Várzea floodplain agriculture in the Colombian Amazon

Recommendations for agroforestry in the Yahuarcaca floodplain

Bachelor thesis

Ellen Rietberg

Forest and Nature Management - Tropical Forestry

Supervisor: Jaap de Vletter

Van Hall Larenstein University of Applied Sciences (VHL)

The Netherlands

Tropenbos International-Colombia

Várzea floodplain agriculture in the Colombian Amazon

Recommendations for agroforestry in the Yahuarcaca floodplain

Leticia, Amazonas, Colombia

Bachelor thesis

Forest and Nature Management - Tropical Forestry

Ellen Rietberg

Van Hall Larenstein University of Applied Sciences (VHL)

The Netherlands

Supervisor: **Jaap de Vletter**

Tropenbos International- Colombia

Supervisors: **Carlos Rodríguez**

Hans Vellema

January 2014

Keywords: agriculture, floodplain, agroforestry, Amazon

Acknowledgements

Firstly, I would like to thank the organisation Tropenbos International for giving me the opportunity to do this thesis. Special thanks to Carlos Rodríguez for welcoming me in Colombia and for his contagious enthusiasm, and to Hans Vellema who always took the time to revise my work and provide useful comments.

This thesis would not have been possible without the help of the University of Colombia in Leticia. I would especially like to thank Santiago Duque for his help and opening the laboratory for me. Also thanks to all other people from the University who helped me.

I would like to thank everybody from the community San Sebastián de los Lagos for giving me the chance to do this research and for their cooperation with interviews. In particular I would like to thank Ángel Fernández Ramos for his help during the whole process and all the efforts during the fieldwork. Furthermore I would like to thank the people from El Castañal whom I interviewed.

I would also like to thank Jaap de Vletter for his guidance from the Netherlands.

In addition I would like to thank my family and friends for supporting me.

Last but not least I would like to thank Kees and Camila, for their helpfulness, patience and positivity. But most of all for their friendship and the wonderful time we had in the jungle.

Abstract

Várzea forests are seasonally flooded forests inundated by white (nutrient rich) water from the Amazon River. The várzea is not only ecologically important but also plays an important role in sustaining livelihoods. The floodplain lake is a characteristic habitat of the Amazon floodplain. During the high water period many tree species start flowering and fruiting. Certain fish species consume the fruits, seeds and flowers of those trees. Many local people depend on the fishery resources of the floodplain lakes, fish serves as the most important source of protein for them. Apart from that, the soils of the várzea floodplain are fertile because of the sediments from the Andes Mountains carried by the river; therefore these areas are very suitable for agriculture. Nowadays the várzea forest is one of the most threatened ecosystems in the Amazon due to deforestation and overexploitation.

The Yahuarcaca floodplain is located in the Amazonas region in southern Colombia, close to the city of Leticia. There, different indigenous communities make use of the floodplain lakes for fishing and use the area for agriculture. Since local people depend on fishery and agriculture, a decrease in the amount of fish and the lack of agricultural land are two important problems. The cause of diminishing fish populations is, apart from overfishing, more often the disappearance of habitat. Furthermore the várzea ecosystem, which provides many environmental goods and services, is degraded. Food security is under threat and malnutrition in the region is common. *Agroforestry* is the combination of trees and crops on agricultural land. It has the potential to decrease pressure on the remaining várzea forest while improving local livelihoods through supporting food and nutritional security. This research focuses on one of the communities near the Yahuarcaca lakes: San Sebastián de los Lagos. San Sebastián is an indigenous community consisting mainly of Ticuna people. The traditional agricultural plots are called *chagras.* Apart from providing food, the chagras of the Ticuna people are of cultural importance to them and related to complex ecological knowledge. The objective of this study was to describe their current agricultural system in the várzea and give an agroforestry-based advice to increase food production and provide alimentation for fish, thereby contributing to food security and sustainability of the várzea. To reach this objective social and ecological research was combined, consisting of interviews with 31 farmers and visiting their 31 agricultural plots.

The agricultural system is small-scale and labour intensive. It was found that the farmers of San Sebastián mainly cultivate cassava *(Manihot esculenta)* in the várzea. Other annual crops frequently cultivated are lulo *(Solanum quitoense),* long coriander *(Eryngium foetidum),* maize *(Zea mays)* and watermelon *(Citrullus lanatus).* Currently agroforestry practices are already a part of the agricultural system and consist of planting trees and sparing trees during weeding that naturally grow in the field. Some species commonly grown are guava *(Psidium sp.),* guamilla *(Inga sp.)* and huito *(Genipa americana).* These trees are usually present in low quantities and placed near the border of the field. During the last decades many changes took place, which has resulted in a greater demand for food but a decline in availability of food from natural resources. Therefore optimally using the agricultural land is particularly important. It can be concluded that there is room for improvement within the current agricultural system. Five species have been selected that can be used for improving agroforestry practices: acaí *(Euterpe oleraceae),* camu-camu *(Myrciaria dubia),* ubo *(Spondias mombin),* guava *(Psidium sp.)* and huito *(Genipa americana).* Planting these species will have direct effects on the sustainability of the várzea and on food security by providing alimentation for fish and increase food production for local people. Other expected benefits are a contribution to maintaining biodiversity and providing goods like timber and firewood.

