" (Husson *et al.*, 2008) was used in R. The code used for the analysis can be found in Annex Figure 25.

As input, the food frequency consumption data from the FFQ was used. After the grouping of the 86 items from the FFQ into the 16 established food groups, to increase the explanatory value of the analysis, foods within food groups were divided according to the condition of if they were cultivated in Jol Mom or not (marked with '1' and '2' respectively for distinction of food groups which included both cultivated and not cultivated foods. Which food belongs to which PCA food group can be consulted in Table 4. This information was derived from the production diversity assessment, meaning that the condition of if the food is produced in Jol Mom can only be attested for the sample population. The 22 resulting variables (Table 4) were calculated by taking the average of the sum of consumed foods in each group.

The initial data set was made of 40 rows (individuals) and 22 columns (food groups of FFQ) with continuous variables, indicating the frequency of consumption of each food. In order to treat the variables as continuous, consumption frequency was expressed on a scale, and seasonal consumption was placed as intermediate frequency. The scale used ranged from never (0) < less than once a month (1) < once a month (2) < twice a month (3) < seasonally (4) < once a week (5) < several times a week (6) < every day (7).

In a first step of the PCA, a correlation matrix demonstrating the correlation between each of the 22 variables was computed. The analysis was continued with 20 variables, as two variables ('oils' and 'cereals1') consisted of only one item which was consumed every day by all respondents, therefore not containing relevant information, which was why these variables were eliminated.

The second step was the identification of the principal components of the data set by computing the eigenvectors and eigenvalues of the correlation matrix. Every eigenvector has an eigenvalue, which is equal to the number of dimensions of the dataset. Eigenvectors are the directions of the axes where there is the most variance (most information), which then constitute the PC, while eigenvalues are the coefficients of the eigenvectors, which is the explained variance of each PC. The new variables or PC are uncorrelated, most information is compressed in first components, with the second component lying orthogonal to the first. PC represent the directions of the data that explain a maximal amount of variance, meaning they are the lines that capture most information of data. The larger the variance, the larger the dispersion of data points along the line, the more information it has. A plane was generated in which the first and second dimension constitute the axis which served as reference for locating individuals in the plane.

5.4.9 Hierarchical Clustering of Principal Components (HCPC)

While automatic clustering methods and principal components methods use similar approaches, as both are exploratory analysis methods and use the same data table, the representation methods differ. Principal component analysis uses Euclidean distance, and clustering uses indexed hierarchy, a classification analysis. Combining both can lead to an even richer and more reliable result (Husson *et al.*, 2011).

The representation combing PCA and hierarchical clustering has the advantage that a continuous view and a discontinuous view can be joint by combining the tendencies that were identified by the PC with the grouping into clusters. Furthermore, while in the PCA ordination the number of dimensions were reduced, and look at the distance between the individuals as a measure of similar characteristics, in HCPC the clusters are defined from classification of all dimensions, and therefore carry additional information to what is displayed in the plane, which allows for a differentiation between individuals which lie close together on the plane but are located in two different clusters, as they are far away from each other in other dimensions (Husson *et al.*, 2011).

After the generation of a dendrogram (Annex Figure 27), capitals were partitioned into six clusters. The rather precise level of partitioning was chosen according to field observations, which according to the investigator's experience displayed a more complex and varied panorama than the suggested division into three groups – and also because the objective of the investigation was not only to investigate dietary patterns but also to find out about underlying characteristics of the households, which resulted as being rather homogeneous and with little explanatory value in the first run with only three clusters.

Finally, named household characteristics derived from the survey were attributed to each cluster. For nominal variables, the mean value was calculated to describe a variable, while for the categorical variables the mode was taken.

6 Results

The results section of this work is divided into two main sections. In the descriptive first section, which aims at responding to the first objective of evaluating the availability and access to nutritious foods in Jol Mom, the farming systems managed by the sample population are presented as the origin of the agricultural biodiversity which contributes to the local availability of foods. Then, a look at the households, their socioeconomic situation and agricultural activity, and their food security situation is taken. At the end of that first section, food consumption habits representing the access to foods of the sample population are presented. The second section is the analytical part of the results, in which according to the second objective with different methods the two main component of the investigation are related: the farming systems and their agrobiodiversity with food security and diets in Jol Mom. Firstly, a look is taken at how the number of production systems can be linked to food security. Then, it is investigated if there is a correlation between production diversity and dietary diversity in Jol Mom. Thirdly, the Principal Component Analysis is used to detect dietary patterns of the sample population and relate them through a Hierarchical Clustering of Principal Components to household characteristics and food security related variables.

6.1 Obj. 1: Evaluate the availability of and the access to nutritious foods in Jol Mom

6.1.1 Farming systems and agrobiodiversity

6.1.1.1 Characterization of farming systems in Jol Mom

In Jol Mom, *solar*, *milpa* and *finca* are the most commonly managed farming systems. In total, 37 of the 40 interviewed households manage a backyard or *solar* containing edible plants, only those who literally do not have any space around their house do not cultivate some sort of crop or have at least some sort of fruit tree in their backyards. Of the households, 31 cultivated swidden *milpa* fields during the past year and 23 of them cultivated maize, the crop the system is traditionally based on, but to which the *milpa* is not limited. The coffee *finca* or *te'lom* agroforestry system is managed by 26 households (Table 15).

Geographically speaking, the *solar* or backyard is situated around the house. The size can vary from few square meters to around one hectare, depending on the location of the house (*solares* in the centre of the community tend to be smaller than in the outskirts). Sometimes, the *solar* merges with another production system, for example with the *finca*. The *milpa* plot is often situated within a certain distance from the house, although plots within walking distance of around 30 minutes are preferred as management is intensive during certain periods of the year. Nevertheless, plots might also lie at a few hour's walk from the house. Generally, even though it depends on the location of owned land, the *finca* is the farming system which is located at the furthest distance from the community when comparing the three production systems, as management requirements are lowest. Management effort in the *finca* depends strongly on the farmers' motivation and goal. The *finca* is therefore often a rather wild terrain, and because of its remote location in the minds of the people it is often associated with wild and partly dangerous animals such as snakes. Nevertheless, various *fincas* are scattered around the community. Furthermore, it is important to mention that the definition of the production system might be diffuse, and that it can vary among farmers. Still, definitions in Jol Mom tend to be in line with literature (see (Alcorn, 1984b) and section 4.3) .

The most important crop in Jol Mom's backyard or *solar* plots is chayote; it was mentioned by 26 respondents out of 40 when they were asked in an open-ended question what they principally cultivate in their *solar*. Banana (plátano) is also very common, followed by orange (naranja), pumpkin (calabaza) and nopal cactus. The *milpa* fields typically consist, in line with literature (see section 4.3), of beans (frijol), maize (maíz), chili (chile) and calabaza. Also commonly grown in Jom Mom's *milpas* is tomate coyol, which has the appearance of cherry tomato. In the *te'lom* agroforestry systems, in Jol Mom commonly called *finca*, the major crop is coffee (café). While the agroforestry system consists mainly of timber, fruit and shade trees, chayote, plátano, vainilla and chile can also sometimes be found (Table 5).

As described, Table 5 indicates which are the most typical crops of each farming system, but also gives information on which crops are most important in Jol Mom, as they come to the people's minds first. Furthermore, it also shows that the most important crops in Jol Mom, such as chayote, chile, calabaza, plátano and café are grown in more than only one production system. Therefore, households which do not cultivate one or two of the traditional farming systems often find a way how to grow desired crops outside of its typical system, for example by cultivating a few coffee plants in the backyard.

Table 5: Most commonly cultivated crops (according to the times they are mentioned) in each of the three farming systems *solar*, *milpa* and *finca*.

Most common crops in *Solar*	**Times mentioned**	**Most common crops in *Milpa***	**Times mentioned**	**Most common crops in *Finca***	**Times mentioned**
Chayote	26	Frijol	27	Café	24
Plátano	21	Maíz	24	Chayote	10
Naranja	13	Chile	22	Plátano	4
Calabaza	10	Calabaza	21	Vainilla	2
Nopal	10	Tomate coyol	10	Chile	2
Café	8	Cilantro	6		
Chile	6	Quelites	5		
Mandarina	6	Chayote	4		

In the closer region, Jol Mom is known for being the number one in producing chayote, having a favourable climate for this crop according to informants, and for producing great quantities of chile piquin (Annex Figure 30), a small chili variety which are used fresh or in dried form. Chili is a popular crop in Jol Mom and seen as one of the crops from which most profit can be made, especially when the farmer achieves an early harvest in the time when demand is high but supply still low. Farmers talk with pride about Jol Mom's capacity to produce a great amount and variety of chayote, chile and calabaza, and that Jol Mom is seen as a community in which farmers still make the effort to produce a variety of crops in their fields: "Aquí salen mucho a vender, mujeres como hombres. La gente está despierta. ¡Jol Mom es primer chayotero!" (24); "Cuando hay productos, se llenan cinco a seis camionetas el domingo. Antes se le llevaba vencedor [el bus del transporte público], todos los días. Ahora es en camionetas. Antes se vendía en Valles. Antes de que pasó la balacera" (38) (Annex Table 23). People from the surrounding villages come to work as "peón" (labourer in the *milpa* fields) in Jol Mom.

> "Aquí todo da, casi todos salen a vender. Ya casi no ayudan uno al otro. Sacan cosas a vender, para el dinero, y después compran. En otras comunidades no hay trabajo, a lo mejor no siembran y no venden. Aquí sí hay trabajo." (45)

The responses to the question of which crops the farmer sells principally confirms Jol Mom's reputation for producing chayote, chile, and calabaza (Table 6).

Table 6: Most frequently sold crops (according to the times they are mentioned).

Crop	Times mentioned
Chayote	24
Chile	23
Calabaza	23
Cilantro	12
Café	10
Frijol	8
Tomate coyol	8
Quelites	5

There are significant differences regarding the frequency in which different crops are grown in Jol Mom. Crops which are grown or collected by 90 % or more of the interviewed households are chayote and hoja de chayote, mandarina, suyo, naranja, hongos, cilantro, calabaza, flor de calabaza, plátano, nopal, chile, tomate coyol, and hierba buena (in descending order, see Table 7). Cacahuate, ajonjolí, aguacate, anona and piña are produced by 20 % or less of the sample population (Table 7).

The production diversity (PD) score, which indicates how many of the 56 crops from the FFQ produced by the sample population are cultivated by each household, gave an average of 33.8 crops, with a standard deviation of 9.5. PD ranges from 18 to 54, meaning that the household with the lowest diversity still cultivates 18 crops, and the household with the highest diversity around three times as much. It is important to keep in mind that this number is restricted to the items accounted for in the FFQ and does not represent the total agricultural biodiversity of the households.

Table 7: List of foods from the Food Frequency Questionnaire (FFQ) which are cultivated in Jol Mom, with frequencies describing which part of the sample population (n = 40) has been cultivating the item during the past year.

Item	Cultivating	
	[N]	[%]
Maíz	25	62.5
Yuca	16	40,0
Nopal	36	90.0
Luum	14	35.0
Calabaza	38	95.0
Camote	9	22.5
Quelite	33	82.5
Suyo	39	97.5
Hoja de chayote	40	100
Lengua de vaca	19	47.5
Verdolaga	23	57.5
Chayote	40	100
Chile	36	90.0
Tomate coyol	36	90.0
Cebollín	27	67.5
Flor de calabaza	36	90.0
Hongos	38	95.0
Pemoche	32	80.0
Flor de ortiga	23	57.5
Flor de gallo	19	47.5
Ut’	28	70.0
Maracuyá	31	77.5
Durazno	31	77.5
Mango	18	45.0
Papaya	15	37.5
Naranja	39	97.5
Mandarina	40	100
Guayaba	29	72.5
Plátano	38	95.0
Lima dulce	31	77.5
Limón	20	50.0
Aguacate	8	20.0
Lichi	17	42.5
Anona	8	20.0
Carambola	9	22.5
Mamey	16	40.0
Chalahuite	32	80.0
Nesfora	14	35.0
Capulín	23	57.5
Jobo	31	77.5
Ojo de guajolote	17	42.5
Piña	8	20.0
Tamarindo	3	7.5
Frijol coloní	7	17.5
Frijol mal te	16	40.0
Frijol pukul	21	52.5
Frijol wet	13	32.5
Frijol sarabanda	22	55.0
Lenteja de árbol	20	50.0
Ajonjolí	6	15.0
Semillas de calabaza	27	67.5
Cacahuate	3	7.5
Café	27	67.5
Cilantro	38	95.0
Hierba buena	36	90.0
Epazote	29	72.5

6.1.1.2 Farming motivation

The *solar*

Generally, the question of whether to manage a backyard garden does not arise in Jol Mom, in a community where livelihoods are based on agriculture the most basic and easiest to manage farming system is simply part of the house. Nevertheless, whereas for some households they constitute an important source of foods, herbs, spices, and medicinal plants, other households barely take notice of some of the fruit trees, and fruits are left to rot or eaten by domestic animals. The advantage of the backyard is its closeness to the house (“Es fácil cosecharlo” (4); “El chayote tiene tusas. Aquí cerca se puede controlar” (41)), and cultivation reasons are “for own consumption” (“Para el consumo” (33)), or to avoid household expenses by producing foods (“También si no tenemos *solar* tendríamos que comprar” (45) (Annex Table 22). While an important feature of some *solar*es is keeping domestic animals like poultry such as turkey, chicken or ducks, and one or several pigs, there might also be difficulties involved in holding animals, as they do not respect horticulture "Gallinas y puerco comen todo, casi no podemos sembrar ahí" (47) and raise household costs, above all because people in Jol Mom have the opinion pigs should be fed purely with maize ("Maíz come el animal. El maíz ya subió de precio, deberíamos sembrar eso." (47); "Antes, compramos puercos y les engordábamos. Ahora es caro engordarlo con maíz." (23); "No nos alcanzó mucho [el maíz] porque tenemos muchos puercos y pollos que quieren comer también" (45) (Annex Table 22)), which is why some household prefer to sell the pig at some stage instead of keeping it. Pigs therefore do not only function as food for feasts or special days, they can also be a backup which brings in money in case money is urgently needed.

The *milpa*

In the *milpa* plots, both crop rotation and polyculture are common practices, which is why a farmer might be cultivating chile and calabaza in one year but in the next year the plot might contain beans and maize. Some farmers tend to cultivate a mixture of many crops in one plot while others might specialize in a few crops. The decision on which crops enter the field is taken carefully every year, considering a variety of factors. The physical conditions of the plot play an important role in this decision, among them inclination, rockiness, soil quality and sun exposure, but also a personal or intuitive preference for certain crops for which the farmer has a 'good hand', knows well or sells well. Other factors include market demand and the available workforce and money to maintain the field, among others. All factors vary strongly every year. The decision to cultivate a *milpa* field at all is a subject of variability, and the level of agricultural activity therefore far from determined.

The *milpa* is the central farming system and agricultural activity is closely related to *milpa* production. Cultivating, "sembrar", is often taken as an equivalent to "hacer *milpa*", and people who do not have any *milpa* plots do often not consider themselves as active in agriculture, even though they might have a considerably large *solar* from which they retrieve nopal, chayote and other crops. The reasons for *milpa* cultivation can be grouped into several groups according to responses. Over half of the respondents (n = 23) claimed that *milpa* cultivation was done to provide something to eat, or not to have to buy: "Para tener alimentos, para no comprarles" (16); "Para que haiga, sino no hay nada" (13); "Cuando haiga no vas a comprar" (17); "Si no hacemos *milpa*, hay que comprar el maíz" (24); "Porque se necesita, para el hambre" (13); "Cuando uno no tiene dinero, de ahí agarra para comer. Es la manera de sobrevivir" (25); "Para comer" (30); "Para sostener la familia, para no comprar maíz" (28) "Para no comprar el maiz, frijol, y muchas cosas" (38) (Annex Table 22). The marketing of produced products is another important reason named by several respondents (n = 7). "Para vender" (10); "Porque me gusta, y porque sale dinero" (14); "Por no sufrir el hambre, así podemos salir a vender y comprar algo para los hijos" (47) (Annex Table 22). Respondents also claimed that cultivating is a tradition and that people are used to cultivating and therefore do it (n = 6). "Todos siembran y creemos que da, uno también siembra y cuando da ya no tenemos que comprar" (2), says one farmer, while another explains: "Cuando no siembras y escuchas la gente que ya cosecha te sientes mal, ya es costumbre de sembrar y cosechar" (44). Some say they like it "Porque nos gusta, y por tradición, porque queremos cosechar algo, como elote y maíz" (Annex Table 22). Elote, the corn cob, which is consumed vegetable-like in boiled form, is a popular food and a commonly named reason for cultivation when people refer to their *milpa* fields. "Para no comprar, y para que haiga elote, nos gusta. Para comer porque a veces no tenemos dinero" (45); "Para que no compran maíz o elote. Para después hacer tortillas de maíz nuevo" (23) (Annex Table 22). The flavour of home-produced crops is therefore also a reason. Finally, cultivating as a preference or choice of occupation faced with the alternative to have to look for work outside of the community is named: "Para comer, y ya no quiere salir afuera para trabajar" (5); "Para sembrar algo para comer. Estamos acostumbrados de trabajar aquí, no quiero salir." (22) "Porque me gusta, y porque sale dinero" (14) "A mi esposo le gusta sembrar maíz" (29) (Annex Table 22). The answers show that the "cultural script" of which authors speaks when referring to *milpa* cultivation (Schmook *et al.*, 2013) is also present in Jol Mom, that *milpa* is not only the production of crops but an institution life orientates after, in terms of time (preparation, seeding and harvesting dates) and food, as the harvesting period when fresh maize and beans are available is recalled as a happy time.

Nevertheless, a part of the population does not cultivate *milpa* or does not do it anymore. Limitations are time and workforce: "Ya no vive el esposo, ya no puedo por falta de tiempo y dinero" and above all money: "Se necesita dinero por qué se necesita terreno y gente para limpiar" (17). The workforce, called 'peón' is mainly needed in times of preparation of the plot and during harvest, and has a cost of approximately 100 to 150 MXN per tarea, which is a local measure of space and labour requirement, and takes around one day to be worked off. "Para hacer una cosa se necesita dinero. Para sembrar maíz se necesita dinero. Cobran 150 pesos con comida, sale a 200 pesos por día de contratar un peón" (38) explains a farmer. Another says "Este año si quiero hacer *milpa*. Pero ya casi no quiero hacer *milpa*, es difícil porque se necesita dinero. Y ya no se puede cazar. Ni pájaros ni ardillas ni víboras." (43) (Annex Table 22). In the latter statement, the farmer refers to the restrictions which have been implemented to prohibit the hunting of wild animals, which is a frequently named issue for the farmers, as they have considerable impact on the harvest, up to leaving "the pure empty corncob" as stated in the first quote below: (Annex Table 23, Table 25):

> "Antes había mucho cazador. Se le espanta. Ahora la *milpa* ni siquiera da para una semana, junta puro jilote. Porque vienen los animales, y porque no puedo limpiar." (43)
>
> "El maíz ya casi no se siembra porque a casi no dejan los animales. Antes trabajaba toda la gente. Ahora ya muy pocos. Antes, había muchos campos y menos animales. Antes no estaba prohibido matar a los animales." (24)
>
> "El año pasado sembramos 35 tareas de maíz, pero no cosechamos nada, el jabalí y el tejón casi no dejan. Sólo dejan el chile." (22)

The financial investment and the losses caused by wild animals were the reasons most often named as to why people had stopped cultivating maize, while often they still cultivated other crops such as chile and calabaza, and sometimes beans, in their *milpa* plots.

The *finca*

The *te'lom* or agroforestry system is called *finca* in Jol Mom, which is probably because coffee has been an important crop in Jol Mom and was previously the most important cash crop in the community according to informants. Livelihoods were based on coffee production until several frost incidents forced people to reorient and look for alternative income generation sources ("El café de abajo viene con fertilizante. Antes hubo más café, antes de las heladas en 83 y 86. Antes, los troncos estaban gruesos, ahora ya no. En Limoncillo estaba la gente con la báscula. Vendíamos el café barato, o lo cambiamos por maíz, frijol y piloncillo." (23); "Antes, no sembrábamos chile, antes éramos cafetaleros, antes estaba todo blanco de flores. Ahora estamos un poco tristes porque no hay café." (24); "Ahora ya llevamos cuatro años que no da el café." (24) (Annex Table 23)). A farmer explains the situation like this:

> "Antes, éramos cafetaleros en Jol Mom. Ahora uso variedades mejoradas, era un regalo del gobierno, para toda la comunidad. Pero antes se usaban las criollas. Antes ganábamos dinero con la venta de café, pero en la helada se perdió todo y después ya la gente se desanimó y ya no daba mucho. Son matas que casi no tienen frutos, están secos. El mejorado crece bien, el mío tiene cinco años. Ahora pronto tengo que tumbar los árboles para que quede libre de sombra." (4)

The issue of the difficulties of producing coffee and the debate on whether to use the improved varieties and the chemical fertilizer which come in a package with subsidies programs, or if the local "*criollo*" variety (generally, the traditional or local varieties are called *criollo* as a differentiation from the commercial or improved varieties which are introduced from outside the region) should be maintained, are common topics of discussion. Along with the search for solutions for the coffee-situation by experimenting with improved varieties and different amounts of inputs (which is, according to informants, the only occasion in which chemical fertilizer is used in Jol Mom) goes the question of how much shade is good for the coffee. While many *fincas* still resemble forests because of their high canopy coverage, some farmers have been trying their luck by cutting down almost all trees in some plots. Both strategies might lead to crop loss, as the introduced varieties do not tolerate as much shade as the traditional *criollo* variety, which is generally cultivated under a dense canopy, but have also been observed to burn under high exposure to sun. Lack of orientation by the programs which introduce the varieties is a commonly named issue.

Despite the difficulties, many farmers keep maintaining their *finca* plots ("Café no da, no sabemos por qué. No han floreado en este año tampoco. Pero igual la gente está cultivando." (37) (Annex Table 23)). A common answer on why people maintain their *finca* is so as to cover or at least contribute to household supply of coffee, as coffee is consumed daily and by everyone (see section

6.1.3.5), and buying it is expensive ("Lo limpiamos para que no se te hecha a perder. Cuando sacas mucho café te alcanza para todo el año. Ya no tienes que comprar, y el kilo está a 50 a 55 pesos." (44); "También para no comprar café." (45); "Para tener café" (38) (Annex Table 22). People opt at being able to sell coffee for the same reason: "Para sacar dinero. El café está ahora a 50 pesos por kilo, es mejor que ir al contrato" (41) "Antes vendían café pero barato, ahora se vende caro, aunque no hay." (28); "Para que haiga café para vender una parte, y la otra parte para el gasto" (28) (Annex Table 22, Table 23).

Nevertheless, some respondents abandoned their *finca* plots, because of named problems ("Ve que no le sale dinero, entonces lo dejó así" (32)) and because the weeding requires time investment ("Casi no da, necesita que lo limpiemos, pero no nos da tiempo" (47); "Sólo voy al café cuando este mi esposo, el limpia. Pero él está en contrato." (44) (Annex Table 22).

While in general people respond overwhelmingly affirmatively when asked if they like cultivating (29 respondents name to like cultivating), four respondents claimed to like cultivating but also expressed the desire to work or learn something else and eight respondents expressed the desire or the preference of working in other fields. Reasons for preferring cultivating were, among others, that the alternative would be to go to the city, which was expressed as undesirable in this case. Reasons for preferring other work instead of cultivating were mainly that there is a regular payment, and more money can be earned.

Having said that, it is regarded as a tendency that young people are not cultivating any more, mainly because they are interested in a different lifestyle, not because of other limitations: "Los jóvenes tienen terreno, pero no les interesa trabajarlo" (28). "Los jóvenes ya puro estudio y los viejos ya no pueden hacer mucho trabajo. Cuando uno se enferma es cuando uno sufre. Los muchachos ya no quieren ensuciarse." (24) (Annex Table 23). Another farmer says the following about the adolescents of the community (Annex Table 23):

> "Ahora la gente tiene otro modo para mantenerse. Los abuelos hacían *milpa*. Sembraban y con eso se mantenían. Por flojera ya no se hace como antes. Antes no había carretera, llegó en 1976. Ahí empezó a salir la gente." (24)

A young farmer explains his own situation:

> "Estuve afuera por 7 años, después regresé. Los jóvenes salen a aventurarse. Algunos si quieren regresar, algunos no. La vida con la familia en la ciudad es más complicada. Aquí uno se ahorra en gas, renta, agua. Eso no se paga aquí." (25)

It is a common phenomenon according to informants that young people migrate to the cities as they want to have the feeling of earning money ("Aquí hay trabajo, pero no hay dinero" (29) (Annex Table 23)). Even though the young people leave in order to earn money, they principally are employed in factories in Monterrey City, Northwest Mexico. Informants do not remember any person who had obtained a higher position or studies from the Jol Mom community. Therefore, some people come back after a while, considering that the life in Jol Mom is low in costs:

> "Aquí no se paga agua. Aquí se paga la luz nada más. En la ciudad se paga la renta, el agua, la luz, el camión. Aquí está en la casa. Si quiere trabajar, trabaja. Si no, no. A veces ni hay que comprar agua. Yo también fui a Monterrey a trabajar, pero dije porque estoy aquí, mejor voy a mi tierra." (46)

6.1.2 Characteristics of participating households

6.1.2.1 Household composition and socioeconomic information

A total of 40 individuals were interviewed, of which 24 (60 %) were female and 16 (40 %) were male (Figure 7). Most heads of households (n = 19) are between 30 and 40 years old, followed by households with family heads between 20 and 30, and between 40 and 50. Only two family heads were under 20 and three between 70 and 80 (Figure 8). The minimum age of any household head interviewed was 16 and female, while the oldest was 79 and male (Table 9). In average, male and female household heads are 46.7 and 42.4 years old respectively (Table 9).

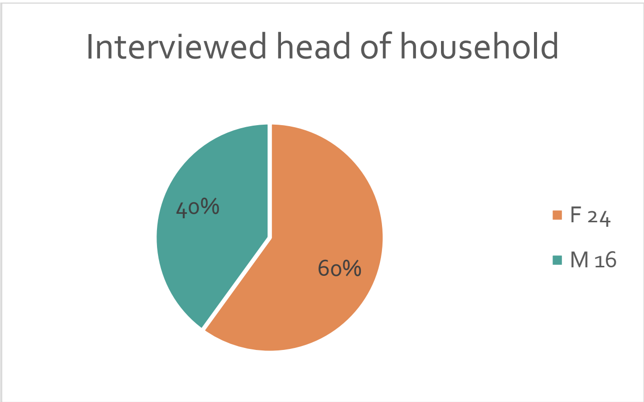


Figure 7: Gender of interviewed household heads (F = female, M = male).

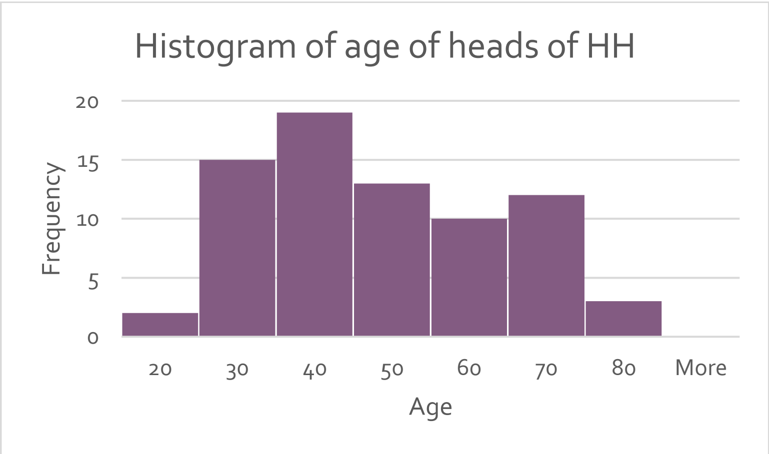


Figure 8: Histogram of the age of the male and female heads of households of the sample population.

Land is reported to be mostly owned property (n = 30, 75 %), nine (22 %) respondents named that it was borrowed or rented (Table 8).

In Jol Mom is part of the ejido of Tampaxal, a form of land administration in Mexico which has its origin in the Mexican Revolution of 1917, in which residents are described by the membership status they have. Most interviewed households (n = 22, 55 %) are *posesesionarios*, meaning that they are working on land which was purchased or inherited (Barnes, 2009) and either formalized or in print of formalization (Table 8). The *ejidatarios* (n = 10, 25 %), the official ejido members which is the only population group that has a voting right in the ejido assembly (Barnes, 2009) – in this case in the ejido of Tampaxal – own their land and are the group which reported highest numbers for land size. It is important to mention that according to statements of informants in the ejido of Tampaxal until the present date ejido status cannot be transmitted and is therefore exclusive to the initial ejido members which were present when the ejido land was first formally registered. Therefore, only elderly community members have this status. Nevertheless, descendants of *ejidatarios* usually inherit or use land from their parents, which explains why properties are smaller because of fragmentation caused by distribution of land among several children, or because land ownership is not formalized and therefore only the actively cultivated part of the land is reported. *Avecindados* are community residents without formal land ownership; only two respondents reported belonging to this group, whereas six of the interviewed did not know their own or their partner's ejido status.

Land size ranges from zero to 15 ha, with an average land size of 2.9 ha (Table 9). Half of the sample population cultivate on two or less ha (Figure 9). Among the *ejidatarios*, half of them possesses four to eight ha, one even more than eight and the rest less than four. The majority of *possessionarios* have up to four ha available for cultivation, but eight of them own or rent between four and eight ha.

Table 8: Ejido status, land ownership and size of land reported by sample population.

Status	Ejidatario			E Total	Posesio-nario		P Total	Avecin-dado	A Total	Unknown	U Total	Grand Total
Land size [ha]	***0-4***	***4-8***	***>8***		***0-4***	***4-8***		***0-4***		***0-4***		
Property	4	5	1	10	12	7	19			1	1	**30**
Rented					2	1	3	1	1	5	5	**9**
Unknown								1	1			**1**
Grand Total	**4**	**5**	**1**	**10**	**14**	**8**	**22**	**2**	**2**	**6**	**6**	**40**

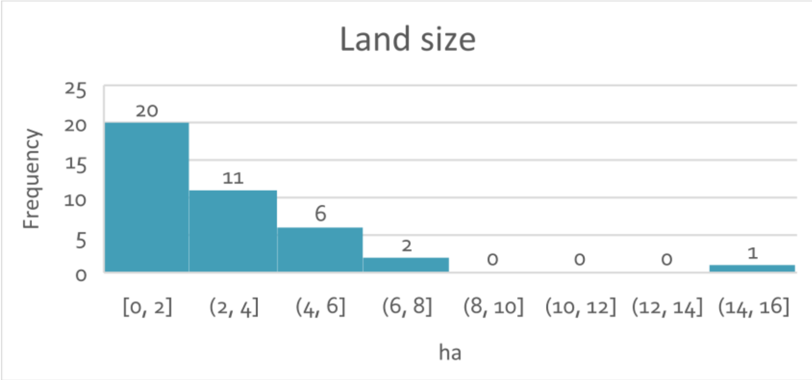


Figure 9: Histogram of land size distribution among the sample population.

Speaking about households characteristics of the sample population, the majority, meaning 35 of female and 32 of male household heads, are from Jol Mom (n = 40 for women, n = 34 for men, as six households are single women), and only five and two households respectively consist of members from outside of Jol Mom. All male household heads speak Teenek, and 85 % speaks Spanish, while among the female household heads 95 % speak Teenek fluently, and two individuals only a little because they are originated from non-Teenek communities (Figure 10 A). 55 % of the women speak Spanish well but 20 % do not speak any Spanish (Figure 10 B). Most survey participants have no educational level above primary school (52 % and 65 % of male and female family heads respectively). Of the women, 43 % attended secondary school, often due to an adult program which allows obtaining the degree at an older age (Figure 10 C). The older population has the lowest educational level, while nowadays at least in theory all children ought to complete secondary school.

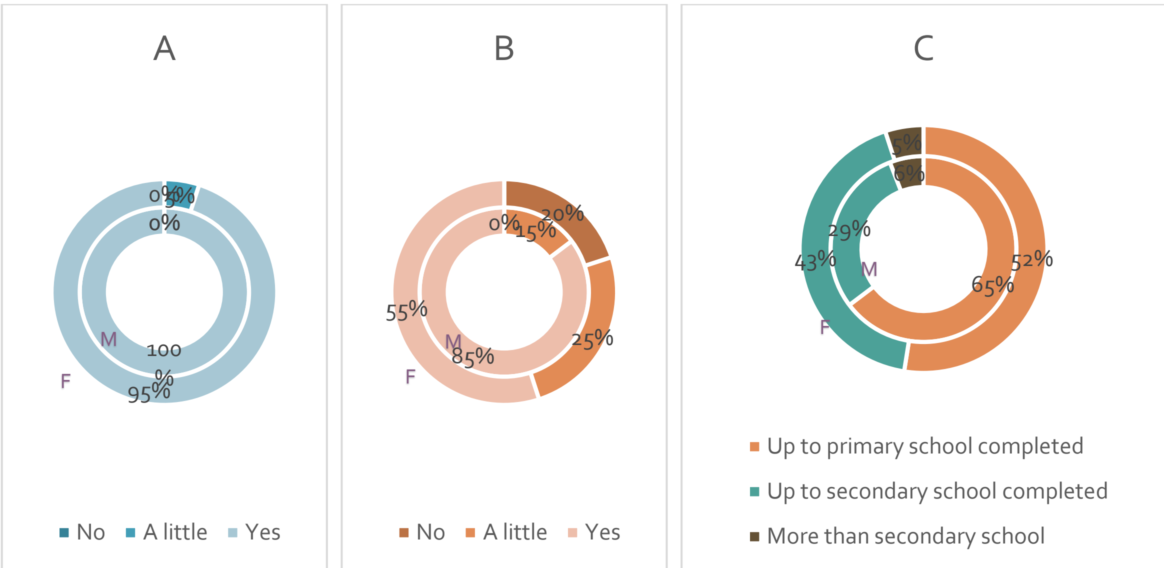


Figure 10: (A) Teenek speaking population among household heads; (B) Spanish speaking population among household heads; (C) Educational level of sample population.

The average household size is 3.9 members, with 2.3 adults and 1.7 children (under 18 years old) (Table 9). As temporal out-migration is common in the community, the number of non-permanent household members was assessed (in average 0.4, Table 9). Most commonly, these persons work 'en contrato' in seasonal harvest, either in orange or other fruit and vegetable plantations in the region or other states such as Chihuahua or Veracruz, or – very commonly – in the sugarcane fields, usually in the form of a three month contract during which time the contracted person does not come home. This does however not include permanently migrated offspring which might have been formerly part of the household.

Table 9: Household (HH) characteristics of sample population with the average (mean), standard derivation (SD), range of variable and minimum and maximum value of variable in brackets.

Variable	Mean	SD	Range (Min-Max)
Age male head of HH	46.7	15.9	58 (21-79)
Age female head of HH	42.4	15.2	59 (16-75)
Number of adult (>18) HH members	2.3	0.8	3 (1-4)
Number of children (<18) in HH	1.7	1.3	5 (0-5)
Total number of permanent HH members	3.9	1.4	5 (2-7)
Number of non-permanent HH members (out of named members)	0.4	0.8	4 (0-4)
Size of land in hectare	2.9	3.0	15 (0-15)

6.1.2.2 Level of agricultural activity

In the survey, eight households (20 % of sample) participated which manage only one production system from the three traditional Teenek farming systems *solar*, *milpa* and *finca*, whereas nine households, representing 22 % of the sample, manage two systems out of the three. The majority (n = 23; 58 %) of the interviewed households manages all three farming systems (Figure 11).

One to four household members might participate in agricultural activity, but on average 1.7 members, mostly the heads of the household, are dedicated to cultivating (Table 10, Figure 11). Even though roles are divided in principle, with the husband doing the heavier work such as preparation of the *milpa* field by slashing and burning, and women preferring to go to *fincas* which are located far away only with their husbands, women were observed to be highly active in agriculture. They are the primarily responsible people for the *solar* maintenance, providing diverse and nutritious products for household consumption, but – depending on household structure and occupation – do also participate in cultivating and harvesting in the further-afield *milpa* plots. In the cases of single women, they are far from abandoning their agricultural activity after separation or loss of the husband. Instead, they were observed to be managing up to three production systems almost by themselves, and up to a high age, or in combination with caring for a whole family. On the contrary, the fact that no single man was among the respondents indicates that men prefer to look for a partner than to stay alone. This impression was confirmed by male and female individuals explaining that a man could not survive alone, because he does not know how to cook, while a woman knows how to cook, care for the family, and cultivate.

Table 10: Average (mean), standard deviation (SD), range with minimum and maximum value of variable giving information about the level of agricultural activity and food security of interviewed households. Jol Mom, Aquismón, SLP Mexico.

Variable	Mean	SD	Range (Min-Max)
Number of persons cultivating	1.7	0.8	3 (1-4)
Number of agricultural systems	2.4	0.8	2 (1-3)
Production Diversity (PD)*	33.8	9.5	36 (18-54)
Weekly expenses in foods (MXN)	528.8	267.9	1200 (100-1300)
Food Variety Score (FVS)**	64.6	7.8	38 (42-80)

**PD is the count of cultivated items during the past year out of 56 crops.*

***FVS is the count of consumed items during the past year out of 81 foods.*

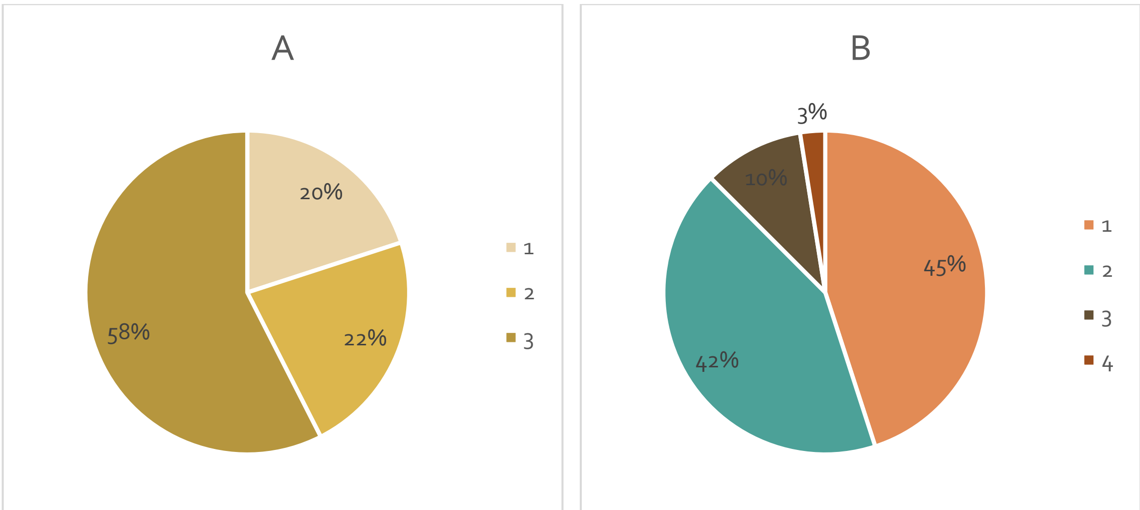


Figure 11: Households' agricultural activity in Jol Mom, Aquismón, SLP Mexico. (A) Number of production systems managed by one household. (B) Number of persons in each household/family dedicated to cultivating

As explained before, farmers in Jol Mom actively participate in the sale of their products. In total, 37.5 % of the farmers reported that they sell more than half of their products but at the same time an even greater number (40 %) reported that they are selling less than half (Table 11). The estimation might indicate on the one hand if the farmer is producing large quantities, and therefore will have a large amount of products available for the market, and on the other hand it might indicate if the farmer prefers to keep the products for the household supply as part of a subsistence strategy instead of selling them. Still, around half of the farmers (n = 19) sell products all year round, while 37.5 % only sell seasonally. Most farmers (55 %) sell their products regularly to intermediaries which take products to the local markets, while 35 % prefer to bring their products themselves to the market and sell them first-hand. Markets where products are sold are reached by pick-ups by intermediaries but often with public transport (or by foot) by individual farmers and are located within an estimated travel time of up to two or three hours. People from Jol Mom go to a variety of markets, including the markets in Axla, Ciudad Valles, Santos, Tamazunchale, Tampaxal, Tancanhuitz, Tanquica, Tanquián, Xilitla, and a few sell their products in the very community of Jol Mom, by offering them while walking around the village.

When asked about the occupation of the household members who contribute to household expenses, most households (87.5 %) state that one or several are involved in the cultivation of products for sale, and 55 % say that household members are (also) working in the local workforce in production systems (as peones). "En contrato", meaning migrating temporally for working in the harvest of sugarcane or other plantations, is exercised by one or several members of 25 % of the households (Figure 12). Also, 32.5 % report to have other occupations, for example having a commercial practice in Jol Mom, such as running a local shop or a little bakery, washing laundry, working as a carpenter, or running a taco stand in local markets. For the question of whether households receive remittances from emigrated family members no exact data could be obtained, but 22.5 % of the households reported to receive money sometimes or regularly. As their major income source, 45 % named the cultivation and sale of products. Working as peón, temporal migration and living from remittances were each respectively named by 10 % of respondents, 15 % have other major income sources (Figure 12).

Similar to the question of whether the household received remittances, the reception of subsidies was perceived as delicate by the investigator, and furthermore, research was conducted in a time in which a federal governmental change led to the suspension of the most common social aid program called "Prospera". According to respondents, 80 % of them had been receiving Prospera before it had been stopped but were not sure if they would qualify for the subsequent program after the transitional period. 15% of the participants are receiving benefit from the program "65 y más" for the elderly generation, while the annual payment from the *milpa* subsidy program PROCAMPO is received by 27.5 % (Figure 13).

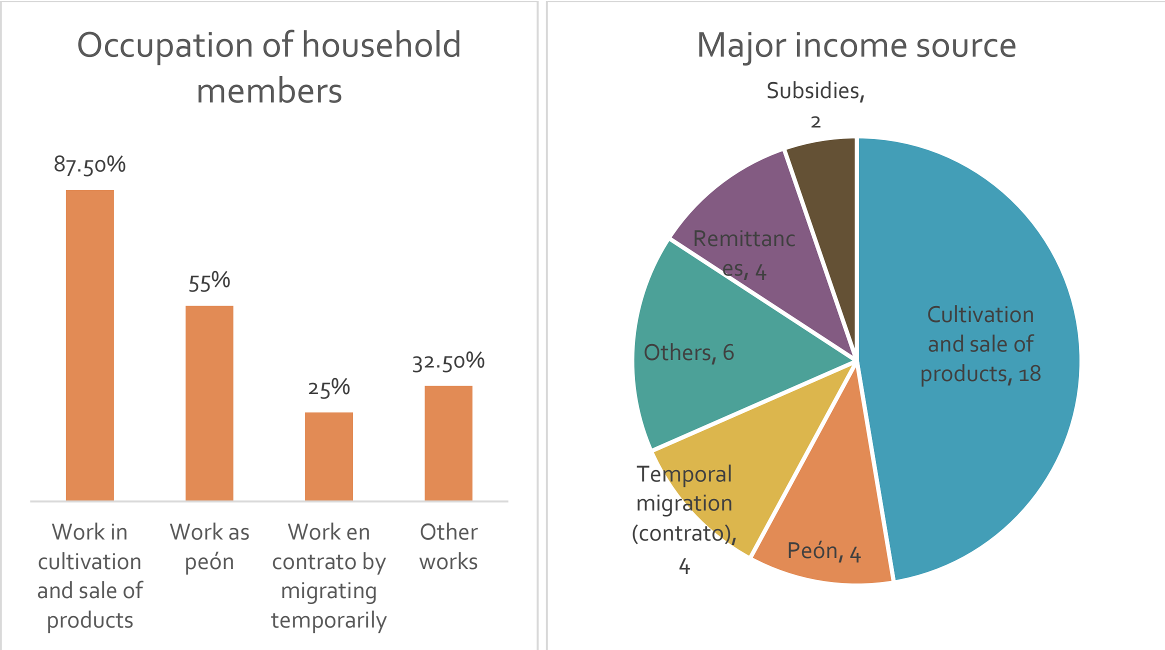


Figure 12: Occupation of household members (multiple responses were allowed, which is why percentages do not sum up to 100), and major income source of the households in Jol Mom, Aquismón, SLP Mexico.

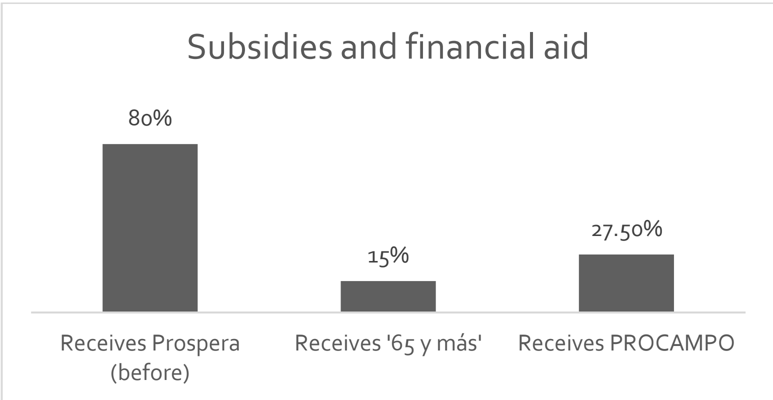


Figure 13: Subsidies and financial aid programmes which are received by the households in Jol Mom, Aquismón, SLP Mexico (multiple responses were allowed, which is why percentages do not sum up to 100).

6.1.3 Food Security

6.1.3.1 Purchase/consumption habits in Jol Mom

Most people need to purchase more than half of the food the household needs (52.5 %); only 12.5 % of the sample produces enough to supply more than half of the food needed (Table 11). Food expenses constitute a significant cost to household expenses, as results indicate that 37.5 % of the population spends more than half of their income on foods, while nine household spend half or less than half of the money on foodstuff (Table 11). Weekly household expenses vary greatly, with a range from 100 to 1300 Mexican Pesos (MXN) (the current currency is 1 € = 21.93 MXN). The weekly average household expenses are 528.8 MXN, with a standard deviation of 267.8 MXN (Table 10). The variance could firstly be due to unrealistic estimates by respondents, on the other hand food expenses are generally strongly linked to the number of household members, and additional factors such as the need to provide food for employed labourer (peón) might influence the discussed variables.

Most households cover their demand by purchasing both in the local shop and in the traditional market (47.5 %), but 35 % does generally not leave the community for purchasing goods and therefore covers their demand only by purchasing in local shops. This is, according to field observations, above all the case for single women who are sometimes managing household, family and farm, and have little to no opportunities to go shopping in markets. Also, elderly people do not leave the community often, nevertheless, relatives might help providing some additional variety from markets or harvested products. Some households generate from their point of view enough variety with their harvest and therefore do not have the need to visit the markets.

Table 11: Sale and purchasing habits of the households (n total = 40; with NA = no answer) expressed in relative frequency of occurrence [%] in Jol Mom, Aquismón, SLP Mexico.

	Less than half	Half	More than half	NA
Amount of products for sale out of total production	40.0	12.5	37.5	10
Amount of foods purchased out of total household needs	12.5	12.5	52.5	22.5
Income inverted in foods out of total income	22.5	22.5	37.5	17.5

Table 12 describes where respondents acquire each food from, the list is composed of the 56 items which were named to be grown in Jol Mom, as the other items are necessarily of purchased origin. For analysis, four categories were differenciated. If the respondent had reported to obtain the item via purchase, by harvesting it, by purchasing and harvesting it, or if was mainly given to him or her as a gift from other community members. The latter category was named as a main source in only very few occasions and is restricted to cultivated crops which are rather low in demand or for which surplus is available when in season, such as it the case for local fruits and vegetables.

The results show that in Jol Mom the most important staple foods maíz, frijol púkul, chile and café are the ones which stand out as being both purchased as harvested. They are commonly cultivated since they are traditional *milpa* crops and because of their important role in diets, but the demand of most households cannot be covered uniquely by home production.

For vegetables and fruits, origin varies strongly, for a better overview they are plotted in Figure 14 and Figure 15. In the case of vegetables and including the food group category 'Vitamin A rich vegetables and tubers', camote is the only frequently purchased crop, along with chile which is purchased or cultivated, and a 30 % of calabaza which is purchased or cultivated. All other vegetables in the list are of almost uniquely cultivated origin (Figure 14). In the case of the fruits the situation is slightly different, even though there are many fruits which are purely harvested it is visible that crops such as mango, papaya, naranja, limón, aguacate, lichi, anona, carambola, mamey, piña and tamarindo are at least partly also of purchased origin (Figure 15).

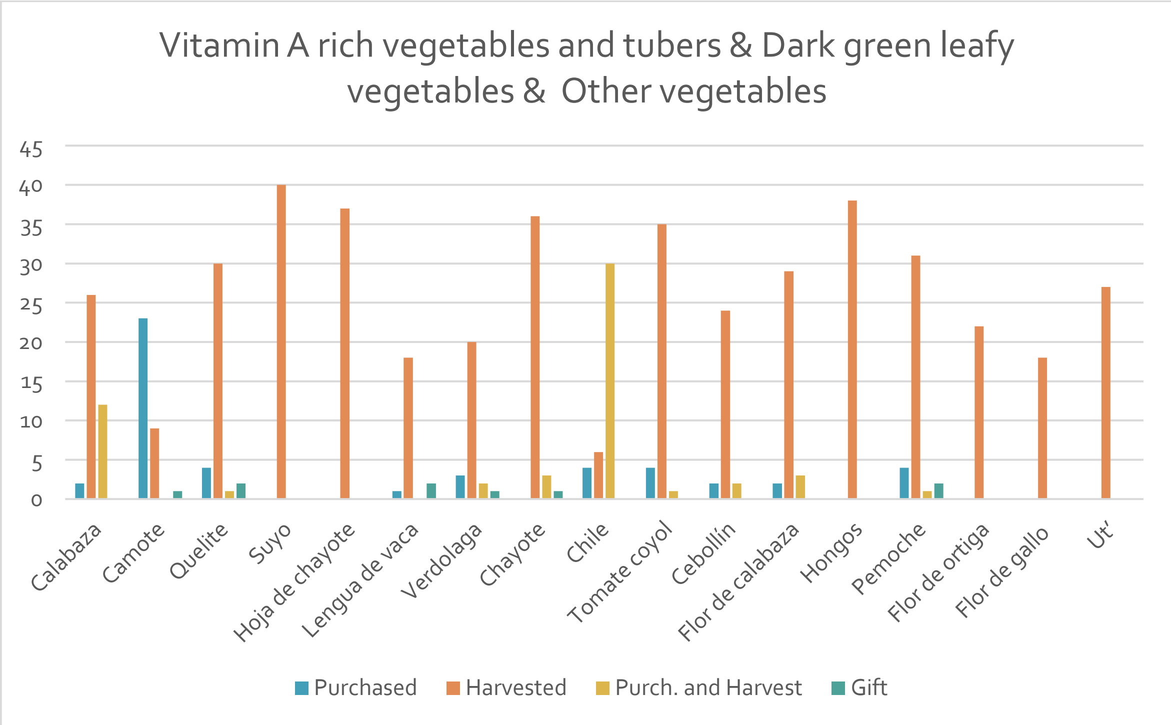


Figure 14: Source from where vegetables grown by the sample population are obtained (in percentage of sample households) in Jol Mom, Aquismón, SLP Mexico.

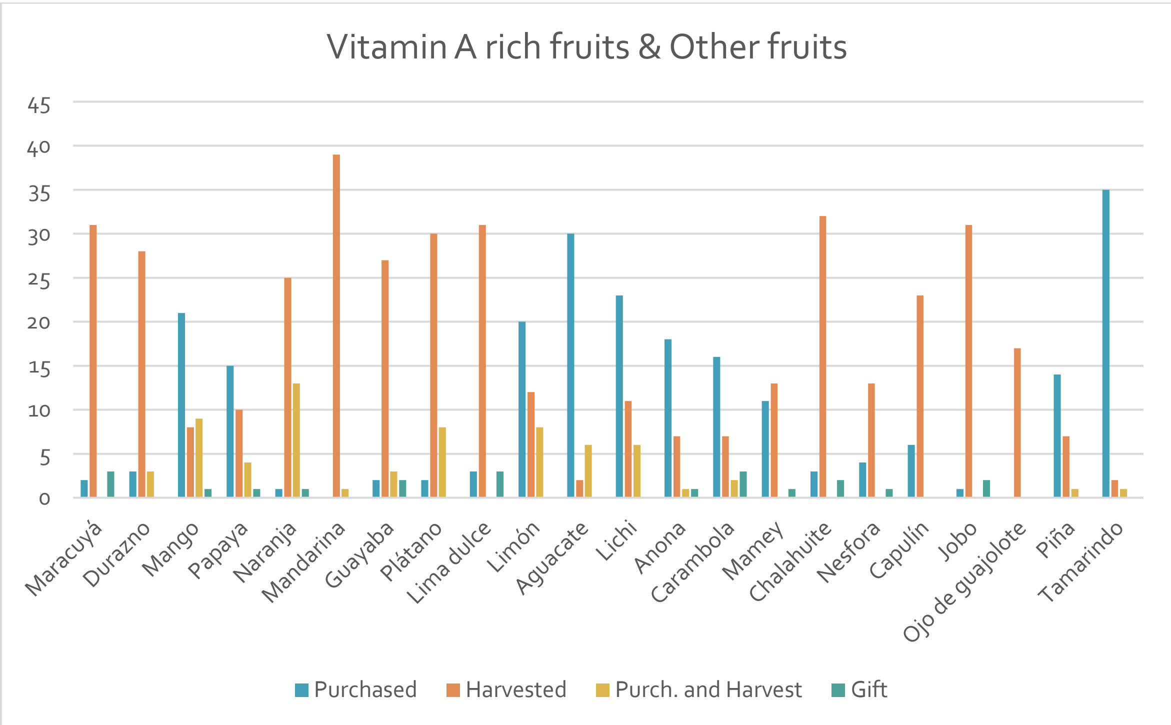


Figure 15: Source from where fruits grown by the sample population are obtained (in percentage of sample households) in Jol Mom, Aquismón, SLP Mexico.

Table 12: List of foods from the Food Frequency Questionnaire which are cultivated in Jol Mom, with frequencies describing how the product has been acquired by the sample population (n total = 40).