Contents

List of figures

List of tables, photos and text boxes

List of abbreviations and definitions

AZCAITA	Asociación de Autoridades Indígenas Tikuna, Cocama y Yagua del Trapecio Amazónico Colombiano (The Regional Association of Indigenous Authorities)
DBH	Diameter at Breast Height
CORPOAMAZONIA	Corporación para el Desarrollo Sostenible del Sur de la Amazonia (Corporation for the Sustainable Development of Southern Amazonia)
CIFISAM	Centro de Investigación, Formación e Información para el Servicio Amazónico (Centre for Research, Training and Information for the Amazonian People)
FAO	Food and Agriculture Organisation of the United Nations
GPS	Global Positioning System
IDEAM	Instituto de Hidrología, Meteorología y Estudios Ambientales de Colombia (Institute of Hydrology, Meteorology and Environmental Studies of Colombia)
PRONATTA	Programa Nacional de Transferencia de Tecnología Agropecuaria (National Program for Agricultural Technology Transfer)
SINCHI	Instituto Amazónico de Investigaciones Científicas (Amazonian Institute of Scientific Research)
TEK	Traditional Ecological Knowledge

Ecosystem goods and services
The benefits that humans receive from the natural processes and functions of healthy ecosystems. *Direct use* involves some form of physical interaction with the good or service, for example the provision of food, fuel and medicines. *Indirect use* refers to ecosystem services with an indirect benefit, for example storm protection by forests.

1 Introduction

1.1 Context

Most of the Amazon River is bordered by floodplain. A characteristic habitat of the Amazon floodplain is the floodplain lake (Goulding, Smith and Mahar 1993). Those lakes are influenced by the flood pulse, which means that during the rainy season increasing water levels of the Amazon River cause an increase of the water level of the lakes, so the lakes are isolated during one part of the year, and connected with the river during the other part. The nutrient rich white water from the river that enters the lakes carries a large amount of sediments from the Andes Mountains (Prieto-Piraquive 2006). Because of this annual inundation the plants and trees growing in the area are partly under water during several months. These seasonally flooded forests which are inundated by white water are called *várzea* (Prance 1979).

One of the reasons the várzea forest is important is because of the ecological functions it performs. It is an important area for biodiversity and contains a high amount of endemic plant and animal species adapted to the fluctuating water levels (Goulding 1980). Furthermore, the high water period coincides with the flowering and fruiting of many tree species, of which the fruits, seeds and flowers are consumed by fish. This causes fish to migrate from the lakes, streams and river to the várzea forests. Besides providing alimentation, the forest serves as a refuge and breeding site as well.

Apart from its biological importance, várzea forests play an important role in sustaining local people's livelihoods; várzea residents often depend on its natural resources (Pinedo-Vasquez, et al. 2011). Fisheries provide the most important source of animal protein for many people. Furthermore, wild plants and trees are exploited for food; many products from the forest like fruits and nuts are being harvested.

Besides, because of the yearly renewal of nutrients, soils of the várzea forests are very productive and therefore the várzea has a great potential for agricultural food production (Goulding, Smith and Mahar 1993). The agricultural system in the várzea usually consists of cultivating annual food crops; crops are planted at the beginning of the low water period and harvested before the water level rises. Although there is a flooding risk, yields can be higher than in the upland shifting cultivation system (National Research Council 1993).

However, nowadays floodplain forests are one of the most threatened ecosystems in the Amazon, caused by intense deforestation and overexploitation (Junk, et al. 2010). Large parts of the Amazonian floodplain forests have been cleared for agriculture, livestock ranching and logging. Deforestation means the disappearance of fish habitats and this is the most important reason for diminishing fish populations, although overfishing also poses a threat (Goulding 1999). The loss and degradation of these ecosystems and diminishing fish populations have consequences for food supply for local inhabitants depending on natural resources; unsustainable use of the várzea threatens local livelihoods (Pinedo-Vasquez, et al. 2011).

Agroforestry is a way to contribute to decreasing pressure on remaining várzea forests (Junk, et al. 2010). The World Agroforestry Centre defines agroforestry as: "A dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels" (Nair 1993).

Agroforestry practices are often included in the shifting cultivation system in Colombia (Hammond, Dolman and Watkinson 1995, Eden and Andrade 1987).

Agroforestry systems partially replicate the forest and support great biodiversity. Furthermore agroforestry has the potential to improve living standards by diversifying income sources, while decreasing soil degradation and improving soil structure (Smith, et al. 1998). Besides, it can support food and nutritional security in different ways, by directly providing tree foods such as fruits, by increasing farmers' incomes and by supporting different ecosystem services (Jamnadass, et al. 2013).