Food group	Item	Purchased		Harvested		Purch. and Harvest		Gift		Not consumed	
		[n]	[%]	*[n]*	[%]	*[n]*	[%]	*[n]*	[%]	*[n]*	[%]
Cereals	Maíz	15	37.5	0	0	25	62.5	0	0	0	0
White roots & tubers	Yuca	17	42.5	15	37.5	1	2.5	1	2.5	6	15
	Nopal	3	7.5	31	77.5	4	10	1	2.5	1	2.5
	Luum	2	5	12	30	0	0	0	0	26	65
Vitamin A rich veg. & tubers	Calabaza	2	5	26	65	12	30	0	0	0	0
	Camote	23	57.5	9	22.5	0	0	1	2.5	7	17.5
Dark green leafy veg.	Quelite	4	10	30	75	1	2.5	2	5	3	7.5
	Suyo	0	0	40	100	0	0	0	0	0	0
	Hoja de chayote	0	0	37	92.5	0	0	0	0	3	7.5
	Lengua de vaca	1	2.5	18	45	0	0	2	5	19	47.5
	Verdolaga	3	7.5	20	50	2	5	1	2.5	14	35
Other veg.	Chayote	0	0	36	90	3	7.5	1	2.5	0	0
	Chile	4	10	6	15	30	75	0	0	0	0
	Tomate coyol	4	10	35	87.5	1	2.5	0	0	0	0
	Cebollín	2	5	24	60	2	5	0	0	12	30
	Flor de calabaza	2	5	29	72.5	3	7.5	0	0	6	15
	Hongos	0	0	38	95	0	0	0	0	2	5
	Pemoche	4	10	31	77.5	1	2.5	2	5	2	5
	Flor de ortiga	0	0	22	55	0	0	0	0	18	45
	Flor de gallo	0	0	18	45	0	0	0	0	22	55
	Ut'	0	0	27	67.5	0	0	0	0	13	32.5
Vitamin A rich fruits	Maracuyá	2	5	31	77.5	0	0	3	7.5	4	10
	Durazno	3	7.5	28	70	3	7.5	0	0	6	15
	Mango	21	52.5	8	20	9	22.5	1	2.5	1	2.5
	Papaya	15	37.5	10	25	4	10	1	2.5	10	25
Other fruits	Naranja	1	2.5	25	62.5	13	32.5	1	2.5	0	0
	Mandarina	0	0	39	97.5	1	2.5	0	0	0	0
	Guayaba	2	5	27	67.5	3	7.5	2	5	6	15
	Plátano	2	5	30	75	8	20	0	0	0	0
	Lima dulce	3	7.5	31	77.5	0	0	3	7.5	3	7.5
	Limón	20	50	12	30	8	20	0	0	0	0
	Aguacate	30	75	2	5	6	15	0	0	2	5
	Lichi	23	57.5	11	27.5	6	15	0	0	0	0
	Anona	18	45	7	17.5	1	2.5	1	2.5	13	32.5
	Carambola	16	40	7	17.5	2	5	3	7.5	12	30
	Mamey	11	27.5	13	32.5	0	0	1	2.5	15	37.5
	Chalahuite	3	7.5	32	80	0	0	2	5	3	7.5
	Nesfora	4	10	13	32.5	0	0	1	2.5	22	55
	Capulín	6	15	23	57.5	0	0	0	0	11	27.5
	Jobo	1	2.5	31	77.5	0	0	2	5	6	15

	Ojo de guajolote	0	0	17	42.5	0	0	0	0	23	57.5
	Piña	14	35	7	17.5	1	2.5	0	0	18	45
	Tamarindo	35	87.5	2	5	1	2.5	0	0	2	5
Legumes	Frijol coloní	19	47.5	4	10	3	7.5	0	0	14	35
	Frijol mal te	12	30	10	25	6	15	0	0	12	30
	Frijol pukul	18	45	0	0	22	55	0	0	0	0
	Frijol wet	8	20	10	25	3	7.5	0	0	19	47.5
	Frijol sarabanda	12	30	16	40	5	12.5	0	0	7	17.5
	Lenteja de árbol	2	5	18	45	0	0	2	5	18	45
Nuts and seeds	Ajonjolí	29	72.5	3	7.5	3	7.5	0	0	5	12.5
	Semillas de calabaza	8	20	22	55	0	0	0	0	10	25
	Cacahuate	31	77.5	5	12.5	0	0	0	0	4	10
Spices, cond., beverages	Café	20	50	5	12.5	15	37.5	0	0	0	0
	Cilantro	1	2.5	35	87.5	3	7.5	0	0	1	2.5
	Hierba buena	1	2.5	36	90	0	0	2	5	1	2.5
	Epazote	1	2.5	27	67.5	1	2.5	1	2.5	10	25

6.1.3.2 Availability of foods

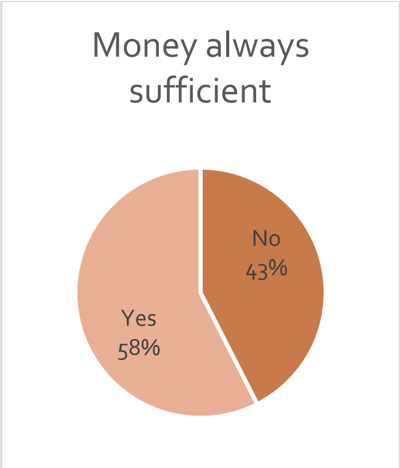
On the question "During the last year, did you always find the variety of foods that you need and which your family likes in the local shop or market?" all respondents replied affirmative, various however added that this was the case for the nearby market but not always for the local shops. People claimed for example that there was no butcher in Jol Mom ("pero no hay carnicería en Jol Mom, sólo pollo congelado" (25)), therefore no beef or pork meat available (with the rare exception of when a pig was slaughtered).

In the interview with a local shop owner (local shop owner personal interview, April 21, 2019) he explains that people generally visit the local market in the neighbouring village Tampaxal on the market days Wednesday and Friday. People who do not leave the community buy tomato, onion and chili in the local shops. In the community seasonal fruits are available, according to the shop owner. In terms of staple foods, he sells "basic stuff" such as onion, chili, tomato, maize, beans and rice, and this offer is similar in other shops. He does not sell fruits because they are not well sold ("no les compran").

6.1.3.3 Access to foods

To the question of if there had always been enough money during the past year to obtain sufficient foods for the whole family, 57.5 % responded affirmatively, while 42.5 % reported that there have been difficulties (Figure 16). A couple of strategies could be identified from the responses to the question of what had been the household's strategy to deal with this situation. "Pedir fiado", to purchase on credit in the local shop is a common practice, 40 % of the households do it in times when money is short. Others (50 %) reported making an additional effort by working more, either by working in the field or by looking for employment possibilities. Only 7.5 % reported to somehow restrict their diet, such as eating only the most basic foods with little variety ("comer puro tortillas con chile" (8)) or by eating less in general (Figure 16).

The qualitative data shows furthermore that households prepare for lean months. A farmer says: "Vendo quelites y chiles. Tengo chile en vinagre que puedo vender durante todo el año." (4) and another explains that the secret lies in selling the products little by little, not everything at one "Vender cilantro y café, siempre poquito, no todo de una vez" (5).



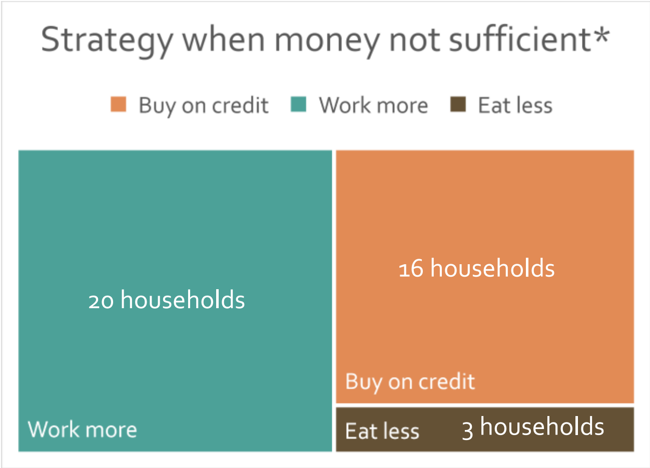


Figure 16: Charts indicating incidence and strategies of restricted economic capital limiting food access in Jol Mom, Aquismón, SLP Mexico.

**multiple responses were allowed; question was not answered by all households*

In general, the perception of the people is that the situation of food security has improved in Jol Mom in comparison to before. This is because more foods are available (*e.g.* meats and vegetable oil are commonly named), and because people earn more money which allows them to buy other foods: "Ahora ya hay todo. Carnes etc., cuando tienen dinero pueden comprar. Antes, compramos puercos y les engordábamos. Ahora es caro engordarlo con maíz." (23); "Toda la gente ha mejorado, salen a vender y compran. Ya hay más dinero, puede buscar más que comer." (28); "Cuando estaba chiquilla sufría mucha hambre. Casi no me daban de comer, fui huérfana. Puro plátano, chayote y cositas, no había tortilla. Ya no sufro hambre. Ahora está mejor la gente. Este año si va a dar." (37) (Annex Table 23). Still, market prices represent a challenge for the smallholders, as mentioned for the maize price which is no longer affordable as a feed for animals. Another farmer complains "Subió el precio del maíz, frijol y del aceite (26)". At the same time, for those selling products, higher prices in the local market represent an opportunity to improve their food security status: "Casi no hay hambre si tienes que vender." (24); "Antes el chayote se vendía barato. Hay gente que piensa que estamos peor, pero son los que no trabajan. Los que siembran pueden sacarlo. Hay gente que se siente más pobre, y otros mejor." (28). Others use subsistence production to avoid the elevated costs of foods: "Casi nos alimentamos de lo que producimos [hablando sobre verduras]. Ya subió el precio de maíz, frijol, azúcar, aceite, café" (23). "Lo que sembramos es para el gasto, para no comprarlo. Sembramos poquito." (28); "Aquí no hay necesidad de comprar nada, y además es otro sabor [los productos de la *milpa*]." (39). These statements show that even though people face challenges to meet their household's needs, they consider their agricultural activity as a decent pathway to meet or improve their food security status.

6.1.3.4 The role of seasonality for food provision

To the question "Were there months, in the past 12 months, in which you did not have enough food to meet your family's needs?", most respondents said no (80 %), that generally they did not lack food, while 10 % said yes, for example "porque no se alcanza a comprar todo. Lo básico sí, pero falta carne, queso, pescado" (38). The answer shows however that it is a matter of interpretation of what 'lack of food' means. While respondent 38 explains the situation, in a context where people are used to living with little resources others might not perceive a lack when there is only money left for the basic foodstuff. Reasons for the lack were either that there is nothing to sell, or that there is nothing to harvest ("Cuando llueve mucho casi no da" (30); "Con la sequía se marchita todo, el chile también." (45)).Another problem was reported, namely that one can't work when it's raining ("No hay nada que vender y llueve, no se puede trabajar" (4); "Cuando llueve mucho no hay que vender" (15)), and a fourth reason was that there was a shortage of money because no work was available ("No hay dinero o no hay trabajo" (20); "No hay que vender, y no hay chamba. Aquí sólo hay que vender temporalmente, no siempre. El chile hay cuando llueva." (38)).

Even though not necessarily perceived as a period of food shortages, seasonality does influence food security dynamics in Jol Mom, as most respondents named one or several months when asked which are the most problematic seasons. Two trends emerged: The population which says most difficulties to provide foods are experienced in the rainy season (defined as the months May to September), which were 30 % of the sample, and the households which said that the other months, *e.g.* the hot and dry period of the year are hardest (32.5 %).

Data from three key informants' interviews was used to create a calendar on the seasonality of the crops mentioned in this study. Shortly before and during the rainy season is the period in which most fruits and vegetables are available, apart from citrus trees whose fruits ripen from October to December. Most beans as well as corn are harvested in the last third of the year, and several fruits, vegetables, and roots and tubers can be harvested throughout the year (Table 13).

Table 13: Seasonality of crops grown in Jol Mom, Aquismón, SLP Mexico.

Crop	Months of harvest period											
	1	2	3	4	5	6	7	8	9	10	11	12
Maíz								■	■	■	■	
Yuca	■	■	■	■	■	■	■	■	■	■	■	■
Nopal	■	■	■	■	■	■	■	■	■	■	■	■
Luum	■	■	■	■	■	■	■	■	■	■	■	■
Calabaza				■	■	■	■				■	
Camote	■	■	■	■	■	■	■	■	■	■	■	■
Quelite			■	■	■	■						
Suyo	■	■	■	■	■	■	■	■	■	■	■	■
Hoja de chayote	■	■	■	■	■	■	■	■	■	■	■	■
Lengua de vaca			■	■	■							
Verdolaga		■	■	■								
Chayote	■	■	■	■	■	■	■	■	■	■	■	■
Chile				■	■	■	■					
Tomate coyol			■	■								
Cebollín	■	■	■	■	■	■	■	■	■	■	■	■
Flor de calabaza				■	■	■	■					
Hongos					■	■	■	■				
Pemoche			■	■								
Flor de ortiga			■	■	■							
Flor de gallo		■				■			■			
Ut’	■	■	■	■	■	■	■	■	■	■	■	■
Maracuyá						■	■	■				
Durazno				■	■							
Mango					■	■						
Papaya	■	■	■	■	■	■	■	■	■	■	■	■
Naranja										■	■	■
Mandarina										■	■	■
Guayaba					■							
Plátano	■	■	■	■	■	■	■	■	■	■	■	■
Lima dulce											■	
Limón										■	■	■
Aguacate						■	■					
Lichi						■						
Anona				■	■							
Carambola				■	■							
Mamey				■	■							
Chalahuite						■	■					
Nesfora				■								
Capulín				■	■							
Jobo						■		■				
Ojo de guajolote				■	■							
Piña				■	■							
Tamarindo				■	■							

Frijol coloní										■	■	
Frijol mal te											■	■
Frijol pukul										■		
Frijol wet											■	■
Frijol sarabanda						■	■	■				
Lenteja de árbol						■						
Ajonjolí										■	■	
Cacahuate					■	■						
Café									■	■	■	
Cilantro	■	■	■									
Hierba buena	■	■	■	■	■	■	■	■	■	■	■	■
Epazote			■	■	■							

6.1.3.5 Diet

“Comemos un día el frijol mal'te, el otro pukul, otro día calabaza y un día chayote”(21) says a respondent about his household’s dietary habits, foods that would be naturally accompanied by maize tortillas prepared on the comal (Annex Figure 31), the smooth and flat iron or clay-made griddle used to cook and toast tortillas and other foods over the fireplace.

Diets in Jol Mom are based on tortillas, beans and/or vegetable stews prepared with calabaza or chayote, and chile for the flavouring. Another daily routine is the preparation of sweetened coffee, taken in the morning, evening and in between meals. Other frequently consumed foods include the use of tomato, onion and garlic for the preparation of stews and chili ‘salsas’, the use of local fruits for juices, and other local vegetables such as suyo, quelites and hojas de chayote as sides or in soups. Sometimes, the coffee in the early morning is accompanied by sweet bread, and the consumption of (scrambled) eggs or the use of chicken or processed meats can be observed. Children like to buy sweets or fried snacks in the local shop when possible, and according to their own statements prefer to eat eggs, chorizo and beans than vegetables. They do, however, also commonly consume local foods. Table 14 shows that almost all recommended food groups include foods which are consumed several times a week or in the season by a high percentage of the population, as specified in the following. Quotes cited in this section can be found in Annex Table 25 if not further specified. For the scientific names of crops cited please refer to Table 2.

In the cereals group, maize is a staple food which is an important part of the Mexican diet and consumed by everybody every day in the form of tortillas. Originally, for making tortillas maize is nixtamalized by soaking it in alkaline water, nowadays lime (‘cal’) is used for this. This practice is still common in Jol Mom, but people also use purchased cornflour (‘maseca’) to make the dough: “Cuando no nos da tiempo para hacer nixtamal, usamos maseca para hacer tortilla” (4); Usamos maseca para hacer tortilla" (15), although people report to prefer the taste of the homemade nixtamal, and a farmer says “El maíz es fuerte. La maseca no quita el hambre” (24) (Annex Table 25). Although there is a mobile seller of tortillas passing through every day, the purchase of already made tortillas is common only in very few households which were visited.

Other popular dishes with maize are 'tamales', for which corn dough is added with legumes or vegetables, wrapped in a palm or plantain leaves and boiled, 'bocoles', which are thick tortillas, often with baked-in legumes, or 'atole', a thick beverage made from boiled dough, often with juice from fruits. Plus, the tender corncob called elote is a popular food in the harvest season.

Bread (pan) is frequently consumed, but its consumption is connected to purchasing power for some respondents: "A veces no hay dinero"(24); "Cuando hay dinero" (38); "Cuando alcanza dinero" (42) (Annex Table 25).

Among the white roots and tubers, nopalito[1] is a food often produced because of its relative low cultivation effort and is also commonly consumed, 52.5 % of the sample eat it once a week and 25 % even more often. Potatoes (papa) from purchased origin is consumed with similar frequency but not everybody eats them.

Vitamin A rich vegetables and tubers are also present in Teenek production systems, with calabaza leading the way, which is consumed by everybody, most commonly once a week (42.5 %). The dark green leafy vegetables are covered by the consumption of suyo and quelite, which are weeds often growing spontaneously in *milpa* plots, but which are commonly tolerated because of their usefulness for food or animal feed. Quelites (the most commonly known local quelite is the red or white variety of *Amaranthus hybridus*) however are also seeded by some farmers in greater amounts, as it can be sold on the market:

> "Antes el quelite no lo compraban. ¿Tal vez porque había bastante? Ahora si lo compran, ahora se vende todo. Comemos poco y más vendemos y compramos otra cosa. Vendemos chayote, quelite, verdolaga, suyo. La gente que vive dónde no hay estas cosas lo compra. Para vitamina." (35)

The leaves of suyo (*Ipomoea dumosa*) are consumed in boiled form. Constituting an important element of the traditional diet, people still consume it, parts of the population which is occupied in other works which do not imply *milpa* cultivation say: "Cuando nos da tiempo de ir al monte" (15); "No si no salimos a buscar" (46). This shows that agricultural activity is closely related to the consumption of traditional foods in Jol Mom. A third item from the dark green leafy vegetables group commonly eaten are the young leaves of chayote. They are boiled or added to soups.

Chayote is a crop everybody cultivates in Jol Mom, and it is also eaten by everybody, most commonly once a week (50 %). Chile is a central element of the Mexican diet and equally in Jol Mom, 67.5 % consume it daily, although in small quantities. "Da sabor a la comida" (43) people say, and "Si no hay chile se siente que uno no está comiendo" (43). Other vegetables which are eaten by most people are tomate and in its season the small locally grown tomate coyol, as well as onion (cebolla) purchased in the shops. Furthermore, almost all collect mushrooms (hongos, species not

[1] The FAO classification which places the nopal cactus among the 'white roots and tubers' was respected, but what actually consumed are tender cladodes, locally called nopalitos or nopal lengüita

specified) in the rainy season to complement their meals, and another popular food is the striking red flower of the colorín tree (pemoche), which is added to tamales or prepared as a side in its season.

Mango and marcuyá are the vitamin A rich fruits which are commonly eaten, while in the food group “other fruits” there are a variety of fruits listed which are consumed by all in the season, as the trees are found in almost every backyard. Naranja, mandarina, plátano, limón and lichi are consumed by everybody, but also aguacate, chalahuite, jobo and manzana are consumed by most, although not always frequently.

In terms of legumes, one bean stands out in terms of popularity, the black bean or frijol pukul, which is consumed by everybody and by 57.5 % of the sample every day. Other beans might be majorly available in certain seasons (frijol sarabanda) or simply not that popular for consumption in this community.

Among the crop containing food groups, nuts and seeds are the worst represented food group in terms of consumption. Still, ajonjolí and cacahuate are eaten by large parts of the population and around 20 % of the sample eats them once a week.

Many households in Jol Mom have chickens in their backyards and produce eggs as well as poultry for consumption. Even though a few households reported to uniquely consume eggs or chicken from their own production, for most households the production is rather complementary and most of the household demand is covered by purchase. Eggs (huevos) and chicken meat (gallina, pollo) are consumed by all households in the sample. Eaten by 32.5 % of respondents once a week, chicken is the most frequently consumed meat. Embutidos, which include sausages and cold meat, are not consumed by all households, but the frequency of consumption is comparable to chicken for those who eat it, with 10 % of the sample consuming it several times a week. Red meats such as beef (res) and pork (cerdo) are not that common; a little bit less than half of the sample does not consume them at all (40 % and 45 % respectively).

Cheese (queso) and milk (leche) are consumed by almost everybody, but consumption frequency varies. Cheese is consumed regularly, 15 % eat it once or twice a month, everybody else more often. Milk is commonly used in small quantities with coffee, and for the children. Vegetable oil (aceite) is used by all households daily, much the same as sugar (azúcar), as coffee is sweetened with considerable amounts of sugar. The consumption of the other foods which enter into the ‘not recommended’ food groups ‘sweets’ and ‘savoury and fried snacks and processed foods’ varies; around a quarter of the population does not consume sodas (refrescos), fried snacks (frituras) and a popular instant soup (sopa intantánea ‘Maruchan’®, yet, the brand name is used for similar products as well), while a quarter of the population consumes them once a week, and the other half of the sample either less than that (around a third consumes them once or twice a month) or more (around ten or 15 % several times a week). Finally, coffee is consumed in sweetened form every day, and herbs from home production are commonly used, such as cilantro and hierba buena.

A few locally produced crops are interesting to name as they were consumed by 30 % or more of the sample (all foods consumed by less than 30 % had been excluded from the list) but many respondents made the spontaneous comment that "nobody eats them anymore" ("Eso ya nadie lo come [Luum]" (26)) or that it is not cultivated anymore ("Ya no hay. Casi no comemos, antes sí. [Luum]" (24)). An example is the root of *Xanthosoma sagittifolium*. Also, the upper part of the spontaneously growing vine commonly called Ut' (*Smilax aristolochiifolia*) is a plant which is relevant to the traditional, local diet but not consumed frequently, and another local dark green leafy vegetable is the lengua de vaca (*Rumex crispus*), used as a side. Also, the flower of *Canavalia villosa* (flor de gallo) is still consumed but was also mentioned to be unknown by some respondents, or the small black fruits of the so-called ojo de guajolote (*Jaltomata procumbens*).

It is worth mentioning that some banana varieties (plátano) can be consumed in their ripe form but are also commonly consumed as a starchy food when still green, constituting a welcomed and uncostly (banana trees are common elements of backyards and *finca*) variation or complement to the diet ("Plátano costillón cuando está tierno se hecha al frijol" (23)). Some legumes and maize can also be consumed either fresh or later in dried form. For various items, the consumption in its fresh state ("tierno") is desired because of its tastiness, such as for maíz, frijol sarabanda, frijol huet, frijol coloní and lenteja de árbol (see comments Table 25 in Annex), and can even be the reason for why a farmer decides to cultivate a certain crop, as mentioned for maize in section 6.1.1.2.

Table 14: Consumption frequency of the food items from the FFQ. Numbers are given in percentage out of the total sample (n = 40) in Jol Mom, Aquismón, SLP Mexico.

Food group	Item	Consumption frequency [%]					
		Never or almost never	Once or twice a month	Once a week	Several times a week	Every day	Seasonally
Cereals	Maíz	0	0	0	0	100	0
	Arroz blanco	2.5	12.5	40	42.5	2.5	0
	Pan	5	5	30	37.5	22.5	0
	Pasta	2.5	0	47.5	47.5	2.5	0
White roots and tubers	Yuca	15	50	17.5	0	0	17.5
	Nopal	2.5	20	52.5	25	0	0
	Luum	67.5	12.5	2.5	0	0	17.5
	Papa	12.5	17.5	52.5	17.5	0	0
Vitamin A rich veg. and tubers	Calabaza	0	20	42.5	30	2.5	5
	Camote	17.5	45	15	0	0	22.5
	Zanahoria	57.5	22.5	20	0	0	0
Dark green leafy vegetables	Quelite	7.5	35	27.5	12.5	0	17.5
	Suyo	2.5	32.5	32.5	30	2.5	0
	Hoja de chayote	12.5	42.5	30	12.5	2.5	0
	Lengua de vaca	55	17.5	15	5	0	7.5
	Verdolaga	32.5	20	12.5	7.5	0	27.5
Other vegetables	Chayote	0	17.5	50	30	2.5	0
	Chile	0	2.5	2.5	22.5	67.5	5
	Tomate coyol	2.5	0	0	0	0	97.5
	Cebollín	35	10	25	7.5	15	7.5
	Flor de calabaza	17.5	0	0	0	0	82.5
	Hongos	2.5	0	0	0	0	97.5
	Pemoche	7.5	0	0	2.5	0	90
	Flor de ortiga	45	2.5	0	0	0	52.5
	Flor de gallo	57.5	0	0	0	0	42.5
	Ut'	32.5	7.5	2.5	0	2.5	55
	Tomate	0	10	37.5	37.5	15	0
	Cebolla	5	0	7.5	15	70	2.5
Vitamin A rich fruits	Maracuyá	12.5	0	0	0	0	87.5
	Durazno	22.5	0	0	0	0	77.5
	Mango	0	22.5	10	0	0	67.5
	Papaya	40	22.5	10	0	0	27.5
Other fruits	Orange	0	0	0	0	0	100
	Mandarina	0	0	0	0	0	100
	Guayaba	20	0	0	0	0	80
	Plátano	0	2.5	5	2.5	2.5	87.5
	Lima dulce	12.5	0	0	0	0	87.5
	Limón	0	20	7.5	0	0	72.5
	Aguacate	10	55	20	2.5	0	12.5
	Lichi	0	0	0	0	0	100

Food group	Item	Consumption frequency [%]					
	Anona	32.5	0	0	0	0	67.5
	Carambola	30	0	0	0	0	70
	Mamey	42.5	2.5	2.5	0	0	52.5
	Chalahuite	7.5	0	0	0	0	92.5
	Nesfora	52.5	0	0	0	0	47.5
	Capulín	27.5	0	0	0	0	72.5
	Jobo	10	0	0	0	0	90
	Ojo de guajolote	62.5	0	0	0	0	37.5
	Piña	47.5	22.5	7.5	0	0	22.5
	Tamarindo	7.5	27.5	17.5	0	0	47.5
	Melón	32.5	47.5	20	0	0	0
	Coco	57.5	35	7.5	0	0	0
	Sandía	17.5	52.5	22.5	0	0	7.5
	Uva	42.5	42.5	12.5	0	0	2.5
	Manzana	10	75	15	0	0	0
	Fresa	67.5	25	7.5	0	0	0
Legumes	Frijol coloní	37.5	22.5	12.5	5	0	22.5
	Frijol mal te	32.5	12.5	12.5	20	2.5	20
	Frijol pukul	0	0	12.5	30	57.5	0
	Frijol wet	52.5	0	12.5	5	0	30
	Frijol sarabanda	20	7.5	0	2.5	0	70
	Lenteja de árbol	42.5	12.5	7.5	0	0	37.5
	Lenteja	20	35	30	12.5	0	2.5
	Soya	7.5	50	37.5	5	0	0
Nuts and seeds	Ajonjolí	15	62.5	17.5	5	0	0
	Semillas de calabaza	30	32.5	5	2.5	0	30
	Cacahuate	15	57.5	22.5	0	0	5
Meats and fish	Gallina, pollo	0	62.5	32.5	5	0	0
	Cerdo	45	45	7.5	0	0	2.5
	Res	40	45	15	0	0	0
	Embutidos	27.5	30	30	10	0	2.5
	Pescado en lata	27.5	57.5	12.5	2.5	0	0
Eggs	Huevos de gallina	0	10	32.5	52.5	5	0
Milk and milk products	Leche	5	7.5	27.5	40	20	0
	Queso	0	15	40	32.5	12.5	0
	Yogurt	35	50	10	5	0	0
Oils and fats	Aceite	0	0	0	0	100	0
Sweets	Azúcar	0	0	0	0	100	0
	Galletas, pan dulce	7.5	10	32.5	30	20	0
	Refrescos	22.5	30	35	7.5	5	0
Savoury and fried snacks/Processed foods	Frituras (sabritas, cuernos)	32.5	27.5	22.5	17.5	0	0
	Sopa instantánea 'Maruchan'	25	32.5	25	15	2.5	0
	Café	0	0	0	0	100	0

Food group	Item	Consumption frequency [%]					
Spices, condiments, beverages	Cilantro	2.5	7.5	5	7.5	2.5	75
	Hierba buena	2.5	17.5	12.5	7.5	0	60
	Epazote	25	7.5	25	7.5	0	35

The Food Variety Score (FVS) is a measure of dietary diversity, and was calculated as the sum of consumed food items from the 81 items of recommended food groups listed in Table 4 over the assessment period of one year. The mean value for the sample population was 64.6, with a variance of 38 and a standard deviation of 7.8 (Table 10). As a minimum, households consumed 42 items out of 81, and the maximum scored value was 80. The findings indicate that dietary diversity can vary strongly among households, but the standard deviation shows that values are centred around a limited range. Also, as discussed above, Table 14 indicates that a great majority of the households consume at least one food item from the recommended food groups regularly.

The interviewees themselves have different opinions about diets in Jol Mom. A general view is that diets have been changing, at least for some part of the population, and that now people are eating more meats, more fried snacks and use more vegetable oil. "Ahora la gente come salchicha, huevos, sabritas, es más diferente. Antes no, y hacíamos el huevo en hoja de plátano, sin aceite. Ahora se ocupa más aceite. Ahora hay muchos que comen pollo de granja, antes no." (38); "Nos acostumbramos a comer así los productos de la *milpa*, y está bien. Carne no ocupan todos. La dieta ha cambiado un poquito. Ahora es mejor, se hace el chayote guisado. Antes no había aceite" (28); "Aquí la gente come igual. Los que van a Valles, ellos ya comen otras cosas. Traen chicharrón, pollo, queso." (23). While some perceive the change as positive, others criticize the new eating habits: "Antes, la gente comía Lúm con frijol guisado. Ahora los niños ya no quieren el Lúm. Ahora comer es más bueno, pero no es verdad. Ahora es carne y queso. Pero no, lo mejor es lo que hay en el monte" (35); "Los jóvenes ya no quieren comer lo que hay aquí. Piden chorizo y huevo y queso" (4).

Even though frequencies from Table 14 indicate that these typical *milpa* crops are consumed regularly by a large part of the sample population, some respondents mentioned that they prefer to sell the harvested crops instead of consuming them, because they are tired of eating them, or because they prefer other, purchased foods. For example, about the quelite some famers say "Vendemos, pero casi no consumimos" (15) and "Vendemos, ya casi no nos gusta comer" (4). The same situation was mentioned for lengua de vaca, verdolaga, chayote and calabaza (Annex Table 25), which are all nutrient-rich vegetables which enrich Jol Mom's diets.

Other foods are, according to comments gathered during the survey conduction, linked to a certain purchasing power, as mentioned for bread and potatoes, and fruits and vegetables which are only available through purchase, such as melón, manzana, coco, zanahoria (some comments in Annex Table 25) and which are only eaten "cuando hay dinero".

According to the local shop owner (personal interview, April 21, 2019), consumption patterns differ between population groups. While there is a new generation which leaves the community to work in the cities and come back with new ideas ("regresan con otra idea") which influences their consumption choices. They buy "salchichas, jamón, mantequilla, champu, gel para el pelo y acondicionador" in his shop. On the other hand, "los que no salen no compran", or only basics such as "azúcar, sal, pimienta, orégano, ajo".

The key informants interviews with the health staff from Jol Mom and the local hospital in Tampaxal reflect that there is a worry about the increase of non-communicable diseases, such as diabetes and hypertension. These are, in the informants' views, connected to bad eating habits and a lack of physical activity. Bad eating habits include the consumption of "comida chatarra", such as deep-fried snacks and processed foods as well as soft drinks, the consumption of large amounts of sugar *e.g.* in coffee, and sweet bread, and the consumption of fatty meats, but also the skipping of meals or uncontrolled consumption in other occasions. The consumption of unhealthy snacks and soft drinks starts at a very early age according to informants. The consumption of local fruits and vegetables has decreased, especially among the young generations which prefer purchasing other, named products, as well as meats and eggs, from earned money (Volunteer for health issues in Jol Mom personal interview, April 3, 2019; Nurse in the local hospital of Tampaxal personal interview, April 3, 2019; Physician responsible of the local hospital of Tampaxal personal interview, April 16, 2019 (Annex Table 24)).

6.2 Obj. 2: Examine the relationship between agrobiodiversity management and food security in Jol Mom

6.2.1 Number of production systems, agrobiodiversity and food security

In this section, the question is explored if the traditional Teenek farming systems which have been described in this work and which are managed in the community of Jol Mom contribute to food security. For this purpose, the question is posed if the number of managed production systems brings certain household characteristics of food security status with it. In the second part, the question of whether there is a correlation between production diversity (PD) and the Food Variety Score (FVS) of the households is pursued.

6.2.1.1 Number of production systems and household characteristics

Among the population group which manages only one production system, the majority cultivates in the *solar*. Households which manage two production systems managed mainly *solar* and *milpa*, but also four out of the nine farmers were managing a *finca* system. *Milpa* is mostly produced traditionally including maize production (Table 15).

Table 15: Management of the different traditional farming systems of the population with different numbers of production systems in Jol Mom, Aquismón, SLP Mexico.

Agricultural production system	Number of households with one, two or three agricultural production systems			Sum
	One	Two	Three	
Solar	7	7	23	**37**
Milpa	1	7	23	**31**
Milpa* with maize	*0*	*4*	*19*	***23***
Finca	0	4	23	**26**

** Although the milpa is strictly defined as a poly-crop system based on the cultivation of maize, crop rotation and farmer's decisions on what to cultivate each year can imply that there are milpas which do not include maize*

Table 16 shows the relation between the number of production systems that manages each household (one, two or three) which include *solar*, *milpa* and *finca*, and variables related to food security and household structure.

The production diversity (Table 16) indicates that farmers with a greater number of production systems also have higher agrobiodiversity indexes, which is logical considering that each farming system is related to a different set of crops (see section 6.1.1.1). Nevertheless, this relationship is not linear, as farmers with one production system cultivate an average of 24 crops out of 61, two production systems contain four more crops (28.1) from the list than only one, but farmers with three production systems report eleven more crops (39.5) than farmers with two systems. A gradient is also visible for the amount of the production which is dedicated to selling/marketing; farmers with one production system tend to dedicate less than half or half of the produced crops to the market (0.6), whereas farmers with three production systems tend to have more products which they sell (1.1). The average size of land registered for each group increases by 1.2 ha with each additional farming system.

The age of the heads of the household is strongly correlated with the number of farming systems, increasing with an average difference of six to 12 years with each farming system. Farmers with a greater number of production systems tend to have slightly more members in the household which contribute to household expenses.

In terms of food security, households with two production systems indicate most frequently that money was not always sufficient to acquire the preferred and necessary foods for the household (0.4), while households with three production systems report this issue less frequently (0.7). Households with one production system have the highest household expenses (575 MXN per week), while farmers with three production systems spend less (530 MXN per week) even though their families are larger (4.1 permanent household members). Households with two production systems spend the least on food (483 MXN per week) but are also among the smallest households

(3.6 members). Households with three production systems spend the smallest proportion of their income on food (1.1, meaning around half of their income), followed by households with two production systems (1.3) Households with one production system spend the largest proportion of their income on food (1.4). Both households with one and two production systems obtain more than half of their foods by purchasing them (2.0), while households with three production systems indicate frequently that around half of their food is provided by producing, and half by purchasing food (1.1). Households with three systems reach the highest Food Variety Score with 68.5 foods consumed out of 86, while farmers with one production system score 59.8 and families managing two production systems even slightly less, 58.8.

In conclusion, the differences between the population groups cultivating one, two or three of the *solar*, *milpa* and *finca* farming systems indicate that the management of three production systems is indeed favourable for food security, as households with three production systems score best regarding worries about meeting food supply of their households and show the highest Food Variety Scores. Nevertheless, other variables, possibly related to generational differences, might also contribute to this tendency. Still, the picture changes when looking at the characteristics of the population cultivating one and two farming systems. Even though production diversity and access to land is higher for the latter group, other variables such as the sufficiency of money or the Food Variety Score indicate that they might be even more vulnerable than the farmers with only one system. In general, the higher share and sums of expenses on food can make us conclude that managing high crop variety in different production systems can be of economic benefit through avoiding expenses and might be favourable for a diverse diet.

Table 16: Average of variables describing the population groups for different numbers of production systems in Jol Mom, Aquismón, SLP Mexico.

Variable	Characteristics of households with one, two or three agricultural production systems (mean value)			Total mean
	One	Two	Three	
Production diversity (PD) *	24.0	28.1	39.5	**33.8**
Amount of products for sale **	0.6	0.9	1.1	**1.0**
Land size [ha]	1.2	2.4	3.6	**2.9**
Age of male household head	31.5	41.9	53.6	**47.3**
Age of female household head	31.9	37.2	48.1	**42.4**
N° of permanent household members	3.9	3.6	4.1	**3.9**
N° of members contributing to household expenses	1.3	1.6	1.8	**1.6**
Money has always been sufficient ***	0.5	0.4	0.7	**0.6**
Food expenses per week [MXN]	575.0	483.3	530.4	**528.8**
Income inverted in food **	1.4	1.3	1.1	**1.2**
Amount of foods purchased **	2.0	2.0	1.1	**1.5**
Food Variety Score (FVS) ****	59.8	58.8	68.5	**64.6**

**PD is the count of cultivated items during the past year out of 56 crops.*

***The variables income spent on food, amount of products for sale, and amount of food purchased are described on a scale from 0 to 2 ranging from 0 corresponding to 'less than half of income spent on food/products used for sale/products purchased' to 1 to 'around half of income spent on food/products used for sale/products purchased' to 2 to 'more than half of income spent on food/products used for sale/products purchased'.*

****With 0 indicating the answer 'no' and 1 'yes'*

*****FVS is the count of consumed items during the past year out of 81 foods.*

6.2.1.2 Agrobiodiversity and dietary diversity

Dietary diversity has been recognized as an indicator for both diet quality and food access (Jones *et al.*, 2013). The relationship between traditional farming systems and food security was already explored, as well as some other household characteristics. In this section, a closer look is dedicated to the agricultural biodiversity grown in the traditional farming systems and the dietary diversity of the population.

Correlation coefficients provide a straightforward approach for testing the relation between household characteristics, and variables describing agricultural biodiversity or food security. When looking at the correlation matrix of the nominal variables taken from the survey (Annex Table 26), it is noticeable that the variable most strongly linked to Food Variety is production diversity.

A linear regression analysis of the Food Variety Score plotted against production diversity shows a significant tendency that linear correlation between the two variables exists ($R = 0.70$, $R^2 = 0.49$, $p < 0.001$). With every 0.85 item of production diversity, Food Variety increases by one (Figure 17).

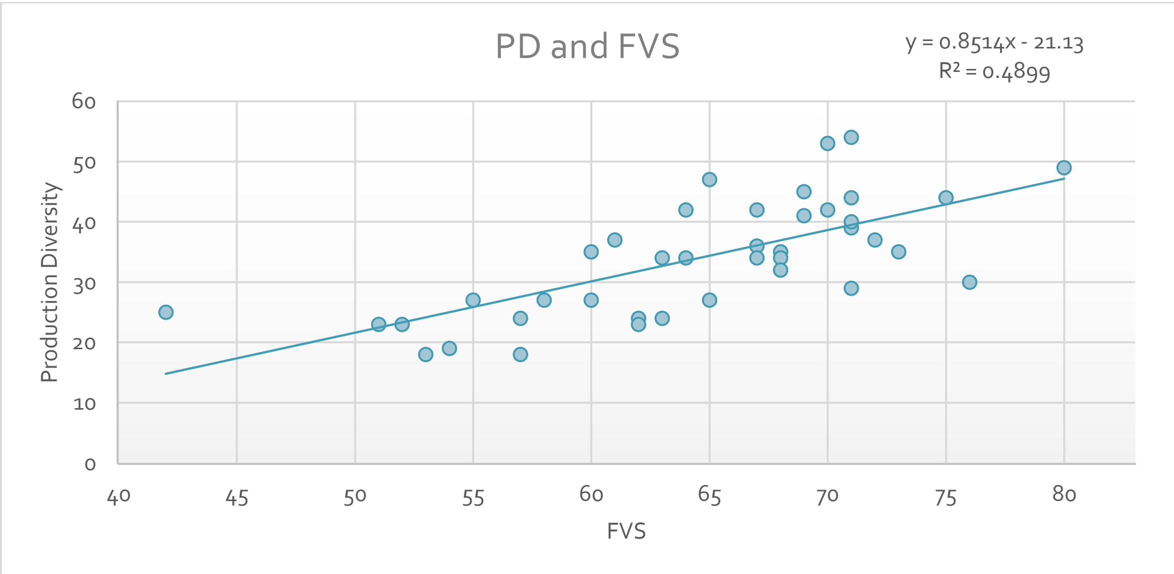


Figure 17: Pearson's correlation for production diversity (PD) and Food Variety Scores (FVS) of the sample population in Jol Mom, Aquismón, SLP Mexico.

The number of production systems and the age of the household heads are also positively correlated variables. Other variables are only slightly or not-at-all correlated with Food Variety.

This non-correlation is an important finding in the sense that it indicates that the detected positive correlation of production diversity with dietary diversity does have significance as no additional relationship from the assessed variables which might undermine the validity of the results is omitted.

6.2.2 Agrobiodiversity, dietary patterns and food security

6.2.2.1 Principal component analysis for the detection of dietary patterns

The correlation matrix of the average food consumption frequency of each food group is a database needed for the multivariate analysis of principal components and is visualized in Figure 18. For exact values of correlation coefficients refer to Annex Table 27.

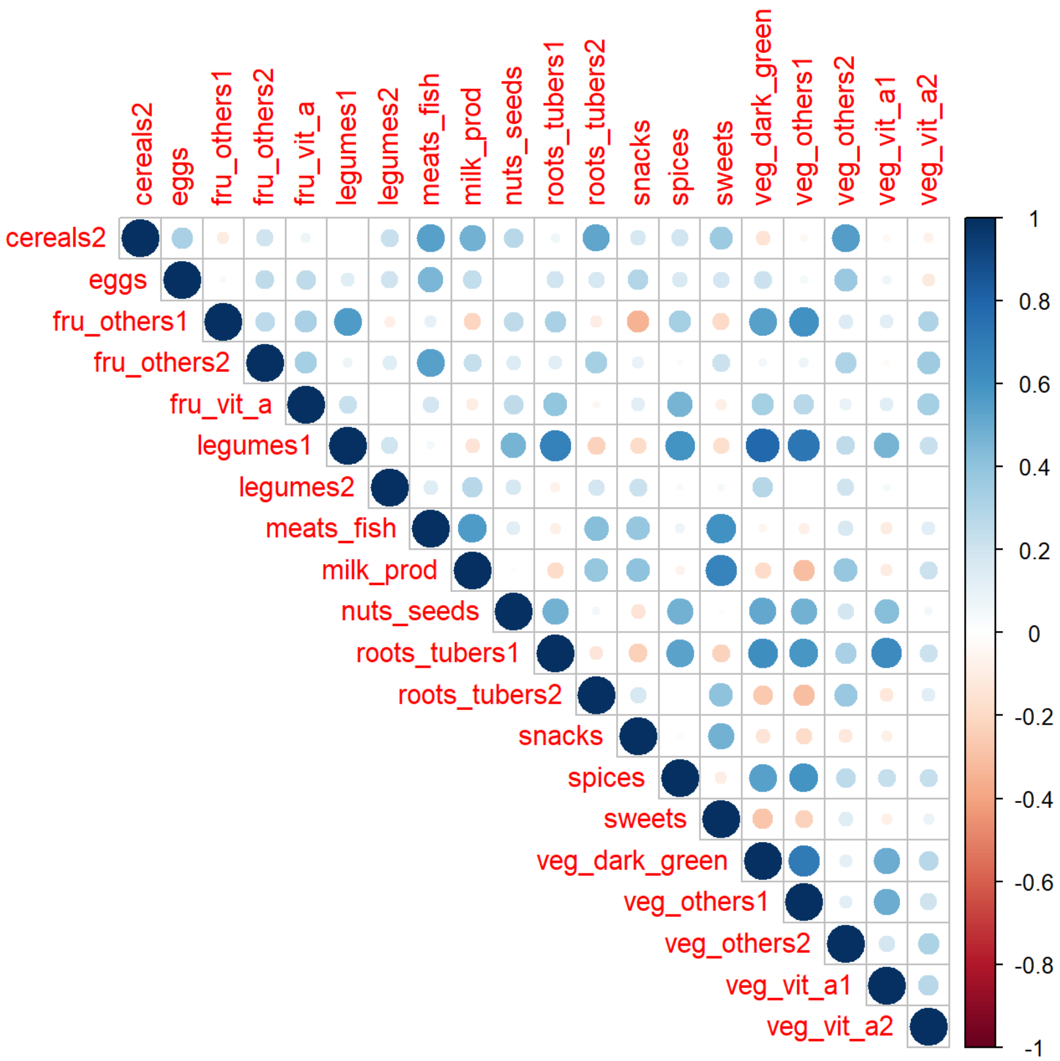


Figure 18: Correlation matrix which describes correlation of consumption of foods from each of the 20 food groups which constitute the initial variables. The size and colour intensity indicate the strength of the correlation (the closer to the extremities -1 and 1 the bigger the dot and more intense the colour, for exact values refer to Annex Table 27).

Figure 19 shows that the first two dimensions together total 46.8 % of the total inertia (the total variance of the dataset), meaning that nearly half of all dietary patterns of the sample population can be explained by the first two principal components. According to Husson, Le and Pages (2011 p. 209), for a table with 40 individuals and 22 variables, 95 % of the percentages of inertia explained by the plane are less than 23 %, which means that the 46.8 % obtained in the present study expresses a significant structure in the data. Also, the first two dimensions can be considered as containing a high explanatory value, as for the following dimensions inertia is smaller than 1 (Annex Figure 26) (Husson *et al.*, 2011).

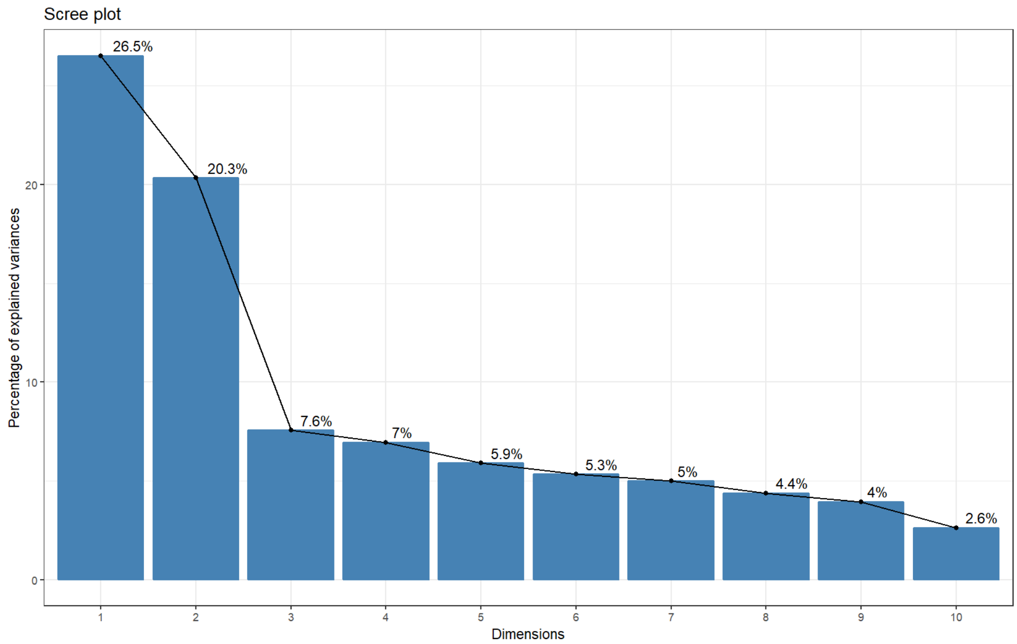


Figure 19: Percentage of explained variance for each dimension (principal component).

The first two axes of the Principal Components Analysis are characterized in Table 17. The first dimension, which can be interpreted as the x axis in the plane, is described by food groups produced by the sample population (refer to Table 4 for consulting which foods correspond to each food group), above all dark green vegetables and legumes from farm production. The second dimension, represented by the y axis, is best described by meats and fish, by milk and milk products, and cereals of purchased origin. Terms serve to describe these two patterns to relate to later on, calling the vegetable and fruits and cultivation-based set observed for dimension 1 the 'traditional *milpa*' and the meats and fish, milk products and purchased goods related pattern as 'westernized'. The variables plotted in a graph with the first and second dimension as coordinates are represented by vectors to facilitate visualization of the angles between variables (Figure 20). The variables are organized in a gradient that goes from a preference for snacks, sweets and other purchased products located at the bottom left side of the graph, to a dietary pattern that feeds on cultivated vegetables on the bottom right side.

The length of the vector can be described as how well the variable is represented by the plane (*e.g.* the first two dimensions). While products associated with named 'westernized' diet lie on one extremity of the group of vectors and foods associated with products from traditional farming systems, on the other side food groups such as legumes 2, eggs, fru_others2, veg_others2, veg_vit_a_2, fruits_ vit_a, nuts and seeds, spices (from left to right) take an intermediate position, and are located in the sector of the plane which is positive for both dimensions.

The representation of the variables can be an aid for the interpretation of the cloud of individuals, which is depicted in Figure 21 and will be discussed in section 6.2.2.2.

Table 17: Description of dimensions by their correlation with variables.

Dimension 1	Correlation	p-value	Dimension 2	Correlation	p-value
veg_dark_green	0.862149	8.89E-13	meats_fish	0.810423	2.35E-10
legumes1	0.857995	1.5E-12	milk_prod	0.753025	2.07E-08
veg_others1	0.844694	7.3E-12	cereals2	0.727666	1.04E-07
roots_tubers1	0.813756	1.73E-10	sweets	0.669388	2.33E-06
spices	0.703584	4.11E-07	roots_tubers2	0.647021	6.44E-06
fru_others1	0.642836	7.72E-06	veg_others2	0.564981	0.000146
nuts_seeds	0.616732	2.26E-05	fru_others2	0.559564	0.000174
veg_vit_a1	0.60119	4.09E-05	eggs	0.536345	0.000361
fru_vit_a	0.4787	0.00178	snacks	0.455154	0.003168
veg_vit_a2	0.349831	0.026911	legumes2	0.348969	0.027315
sweets	-0.3184	0.045246			

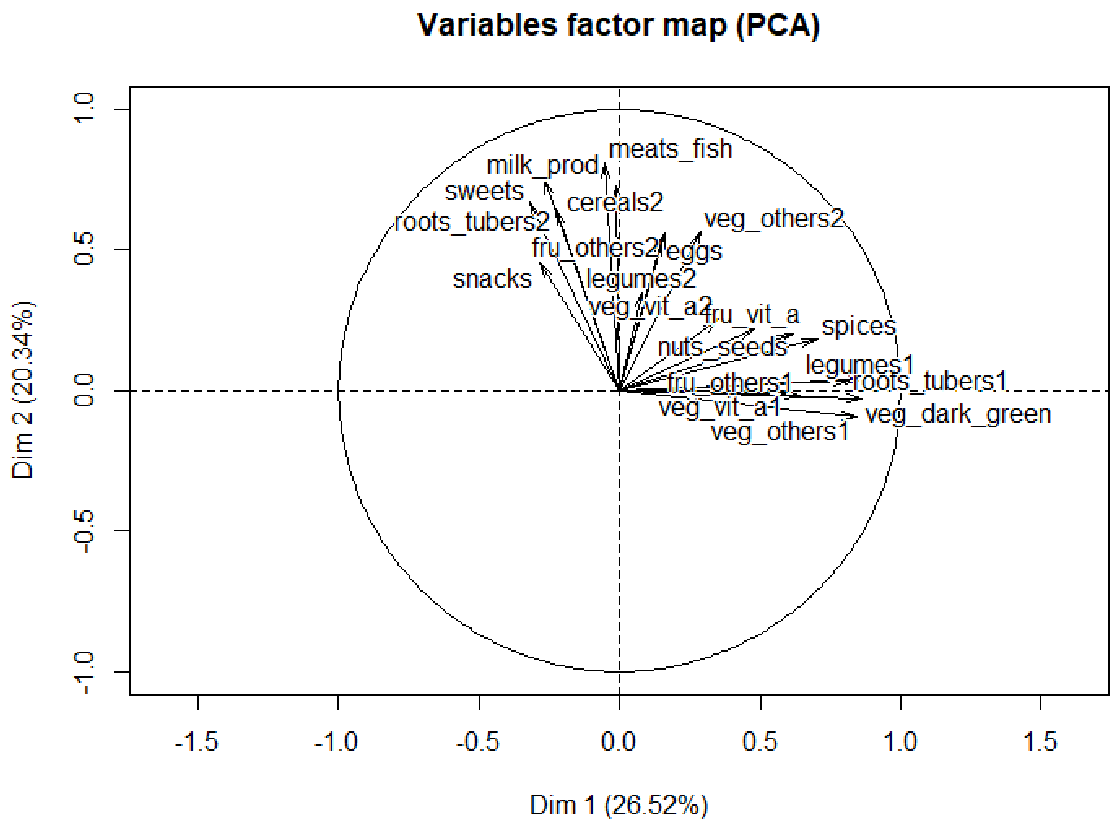


Figure 20: Graph of the multivariate analysis of principle components, depicting the food groups in form of vectors in the plane of the first two dimension.

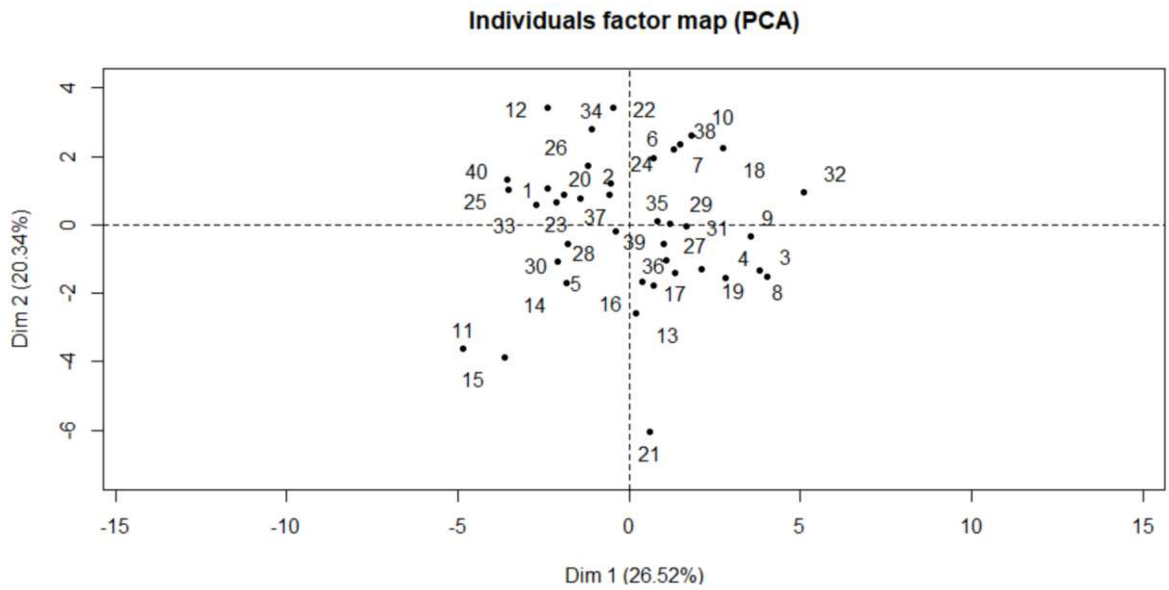


Figure 21: Individuals (which correspond to the interviewed households) represented in the plane according to their position in the first two dimensions.

6.2.2.2 Hierarchical Clustering of Principal Components (HCPC)

The application of the Hierarchical Clustering of Principal Components (HCPC) generated a dendrogram (Figure 22, see also Annex Figure 27) which was partitioned into six clusters and projected on the principal components. Individuals belonging to distinct clusters appear in different colours in the projection of Figure 22 and the biplot (Figure 23).

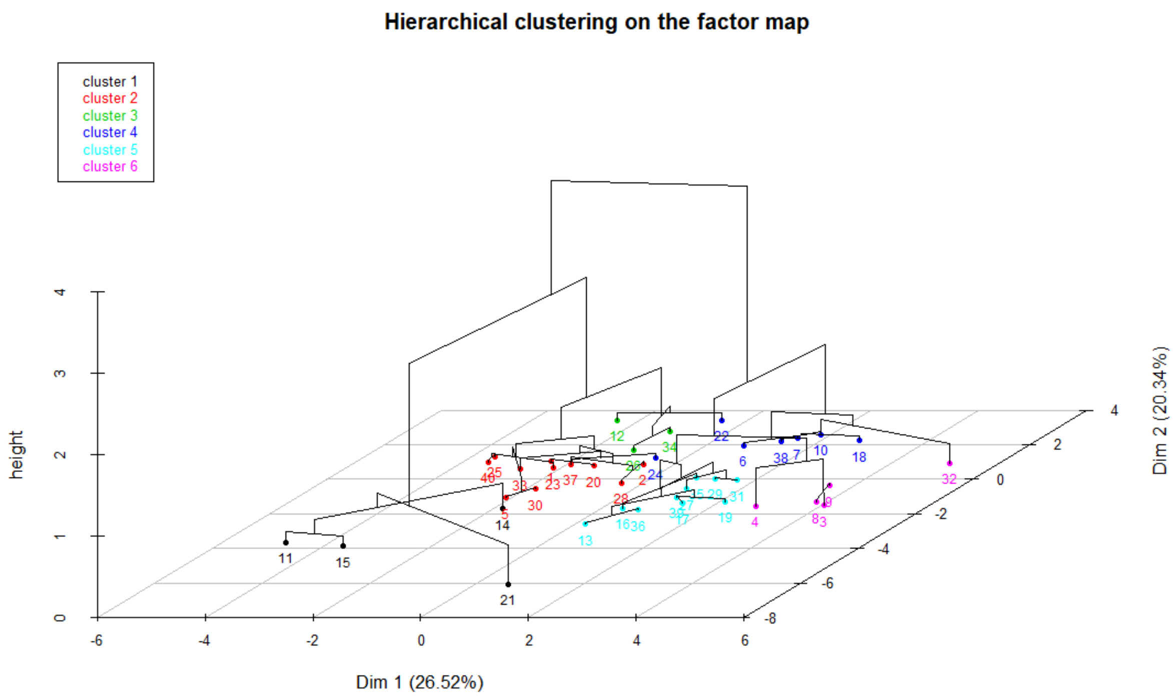


Figure 22: Hierarchical clustering projected on the factor map. Each number represents an individual which was located on the factor map during the PCA.