An example of the use of agroforestry species in a floodplain area to improve local livelihoods is the planting of *Myrciaria dubia* ("Camu-camu") in várzea forests of the Peruvian Amazon. This is a tree with edible fruits that serve as alimentation for fish as well (Rodrigues, et al. 2001). Another example is a project for the conservation of river dolphins of the Omacha Foundation. Part of the program was to reforestate the flooded forests of the Tarapoto lakes in Puerto Nariño with *pepeaderos.* These are tree species of which the fruits, seeds or flowers are eaten by fish, as shown in Photo 1 (Omacha Foundation 2009).

However, just a small portion of the different land uses in Amazonia consists of agroforestry (Smith, et al. 1998). According to Smith (1996) "economically viable agroforestry systems are urgently needed in the Amazon". It is seen as a good option when shifting cultivation is no longer sufficient to feed a growing population, especially in the humid tropics (Smith, et al. 1998).

This thesis focuses on the agricultural system and agroforestry in the várzea of the Yahuarcaca floodplain in the Amazonas region in Colombia. The Yahuarcaca floodplain lakes are an important part of this wetland ecosystem. Apart from agriculture, important uses of the area are: tourism, livestock keeping, fishing and extraction of timber and non-timber forest products. Besides, the water from the lakes serves as a source of drinking water for the people of Letícia. At the moment seven communities, consisting mainly of an ethnic group called Ticuna, use the lakes for fishing: La Playa, El Castañal, San Antonio de los Lagos, San Juan de los Parentes, San Antonio de los Lagos, San Pedro de los Lagos and San Sebastián de los Lagos. Part of the fish is for their own consumption and part of it for small scale selling at the local market. Fish serves as the most important source of protein for the people (Corpoamazonia 2006).

Photo 1 A pirarara catfish eating the fruit of the jauari palm (Goulding 1993)

1.2 Problem analysis

In general, modernization often results in loss of traditional knowledge and traditional cropping patterns and management practices (Altieri and Merrick 1987). For Colombia's indigenous population, the loss of natural resources within their territories and loss of traditional knowledge are two important reasons for their vulnerability to food insecurity (Peña-Venegas, et al. 2009).

Because of its location near the city of Letícia and the nearness to the borders of Peru and Brazil, many people are using the resources of the Yahuarcaca lakes. The ecosystem of the lakes is degraded due to human activities. In many parts of the várzea forest the soil is eroded, mainly because of overgrazing. Clearing land for the establishment of agricultural fields and livestock keeping as well as timber extraction have contributed to deforestation. Furthermore, at some parts of the lake there have been forest fires in 2006 (Corpoamazonia 2006). Therefore, about 10 hectares consists of severely degraded forest dominated by *Cecropia sp*. (Van Vliet 2012).

Van Vliet (2012) also describes that the extraction of timber and non-timber forest products has caused an impoverishment of habitats and a decrease in availability of goods and services in the study area.

Sustainability of fishery resources in the Yahuarcaca lakes is under pressure because of overfishing (Prieto-Piraquive 2006). The deforestation in the area contributes further to the diminishment of fish populations. This poses a problem for the local population.

Besides fishery, agriculture is an important means of existence, as mentioned before. Due to population growth there is a decrease in agricultural area available per family. Shortage of land is a problem for the communities in the area, which is worsened by conversion of land into grazing area for livestock. Some people have to rent agricultural land so their growing areas are minimal and productivity low. The population of San Sebastian which consists of 513 people only has 58 hectares of land at their disposal (Corpoamazonia 2006). Peña-Venegas, et al. (2009) state that the situation of indigenous communities surrounding Leticia is extreme, there is not enough land to produce sufficient food and people are economically dependent on temporary work like road building and construction. The community of San Sebastián de los Lagos has the least amount of hectares of land available per family of all communities surrounding Leticia (Peña-Venegas, et al. 2009). Although the local government has plans to buy new land, they have not succeeded yet. This means that the agricultural fields people have in the várzea is not only good for production because of the fertile soil, but necessary because there is no other option for cultivation.

Food security is at high risk and agricultural practices are said to be inadequate to feed the population. Therefore quality of life has diminished (Municipality of Leticia 2004). Food insecurity is one of the main causes of malnutrition. In the Amazonas region malnutrition is common. More than half of the people suffer from protein (50.3%) and vitamin A (51.5%) deficiency. 96.8% of the people do not get enough calcium and 29.2% has a vitamin C shortage, percentages are higher than in the rest of the country. Children often lack iron (Peña-Venegas, et al. 2009).

From the foregoing it can be concluded that increasing and diversifying food production from the agricultural fields could contribute to local livelihoods. In addition, these benefits would be further enhanced if the improvement would be a contribution to other ecosystem goods and services such as providing food and habitat for fish and contributing to biodiversity.

1.3 The study area

1.3.1 Location and climate

The fieldwork for this thesis has been executed in Colombia between June and September 2013 working with an indigenous community living near the Yahuarcaca lakes: San Sebastián de los Lagos. The focus is on their agricultural system. Although they cultivate in the várzea as well as on the surrounding mainland, only the agricultural fields that are located in the várzea are included.

The Yahuarcaca lakes are located 2 kilometers west of the city of Letícia in the Amazonas department of southern Colombia, close to the Peruvian and Brazilian border (Figure 1). The coordinates are 4° 11’ 48’ south and 69° 57’ 19’ west and the altitude is about 80 meters above sea-level (Prieto-Piraquive 2006). The total aquatic system of the Yahuarcaca lakes has an area of about 950 hectares; the size of the lakes is about 250 hectares during high water period and 50 hectares during low water period (Corpoamazonia 2006).

According to the Köppen-Geiger climate classification, the Amazonas department belongs to group *Af*, equatorial rainforest climate, fully humid. This means precipitation in all twelve months is at least 60 millimeters and average temperature of the coldest month is not below 18°C (Peel, Finlayson and McMahon 2007). As can be seen in Figure 2, average yearly precipitation is 3256 millimeters; average precipitation in the driest month is 160 millimeters. The average temperature is 25.8°C and average humidity is about 86% (IDEAM 2000).

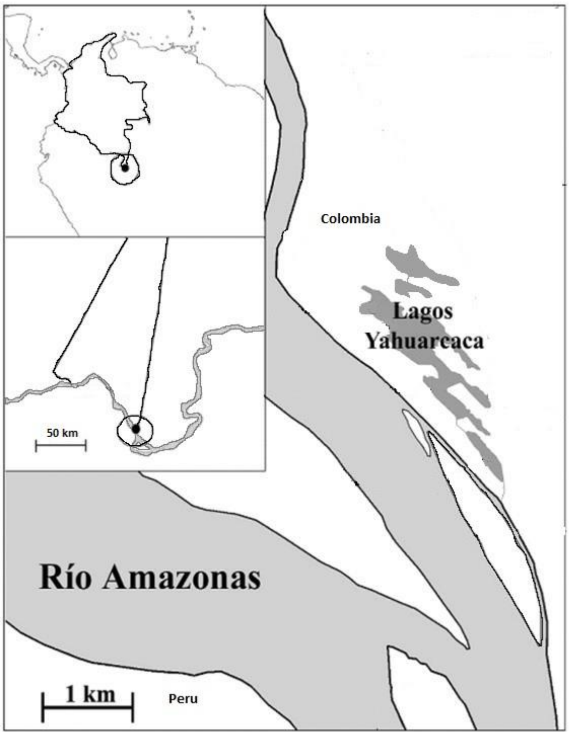

Figure 1 Location of the study area (National University 2011)

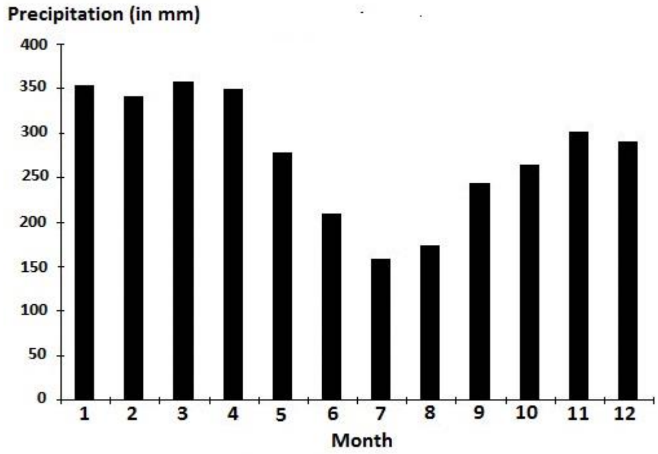

Figure 2 Precipitation per month in the Yahuarcaca floodplain (IDEAM 2000)

1.3.2Local population

The community of San Sebastián de los Lagos is situated at 4.5 kilometres from Leticia and has the largest population of all seven communities, 513 (of which more than 50% are minors). The level of education in the community is quite low, a quarter of the population finished primary school and only 4.1% finished secondary school (Corpoamazonia 2006).

The people consist mainly of Ticuna; however other ethnical groups are present as well like Cocama, Yagua and mestizo. The Ticuna and Cocama are indigenous people living in Brazil, Colombia and Peru while the Yagua live in northern Peru and southern Colombia. Mestizos are people whose ancestors are both American Indian and European. The first Ticuna people who were emigrants from Brazil arrived at the area of the Yahuarcaca lakes in the 1930's (Corpoamazonia 2006).

Just like in other nearby communities, the people of San Sebastián depend partly on fishery resources and partly on agricultural cultivation. In the past years there has been a process of increased economic dependence on the city; before people where more self-sufficient but now they often work in Leticia (Corpoamazonia 2006).

1.3.3 Agriculture

Shifting cultivation is the main agricultural system in the area; it is a system in which periods of cultivation are followed by periods of fallow. The fallow period is usually longer than the cultivation period and the system may or may not require an actual shift (Altieri 1987). Agricultural fields are called *chagras*. The chagra is a traditional agricultural system used by indigenous people. It is said that chagra management in the Amazon is closely related to complex agronomic and ecological knowledge and that these systems often contain high species diversity (van der Hammen 1991, Dufour 1993).

The fields in the várzea are flooded during part of the year; cultivation is thus closely linked to the flood pulse. The flood pulse is characterized by four stages: *descending waters* from May until July, *low waters* from August until September, *rising waters* from October until December and *high waters* from January until April. Cultivation begins in June-July and ends with the harvesting in September-October; there is a production period of 4 to 5 months. After the abandonment of an agricultural field, a secondary forest grows there which is called *rastrojo* (Corpoamazonia 2006).