From the characteristics derived from Table 18, and the location on the biplot which combines the clustering of the individuals with the vectors of the variables (Figure 23), dietary patterns corresponding to each cluster were derived.

In cluster 1, all means of consumption scores are below the total average of each food group, and v-test values are negative. Individuals are spread widely across the quartile of the plane which carries negative numbers for both dimensions. This cluster is therefore called 'Overall low consumption diet'. Cluster 2 is located around the axis of the first dimension with negative values, and with only slightly positive values in the second dimension. In this cluster, individuals are characterized by high scores of purchased roots and tubers (potatoes), but all of the other food groups are below the average. According to the location in the biplot, this diet is called 'Low consumption diet relying on purchased foods'. The third cluster is easier to interpret, as it is clearly characterized by high values and v-test scores of the variables meats and fish, sweets and milk and milk products. In the plane it is furthermore visible that the vector of snacks, although less well described by the first two dimensions, is also located between the individuals. This diet is called 'Westernized diet'. Individuals in cluster 4 are located on a similar height of values of the second dimension, but the cluster is shifted further into positive values of the first dimension. Apart from meats and fish, households in this cluster consume eggs, snacks, and other fruits, legumes and cereals of purchased origin. This diet is called 'Diverse diet consuming purchased foods'. The fifth cluster is characterized again by negative v-test scores and values below the average, this time in the negative section of the second dimension, on the opposite side of the vectors of snacks, meats and fish, sweets and eggs, while the first dimension has low positive values. This cluster is named 'Low consumption diet relying on cultivated foods'. The cluster 6 is situated at the high values of the first dimension and relies heavily on foods available in the local production systems, such as dark green vegetables, cultivated legumes and roots and tubers, and food groups of cultivated fruits and vegetables. 'Traditional *milpa* diet' is the name given to this cluster.

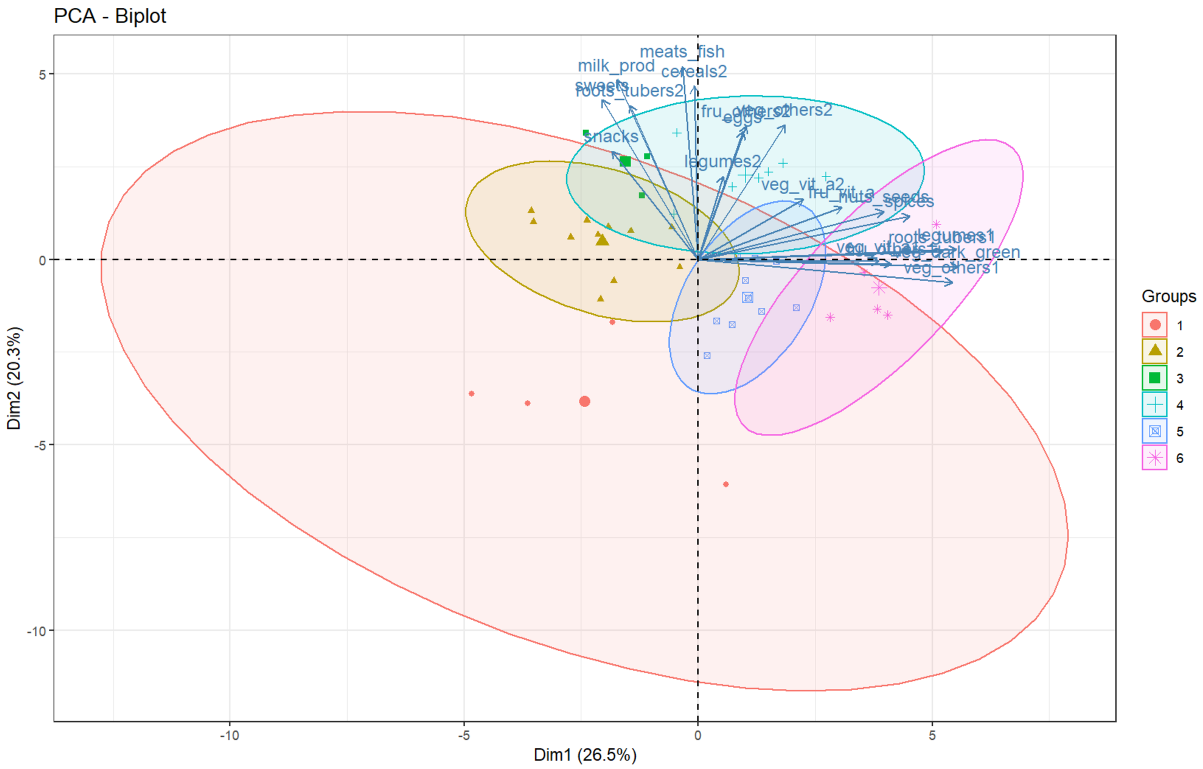


Figure 23: Biplot including the centres of gravitation of each cluster derived from the HCPC. The barycentre of each cluster is represented by a bigger symbol.

Table 18: Clusters described by food groups variables, with the mean obtained by the individuals belonging to the cluster, compared to the overall mean, as well as the respective values for the standard deviation (SD). All p-values are a smaller than 0.05. The v-test indicates if a category is over (>0) or under represented (<0) among individuals.

Cluster N°	Variables	v-test	Mean in category	Overall mean	SD in category	Overall SD	p-value
1	nuts_seeds	-2.02	1.5	2.6	1.0	1.2	0.043
	legumes1	-2.10	2.0	3.2	1.1	1.2	0.036
	roots_tubers1	-2.18	1.9	2.9	1.0	1.0	0.030
	spices	-2.42	3.8	4.6	1.0	0.7	0.016
	milk_prod	-2.67	2.9	4.3	1.3	1.1	0.008
	roots_tubers2	-2.69	2.0	4.2	2.1	1.7	0.007
	eggs	-2.79	4.0	5.4	1.0	1.0	0.005
	cereals2	-3.55	3.8	5.3	0.9	0.9	0.000
	veg_others2	-4.95	3.5	5.9	0.6	1.0	0.000
2	roots_tubers2	2.54	5.4	4.2	0.5	1.7	0.011
	veg_vit_a2	-2.02	0.9	1.8	0.7	1.7	0.043
	spices	-2.30	4.2	4.6	0.6	0.7	0.021
	roots_tubers1	-2.60	2.3	2.9	0.5	1.0	0.009
	veg_dark_green	-2.73	2.4	3.3	0.7	1.2	0.006
	legumes1	-2.74	2.4	3.2	0.9	1.2	0.006
	veg_others1	-2.85	3.1	3.7	0.7	0.8	0.004
	fru_others1	-3.02	2.8	3.2	0.6	0.5	0.003
	fru_vit_a	-3.39	2.5	3.2	0.6	0.8	0.001
3	meats_fish	2.41	4.0	2.5	0.4	1.1	0.016
	sweets	2.38	6.7	5.2	0.3	1.1	0.017
	milk_prod	2.34	5.7	4.3	0.5	1.1	0.019
4	meats_fish	3.52	3.9	2.5	0.5	1.1	0.000
	fru_others2	2.96	3.0	2.0	0.9	1.0	0.003
	snacks	2.55	4.7	3.2	1.1	1.7	0.011
	eggs	2.44	6.3	5.4	0.5	1.0	0.015
	legumes2	2.35	4.5	3.3	1.2	1.4	0.019
	cereals2	2.06	6.0	5.3	0.5	0.9	0.039
5	sweets	-2.01	4.6	5.2	0.9	1.1	0.045
	eggs	-2.07	4.8	5.4	1.2	1.0	0.038
	meats_fish	-2.16	1.9	2.5	0.6	1.1	0.031
	snacks	-3.33	1.6	3.2	1.1	1.7	0.001
6	veg_dark_green	4.09	5.3	3.3	0.5	1.2	0.000
	roots_tubers1	3.61	4.4	2.9	0.4	1.0	0.000
	nuts_seeds	3.21	4.2	2.6	1.2	1.2	0.001
	veg_vit_a1	3.17	5.3	3.7	0.2	1.2	0.002
	legumes1	2.82	4.7	3.2	0.4	1.2	0.005
	spices	2.78	5.5	4.6	0.3	0.7	0.005
	veg_others1	2.66	4.5	3.7	0.4	0.8	0.008
	fru_vit_a	2.08	3.9	3.2	0.3	0.8	0.037
	fru_others1	2.00	3.6	3.2	0.4	0.5	0.045

It is important to note that not all clusters are best described by the first two dimensions, which explains why some clusters are more tangible for interpretation of patterns than others. For example, only clusters 3, 4, and 6 have positive v-test values for either of the first two dimensions. All other clusters only have positive v-test scores in other dimensions or report negative scores for dimension 1 and 2 (Annex Table 28).

After the characterization of clusters by food groups in the form of vectors obtained by the PCA, the clusters were described by the supplementary information collected on the characteristics of the individuals (*i.e.* the households) which conformed to each cluster. Table 19 lists all the variables obtained from the survey questions, which helps to get further insight into what household characteristics are related to which eating pattern in Jol Mom.

Looking at age, there are major differences visible. Cluster 6 'Traditional *milpa* diet' captures the households with the highest age, with the average age of the female household head of 54 and for the male 59. Cluster one (Overall low consumption diet) and 3 (Westernized diet) are youngest in their early to later 30s. The number of children is highest in cluster 3 and 6, and lowest in cluster 1. Educational level is higher for clusters 2, 3 and 4. In cluster 6, the female head of the household does generally not speak Spanish, and in cluster 1 only a little.

Only cluster 1 is constituted of households which generally do not own the land they are cultivating. Cluster 1 is also the one reporting lowest land size numbers, while cluster 6 has the biggest surfaces available. The number of agricultural systems which are managed does not differ strongly for most clusters. Clusters report numbers a little bit above two production systems, only cluster 4 lies closer to reporting 3 systems, and cluster 6 has an average of 3 systems which are managed by households. It is important to note that the relative overrepresentation of farmers with three production systems might distort their occurrence in the different clusters. Production diversity is lowest for cluster 1 and 2, closely followed by 3 and 5. Cluster 4 lies a little bit above, but cluster 6 is scoring highest by a distance. While cluster 2 and 6 sell less than half of their products, 3, 4 and 5 sell more than half and cluster 1 around half. All clusters need to purchase more than half of their products, only cluster 3 purchases around half and cluster 6 less than half. Cluster 1, 4 and 6 purchase their products overwhelmingly in the small, local shops, cluster 2, 3 and 5 visit additionally a close by market to cover their demand.

Households from clusters 1, 4 and 5 spend most of their money on foods, and only cluster 2 and 3 report frequently that they do not spend more than half of their income on foods. Money was generally sufficient for clusters 2, 3 and 6, but not for 1, 4 and 5. Cluster 2 and 4 suffer more during rainy season from inadequate food supply, while clusters 1, 5 and 6 suffer more in other seasons. Only cluster 4 and 6 do not regularly ask for credit in the shop. Finally, the FVS was highest for cluster 6, followed by clusters 5 and 3 and 4, and was lowest for cluster 1 and 2.

Table 19: Characterization of clusters by variables from survey indicating household composition, socioeconomic status, level of agricultural activity and information on food security related topics. The mean value was calculated for numerical variables, for categorical variables the mode was taken.

Variable	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
Name attributed to dietary pattern	Overall low consumption diet	Low consumption diet relying on purchased foods	Westernized diet	Diverse diet consuming purchased foods	Low consumption diet relying on cultivated foods	Traditional *milpa* diet
Household composition						
Age male head of HH	38.5	40.8	37.3	53.1	48.3	59.4
Age female head of HH	31.5	36.3	35.3	46.7	46.7	54.2
Number of adult (>18) HH members	2.3	2	2.7	2.4	2.4	2.6
Number of children (<18) in HH	1	1.9	2.3	1.7	1.3	2.2
Number of permanent HH members	3.3	3.9	4.7	4.1	3.7	4.2
Number of non-permanent HH members (out of named members)	0	0.6	0.3	0.3	0.3	0.6
Education						
Educational level of male head of HH	≤ Prim	≤ Prim	≤ Prim	Sek	≤ Prim	≤ Prim
Educational level of female head of HH	≤ Prim	Sek	> Sec	≤ Prim	≤ Prim	≤ Prim
Male head of HH speaks Spanish	Yes	Yes	Yes	Yes	Yes	Yes
Female head of HH speaks Spanish	A little bit	Yes	Yes	Yes	Yes	No
Finances						
Number of members contributing to HH expenses	1	1	2	1	1	1
Work in cultivation and sale of products	Yes	Yes	Yes	Yes	Yes	Yes
Work as peón	Yes	No	Yes	Yes	Yes	Yes
Work in contrato by migrating temporarily	No	No	No	No	No	No
Other works	No	No	No	No	No	No
Remittances	No	No	No	No	No	No
Subsidies						
Receives Prospera (before)	Yes	Yes	Yes	Yes	Yes	Yes
Receives 65 y más	No	No	No	No	No	No
Receives PROCAMPO	No	No	No	No	No	No
Receives Coffee seedlings	No	No	No	No	No	No
Agriculture						
Solar	Yes	Yes	Yes	Yes	Yes	Yes
Milpa	Yes	Yes	Yes	Yes	Yes	Yes

Variable	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
Milpa with maize	Yes	No	Yes	Yes	Yes	Yes
Finca	Yes	No	Yes	Yes	Yes	Yes
Land ownership	Lent	Property	Property	Property	Property	Property
Status in ejido	Unknown	Posesionario	Posesionario	Posesionario	Ejidatario	Posesionario
Land size [ha]	0.4	1.9	2.3	3	3.5	5.8
Number of agricultural systems	2.3	2.2	2.3	2.6	2.2	3
Production diversity (out of 56 crops)	29	29	31.7	37.3	31.7	49
Sale seasonal or permanent	All year	Seasonal	Seasonal	Seasonal	All year	All year
Sales in markets	No	Yes	No	No	Yes	Yes
Sales to intermediary	Yes	Yes	Yes	Yes	Yes	No
Amount of products for sale	half	< half	> half	> half	> half	< half
Amount of products purchased	> half	> half	half	> half	> half	< half
Where purchased	Local shop	Local shop and market	Local shop and market	Local shop	Local shop and market	Local shop
Number of HH members cultivating	1.5	1.5	1.7	2	1.3	2.8
Food security						
Food expenses per week [MXN]	650	427.3	416.7	614.3	610	440
Income inverted in foods	> half	half	half	> half	> half	> half
Money always sufficient	No	Yes	Yes	No	No	Yes
Lack of foods	No	No	No	No	No	No
Months of inadequate food supply in rainy season (May to September)	No	Yes	NA	Yes	No	No
Months of inadequate food supply not in rainy season (October to April)	Yes	No	NA	No	Yes	Yes
Strategy pedir fiado	Yes	Yes	Yes	No	Yes	No
Strategy work more (sale of products or employment)	No	Yes	Yes	Yes	Yes	Yes
Strategy eat less	No	No	No	No	No	No
Meals per day	2	3	3	2	2	3
Food Variety Score (out of 81 items)	61	59.8	66	65.6	67	70.6

Summarizing the characteristics per cluster it can be said that cluster 1 belongs to the most vulnerable population group in terms of the assessed variables. With young household heads with low education and very restricted land access and low production diversity, their social and economic status is reflected in their diet, as they show low consumption of all food groups and a rather low FVS. Cluster 2 is composed of young households with better educated female household heads and low levels of agricultural activity they constitute a cluster which does not seem to rely on farming for livelihoods but rather looks for alternative ways to provide foods.

Consuming few products from *milpa* food groups they rely heavily on purchased foods and tend to consume foods from not recommended food groups, which together with a rather low FVS might result in problems to ensure food security. The third cluster is equally composed of young household heads, and educated female household heads, but with bigger families. While relying on purchased foods, FVS is higher, but the low consumption of fruits and vegetables might constitute a risk to food security. Cluster 4 is older and has a higher production diversity. Their diet is also based on purchased foods, but fruits are also consumed. At a similar age to cluster 4 is the fifth cluster, and other household characteristics are also similar, even though the household head's educational level is lower. While they tend to rely less on purchased foods, consumption of *milpa* food groups is not as pronounced as for the sixth food group, which is the cluster with the oldest household heads, scoring the highest FVS and clearly relying, both regarding livelihoods and diet, on *milpa* production.

Finally, two main findings can be extracted from these results. Firstly, some parts of the population (*e.g.* individuals from cluster 2) consume foods of purchased origin and at the same time tend to not consume or very little foods which can be found in Jol Mom's farming systems (as in the plot they are located on the opposite side of the vectors which indicate the consumption of food groups which are produced), indicating that these foods (if consumed before) have been replaced by purchased foods of low nutritional value (individuals of these clusters are located close to the vectors which indicate the consumption of sweets and snacks). On the other hand, other parts of the population (*e.g.* individuals from clusters 4) seem to combine the consumption of purchased foods of higher nutritional value (meats and fish, eggs, fruits), with the consumption of fruits and vegetables of cultivated origin. Consequently, it can be concluded that the reliance on purchased foods can have but does not necessarily have a deteriorating effect on diet quality in Jol Mom. Secondly, the population which has the highest numbers of production diversity (*e.g.* individuals from clusters 4 and 6) do also show high dietary diversity scores and a consumption of nutrient-rich food groups, indicating that agrobiodiversity management is associated with higher diet quality in Jol Mom, although not necessarily all people who consume healthy food groups also have high production scores.

6.2.3 Pathways of how agrobiodiversity contributes to food security in Jol Mom

Combining the results from the previous sections, including the results from the informal interviews and the impressions from the participant observation, a scheme of the mechanisms of food security procuration was elaborated (Figure 24). There are several pathways of how food security is ensured by the Teenek farming systems *solar*, *milpa* and *finca*. First, the immediate provision of harvested crops can result in direct consumption and contribute to diverse and nutritious foods. Furthermore, products can be sold, which leads to income generation and the possibility to provide purchased foods. Additionally, the seeds obtained either directly from harvested crops or through purchase can be seeded and ensure the continuity of production. Seeds are conserved "para volver a sembrar otra vez. Para que no se pierde lo que tenemos" (26) (notes from fieldwork, 20/4/2019). On top of that, products are commonly stored to ensure food security across seasons, especially the staple crops maize and beans, while a high diversity in farming systems continues providing diverse fruits and vegetables throughout the seasons. Storage also allows the selling of crops in small quantities when money is needed, or market prices are favourable, or to protect the household from exposure to price fluctuations (*e.g.* by storing coffee). Over the years, the flexibility of the cultivated crops, adjusted to market demand and price fluctuations, the *in situ* conservation of crop genetic resources which are adapted to local conditions, and the sustainable farming methods which conserve resources can ensure long-term household food security in Jol Mom. It is important to note that this mechanism relies on certain assets/capitals of the households, and on the condition that the household is actively cultivating. Vulnerable households which lack one or several assets, *e.g.* insufficient disposition over land, health problems of a household member, absence of workforce usually provided by household members or money to hire labourers (among others), might not be able to take advantage of the depicted mechanism.

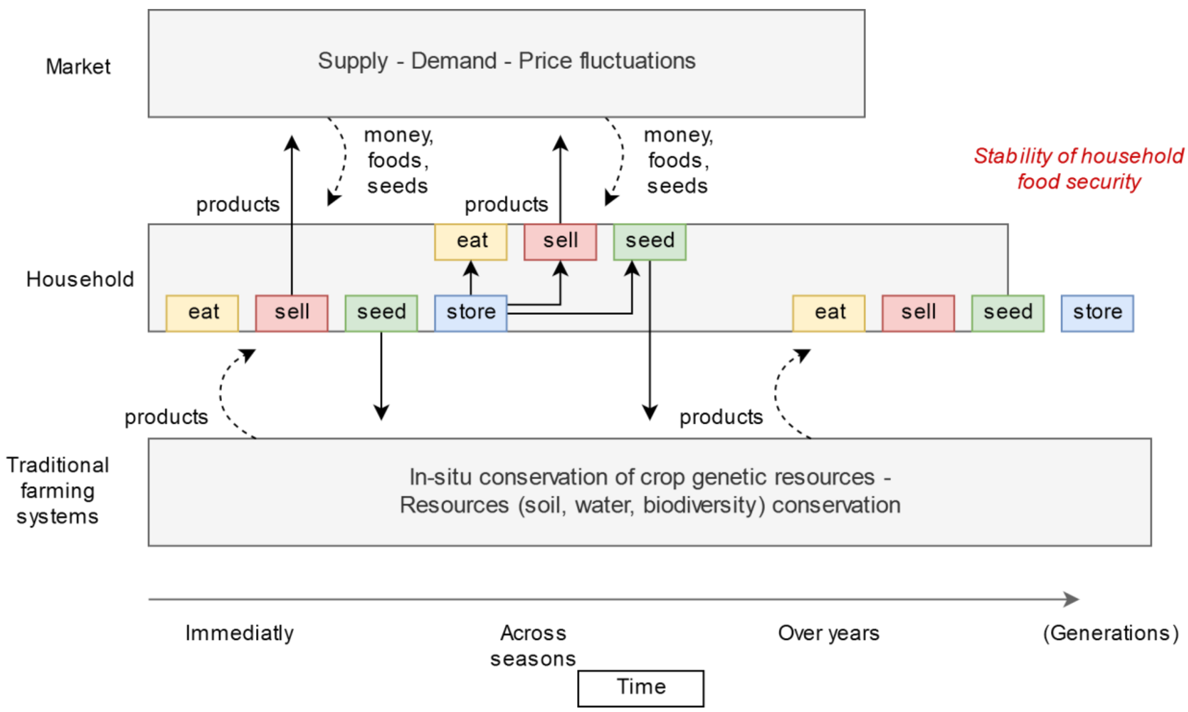


Figure 24: The chart shows how agricultural biodiversity from the traditional farming systems can contribute to long-term food security in the community of Jol Mom, Aquismón, SLP Mexico.

7 Discussion

The following discussion has the principal aim of answering the research questions proposed for this investigation, while laying a focus on the findings which are considered as most interesting. For each of the two research questions, a short summary of the findings is provided. Then, the background for the drawn conclusion is explained and discussed with literature, aiming to contributing to the greater scientific frame of the research. In a third section, overlapping topics which have emerged to be important in the context of the investigation are discussed and in the end limitations of the presented research are highlighted.

7.1 Do traditional Teenek farming systems contribute to the availability of foods and the access to nutritious foods in Jol Mom?

> The traditional Teenek farming systems and their related agrobiodiversity contribute to the availability of foods in the community of Jol Mom, as they provide crops at the household level which are otherwise not available for purchase in the community. Also, they add to the supply of local markets by providing horticultural crops.
>
> The traditional Teenek farming systems and their related agrobiodiversity contribute furthermore to the access to nutritious foods in the community of Jol Mom, as they provide nutrient-rich crops for home consumption, increase the peasant's dietary diversity with increased production diversity, and allow the household a certain degree of independence from market fluctuations and other adverse effects. They also provide products for sale, generating cash which then can be invested in the purchase of foods; and provide seeds which ensure the persistence of the production systems and therefore (depending on certain conditions) long-term food security.

Respondents in this study claimed that while in the local market in the neighbouring village all desirable foods are available, in the community of Jol Mom some foods were said to not be available and furthermore were more expensive than in the market. A decrease in agricultural production might therefore have negative effects on diets, as people rely largely on home production for the supply of fruits and vegetables, above all single women or elderly people which have no time, or have physical or economic restrictions which prevents them from visiting the market. Secondly, from farmers' comments can be deduce that the food supply of the markets depends largely on local production. While there are products which come from outside the region, large parts of the local markets are covered by single vendors selling their own products or by intermediaries selling products from the surrounding communities. It is possible that the availability of local products such as chayote, certain chili varieties and other local fruit and vegetable varieties would decrease if the communities would cease to produce them due to an abandonment of farming systems. Dewey's (1989) worry of the potential effect of increased cash crop production on the local availability of foods and on food prices is that the exportation of the cash crops and decrease of production for home consumption might lead to a decrease of food supply, during an increasing demand. Even though the availability of foods is a decreasing issue thanks to globalization, in the case of Jol Mom the availability of a certain part of foods still depends largely on local producers, a role in the supply chain which is important to recognize in the current scenario of rural exodus and cash crop specialization.

The importance of local production for availability and access to nutritious foods becomes even more striking when noticing that for a good number of crops peasants in Jol Mom have no need to purchase them. Of the 56 crops from the list which are produced in Jol Mom (*i.e.* by the sample population), 29 are obtained almost exclusively through harvest (Table 14). Of these crops, 20 are frequently consumed (nopal, quelite, suyo, hoja de chayote, chayote, pemoche, tomate coyol, hongos, flor de calabaza, maracuyá, durazno, guyaba, mandarina, plátano, chalahuite, lima dulce, jobo, epazote, cilantro, hierba buena), meaning that Teenek production systems play an important role for food provisioning, not only as a complement as often mentioned in literature (Ávila-Uribe *et al.*, 1994; Bellon *et al.*, 2016; Bioversity International, 2013) but as main source of foods for certain food groups, such as 'dark green leafy vegetables', 'other vegetables', 'vitamin A rich fruits', 'other fruits' and 'spices and condiments', implying that a reduction of the production of these foods could lead to a reduction of the consumption of named food groups.

Of the 31 foods named above which are almost purely harvested, among the ones frequently consumed there are also 9 which are only consumed by a small population group, among these foods are the following crops: luum, lengua de vaca, verdolaga, flor de ortiga, flor de gallo, ut', nesfora, ojo de guajolote, lenteja de árbol. In contrast to the frequently consumed crops, most of these are less frequently sold on local markets, for the same reason that their demand is low. Therefore, there is a risk that if people stop cultivating these underutilized species, they would not be there for consumption any more due to their unavailability through purchase. On the other hand, cultivars might get lost if the use of these plants diminishes (less applicable for wild cultivars, although presence might also go down if they were favoured by human intervention), as the *in situ* conservation of plant genetic resources by farmers is based on their usefulness for them and utilization (Bergamini & Lawrence, 2011).

The most frequently mentioned plants detected in production systems of Teenek households in the study of Cilia López *et al.* (2015) in Tocoy coincide with plants frequently cultivated in the community of Jol Mom: *Vigna unguiculata*, *Ipomoea dumosa*, *Musa paradisiaca*, *Manhiot esculenta* and *Erythrina americana* are also found in Jol Mom. Nevertheless, only *M. paradisiaca* is also named among the most popular crops in Jol Mom. The seasonal availability of the crops mentioned by Cilia López *et al.* (2015) also coincide with the given findings (*I. dumosa, M. paradisiaca, M. esculenta* year-round; *E. americana* in the dry season, *V. unguiculata* in the rainy season).