2 Research questions and objective

2.1 Main research question

As mentioned before the focus of this thesis is on the agricultural system and agroforestry in the várzea of the Yahuarcaca floodplain in the Amazonas region in Colombia, which is a threatened ecosystem. As it is concluded that fishery resources of the Yahuarcaca lakes are under pressure and increasing food production from the agricultural fields could contribute to local livelihoods, the following research question can be formulated:

What agricultural system is being applied in the várzea and how can agroforestry increase food production and provide alimentation for fish, thereby contributing to food security of local inhabitants and sustainability of the várzea?

2.2 Main objective

Describing the current agricultural system in the várzea and giving an agroforestry-based advice to increase food production and provide alimentation for fish, thereby contributing to food security of local inhabitants and sustainability of the várzea.

2.3 Sub- questions

A. What are the most important changes over the last decades in the agricultural system and in natural resource use that have influenced food security and sustainability of the várzea?
(Results in Chapter 5.2)

B. What management practices are applied, what types of crops are being cultivated, what are their direct uses and what is their temporal and spatial distribution?
(Results in Chapter 5.3 to 5.5)

C. Which useful herbaceous and woody plant species are present in the chagras and what are their direct uses?
(Results in Chapter 5.6)

D. Which herbaceous and woody plant species present in the chagras provide alimentation for fish, when is their flowering and fruiting period and on which part do the fish feed?
(Results in Chapter 5.7)

E. Which agroforestry species can be used to improve the agricultural system to benefit local inhabitants by providing fruits while at the same time providing alimentation for fish?
(Results in Chapter 5.8)

2.4 Expected results

A. Important changes in the agricultural system and natural resource use over the last decades that have influenced food security and sustainability of the várzea have been described.

B1. The current management of the chagras has been described.

B2. Types of crops that are being cultivated have been identified and their direct uses described.

B3. The spatial and temporal distribution of the crops present in the chagras has been identified and described.

C1. Other useful herbaceous and woody plant species present in the chagras are identified.

C2. The direct uses of the herbaceous and woody plant species in the chagras have been described.

D1. The herbaceous and woody plant species present in the chagras that provide alimentation for fish and their fruiting and flowering period have been identified.

D2. The part of the herbaceous and woody plant species on which the fish feed has been identified.

E. Tree species suitable for agroforestry have been selected and described in terms of direct use by local inhabitants and alimentation for fish.

3 Materials and methods

3.1 General description

To provide an answer to the research question and sub-questions as stated in Chapter 2, ecological and social research was combined. The social research consisted of interviews and the ecological research of field visits. This was preceded by a literature review and followed by data analysis.

3.2 Interviews

All 31 farmers of San Sebastián de los Lagos who have their field in the várzea have been interviewed. 16 of these farmers are women and 15 men with ages varying between 19 and 72. 22 of the interviews took place in the houses of the respondents while 9 interviews took place in the chagra; see Table 1 for an overview. The goal of these interviews was to gather information about crops cultivated, tree species planted, useful species in the field, direct uses, management of the chagra and changes in in the várzea and the agricultural system that have been observed during the last decades. The interviews were semi-structured; meaning a list of relevant topics is made in advance which form the basis of more specific questions not prepared beforehand. This type of interview is suitable for qualitative research and allows for the interviewer and respondents to have their own input (FAO 1990). The interviews were accompanied by Ángel Fernández Ramos, an inhabitant of the community who speaks Ticuna (the local language) and knows the people; he approached them first explaining the goal of the interview. Questions were asked in Spanish and translated to Ticuna when necessary.

So-called key informants like elders with a lot of knowledge and fishermen were interviewed again; during these interviews information was gathered about direct uses of plants and trees in the chagras, species that provide alimentation for fish and the part on which the fish feed and flowering and fruiting of these tree species. Data gathering was partly based on traditional ecological knowledge (TEK); this term refers to knowledge of indigenous and local people arisen from many decades of living in close contact with the environment (Inglis 1993). In total 36 interviews were held in San Sebastián, 5 people were interviewed twice (with ages varying between 53 and 72).

Table 1 Amount of interviews held in San Sebastián, per gender and location

Interviews	Total	Gender		Location	
		Male	Female	House	Chagra
People interviewed	**31**	**15**	**16**	**22**	**9**
People interviewed twice	**5**	**4**	**1**	**5**	**0**
Total interviews	**36**	**19**	**17**	**27**	**9**

Other interviews (5) were held outside the community, some with inhabitants of El Castañal (the community closest to San Sebastián), with Corpoamazonia and with professors from the University of Leticia. One group interview was held with the council of village elders. This is a group of elders involved in the community's decision making.

3.3 Field visits

3.3.1 Field description and crops present

In June and July, 13 randomly chosen agricultural fields were visited of which 8 on one side of the Yahuarcaca creek and 5 at the other side, covering more than 40% of the total amount of fields. In this period only 3 fields were under cultivation because water levels had not lowered sufficiently in all parts. First a general description of the field was noted down. All crops present in the fields were listed, both temporary and permanent crops. The division between temporary and permanent crops is made based on their duration in the field; temporary crops are sown and harvested during the same agricultural year while permanent crops are sown and planted once and then remain in the field for several years (FAO 2011). In this case temporary crops are grown in a period of 4 to 5 months, being planted when the water level has lowered sufficiently and harvested before the water level rises, while permanent crops remain in the field during floods. Of the fields that were abandoned, owners were asked what they were planning to cultivate there. An example of the field form used for the general description can be found in Annex A.

3.3.2 Inventories of useful species

In all 13 fields inventories were held of the useful plants and tree species present. This was done walking slowly across the field writing down all species that are considered useful by local inhabitants and estimating quantities. Furthermore the location of the fields was recorded with a GPS (Armin GPSmap 62sc) and the size of the field measured, by using the GPS function “area calculation”. An example of the field form used for the useful species inventory can be found in Annex B.

3.3.3 Transect lines

In 10 fields transect lines were laid out (1 in each field) with the goal to make vegetation profiles and gather information about chagra structure; 2 transects were of fields in use, 8 transects of abandoned fields. This is a method described by CIFISAM and PRONATTA (2006); they explain the method is useful for gathering information about spatial distribution of chagras and its components.

The transect lines were laid out from one side of the field where the Yahuarcaca creek is to the other side. Most of the times there was a forested buffer zone on both sides of the field; to give an impression of the vegetation there, measurements were done 5 meters outside the fields into the borders. A measuring tape (decameter) was used and distance of the vegetation along the transect line was measured. The transect lines were 2 meters wide, measuring vegetation within 1 meter on each side of the line. The DBH was measured with a diameter tape. When possible, a clinometer was used to measure tree height, when this was not possible (due to dense vegetation) height was estimated. A distinction was made between commercial height (until the first big branch) and total height. Vegetation was included with a minimum of 1.30 meter high (breast height), although apart from measuring this vegetation all crops (permanent and temporary) found along the transect line were included in the measurements. Vegetation smaller than 1.30 m was not included because vegetation in the border was too dense to be able to draw these on the vegetation profile. Field forms were used to write down the results, an example can be found in Annex C. The data gathered was used to draw vegetation profiles showing the height and distance between plants, trees or crops using graph paper.

3.3.4 Visiting remaining fields

In August and September when the water level had lowered completely, those 13 fields visited in June and July were visited again to see which fields were actually in use and what temporary and permanent crops were present, so earlier gathered information was verified. Furthermore, the other 18 fields were visited recording the location in the GPS and measuring field size by using the GPS function "area calculation". The state of the field was described ("in use" or "abandoned") and of the fields in use the permanent and temporary crops present were described. See Figure 4 for a map with the location of the fields.

3.3.5 Spatial distribution of crops

To gather information about the spatial distribution of crops, 5 of the fields that were being used at that time were drawn. The drawings show the type and amount of crops (permanent and temporary) and their location (not based on exact measurements but on estimations). This method is described by Van der Hammen et al. (2012) in a document made for diagnosing agricultural systems of indigenous communities; Figure 7 shows an example. The other fields that were being used showed similar patterns and were therefore not drawn. One field was drawn without temporary crops; it was interesting because of the high amount of permanent crops it contained.

To summarize the information above, Table 2 and Table 3 show the amount of fields visited and the type of information gathered. For an overview of the information gathered per field, see Annex D and E. In total 31 fields were visited, in total 44 visits, 13 in June and 31 in August, 13 fields were visited twice.

Table 2 Amount of fields visited, in use and in fallow, and information gathered in June-July

State of the field	Amount of fields	Field numbers
In use	3	2,7,11
Fallow	10	1,3-6,8-10,12,13
Information gathered		
Location, size, general information	13	1-13
Useful species inventory	13	1-13
(Expected) temporary crops	13	1-13
Permanent crops	13	1-13
Transect lines	10	1,2,4-7,9,10,12,13
Visit with owner	9	1,3,4-6,8,9,11,12

Table 3 Amount of fields visited, in use and in fallow, and information gathered in August-September

State of the field	Amount of fields	Field numbers
In use	9	2,4,6,7,8,11,14,17,19
Fallow	22	1,3,5,9,10,12,13,15,16,18,20-31
Information gathered		
Location, size, general information	18	14-31
Temporary crops	9	2,4,6-8,11,14,17,19
Permanent crops	16	1-14,17,19
Spatial distribution crops	6	2,4,6,7,10,11

4 Várzea vegetation

Várzea forests can be divided into two main vegetation types: high várzea forest and low várzea forest (Figure 3). The high várzea forest has mean flooding levels of less than 3 meters, corresponding to a flooding period of less than 140 days a year. Tree species diversity is relatively high, the forest contains up to 120-160 species per hectare and some common species are *Brosimum lactescens, Hura crepitans* and *Trichilia septentrionalis*. The low várzea forest has mean flooding levels between 3 and 7.5 meters, corresponding to a flooding period of 140-230 days a year. Tree species diversity is somewhat lower, up to 70-90 species per hectare and some common species are *Pseudobombax munguba, Laetia corymbulosa* and *Crataeva benthamii* (Junk, et al. 2010, Van Vliet 2012).The vegetation of high and low várzea forests grows on levees or *restingas.* These are formed by the deposition of sediments during the flooding (Steward 2008).