The importance of home-produced foods is also sustained by the comments from informal interviews which indicate that the purchase of non-staple foods, especially fruits, is only realized in times when surplus money is available. The low consumption of nutrient-rich food groups such as fruits and vegetables which is attributed to the lack of money of households of low socioeconomic status is an issue often found under the topic "the cost of a healthy diet" (Bioversity International, 2017, p. 37), and is especially relevant in the face of a high availability of cheap, nutrient-poor processed foods: Mexico is occupying first place among Latin American countries when it comes to the sale of processed foods (FAO, 2019a), and nutrient-rich foods were found to be more expensive in a community in the Huasteca Potosina than in urban centres, while nutrient-poor, industrialized products were cheaper (Castañeda-Díaz De León *et al.*, 2015).

The management of farming systems therefore contributes to the access to nutritious foods, which is especially important as the study is set the context of a highly marginalized community which is classified as poor, meaning that their purchasing power is low and the farming systems help to buffer this component, providing foods without depending on cash. But more than only providing foods, the subsistence-orientation is a complex system which functions as an insurance policy against adverse climatic events or economic shortages. An illustrative example is the production of coffee firstly for home consumption, and then in stored form it is used to avoid expenditures which the household might face due to the price volatility often observed for this product. Furthermore, in difficult times or when prices are convenient, it serves the purpose of generating cash when it is needed. All in all, the 'safety-net' de Janvry & Sadoulet (2011) described as an opportunity in the context of developing countries if there are no other policies which would protect the farmers against price shocks. Dewey (1989) says that the difference between cash cropping and growing food for home consumption is that while the value of a crop produced for consumption is a function of their nutritional value, the value of a cash crop is monetary and set by the operation of the economic system in which it is participating. The goals of subsistence and commercial agriculture differ; while subsistence farmers aim at minimizing risk in agricultural production, in the market economy the maximization of profit requires farmers to expose themselves to the risk which is involved in participating in a market with price volatility/variability. In Jol Mom a combination of subsistence and market thinking is observed; on the one hand, families use subsistence agriculture as an insurance policy firstly to always be provided with diverse foods, and secondly in times of money shortage to have something to sell, even though it might be little or for a low price, hence, to insure that they never have to suffer from hunger. On the other hand, chili and some other crops serve as cash crops whose sale is carefully calculated, *e.g.* by trying to achieve an early harvest so to obtain a good price in the market, and farmers are aware of the potential return of their crops. This combination of strategies, combined with the adaptability of Jol Mom's farmers and agriculture which was demonstrated when the community's economy had to shift from basing their income on coffee to other horticultural crops demonstrates the resilience of the communities' livelihood strategy, very similar to the findings of Iskason (2009) of the indigenous Guatemalan peasants which base their livelihoods on a variety of strategies but without abandoning *milpa* production.

The surrounding markets are not only a vital place for the sale of the harvest for the people in Jol Mom, they are also a place of exchange of knowledge and seeds. Seeds are kept, according to the people's statements, so that they can continue seeding. For some varieties farmers prefer to use the own seeds, while for others purchase on markets is common.

Overall, in the described pathways of how some peasants manage to procure their food security in Jol Mom (Figure 24), above just the direct consumption of crops, sale of crops, purchase of products, storage for consumption or sale, and seed conservation and exchange, the interplay between the peasant, the farm and the market is crucial for food security and the persistence of this food system. Conceptual frameworks linking agriculture and human health either broadly or in detail have come to similar models; one example is the conceptual model from Bellon *et al.* (2016) which links agricultural biodiversity, dietary and market diversities (Figure 3). Many authors lay the focus on the linkages between the components, while the model presented in this study wants to highlight the temporal component, which can lead to the stability of food availability and access. The functioning of a localized food system and the role of smallholder farmers and their agricultural biodiversity in it are thematized by a variety of authors (Bioversity International, 2017; Ickowitz *et al.*, 2019). It is a topic which overlaps with the presented research and would be interesting to investigate in depth for the case study in order to explore opportunities which *e.g.* might enhance the farmer's possibilities to acquire just prices for their crops or improve collective transportation which could decrease side costs which arise.

An expected but nevertheless significant finding of the presented research is that diets in Jol Mom rely largely on traditional Mexican foods, such as tortillas and beans, which are eaten daily, accompanied by freshly made salsa with chili, and coffee as a beverage. This is against the national trend, which reports a stark decrease in the consumption of maize and beans, while the consumption of fats and meats has gone up (FAO, 2019a). Although no food group dietary diversity score was calculated, results indicate that at least the food groups cereals, legumes, eggs and milk products are covered daily or almost daily, and the high consumption rate of local fruits in the respective season indicates a frequent consumption of fruits. Furthermore, the consumption of some types of vegetable as a side, especially chayote or calabaza, and the frequent use of tomato and onion indicates that the vegetables food group is also covered almost daily. Food groups with lower consumption rate are roots and tubers, meats, and nuts and seeds. While the consumption of basic food groups coincides with findings for Mexico in the literature (FAO, 2019a), meat consumption seems to be lower than the national trend and the consumption of fruits and vegetables higher.

A highlight of the findings of this research is the linear correlation, which was detected between production diversity and food variety, a dietary diversity measure (Figure 17). Reviews show that empirical findings on this topic are mixed (Johns, 2007; Jones, 2017a; Sibhatu *et al.*, 2018), but the tendency is that production diversity has a small but positive impact on dietary diversity (Ickowitz *et al.*, 2019). While most authors use food group dietary diversity scores, such as adapted version of the HDDS (Sibhatu *et al.*, 2017) or the MDD-W (Jones, 2017b), among others, it was refrained from calculating a dietary diversity score for food groups, as the long recall period would not have allowed us to compare the score among studies, and could have led to misguiding assumptions about the results. Nevertheless, the Food Variety Score (FVS) is a more flexible and also valid measure of dietary diversity (Hatløy *et al.*, 1998; Torheim *et al.*, 2003). Although the underlying reasons for the given correlation would have to be investigated in detail it is possible that the correlation is due to Jol Mom's high production of fruits and vegetables, as explained at the start of this chapter. While Sibhatu & Qaim (2017) found that subsistence production was more important for calorie-dense staple foods, therefore not increasing the dietary diversity score significantly, in the case of Jol Mom most fruits and vegetables are retrieved from the production systems, which increases the dietary diversity score with foods which are otherwise unlikely to be purchased.

Still, other factors might interfere. The assessment of household characteristics, the socioeconomic situation of the household, and other variables relating to income generation and agricultural activity were an attempt to account for possible factors interfering in the linkages between agricultural biodiversity and dietary diversity, or food security in general. While there are some weak tendencies regarding land size and agricultural activity which tend to enhance production diversity and food variety, a strong correlation was found with the age of the household heads. This demonstrates that relations are complex, as the age of a household can bring a variety of factors with it. First, the socioeconomic situation of a newly founded household tends to differ from a well-established household which has possibly inherited land, and/or has grown-up children which might even contribute to some financial assistance from outside the community or help cultivating. Secondly, results show that there is also a generational effect of dietary diversity and eating habits (the latter will be discussed in detail further below). Land tenure is found in literature as a factor which increases production diversity (Bellon *et al.*, 2016; Jones, 2017b), but that it was independent from consumption decisions (Bellon *et al.* 2016), which is in line with the presented findings. In general, multiple factors, among the more debatable market access vs. subsistence-orientation are discussed when analysing the link between agricultural biodiversity with dietary diversity (Bellon *et al.*, 2016; Ickowitz *et al.*, 2019; Koppmair *et al.*, 2017). The debate in literature shows that factors are highly context specific, which is also the case for the presented results, which is why it is important to resist from generalizing the findings.

7.2 How are dietary patterns in Jol Mom linked to the management of traditional Teenek farming systems and their associated agrobiodiversity?

Dietary patterns in Jol Mom are heterogeneous, some people rely more on foods from the traditional Teenek farming systems and their related agrobiodiversity than others, but dietary choices do not or only marginally depend on the management of farming systems. Increased management of agrobiodiversity goes necessarily in line with a diverse diet and healthy dietary patterns, although it is not a sufficient criterion for the consumption of healthy food groups. On the other hand, the reliance on purchased foods is a necessary but not a sufficient criterion for unhealthy dietary patterns. Agrobiodiversity management therefore contributes to a healthy diet.

The look at the overall consumption of the sample population suggests an overall adherence to a traditional diet but with a tendency to an increased consumption of processed foods. Such findings have been reported in several studies, they form part of the 'nutrition transition' Mexico is experiencing. In studies in Yucatan for example, authors called it the "coca-colonization of diets" and culture (Leatherman & Goodman, 2005). Nevertheless, observation during fieldwork gave the impression that while on first sight similar products were consumed in the sense that no respondent would report a frequent consumption of foods which were not on the list, and the principal elements of the diet were similar (tortilla, beans, some purchased staple foods, chili, coffee, oil, chicken, some snacks, plus local fruits and vegetables), the consumption frequency of these foods seemed to differ among households. The Principal Component Analysis (PCA) then revealed that in fact dietary patters diverge, and the highlight of the findings was that the food groups which were the most opposing were firstly the nutrient-rich (*e.g.* dark green leafy vegetables, other vegetables from production) vs. the nutrient-poor (*e.g.* sweets, snacks) food groups, and secondly the ones which are exclusively obtained through purchase vs. the ones that are almost exclusively obtained through harvest (Figure 23). What is more, the opposing food groups correspond to in literature established consumption patterns of a westernized diet vs. a diet relying on traditional foods (Flores *et al.*, 2010; Monge *et al.*, 2018; Rodríguez-Ramírez *et al.*, 2011).

A revision of the before discussed is necessary: Yes, the consumption of traditional crops in Jol Mom remains high, but the tendency of decreased consumption of some traditional foods is also visible for a part of the population, *i.e.* the individuals which are situated around the food groups which indicate a westernized diet. For example, beans constitute the main part of the legumes1 group, and the vector points into the direction opposite to the cluster 2, meaning those respondent's bean consumption is relatively low. Also, the presence of the food groups roots_tubers2 (potatoes) and cereals2 (rice, bread, pasta) which point in the direction of the second dimension indicate that those purchased staple foods are preferred over traditional staple foods by a part of the population, hence those households reaffirm the national trend discussed before. The same case is true for an increasing consumption of meats by a part of the population, while fruits and vegetable consumption is low. Nevertheless, there are also similarities shared by the whole sample, such as the consumption of maize, or the use of oil, which were excluded from the analysis because of the uniform daily consumption.

There might therefore be a trend of replacing traditional foods with purchased foods, a finding Dewey (1989) reported in a study where food commoditization lead to a substitution of previous traditional foods grown for home consumption with purchased foods of inferior nutritional quality to the traditional diet.

These findings are highly related to the nutrition transition which is happening on national and even global level, and which is leading, along with the decrease of physical activity, to the high rates of overweight and obesity and noncommunicable chronic diseases which have been declared as Mexico's main nutritional challenge (FAO, 2019a). The contribution of agricultural biodiversity to the traditional and nutrient-rich diet in Jol Mom indicates that the cultivation of food biodiversity could be a window for improving diets in similar contexts, and sustains the validity of the call for food-based, integrated solutions which reunite agricultural production with diets and nutrition (Lamine, 2015). Strategies and trends also include 'nutrition-sensitive agriculture', 'sustainable diets' (Allen *et al.*, 2014; Lairon, 2012), or movements under terms such as 'slow food', 'local food', 'ecological agriculture' and 'agroecology' (Ickowitz *et al.*, 2019).

When getting back to the initial motivation of the study, to find out if the population which is managing all the three traditional Teenek farming systems *solar*, *milpa* and *finca*, is more food secure than the population which has abandoned some of the production systems, there are different trends which can be observed. Firstly, increased age seems to be a main factor which is augmenting production diversity and food variety, tends to maintain a greater number of production systems, and leads to different dietary choices, less influenced by the westernized dietary pattern. Still, there are also younger households managing all three production systems, therefore leading to the heterogeneous pattern. The cluster analysis with the high level of partitioning gives more insight in the different trends (Table 19). Both in the traditional as in the westernized diets there are households which have low overall consumption frequencies, often correlated with lower FVS, and households with high diversity and frequency. Younger vulnerable households tend to correspond to the first, while wealthier young or older households tend to correspond to the latter pattern.

In conclusion, there are two main strategies of ensuring food security in Jol Mom. A traditional way, which implies a high consumption from home produced foods and active management of the farming systems. The second is a provisioning of foods mainly through purchase, and income generation either through wage labour activities or agricultural activity. Consequently, the management of a high number of farming systems seems to help to ensure food security in Jol Mom but is not the only possible mean.

7.3 Final remarks and limitations

In the context of traditional agriculture and rural exodus or poverty, authors discuss the pressures on peasants' livelihoods. Wage employment in Jol Mom is, similar to the situation described in other studies, either preferred to cultivation (Leatherman *et al.*, 2005), which leads to the abandonment of agricultural systems, or is complementing *milpa* production (Isakson, 2009; Schmook *et al.*, 2013). Although it can be considered as a way to continue *milpa* production, a fact that is also claimed by authors (Isakson, 2009; Leatherman *et al.*, 2005) is that engaging in wage employment for an indigenous population means working in the lowest chain of production and assuming the according position in society. Equally, people from Jol Mom have to deal with discrimination outside of the community, and people engaging in wage employment in the countryside or in the cities work in the harvest or in fabrics, earning just enough to make a living. Even among those who have worked in the USA, some prefer to come back to Jol Mom, due to the strong territorial and family attachment, and/or because they prefer the livelihoods and social or natural environment present in Jol Mom.

While models such as "synergies linking biodiversity conservation and human nutrition in developing countries" (Johns *et al.*, 2004, p. 144) (Figure 2) serve to explain desired scenarios, concrete and local case studies often show a different reality. For example, while in the presented case there are indicators that nutrition, socio-cultural traditions and biodiversity conservation might go hand-in-hand, this does not mean that income generation is guaranteed. The evidence from this study can be used to highlight such problems to target the adequate leverage points.

Authors writing about the future of agricultural biodiversity and food security name the *milpa* crop combination of maize, beans and squash as a prime example of nutritionally and environmentally complementary crop combination (Allen *et al.*, 2014; Bioversity International, 2017). Furthermore, in the face of the environmental crisis, the search for sustainable solutions calls for the necessity of integrated systems which support both ecosystem functions as well as promoting human health and other ecosystem services. A broad range of literature which goes beyond the scope of the discussion has discussed the role of indigenous and traditional ecological knowledge in general (Altieri *et al.*, 2011; Berkes *et al.*, 1995; Van Oudenhoven *et al.*, 2011) and of traditional agroforestry systems and the *milpa* specifically (Alcorn, 1984a; Moreno-Calles *et al.*, 2013; Nigh *et al.*, 2013) for the conservation of natural resources, and their cultural importance. This study aims at providing evidence that these farming systems do not only sustain ecosystem functions and fulfil a cultural role but also play a valuable role in ensuring peasants' short- and long-term food security.

In the following, limitations regarding methodology, interpretation of results or the scope of the study are discussed.

When discussing possible variables which might play into the food security status it must be mentioned that a limitation of the present work is that insufficient attention could be paid to the influence of interconnections between households, especially among households with relatives, which can be very strong in traditional communities. Although informants themselves did not draw attention to it, interactions between households could be observed regularly, indicating that there are mechanisms of a community safety net, including food exchange, which have been reported for other studies (Isakson, 2009). Apart from food exchange, family bonds might also play a role in the vulnerability of young families. While the youngest, newly founded families were observed to be the most vulnerable, as generally the only workforce is the man, providing just enough money or products from the field to sustain the woman with the young kids, family bonds in this case which support the young mother by taking care of the kids or providing food, or a more stable work environment if the men can work together with other family members, might make a considerable difference and increase food security – a point which would be worth paying more attention to but which was beyond the scope of this study.

When it comes to food security of the sample population it must be said that while the methods applied in this research served for detecting dietary patterns and pathways of food provisioning, they partly failed in providing evidence about the situation of food security of the sample households. It is important to note that it was not the purpose of the presented study to evaluate the food security status of the population, but it was intended to collect evidence which would indicate tendencies among the households. There are some conclusions that can be drawn, *e.g.* that households from cluster 1 are the most vulnerable as they score low in both consumption scores and in the variables from the survey questions, but overall evidence is limited. For example, the indicator which was supposed to indicate seasonal food insecurity and is also designed to measure food access, the MAHFS tool, failed to provide significant results. The combination of the research with a more extensive and proven tool such as the ELSCA or an adapted version to the indigenous context might generate more informative results on the status of household food security in Jol Mom.

On the other hand, no food security assessment instrument has yet been developed for the application in indigenous communities in Mexico, and the scarce use of standardized tools and a preference of qualitative methods apart from nutritional assessment in the literature dealing with indigenous agriculture and food security demonstrates that there is still room for the development of adequate food security measures in the rural context and especially when working with indigenous communities, as this implies an understanding and respect for cultural differences and livelihoods.

While not possible in this research due to the limited timeframe, an assessment of dietary diversity with standardized tools which have been found to be adequate measures for dietary quality and nutrient adequacy, such as the Minimum Dietary Diversity – Women (MDD-W) (CBD & WHO, 2015; FAO *et al.*, 2017; Jones *et al.*, 2018) would be valuable in order to compare results among studies. Furthermore, results indicate that the application of indicators which are being newly developed specifically for assessing biodiversity in diets, such as the dietary species richness (Lachat *et al.*, 2017), or the nutrition functional diversity score (Luckett *et al.*, 2015) might contribute to support the evidence provided in this study. Nevertheless, in order to adequately use the indicators, official and complete databases must be available, or data must be generated with daily observations of the crop species or cultivars consumed in at least two seasons of the year.

Another limitation of this study which is worth mentioning as it is important for the context of the study are the reliability or the exactitude of the answers regarding some questions of the survey. Questions which involved the estimation of shares, and of amounts of money presented a challenge to the respondent. Firstly, because they possibly presented questions the interviewee had not been exposed to before and were therefore difficult to interpret, and secondly because all the variables which were the subjects of the question, *e.g.* income, expenses and production, are variables which vary strongly throughout the year, and estimations become almost arbitrary when considering this. Nevertheless, they served for getting a rough impression on the level of cultivation activity, on market integration, or on income and expenditure. Another question which was considered as carrying unprecise answers was the question on land size, as the portion of the farmers which has not been enrolled in the formalization of land has generally never tried to find out the size of the land they are working. While the *milpa* fields are measured in a local measure called *tareas* and the farmer knows the land he or she has been working in this year, *finca* and *solar* plot size can be difficult to interpret, and even moreso when the systems merge into the secondary forest which surrounds them, or the *mizcahual*, which is the fallow land from former *milpa* cultivation. Furthermore, some farmers might give a number of the total size of land they know that they possess, even though they are only working on a part of it at the moment, while other farmers name the size of the actively cultivated plot(s) – explaining the wide range of the values of land size. The numbers of land tenure are therefore not to be taken as definitive but rather as a rough estimate indicating the availability of land.

The realization that named data would not represent a good foundation to base the research on, but would nevertheless have complementary or explanatory value, contributed to the decision to lay a focus instead on the data obtained with the food frequency questionnaire, and the analysis of consumption frequency through factor analysis turned out to be a rich source of relevant information.

Regarding the assessment of production diversity, food frequency and division into food groups, all related to the FFQ, several observations can be made. Firstly, the assessment of agricultural diversity in this study is of limited scope. The reduced list of species which was taken into account does not represent the overall agrobiodiversity of the households. There might be farmers which have specialized on non-edible crops, or crops not included in the list, or farmers who rather cultivate a large intra-specific diversity instead of different species, such as has been found by Heindorf *et al.* (in print). In general, an assessment of the contribution of agrobiodiversity on the level of farmer-recognized varieties to food security is a research gap yet to be filled. Regarding the choice of elements in terms of foods, the restriction to the most frequently eaten products does not necessarily reflect the cultural importance of the food. Guajolote, an ancient Mexican domesticated turkey species, might not often be seen on the plates of the people, but was frequently spotted in the home gardens of the respondents. Similar things might happen with seasonally harvested crops which are important in certain feasts. Furthermore, the classification into the different food groups can be a topic of discussion. For example, banana is classified as a fruit, although plantains (the differentiation is complex, as there are varieties which can be eaten at any degree between green and matured) should be classified as 'white roots and tubers' (FAO, 2010), it would therefore have been appropriate to name them in both food groups. Another case is the nopal, according to FAO (2010) classified as the category 'white roots and tubers', where they include "all non-grain-based starchy staples" (p. 38) but botanist might argue that as a succulent stem a classification under 'vitamin A rich vegetables and tubers' or 'other vegetables' would be more appropriate.

As this study was conducted with a small sample size, an application of the methodology with a community-representative sample to ascertain the findings is recommended. The author hypothesizes that it would reaffirm the tendencies of the detected consumption patterns but that the clustering would be adjusted in a way that it sheds further light on the household characteristics of different population groups. Because, although some trends emerged among the households (the age differences, production diversity, FVS), the rather homogeneous or minor revelatory patterns of some variables suggest room for improvement. Clearly, the small sample size which lead to clusters of as few as three or four individuals, also due to the high level of partitioning which was chosen, does not allow for generalisations. Additionally, as mentioned above, the questions regarding household characterization have some limitations regarding the reliability of the answers.

While the study used a small sample size and a single community with similar farming methods and cultural background, it did reveal a heterogeneous picture of households' dietary patterns and livelihoods. A comparison among different communities or farming methods could shed light on the influence of different contexts on the investigated relationship between agrobiodiversity, food security and diets. The suggestion to make comparisons, also according to the settings presented in relevant studies of the topic, between for example communities with high vs. low market integration or high vs. low remoteness, or comparisons between communities or farmers which rely strongly on cash crops vs. subsistence-orientated agriculture, which practice agroecological vs. conventional agriculture, and so on.

Finally it is important to highlight that although a variety of papers have been published which analyse nutritional values of produced or consumed foods in the context of *milpa* cultivation or agroforestry systems (Falkowski *et al.*, 2019; Leatherman *et al.*, 2005), and dietary pattern analysis is an emerging trend in nutrition and has been applied for the risk of Mexicans for noncommunicable diseases (Monge *et al.*, 2018) the combination of both of these types of analysis to detect the contribution of agrobiodiversity to healthy diets seems to not have been explored yet. The presented exploratory study in an indigenous community in the Huasteca Potosina demonstrated that the combination of data collection and analysis tools which was used is valuable for the analysis of the contribution of agrobiodiversity to diets, especially in the face of the current trends of nutrition transition and the urgency to take measures against it. What is more is that the used tools are well established in literature, and both assessment and analysis are relatively quick and easy. They can be adapted to the local context (Food Frequency Questionnaires are one of the most widely used tools for assessing diets and dietary diversity) and adjusted for the aim of the study (*e.g.* by working with portion size in weight or in an ordinal scale for the Principal Component Analysis, instead of consumption frequency). The methodology might also help to address the knowledge gaps highlighted by authors studying the relationship between agrobiodiversity, diet and nutrition, mainly to establish a link between the potential impacts of agricultural biodiversity on overweight and obesity (Jones, 2017a) and to how cultivated and wild biodiversity contribute to overall diet quality instead of the focus in certain nutrients or food groups (Powell *et al.*, 2015).

8 Conclusions and outlook

The research parted from the question of if food provisioning in Jol Mom can rather be explained as a result of the abundance of the traditional farming systems or the high poverty rates the community displays.

Findings show that diets in Jol Mom rely on traditional foods such as maize, beans, chili, and local fruits and vegetables. While staple foods are grown in the *milpa* plots but also obtained through purchase, vegetables such as chayote, calabaza, quelites, nopal and seasonal fruits are mostly derived from the home gardens (*solar*), the *milpa* plots, or the agroforestry systems (*te'lom* or *finca*). Farmers with a greater number of production systems have higher agrobiodiversity indexes.

As almost no perishable foods are sold in the community, the farming systems ensure both availability and direct access to nutritious foods in Jol Mom. A significant correlation was found between production diversity and dietary diversity. Furthermore, cultivation for home consumption functions as a safety-net or insurance against times of low economic resources. The production systems can ensure food security through several pathways. Foods can be either consumed after harvest or sold to generate income which can be used for the purchase of other foods or other household needs. It can also be stored to be consumed at a later stage; a reserve to draw on for sale in times when cash is needed. Finally, the conservation of seeds ensures the continuity of the farming systems and can lead to long-term food security. While the mechanism applies for most households which are actively cultivating and manage several production systems, although the degree of market integration and reliance on cultivated vs. purchased foods varies, the most vulnerable households in Jol Mom which lack resources (land, money, workforce) needed for cultivation are struggling to cover the household's needs.

The multivariate factor analysis of dietary patterns in Jol Mom resulted in two opposing trends. One was characterized by the consumption of purchased foods, *i.e.* products such as meats, eggs, dairy, snacks and sweets, which are related to a westernized diet, while the other one relies on traditional *milpa* crops, with dark green leafy vegetables, legumes, and other fruits and vegetables from the production systems. The clustering of individuals according to food consumption frequency and description of the clusters by household characteristics resulted in a heterogenic picture. The older generation sticks to traditional dietary patterns while the younger generation tends to consume either nutrient-poor purchased foods (sweets and snacks) or nutrient-richer purchased foods (meats, eggs, diary), or combines purchased and produced foods. Generally, among the younger generation more vulnerable households can be found, characterized by the low consumption frequencies, low FVS, and other household characteristics.

While the relationship between agrobiodiversity and food security cannot by described by a single variable, it appears as though there is a positive correlation, above all due to the provisioning of healthy foods. The mixed methods approach allowed to furthermore account for the farmers' own perspectives on diets, food security and agriculture in Jol Mom, and reflects an appreciation of selfproduced foods for their flavour, as well as a pride of local agricultural knowledge – but also a simultaneous awareness that the younger generation strives for other livelihoods.

With the modernization of lifestyles comes the inevitable westernization or 'coca-colonization' of diets and culture. The deprecative and discriminatory treatment of the indigenous population is seen reflected in the rejection of traditional foods by the younger generations, with the aspiration to fit into a modern society. But the association of, for example, meats and diary and purchased foods in general with an elevated social status all but leads to a consumption of factory chicken, processed meats and yoghurt-like drinks, plus the ubiquitous 'comida chatarra', soft drinks and fried snacks. Paradoxically, when looking back to the industrialized countries where named influence comes from, there is a never-before-seen popularity of vegetarian or vegan diets and of the very same 'functional foods' which originate in the traditional agricultural systems of developing countries.

What comes when the traditional way of food provisioning which is still present in Jol Mom for a part of the population is eroded? What are the environmental, cultural and nutritional consequences? What are the consequences for the *in situ* conservation of crop genetic resources? Or, to ask the question a different way, what would happen if the traditional diets and the contribution of Jol Mom's farmers and farming systems to food security and the conservation of resources would be appreciated? This research gave first insights into diet-related outcomes, while the other dimensions are still to be explored, and policy implications to be clarified. In conclusion, when investigating food insecurity or diet-related diseases, especially in the context of marginalized population groups, underlying causes of the social gradient that leads to the divide between rural and urban, indigenous and non-indigenous, female and male, and low socioeconomic and high socioeconomic status in developing countries cannot be ignored. Among others, the food sovereignty movement and the agroecological movement are examples of the recognition of the political dimension of the problematic, which must be more considered in academic food security literature.

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10 Annex

Table 20: Survey applied and evaluated for 40 households in the community of Jol Mom.

Date _____ Participant N° : ______ Nombre : _______________________ Jefa / Jefe

1.	Jefe **(M)**	Jefa **(F)**
De Jol Mom	□ Si □ No	□ Si □ No
Habla Teenek	□ Si □ No	□ Si □ No
Habla Español	□ Si □ No	□ Si □ No
Escolaridad	□ Prim □ Sek □	□ Prim □ Sek □
Estatus ejido	Ejidatario/Posesionario/Comunero	Ejidataria/Posesionaria/Comunera

2. ¿**Cuántas personas** viven en el hogar? ¿Edad? ¿Viven **permanentemente** ahí o no?

Tipo de hogar: □ **núcleo** □ **compuesto**

____ adultos Edad: __________ F / M Perm. □ Si □ No
Edad: __________ F / M Perm. □ Si □ No
Edad: __________ F / M Perm. □ Si □ No
Edad: __________ F / M Perm. □ Si □ No
____ niños Edad: __________ F / M Perm. □ Si □ No
Edad: __________ F / M Perm. □ Si □ No
Edad: __________ F / M Perm. □ Si □ No
Edad: __________ F / M Perm. □ Si □ No
Edad: __________ F / M Perm. □ Si □ No
Edad: __________ F / M Perm. □ Si □ No

SISTEMAS AGRÍCOLAS

3. ¿**Cuántas personas en su hogar cultivan** algo o hacen la *milpa*? ¿Quiénes?