Another vegetation type common in the várzea is called "bajial"; this is a low lying area which is flooded during most of the year. Because trees growing there must tolerate extreme waterlogging (saturation of the soil with water) species diversity is low (Junk, et al. 2010).

Since várzea forests are seasonally flooded, they are considered to be boundaries between terrestrial and aquatic ecosystems (Junk, et al. 2010). Since plants and trees in the várzea are subjected to periods of waterlogging and submersion, different growth strategies and adaptations allow them to survive. It may concern adaptations in tree morphology or tree phenology. Morphological adaptations which require high nutrient supply allow the plants to maintain growth and photosynthetic activity at high levels, even during waterlogging. Regarding tree phenology, seeds are spread by the water and by fish. When fish consume the seeds, in some cases seeds are destroyed while in other cases seeds remain intact (Gottsberger 1978).

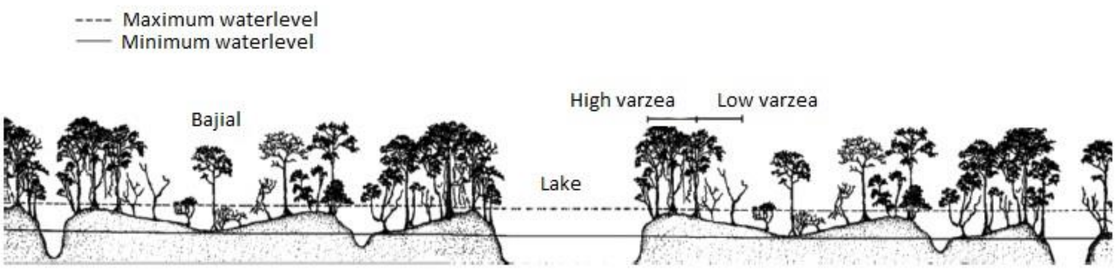

Figure 3 Cross-section of a várzea landscape showing characteristic vegetation types (Ayres 2006)

5 Results

5.1 General findings

All families of the community have a chagra on the mainland; the amount of fields they own there varies between 1 and 3. Only some people have their field in the várzea and they never own more than one field there.

The agricultural land in the várzea is not a part of the indigenous reserve of San Sebástian. This means there is no official division of land, but all families are well aware of the land they can use and which families occupy the other pieces of land. The location of the chagras in the várzea can be seen on the map (Figure 4). The total space taken up by agriculture in the whole várzea is 55 hectares, which is 5.6% of the total area (980 ha). The total space taken up by the chagras of this community is 2.33 ha. In total there are 31 fields located at two sides of the Yahuarcaca creek, at one side there are 15 chagras and at the other 16. The size of the fields is small and varies from 0.0066ha (66m^2) to 0.2585ha (2585m^2); the average size is 0.0752 ha (752m^2). As can be seen on the map the chagras are located next to Yahuarcaca creek.

According to observations on trees in the fields flooding levels last year varied between 2,40 m and 0,80 m. According to an agreement with Corpoamazonia the trees within 20 m of the creek should not be cut down. In this buffer zone minor timber products and non-timber forest products like fruits are harvested.

Although the majority of the people stated during interviews that they use their fields every year, during field visits during the low water period it was observed that only 9 out of 31 chagras were considered "in use" indicating the presence of temporary crops. The low amount of fields in use is due to the presence of buffalos in the area that destroy the crops, lowering motivation of the inhabitants to cultivate the land. This is apparent from interviews held and is confirmed by Lopez (2009) who performed research about agriculture in the same community. As one of the farmers comments: "Why would I take the effort to plant there, if later a cow comes and destroys everything" (Photo 2).