____

4. ¿La parcela de usted le está rentando o es su **propiedad**?
   - □ Propiedad Hectáreas: ______________________________
   - □ Alquilado/prestado

SOLAR

5. ¿Cultiva su ***solar*** con especies comestibles?
   - □ Si
   - □ No ¿Antes tenía? □ Si □ No
     ¿Por qué lo dejó? ___________________________________
6. ¿Qué son los **cultivos principales** de su *solar*? (chayote, mango, plátano, cítrico, …)

____

MILPA

7. ¿En el año pasado, tenía ***milpa***?
   - □ Si
   - □ No ¿Antes tenía? □ Si □ No
     ¿Por qué lo dejó? ___________________________________
8. ¿Qué son los **cultivos principales** de su *milpa*? (frijol, maíz, calabaza, chile, …)

____

TE'LOM

9. ¿Tiene ***finca / te'lom***?
   - □ Si
   - □ No ¿Antes tenía? □ Si □ No
     ¿Por qué lo dejó? ___________________________________
10. ¿Qué son los **cultivos principales** de su *te'lom / finca*? (café, plátano, cítrico, …)

____

11. ¿Tiene algún **otro cultivo**? (Nopal, naranjal, platanal, …)

____

DESTINO DE PRODUCTOS AGRÍCOLAS

12. ¿Cuánto de la producción agrícola es para el **consumo propio, cuanto es para la venta o intercambio**?
    - ☐ Menos de la mitad para la venta
    - ☐ Mitad
    - ☐ Mas de la mitad para la venta

13. ¿**Vende** durante todo el año o únicamente en una temporada específica?
    - ☐ Todo el año
    - ☐ Temporada (meses): ______________________________________

14. ¿Cuáles son los productos que **más vende**?
____

15. ¿A quién? o ¿Donde?
- ☐ Intermediarios de Xol Mom
- ☐ Venta directa en: □ Tancanhuitz □ Tamapatz □ Tamapaxal
  □ Aquismón □ Cd. Valles □ Otros: __________________________

CONSUMO

16. ¿Cuánto de los productos que consumen en el hogar **tienen que comprar**?
    - ☐ Menos de la mitad tienen que comprar
    - ☐ Mitad
    - ☐ Mas de la mitad tienen que comprar

17. ¿**Dónde** compra/consigue los productos que NO produce?
    - ☐ Tienda de Xol Mom
    - ☐ Mercados: _______________________________
    - ☐ Préstamo, trueque, cambio por mano de obra, regalo de amigos o parientes
    - ☐ Otros (ayuda alimentaria, …): _____________________________

18. ¿Cuánto de sus ingresos se invierten en **gastos para alimentos**? **Suma/semana: ____________**
    - ☐ Menos de la mitad se invierte en alimentos
    - ☐ Mitad
    - ☐ Más de la mitad se invierte en alimentos

SEGURIDAD ALIMENTARIA

19. ¿En el año pasado, siempre **alcanzó el dinero** para conseguir los alimentos suficientes para darle de comer a toda la familia?
□ Si □ No Estrategia: ____________________________

20. ¿En el año pasado, siempre encontró la variedad de alimentos que necesita y le gustan para su familia en la **tienda** o **mercado**?
□ Si □ No

21. ¿Hubo algún mes dentro de los últimos doce en los que **no tuvieron suficientes alimentos** para satisfacer las necesidades de la familia?
□ Si □ No

22. **En caso de que si:** ¿cuáles fueron los meses (en los últimos 12 meses) en los que no hubo suficientes alimentos para satisfacer las necesidades de la familia?

	2018									2019		
(Mar)	Abr	Mayo	Jun	Jul	Agos	Sept	Oct	Nov	Dic	En	Feb	Mar

Razones de la falta: ____
Estrategias de adaptación/mitigación: ____
[¿Qué alimentos escasean?] ____

23. ¿En su hogar, **cuántas veces** comen al día?
□ 1 □ 2 □ 3 □ 4 □ 5

24. Cuestionario de frecuencia de consumo de alimentos

ASPECTOS ECONOMICOS

25. ¿Recibe **apoyo gubernamental**?
    - ☐ No
    - ☐ Si
        - o Prospera (antes Oportunidades)
        - o Programa de apoyo alimentario (despensa → productos básicos)
        - o Programa de 65 y más
        - o PROCAMPO (para cultivo, efectivo, 1 vez al año)
        - o Otros: ___________________________________

26. ¿Cuántas personas de su familia trabajan / contribuyen para los gastos domésticos?
    - ☐ Número: __________________

27. ¿En qué trabajan?
    - ☐ Venta de productos agrícolas
    - ☐ Venta de mano de obra
    - ☐ Trabajo fuera de Xol Mom por migración temporal
    - ☐ Trabajo fuera de Xol Mom permanente (emigración)
    - ☐ Trabajo fijo en Xol Mom
    - ☐ Otros: ______________________________

28. ¿Recibe apoyos de personas que han emigrados? (remesas)
    - ☐ No
    - ☐ A veces
    - ☐ Regularmente / constantemente

29. ¿Cuál de los ingresos económicos mencionados es la fuente de ingresos más importante del hogar? (¿Cuál es la mayor fuente de ingresos?)
    - ☐ Venta de productos agrícolas
    - ☐ Venta de mano de obra
    - ☐ Trabajo fuera de Xol Mom por migración temporal
    - ☐ Trabajo fuera de Xol Mom permanente (emigración) → remesas
    - ☐ Trabajo fijo en Xol Mom
    - ☐ Subsidios y apoyos gubernamentales (Oportunidades, PROCAMPO, …)
    - ☐ Otros: ________________________

ULTIMAS PREGUNTAS (ABIERTAS)

30. ¿Si usted tuviera la opción de trabajar en algo diferente que la agricultura, lo haría? ¿Le gusta cultivar?
____

31. Si tiene *milpa*: ¿Usted, porque hace la *milpa*, porque cultiva?
____

32. Si tiene *solar*: ¿Usted, porque cultiva plantas comestibles en su *solar*?
____

33. Si tiene *finca*: ¿Usted, porque mantiene una *finca*?
____

34. ¿Considera que es importante conservar las semillas y cultivos criollas en Xol Mom? ¿Por qué?
____

35. ¿Usted conserva semillas?
____

36. ¿Sus hijos saben cultivar? □ Si □ No ____

37. ¿Piensa que alguno de sus hijos se dedicará a la agricultura en el futuro?
    □ Si □ No ____

Table 21: Food Frequency Questionnaire applied and evaluated for 40 households in Jol Mom.

		Cultiva		Consumo							Origen		
	PRODUCTO	Si	No	Nunca	En temp	1/mes	2/mes	1/sem	2-6/se	7/sem	Prod.	Compra	Otros
1	**Maíz** (Tortilla nixt/comp)												
2	**.Arroz**												
3	**.Pan**												
4	**.Pasta** (fideos, ...)												
5	**Frijol coloní**												
6	**Frijol mal te**												
7	**Frijol pukul**												
8	**Frijol huet**												
9	**Frijol sarabanda**												
10	.Soya												
11	Lenteja de árbol												
12	Lenteja												
13	**Jícama**												
14	.Papas												
15	Camote												
16	Yuca												
17	Luum												
18	Papa del monte												
19	**Quelite**												
20	**Suyo**												
21	**Lengua de vaca**												
22	**Chayote**												
23	**Hoja de Chayote**												
24	**Calabaza pipián**												
25	**Calabacita** aguad/seca												
26	**Chile**												
27	Cebollín												
28	**.Cebolla**												
29	Epazote												
30	**Nopal**												
31	Pemoche												
32	**Tomate**												
33	.Zanahoria												
34	Verdolaga												
35	**Cilantro**												
36	Tomate coyol												
37	**Guayaba**												
38	**Maracuyá**												
39	Mandarina												
40	**Mango**												
41	Melón												
42	**Naranja**												
43	**Papaya**												
44	Piña												
45	**Plátano**												
46	**Nesfora**												
47	**Capulin**												
48	**Chalahuite**												
49	Zapote												
50	Sandia												
51	Uva												
52	Mamey												
53	Lichi												
54	Limón												
55	Anona												
56	Fresa												
57	**.Manzana**												
58	Aguacate												
59	.Coco												
60	Durazno												
61	.Tamarindo												
62	Carambola												
63	Lima dulce												
64	**Ajonjolí**												
65	Sem. de calabaza												
66	**Cacahuate**												
67	**Pipián; Piñón**												
68	.Leche												
69	.Queso												
70	Yogurt												
71	**Huevos**												
72	Gallina, pollo												
73	Cerdo												
74	.Res												
75	.Pescado en lata												
76	Embutidos												
77	**.Aceite**												
78	**.Comida chatarra (Sabritas, cuernos)**												
79	Manteca												
80	**Pilonc/Azúcar**												
81	**.Galletas, pan dulce**												
82	**.Refrescos**												
83	Piloncillo												
84	**Café**												
85	.Sopa marucha												
86	Hongos												
87	Hierba buena												
88	Flor de calabaza												
89	Flor de hortiga												
90	Fl de gallo Koxolhuiz												
91	Jobo K'inim												
92	Café bomba												
93	Ut'												
94	Ojo de guajolote Hual palaz												
95													
96													

Table 22: Notes and quotes on farmer's motivation to maintain farming systems or reasons why they decided to abandon them.

Part N°	¿Pq tiene *solar?*	Pq dejó *solar*	¿Pq hace *milpa*?	Pq dejó *milpa*	¿Pq tiene *finca*?	Pq dejó *finca*
2			"Todos siembran; y creemos que da, uno también siembra y cuando da ya no tenemos que comprar"			
4	Es fácil cosecharlo		"Porque nos gusta, y por tradición, porque queremos cosechar algo, como elote y maíz"		"Para no comprar café". "También para sacar dinero." Un poco es para el consumo, un poco para la venta	
5			"Para comer, y ya no quiere salir afuera para trabajar"			
6			"Aquí da todo"			
8				Nunca tuvo. Es pareja joven y no tienen dinero para hacer *milpa*.		
10			Para vender			
11			Porque se necesita, para el hambre			
12			Para comer			
13			"Para que haiga, sino no hay nada"			
14			"Porque me gusta, y porque sale dinero"			

Part N°	¿Pq tiene *solar?*	Pq dejó *solar*	¿Pq hace *milpa*?	Pq dejó *milpa*	¿Pq tiene *finca*?	Pq dejó *finca*
16			Para tener alimentos, para no comprarles			
17			"Cuando haiga no vas a comprar"	Se necesita dinero por qué se necesita terreno y gente para limpiar		Ya no tiene terreno, el esposo vendió todo
22			"Para sembrar algo para comer. Estamos acostumbrados de trabajar aquí, no quiero salir."			
23			Para que no compran maíz o elote. Para después hacer tortillas de maíz nuevo.			
24			"Sino hacemos *milpa*, hay que comprar el maíz"			
25			"Cuando uno no tiene dinero, de ahí agarra para comer. Es la manera de sobrevivir"			
26			Para comer			
28		Sólo tiene un plátano, el *solar* es muy chiquito	Para la familia, para sostener la familia, para no comprar maíz		Para que haiga café para vender una parte, y la otra parte para el gasto	
29		No tiene terreno, *solar* sólo abarca la casa. Solo tiene una mandarina y un lichi.	"A mi esposo le gusta sembrar maíz"		También para sembrar ahí	
30	Para trabajar		Para comer			
32	Para sembrar algo			Trabaja en la carpintería, ya no le da tiempo		Ve que no le sale dinero, entonces lo dejó así
33	Para el consumo					
34			Cultiva para mantener la familia	Ya no vive el esposo, ya no puede por falta de tiempo y dinero	También para mantener	
35	Si uno quiere trabajar, y sembrar, sale para comer. "Si sembramos algo y sale ya no tenemos que comprar"		Para no comprar elotes		A veces da mucho el café. Lo venden y sale dinero	
36	Para vivir también		Para comer, para ya no comprar		También, para cosechar	
37			Por qué le gusta hacer la *milpa*		Para tener café	
38	Para no comprar		Para no comprar el maíz, frijol, y muchas cosas		Para que haiga café, y es como un patrimonio (para que no se acab"a luego. Antes vendía mucho	

Part N°	¿Pq tiene *solar?*	Pq dejó *solar*	¿Pq hace *milpa?*	Pq dejó *milpa*	¿Pq tiene *finca?*	Pq dejó *finca*
					café, y llevaba muchas cosas)	
39	Para que la tierra no se quede sin sembrar		Siembra "por qué lo vendo, y para comer". *Milpa* porque esposo tiene procampo (un pedazo)			
40			Para que haiga cosas			
41	El chayote tiene tusas. Aquí cerca se puede controlar		Para no comprar maíz		Para sacar dinero. El café está ahora a 50 Pesos por kilo, es mejor que ir al contrato	
42				No hay terreno		
43			Queremos volver al tiempo cuando estábamos trabajando, hacer la lucha para que salga	Este año si quiere hacer *milpa*. Pero ya casi no quiere hacer *milpa*. Es difícil porque se necesita dinero. Y ya no se puede cazar. Ni pájaros ni ardillas ni víboras.		
44			"Cuando cosechan sale dinero." "Cuando no siembras y escuchas la gente que ya cosecha te sientes mal, ya es costumbre de sembrar y cosechar."		Lo limpiamos para que no se te hecha a perder. Cuando sacas mucho café te alcanza para todo el año. Ya no tienes que comprar, y el kilo está a 50-55 pesos.	Sólo voy al café cuando este mi esposo, el limpia. Pero él está en contrato
45	También si no tenemos *solar* tendríamos que comprar		Para no comprar, y para que haiga elote, nos gusta. Para comer porque a veces no tenemos dinero		También para no comprar café.	
46				Es mucha inversión pagar al trabajador, y tiene que tumbar		Por la plaga, y ya no limpia
47	Gallinas y puerco comen todo, casi no podemos sembrar ahí.		Por no sufrir el hambre, así podemos salir a vender y comprar algo para los hijos	Esposo sale a trabajar, ya no puede ir mucho, está lejos, no quiere ir sola (tiene miedo de víboras), trabajadores ya no quieren trabajar	Para sembrar algo ahí (en patio no da nada)	Casi no da, necesita que lo limpiemos, pero no nos da tiempo

Table 23: Notes and quotes from informal interviews on Food Security and diet in Jol Mom, issues related to agriculture-based livelihoods, and migration. The number in brackets corresponds to the ID of the interviewee who made the statement.

Topic	Comments
Food security	Food security now versus before - "Ahora ya hay todo. Carnes etc., cuando tienen dinero pueden comprar. Antes, compramos puercos y les engordábamos. Ahora es caro engordarlo con maíz." (23) - "Toda la gente ha mejorado, salen a vender y compran. Ya hay más dinero, puede buscar más que comer." (28) - "Cuando estaba chiquilla sufría mucha hambre. Casi no me daban de comer, fui huérfana. Puro plátano, chayote y cositas, no había tortilla. Ya no sufro hambre. Ahora está mejor la gente. Este año si va a dar." (37)

Topic	Comments
	- "Subió el precio del maíz, frijol y del aceite." (26) - "Antes, no había carne de puerco y pollo ni nada para comprar. Ahora es rápido comprar pollo de granja, y huevos de granja. Antes no había aceite, pura manteca." (23) Subsistence production - "Casi nos alimentamos de lo que producimos (verduras). Ya subió el precio de maíz, frijol, azúcar, aceite, café." (23) - "Casi no hay hambre si tienes que vender." (24) - "Lo que sembramos es para el gasto, para no comprarlo. Sembramos poquito." (28) - "Antes el chayote se vendía barato. Hay gente que piensa que estamos peor, pero son los que no trabajan. Los que siembran pueden sacarlo. Hay gente que se siente más pobre, y otros mejor." (28) - "Aquí no hay necesidad de comprar nada, y además es otro sabor [los productos de la *milpa*]." (39)
Diet	- "Nos acostumbramos a comer así los productos de la *milpa*, y está bien. Carne no ocupan todos. La dieta ha cambiado un poquito. Ahora es mejor, se hace el chayote guisado. Antes no había aceite." (28) - "Antes, la gente comía Lúm con frijol guisado. Ahora los niños ya no quieren el Lúm. Ahora comer es más bueno, pero no es verdad. Ahora es carne y queso. Pero no, lo mejor es lo que hay en el monte. "(35) - "Tengo alta presión. El doctor dice: No comes ese, ese, ese, como el café, refresco, carne de puerco, manteca, calabaza, nopal. Lo que es bueno es el frijol con sopa. Y el chayote reseco, el moothid. Sólo ese es bueno." (35) - "El problema es que los que venden tacos comen mucha carne." (35) - "Ahora la gente come salchicha, huevos, sabritas, es más diferente. Antes no, y hacíamos el huevo en hoja de plátano, sin aceite. Ahora se ocupa más aceite. Ahora hay muchos que comen pollo de granja, antes no." (38) - Positivos: "Ahorita hay todavía tierra que trabajar. Uno come y vende." (36) - "Comemos un día el frijol mal'te, el otro pukul, otro día calabaza y un día chayote" (21) - "Los jóvenes ya no quieren comer lo que hay aquí. Piden chorizo y huevo y queso." (4) - "Aquí la gente come igual. Los que van a Valles, ellos ya comen otras cosas. Traen chicharrón, pollo, queso." (23)
Agriculture	Daño por animales - "El maíz ya casi no se siembra porque a casi no dejan los animales. Antes trabajaba toda la gente. Ahora ya muy pocos. Antes, había muchos campos y menos animales. Antes no estaba prohibido matar a los animales." (24) - "Antes había mucho cazador. Se le espanta. Ahora la *milpa* ni siquiera da para una semana, junta puro jilote. Porque vienen los animales, y porque no puedo limpiar." (43) Climate, environmental conditions - "Hay climas diferentes en Jol Mom. Aquí es más fresco, al otro lado pega más el sol, ahí da más temprano." (24) - "Ahora está más temprano todo. Antes, estaba tan húmedo que ni podían quemar en marzo. Antes no daban los mangos, ahora si (mango y aguacate)." (24) Agricultural activity in Jol Mom - "Antes, éramos cafetaleros en Jol Mom. Ahora uso variedades mejoradas, era un regalo del gobierno, para toda la comunidad. Pero antes se usaban las criollas. Antes ganábamos dinero con la venta de café, pero en la helada se perdió todo y después ya la gente se desanimó y ya no daba mucho. Son matas que casi no tienen frutos, están secos. El mejorado crece bien, el mío tiene 5 años. Ahora pronto tengo que tumbar los árboles para que quede libre de sombra." (4) - "Aquí salen mucho a vender, mujeres como hombres. La gente está despierta. Jol Mom es primer chayotero!" (24)

Topic	Comments
	- "Antes el quelite no lo compraban. ¿Tal vez porque había bastante? Ahora si lo compran, ahora se vende todo. Comemos poco y más vendemos y compramos otra cosa. Vendemos chayote, quelite, verdolaga, suyo. La gente que vive dónde no hay estas cosas lo compra. Para vitamina." (35) - "Cuando hay productos, se llenan cinco a seis camionetas el domingo. Antes se le llevaba vencedor (el bus, transporte público), todos los días. Ahora es en camionetas. Antes se vendía en Valles. Antes de que pasó la balacera." (38) - "Los señores son los que cultivan. Siembran todo lo que da aquí." (41) - "Aquí todo da, casi todos salen a vender. Ya casi no ayudan uno al otro. Sacan cosas a vender, para el dinero, y después compran. En otras comunidades no hay trabajo, a lo mejor no siembran y no venden. Aquí si hay trabajo." (45) - "Maíz come el animal. El maíz ya subió de precio, deberíamos sembrar eso." (47) - Tiene 2 ha de café en 2 pedazos. De mizcahual tiene 3 pedazo. De ¾ ha, de ¼ ha, de 1 ha *milpa* (28) - Las mujeres cuando se juntan con un hombre ya no están apoyadas por su papá, ya es responsabilidad de la familia del hombre. No reciben tanto terreno como el hijo, eso depende de la familia. (4) Coffee-based livelihoods - "Ahora ya llevamos cuatro años que no da el café." (24) - "Antes vendían café pero barato, ahora se vende caro, aunque no hay." (28) - "Café no da, no sabemos por qué. No han floreado en este año tampoco. Pero igual la gente está cultivando." (37) - "Más de 100 personas entraron al programa de café." (41) - "El café de abajo viene con fertilizante. Antes hubo más café, antes de las heladas en 83 y 86. Antes, los troncos estaban gruesos, ahora ya no. En limoncillo estaba la gente con la báscula. Vendíamos el café barato, o lo cambiamos por maíz, frijol y piloncillo." (23) - "Antes, no sembrábamos chile. Antes éramos cafetaleros. Antes estaba todo blanco de flores. Ahora estamos un poco tristes porque no hay café." (24) Changes in livelihoods - "Antes se cultivaba más. Era más grande el terreno. Ya salen a trabajar. Ganan más a trabajar afuera que trabajar aquí." (30) - "Ahora ya no es igual como antes. Antes, no necesitabas mucho estudio para el trabajo. Ahora, hay que saber de computadores, y del teclado. El tiempo ya no es como antes. Antes había mucho chayote, hasta se perdía. Ahora se seca ¿falta fertilizante? ¿Mucho sol? Ahora hace más calor." (38) - "Ahora estamos en la gloria." Antes tenían que cargar en lomos para ir al mercado, hasta Santos. (23) - "Ahora la gente tiene otro modo para mantenerse. Los abuelos hacían *milpa*. Sembraban y con eso se mantenían. Por flojera ya no se hace como antes. Antes no había carretera, llegó en 1976. Ahí empezó a salir la gente." (24) Price of workforce in *milpa* - Pagan 100 Pesos por tarea en Jol Mom. (42) - "Para hacer una cosa se necesita dinero. Para sembrar maíz se necesita dinero. Cobran 150 Pesos con comida, sale a 200 Pesos por día de contratar un peón." (38) Use of inputs for agriculture - No usa fertilizante. (23) - No aplica herbicida. Tiene fertilizante, pero no lo ocupa. Porque dicen que cuando aplican fertilizante, después ya se seca la tierra. Para el café si ocupa el fertilizante. 200 gramos por mata, cada año. Pero para *milpa* no. El uso de fertilizante seca la tierra al otro año. (28)
Migration	Migration - "Aquí no se paga agua. Aquí se paga la luz nada más. En la ciudad se paga la renta, el agua, la luz, el camión. Aquí está en la casa. Si quiere trabajar, trabaja. Si no, no. A veces ni hay que comprar agua. Yo también fui a Monterrey a trabajar, pero dije porque estoy aquí, mejor voy a mi tierra." (46)

Topic	Comments
	- "Mucha gente no tiene terreno donde trabajar, entonces mejor se van por otro lado." (41) - "Algunos se van y ya no trabajan la tierra. Ya no quieren trabajar en el monte." (37) - "aquí hay trabajo, pero no hay dinero" (29) Ganancia en contrato - En el contrato se ganan aprox. 200 Pesos/día. (41) - Ahora trabajan con contrato, casi todos los jóvenes. Cuando se termina el dinero, ya se van otra vez. (41) Young people and their preferences - "Los jóvenes tienen terreno, pero no les interesa trabajarlo." (28) - "Los jóvenes ya puro estudio y los viejos ya no pueden hacer mucho trabajo. Cuando uno se enferma es cuando uno sufre. Los muchachos ya no quieren ensuciarse." (24) - "Estuve afuera por 7 años, después regresé. Los jóvenes salen a aventurarse. Algunos si quieren regresar, algunos no. La vida con la familia en la ciudad es más complicada. Aquí uno se ahorra en gas, venta, agua. Eso no se paga aquí." (25) - El grande no quiere ir a la escuela, se porta mal. El en medio ya lee y escribe. Quiere que siga, le dicen que tiene que seguir estudiando. No quiere que pase a sus hijos lo mismo como a ella. "Yo quería estudiar, pero antes no daban el apoyo." Aquí no hay trabajo, se fue a trabajar afuera. Cuando se cansó y regreso, ahora tiene los hijos. (44)

Table 24: Summary of interviews with key informants on the perception of challenges regarding food security in the region and in Jol Mom.

Interviewee	Summary of interview
Volunteer for health issues (Voluntaria de la salud) in the community of Jol Mom – 03/04/2019	Los hábitos alimenticios si han cambiado. Ahora lo que quieren es el queso, el chorizo, ahora pega mucho la diabetes. Ellos prefieren vender sus productos que comerles. Aproximadamente la mitad de los diabéticos son hereditarios, es decir que la enfermedad es genética. Para los que salen positivos por mala alimentación es porque comen grasas, pan, refresco y el problema es la falta de ejercicio, y que comen descontroladamente. Y pasan días sin comer después se descontrola la alimentación. Son los mayores de 35 en adelante. Ahora tenemos 32 diabéticos, más los nuevos que vienen el 17 de abril. En 2018 augmentó mucho el número. Para hipertensión el problema es la falta de ejercicio. De obesidad tenemos unos cinco o seis casos, cuatro son adolescentes y dos adultos. La gente sale a vender y lo que traen es puro pollo, chorizo y salchicha. Los niños ya no quieren comer nopal, chayote y suyo. Puro huevo, y la gente compra otras cosas de abajo. De ahí nace todo que tiene que ver con las enfermedades. Los abuelitos consumen chayote, verdolaga, suyo.
Nurse in the local hospital 'Unidad médica rural Tampaxal N° 163' – 03/04/2019	Desnutrición hay poco en Jol Mom. Ellos viven de sus plantas, del Chayote, Chile, estas cosas. Lo que más pega ahí es la falta de saneamiento básico. Lo que es la diarrea, los vómitos, los parásitos, las enfermedades de vías respiratorias. Por la falta de higiene. Toman agua del pozo, solo algunos compran agua de botellas. Se les dice que hay que hervirlo, pero no les gusta el sabor y después no lo hacen. De obesidad si tenemos algunos casos. Es por la comida chatarra, comen mucho lo que son las Sabritas, los cueros preparados, las frituras, las palomitas, chicles, paletas y dulces. También comen la sopa marucha y el pollo con cuero [la grasa/piel]. Eso tiene mucho colesterol. La desnutrición ha bajado. Pero la obesidad ha augmentado, la hipertensión ha augmentado y la diabetes ha augmentado. De diabetes hace 12 años teníamos 40 casos. Ahora son 160 a 180 casos aproximadamente. De hipertensión teníamos 100 a 150 casos hace 12 años, ahora son más de 200. Tenemos talleres, es parte de las medidas de prevención de primer nivel. Cada mes o cada dos meses. Ya ha mejorado poquito. Antes se consumía mucha carne de puerco. Ahora es menos manteca, antes comían pura manteca. Ahora es más aceite y ya casi no carne de puerco, más res. Ya no consumen tanto refresco, más agua.

Interviewee	Summary of interview
Physician responsible of the local hospital 'Unidad médica rural Tampaxal N° 163' – 16/04/2019	En este momento tenemos cuatro niños entre las tres localidades Jol Mom, Tampaxal, San Isidrio de desnutrición leve, y les solicitamos cada mes para control. Pero son más, pero estoy valorándoles todavía. Quiero implementar un día a la semana para hacer la prueba EDI, queremos ir por localidad para ver cuántos niños hay en riesgo. Pero todavía estamos en el proceso de iniciarlo. Aquí, desde pequeños la alimentación es mala. Ya están comiendo frituras, ya están tomando refrescos. Y los niños que tienen antecedentes de los papas o abuelos con enfermedades, ya son más propicios a tenerlo también. Niños con sobrepeso tengo pocos, pero no tengo los datos exactos. Tenemos ahora 82 personas diabéticas y 143 personas hipertensos, entre Jol Mom, Tampaxal y San Isidrio. La tendencia va augmentando. Por ejemplo, en Jol Mom ya hicimos la detección de las personas mayores, a partir de los 20 hacia arriba. Hicimos 120 detecciones. 38 salieron sospechosos, 80 normales, uno ya es confirmado. De 70 mujeres y 50 hombres. Es para la detección de glucosa. Si en la segunda toma salen también positivos, se inicia el tratamiento. Pueden ser hereditarios o por los usos y hábitos alimenticios que se tiene. Aquí se necesita orientación sobre nutrición y tratamiento. Piensan si están en tratamiento ya pueden tomar refresco, o las frituras. Aquí el problema es el refresco, el café con azúcar y el pan. Los pacientes que veo entre 30 y 50 años son los más descontrolados. Los de 50 hacia arriba son un poco más controlados. Nunca hace falta las verduras y las frutas, aquí producen y además aquí hay días de comercio, donde pueden vender sus cosas y comprar otras cosas.

Table 25: Comments on foods captured during the conduction of the survey. The number in brackets corresponds to the ID of the respondent who made the statement.

Food item	Comment
Maíz	"Cuando no nos da tiempo para hacer nixtamal, usamos maseca para hacer tortilla" (4) (15) "Usamos maseca para hacer tortilla" (15) "El año pasado sembramos 35 tareas de maíz, pero no cosechamos nada, el jabalí y el tejón casi no dejan. Sólo dejan el chile" (22) "No salió, se lo comió el tejón" (35) "Lo que cosechamos es sólo para comer elotes" (40) "Tortillas de maseca, casi no de maíz. Preparar la tortilla de maíz nixtamalizado ocupa mucha agua, y nos hace falta agua" (40) "Los animales no dejan" (45) "No nos alcanzó mucho porque tenemos muchos puercos y pollos que quieren comer también" (45)
Pan	"A veces no hay dinero" (24) "Cuando hay dinero" (38) "Cuando alcanza dinero" (42)
Pasta	"Para el bebé" (40)
Frijol coloní	"Casi no se cultiva en Jol Mom. Se compra en temporada y en tienda cuando hay" (4). "Para bocoles" (2) "No hay" (28) "Tierno más rico, después para atole" (39) "Casi no se puede conseguir aquí" (44) "Casi no hay" (46) "Casi no nos gusta" (47)
Frijol mal te	"No me gusta casi" (36) "En bocol" (39) "Casi no siembran" (46)
Frijol pukul	"Chichalaca lo comió, no dio" (35)
Frijol huet	"Cuando está tierno, tiene sabor. Después ya no" (38) "Tierno nada más, con suyo" (39) "Casi no le gustan a los niños, quieren enlatados" (41) "Mi abuela comía pero ya no he visto ese frijol" (44)
Frijol sarabanda	"Sólo en temporada" (23) "Tierno y seco, en bocol y tamales" (39) "Casi no lo comemos, sólo lo vendemos" (41) "Lo comemos tierno y seco, pero después ya no hay dónde comprar" (44) "Casi todo lo vendemos, no comemos" (47)
Lenteja de árbol	"En el bocol" (12) "Nos regalan" (35) "De los vecinos" (36) "Cuando está tierno, tiene sabor. Después ya no" (38) "Tiernitos se venden" (38) "Tierno, en bocol" (39) "Casi no lo quieren los niños" (41) "Antes sí" (43)
Lenteja	"No me gusta" (45)
Jícama	"No alcanza el dinero" (38) "No lo deja el tejón" (43) "Aquí no hay" (46)
Papas	"Cuando hay dinero" (42)
Camote	Muchos dijeron que se come cuando hay (?) "En *finca*" (39) "Regalan" (40) "Tejón no deja, casi no hay" (41)

Food item	Comment
Yuca	Igual como camote "Regalan" (40) "En monte" (42)
Luum	"Antes era común comer" (4). "Mis hijos y los niños ya no quieren comerlo" (2) "Ya casi no hay" (21) "Se cose con cáscara, a veces arde en la boca" (23) "Perdí las semillas" (23) "Hay una que hace comezón y otra que no." (12) "Ya no hay. Casi no comemos, antes sí." (24) "Ya no lo quieren comer" (24) "Sólo yo lo cómo, a los otros no les gusta" (35) "De vecinos" (36) "Si piensas algo malo, no lo puedes sacar" (38) "Con frijol" (39) "No conozco" (40) "Los niños ya no quieren" (41) "Casi no hay" (46) "Da comezón en la boca" (47)
Papa del monte	"Eso ya nadie lo come" "Ya no hay" (23) "No hay" (26) "Antes sí" (35) "no hay aquí" (38) "Atole, o cocido" (39) "Cuando encuentra en monte" (39) "En el café" (45) "Casi no hay" (46)
Quelite	"Vendemos, pero casi no consumimos" (4), (15) "Encontramos" (42)
Suyo	"Cuando nos da tiempo de ir al monte" (15) "En monte" (32) (45) "No si no salimos a buscar" (46)
Lengua de vaca	"Vendemos, pero casi no consumimos" (4) "Las gallinas no dejan" (23) "ya no, antes si había" (46) "Casi no me gusta" (47)
Chayote	"Vendemos, pero casi no consumimos"(15)
Calabaza pipián	"Sólo tierno" (39)
Calabacita aguad/seca	"Vendemos, pero casi no consumimos" (4) "Al niño no le gusta" (23) "La mayoría vendemos" (24)
Chile	"Da sabor a la comida" (43) "Si no hay chile se siente que uno no está comiendo" (43)
Cebollín	"Se come cuando no hay cebolla" (5) (23) (39) (41) (45) "Cuando está cara la cebolla" (39)
Epazote	Se come con nopalitos (6) (16) (43) "No les gusta a mis hijos" (29) "Con nopal" (35) "No dejan los pollos" (41)
Nopal	"Lo vendo con espina porque no nos gusta limpiarles. Lo compramos sin espina" (38) "Cuando no tengo tiempo para limpiar no lo comemos" (45)
Pemoche	Es difícil cosechar, ya se han muerto personas por caer del árbol (?) "No hubo tiempo de buscarlo" (28) "A veces regalan" (36)
Zanahoria	"Para el caldo" (28)
Verdolaga	"Vendemos, pero casi no consumimos" (4) "No hay" (26) "En *milpa*" (39) "Se encuentra a veces" (43)
Cilantro	"Con frijol" (12)
Tomate coyol	"No he ido a verlo" (43) "No me ha dado tiempo a verlos, están lejos" (45)
Guayaba	"Salen mal" (4)
Maracuyá	No da (26)
Mango	"Salen piqueados" "No da" (26) (38) "No sale bien, tiene gusanos" (39) "A veces no da" (41) "Lo compramos cuando venden en frutería" (41)
Melón	"No hay dinero" (42) "Compramos cuando dan el apoyo, cada 2 meses" (45)
Papaya	"Regalan" (42)
Plátano	"Plátano cotillón cuando está tierno se hecha al frijol" (23)
Nesfora	"Encontramos" (26) "Pedimos a vecinos" (38)
Capulín	"No me gusta" (4)
Hoja de Chayote	"Cuando no hay frijol" (12) "Cuando no hay nada" (26) "Sólo las más tiernas. Cuando se quita la hoja, ya no da chayote" (44)
Chalahuite	"En monte" (26) "A veces regalan" (36)
Zapote	"Salen mal" (4)
Mamey	"Sale gusanado" (41)
Manzana	"Es caro" (12)
Tamarindo	"Pasa una muchacha que vende" (39)
Carambola	"Regalada de la sobrina" (39)
Semilla de calabaza	"No, porque se guarden para sembrar" (44)

Food item	Comment
Leche	"Consumen los niños" (los lácteos) (6) "Para los chiquillos" (43)
Yogurt	"La niña" (35) "Para el bebé" (43)
Gallina, pollo	"Cuando hay dinero" (47)
Cerdo	"No venden aquí" (28) "Caro" (35) "Casi no nos gusta" (35)
Res	"Es caro" (4)
Comida chatarra	"Ahora ya no, porque está enferma del riñón" (39) "Cuando tenemos dinero" (41) (42) "Los chiquitos" (45) "Los muchachos comen" (47)
Azúcar	"Cuando no hay azúcar, no tomamos café" (26)
Galletas, pan dulce	"Cuando hay dinero" (41)
Sopa "Maruchan"	"Los niños quieren" (2) "La muchacha" (45)
Hierba buena	"Con caldo" (2) "Con pollo" (35)
Flor de ortiga	"Se come en pascua" (4) (21) "Miedo de las espinas" (38) "No fuimos a buscar" (43) "No me gusta" (47)
Flor de gallo	"No da seguido" (4) "Casi ya no" (24) "A veces se encuentra en el monte, no hay sembrado" (28) No sabe de eso (32) "Cuando buscamos" (33) "En monte" (35) (38) "Pica feo" (41) "Cuando nos dé tiempo a buscar" (43) "Se encuentra en la aurilla de carreteras, aquí no se encuentra" (44) "Antes si, ya no quieren los jóvenes" (46) "No me gusta" (47)
Jobo	"Para agua" (24) (39) "Crece en *finca*" (33) (44) "Regalan" (36)
Café bomba	"Tierno se come con cebolla, chile, ajo, comino. Seco se prepara como el café" (39)
Ut'	"Casi nadie lo quiere comer" (24) "Hay lejos" (26) "Cuando buscamos en el monte" (28) "Con frijol" (35) (39) "Casi no comemos, es difícil conseguir" (44) "Crece en el monte, nace sólo. Después de quemar empieza a brotar la guía, da en los cerros" (44) "Crece en *milpa*, nace solo." (45) "Con suyo" (45)
Ojo de guajolote	"En mizcahual" (21) "Ya no, porque ya se taparon. Antes si había" (24) "Cuando encontramos (26) "Crece en el monte" (33) "No sé qué es" (35) "En monte" (38) "Casi no comemos. Si hay bastante pero no nos gusta. Mejor compramos refresco, es más fácil" (41) "Cuando encontramos" (43) "Ya no lo he visto, antes si" (44) "Hay en la *finca*" (45)

Table 26: Correlation matrix of nominal variables from survey, plus calculated production diversity and Food Variety Score (FVS).

	nr_cultiv	*ha*	*nr_systems*	*m_age*	*f_age*	*nr_hh_perm*	*nr_adults*	*nr_children*	*nr_not_perm*	*expenses_foo*	*FVS*	*Prod_div*
nr_cultiv	1											
ha	0.102591	1										
nr_systems	0.440415	0.329325	1									
m_age	0.200018	0.569137	0.513007	1								
f_age	0.201695	0.518549	0.448713	0.931273	1							
nr_hh_perm	0.28805	0.108894	0.092263	-0.03284	-0.14309	1						
nr_adults	0.25045	0.248267	0.443701	0.368303	0.369205	0.429517	1					
nr_children	0.168505	0.215782	-0.11132	-0.17538	-0.28585	0.773596	-0.12768	1				
nr_not_perm	-0.08848	0.112675	0.113361	0.168896	0.081247	0.090074	-0.08413	0.137572	1			
expenses_foo	0.011997	0.266745	-0.0393	0.071694	0.018788	0.089983	0.123228	0.033142	-0.08077	1		
FVS	0.322963	0.366002	0.5237	0.528756	0.498724	0.103078	0.38222	-0.05464	0.106085	0.074916	1	
Prod_div	0.601176	0.525935	0.697685	0.57345	0.547394	0.154642	0.407066	0.05227	0.060284	0.028708	0.699955	1

Figure 25: Code used for the conduction of PCA and HCPC in R. Tables used as input for analysis can be requested from the author.

```
# Load libraries ----------------------------------------------------------
library(pacman)
pacman::p_load(tidyverse, corrplot, readxl, raster, FactoMineR, factoextra)

g <- gc(reset = TRUE)
rm(list = ls())
```

```
options(scipen = 999)
# mutate(variable = str_extract(var, "[a-z]+"))

# Load data ----------------------------------------------------------------
sht  <-  excel_sheets(path  =  'C:/Users/kgueb/Desktop/Data_R/2019_07_18_cortando/Resultados
Cuestionario and FFQ 10_for R.xlsx')

# FFQ_freq_groups ----------------------------------------------------------
print(sht[[1]])
tbl  <-  read_excel(path  =  'C:/Users/kgueb/Desktop/Data_R/2019_07_16_1st_alone2/Resultados
Cuestionario and FFQ 10_for R.xlsx', sheet = sht[[1]])
colnames(tbl)
tbl <- tbl %>%
  gather(var, value, -ID) %>%
  mutate(variable = gsub("\\..*", "", var)) %>%
  dplyr::select(ID, variable, value) %>%
  group_by(ID, variable) %>%
  summarise(avg = mean(value),
            mod = modal(value)) %>%
  ungroup() %>%
  dplyr::select(-mod) %>%
  spread(variable, avg) %>%
  dplyr::select(-oils)

# Correlation analysis -----------------------------------------------------
myFunction <- function(tbl){

  print('To start...!')
  tbl <- tbl[,2:ncol(tbl)]
  mtx <- as.matrix(tbl)
  mtx <- mtx[,2:ncol(mtx)]
  colnames(mtx)[colSums(is.na(mtx)) > 0]
  M <- cor(mtx)

  png(filename = 'corplot.png', width = 14, height = 14, units = 'in', res = 300)
  corrplot(M, method = 'circle', type = 'upper')
  dev.off()

  print('Principal Component Analysis')
  res.pca <- PCA(mtx)
  plot(res.pca, invisible = 'quali')
  lapply(dimdesc(res.pca), lapply, round, 2)

  gg1 <- fviz_eig(res.pca, addlabels = TRUE, hjust = -0.3) +
    theme_bw()
  ggsave(plot = gg1, filename = 'fviz_eig.png', units = 'in', width = 11, height = 7, dpi =
150)

  png(filename = 'dims_percentage.png', units = 'in', width = 11, height = 7, res = 100)
  barplot(res.pca$eig[,2], main = 'Percentage of variance',
          names.arg = paste0('dim', 1:nrow(res.pca$eig)))
  dev.off()

  res.hcpc <- HCPC(res.pca)

  gg2 <- fviz_pca_biplot(res.pca,
                         label= "var",
                         habillage = res.hcpc$data.clust$clust,
                         addEllipses = TRUE,
                         ellipse.level = 0.95) +
    theme_bw()
  ggsave(plot = gg2, filename = 'fviz_eig_biplot.png', units = 'in', width = 11, height = 7,
dpi = 150)

  cls <- res.hcpc$data.clust %>%
    as_tibble()
  res.hcpc$desc.axes
  res.hcpc$desc.ind
  res.hcpc$desc.var$quanti.var
  res.hcpc$desc.var$quanti

  tb2  <-  read_excel(path  =  'C:/Users/kgueb/Desktop/Data_R/2019_07_18_cortando/Resultados
Cuestionario and FFQ 10_for R.xlsx', sheet = 'Surv_PCA_Nominal')

  tb2_cnt <- tb2 %>%
    dplyr::select(nr_cultiv,  ha,  nr_systems,  nr_sys_exact,  m_age,  f_age,  nr_hh_perm,
nr_adults,  nr_children,  nr_not_perm,  expenses_food,  FCS_healthy,  FCS_all,  FCS_produced,
Prod_div) %>%
    mutate(cluster = pull(cls, 21)) %>%
    gather(var, value, -cluster) %>%
    group_by(cluster, var) %>%
    summarise(value = mean(value, na.rm = TRUE)) %>%
    ungroup()

  tb3  <-  read_excel(path  =  'C:/Users/kgueb/Desktop/Data_R/2019_07_18_cortando/Resultados
Cuestionario and FFQ 10_for R.xlsx', sheet = 'Surv_PCA_Categorical')
  tb3_clt <- tb3 %>%
```

```
    dplyr::select(status_ej,  ownership,  solar,  milpa,  milpa_maize,  finca,  m_spanish,
f_spanish,  m_education,  f_education,  hh_type,  sale_amount,  sale_seasonal,  sale_interm,
sale_markets, purch_amount, purch_where, income_food, money_sufficient, strat_pedir_fiado,
strat_work_more,  strat_eat_less,  lack_food,  lack_rainy_season,  lack_other_seasons,  meals,
prospera,  sesentaycinco_mas,  procampo,  coffee,  work_production,  work_peon,  work_contrato,
work_others, remittances, mayor_income, mem_hh_expen) %>%
    mutate(cluster = pull(cls, 21)) %>%
    gather(var, value, -cluster) %>%
    mutate(value = as.numeric(value)) %>%
    group_by(cluster, var) %>%
    summarise(value = modal(value, na.rm = TRUE)) %>%
    ungroup()

  write.csv(tb2_cnt, 'variables_cuantitativas.csv', row.names = FALSE)
  write.csv(tb3_clt, 'variables_cualitativas.csv', row.names = FALSE)
}
```

Table 27: Correlation matrix with exact values corresponding to Figure 18.

	cerea ls2	eggs	fru_o thers 1	fru_o thers 2	fru_v it_a	legu mes1	legu mes2	meat s_fis h	milk_ prod	nuts_ seeds	roots _tub ers1	roots _tub ers2	snac ks	spice s	swee ts	veg_ dark_ green	veg_ other s1	veg_ other s2	veg_ vit_a 1	veg_ vit_a 2
cereals2	1	0.32	-0.1	0.2	0.07	0	0.23	0.54	0.48	0.27	0.07	0.52	0.17	0.2	0.36	-0.2	-0	0.55	-0	-0.1
eggs	0.32	1	0.03	0.25	0.26	0.13	0.2	0.46	0.25	0.01	0.2	0.17	0.29	0.16	0.19	0.22	0.05	0.37	0.06	-0.1
fru_others1	-0.1	0.03	1	0.26	0.33	0.56	-0.1	0.11	-0.2	0.26	0.32	-0.1	-0.3	0.34	-0.2	0.54	0.6	0.14	0.12	0.3
fru_others2	0.2	0.25	0.26	1	0.34	0.07	0.14	0.54	0.23	0.14	0.12	0.33	0.1	0.02	0.22	0.05	0.07	0.31	-0	0.36
fru_vit_a	0.07	0.26	0.33	0.34	1	0.23	0	0.18	-0.1	0.26	0.4	-0	0.13	0.46	-0.1	0.33	0.28	0.1	0.12	0.33
legumes1	0	0.13	0.56	0.07	0.23	1	0.19	0.05	-0.2	0.46	0.68	-0.2	-0.2	0.6	-0.2	0.79	0.73	0.25	0.46	0.23
legumes2	0.23	0.2	-0.1	0.14	0	0.19	1	0.14	0.28	0.17	-0.1	0.18	0.22	0.03	0.04	0.28	0	0.2	0.04	0
meats_fish	0.54	0.46	0.11	0.54	0.18	0.05	0.14	1	0.57	0.12	-0.1	0.43	0.38	0.07	0.61	-0.1	-0.1	0.16	-0.1	0.13
milk_prod	0.48	0.25	-0.2	0.23	-0.1	-0.2	0.28	0.57	1	-0	-0.2	0.39	0.4	-0.1	0.67	-0.2	-0.3	0.38	-0.1	0.22
nuts_seeds	0.27	0.01	0.26	0.14	0.26	0.46	0.17	0.12	-0	1	0.48	0.05	-0.1	0.48	-0	0.52	0.48	0.18	0.42	0.05
roots_tubers1	0.07	0.2	0.32	0.12	0.4	0.68	-0.1	-0.1	-0.2	0.48	1	-0.1	-0.2	0.54	-0.2	0.62	0.59	0.32	0.63	0.22
roots_tubers2	0.52	0.17	-0.1	0.33	-0	-0.2	0.18	0.43	0.39	0.05	-0.1	1	0.18	0	0.41	-0.3	-0.3	0.38	-0.1	0.13
snacks	0.17	0.29	-0.3	0.1	0.13	-0.2	0.22	0.38	0.4	-0.1	-0.2	0.18	1	-0	0.47	-0.2	-0.2	-0.1	-0.1	0.01
spices	0.2	0.16	0.34	0.02	0.46	0.6	0.03	0.07	-0.1	0.48	0.54	0	-0	1	-0.1	0.54	0.59	0.26	0.23	0.23
sweets	0.36	0.19	-0.2	0.22	-0.1	-0.2	0.04	0.61	0.67	-0	-0.2	0.41	0.47	-0.1	1	-0.3	-0.2	0.14	-0.1	0.09
veg_dark_green	-0.2	0.22	0.54	0.05	0.33	0.79	0.28	-0.1	-0.2	0.52	0.62	-0.3	-0.2	0.54	-0.3	1	0.7	0.11	0.49	0.28
veg_others1	-0	0.05	0.6	0.07	0.28	0.73	0	-0.1	-0.3	0.48	0.59	-0.3	-0.2	0.59	-0.2	0.7	1	0.12	0.49	0.2
veg_others2	0.55	0.37	0.14	0.31	0.1	0.25	0.2	0.16	0.38	0.18	0.32	0.38	-0.1	0.26	0.14	0.11	0.12	1	0.19	0.32
veg_vit_a1	-0	0.06	0.12	-0	0.12	0.46	0.04	-0.1	-0.1	0.42	0.63	-0.1	-0.1	0.23	-0.1	0.49	0.49	0.19	1	0.28
veg_vit_a2	-0.1	-0.1	0.3	0.36	0.33	0.23	0	0.13	0.22	0.05	0.22	0.13	0.01	0.23	0.09	0.28	0.2	0.32	0.28	1

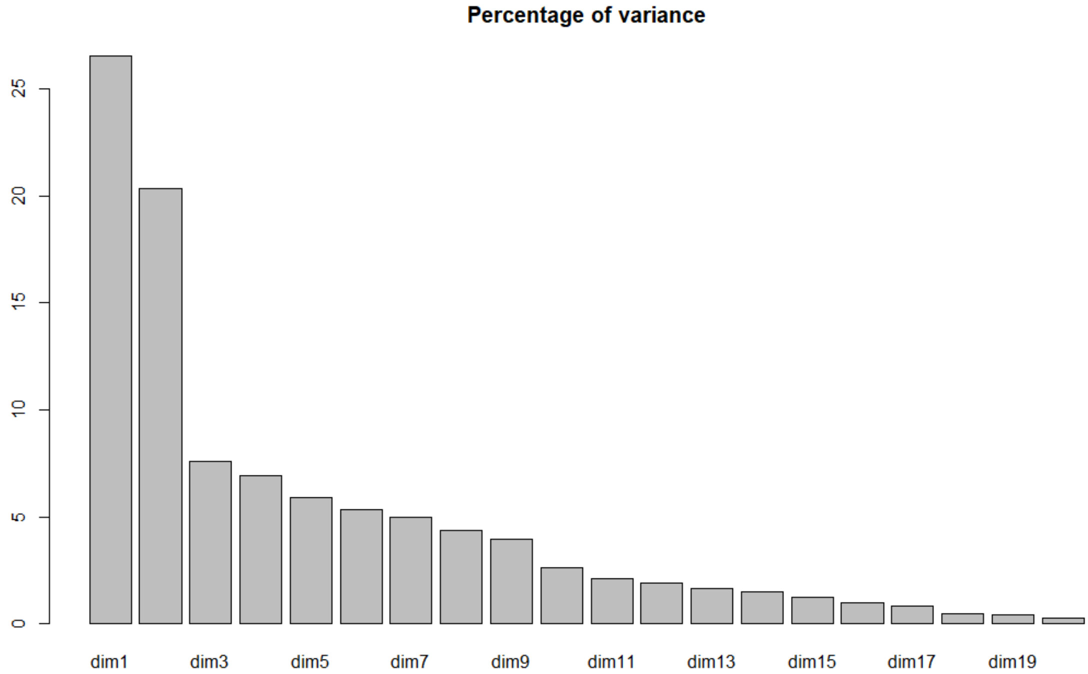

Figure 26: The eigenvalues which are associated with each dimension of the PCA. It shows that a great part of variability of data can be explained by the first two dimensions, and that it drops on lower than 10 % of variance (lower than 1) for the third dimension.

Table 28: Definition of clusters by principal components or dimensions.

```
Description of each cluster by quantitative variables
=====================================================
$`1`
         v.test Mean in category  Overall mean sd in category Overall sd      p.value
Dim.1 -2.193970        -2.427478 -3.233525e-16       2.046978   2.303221 0.0282375803
Dim.2 -3.935321        -3.813111 -9.088216e-16       1.549096   2.017021 0.0000830857

$`2`
         v.test Mean in category  Overall mean sd in category Overall sd      p.value
Dim.3 -2.731987       -0.8741929  9.011888e-16      0.7548387   1.230717 0.0062953704
Dim.1 -3.419286       -2.0475824 -3.233525e-16      0.9736482   2.303221 0.0006278573

$`3`
        v.test Mean in category  Overall mean sd in category Overall sd    p.value
Dim.3 2.370661         1.640724  9.011888e-16      0.6865652   1.230717 0.01775633
Dim.2 2.326354         2.638725 -9.088216e-16      0.7017923   2.017021 0.01999967

$`4`
        v.test Mean in category  Overall mean sd in category Overall sd     p.value
Dim.2 3.261941         2.287505 -9.088216e-16      0.6142695   2.017021 0.001106522
Dim.4 2.445942         1.002928 -4.648192e-16      0.5637840   1.179364 0.014447417

$`5`
         v.test Mean in category  Overall mean sd in category Overall sd     p.value
Dim.4 -2.920716       -0.9553565 -4.648192e-16      0.7478485   1.179364 0.003492275

$`6`
        v.test Mean in category  Overall mean sd in category Overall sd      p.value
Dim.1 3.956425         3.860604 -3.233525e-16      0.7384306   2.303221 7.607985e-05
```

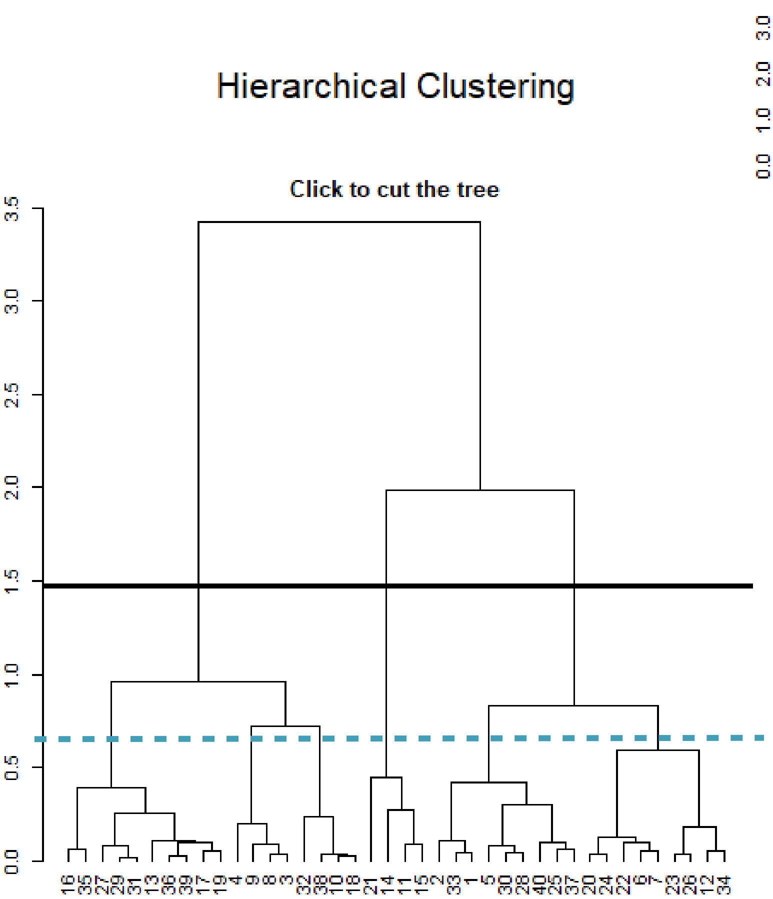

Figure 27: Dendrogram of hierarchical clustering of individuals, with the dashed line representing the level of partitioning.

Figure 28: A *milpa* plot situated on a steep slope close to the community of Jol Mom, Aquismón, SLP Mexico.

Figure 29: Maize is hung up over the fireplace to conserve seeds for the next season.

Figure 30: Chile piquin, a commonly cultivated chili variety in Jol Mom.

Figure 31: The comal, a flat clay-made griddle used to cook and toast tortillas and other foods over the fireplace.

Figure 32: Example of a biodiverse dish including quelites, nopal, flor de ortiga and tomate, prepared in the community of Jol Mom.