Photo 2 Cows that roam freely through the várzea cause problems for the farmers

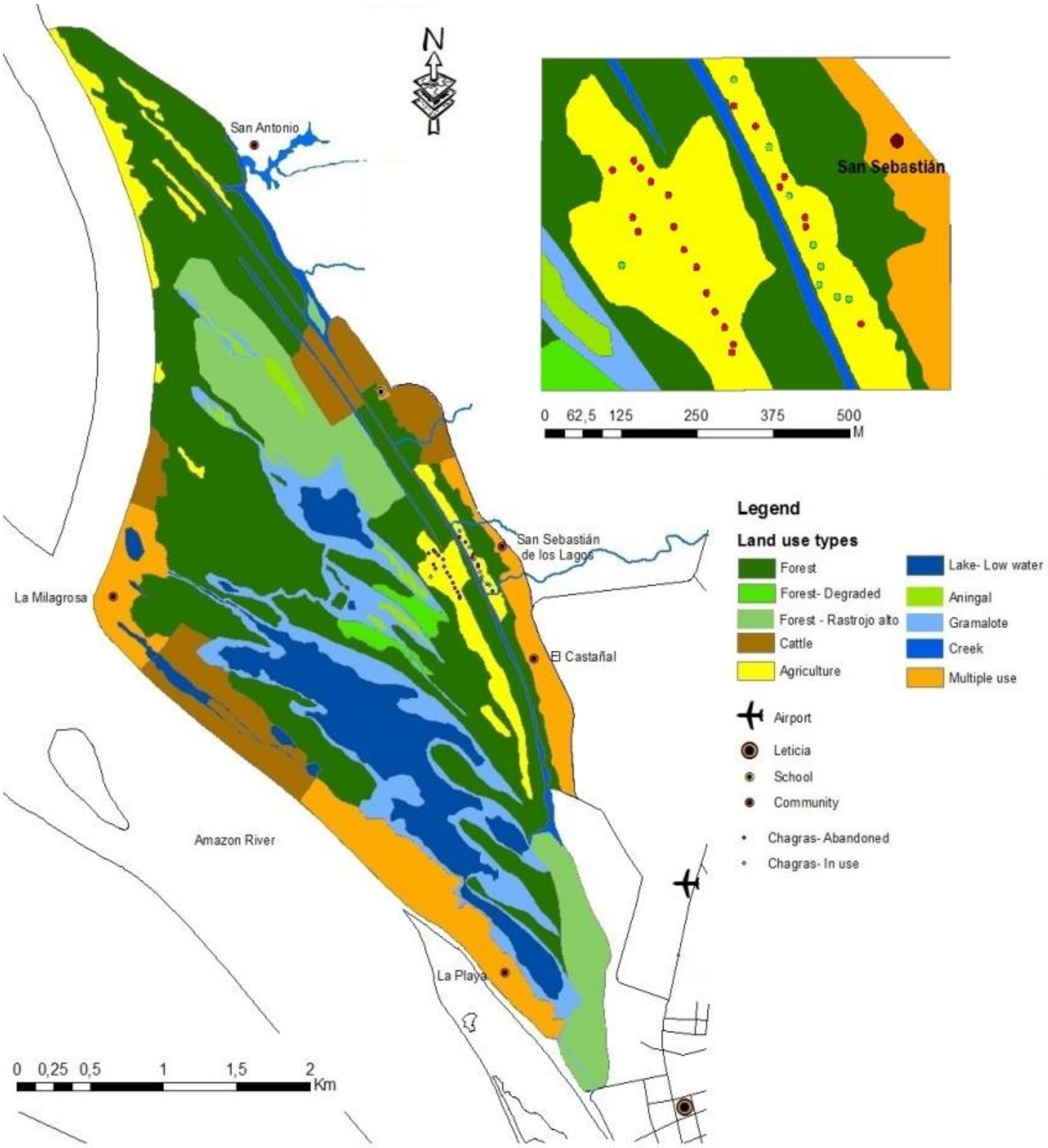

Figure 4 Map of the Yahuarcaca floodplain showing agricultural fields of San Sebastián de los Lagos

This map is made in ArcGIS combining information from field visits and Google earth images with an existing map (Van Vliet 2012). On the right side a magnified image is shown with the chagras and the community. Red dots indicate abandoned fields while green dots represent fields being used when this research was done. An *aningal* is an area where vegetation is dominated by *Montrinchardia arborescens* while *gramalote* indicates that vegetation is dominated by *Paspalum repens* (Lucas 2008).

5.2 Changes over the last decades

5.2.1 Changes in natural resource use

Although there is some debate about the exact year the first Ticunas arrived in the area, it was during the first half of the 20th century, between 1910 and 1930. At that time there lived a few other people near the Yahuarcaca lakes, of the ethnic group Cocama (Santos, et al. 2008). The Ticunas settled there where nowadays the community El Castañal is. The Ticunas usually established themselves at places suitable for hunting, fishing and gathering food from the forest, until the amount of natural resources diminished, and then they went to another place. Therefore they saw themselves as semi-nomads. They were, however, also horticulturists, making agricultural plots in the jungle. According to literature (Santos, et al. 2013) and interviews, when first people arrived, it was a "land of plenty" with good quality food continuously available: fish, bush meat, forest fruits and a high variety of products from the chagra. The soils were fertile.

During the period from 1930 to 1980 the so-called "internal colonization" took place. People arrived from other regions of the country; the land where the first Ticunas settled was now given away and sold to new inhabitants. They started to cut down trees for cattle; this caused deforestation of large parts of the area and a decline in soil fertility because of the cattle treading that damaged the soil. Many young indigenous people started working for the people of the cattle farms, and lot of hunting was done to supply food for the owners of cattle ranches. These colonists were gaining territory while the Ticunas were losing it. In the 1970's en 1980's economic activities and commercialization of natural resources contributed to a further decline in quality of the ecosystems: timber extraction, fishing, drug trafficking, hunting and fur trade (Santos, et al. 2013).

As a consequence of these processes the government and NGO's made an effort for creating an indigenous reserve for Ticuna, Cocama and Yagua people. The community San Sebastián de los Lagos got 58 hectares in 1982 (Corpoamazonia 2006). Although now the community has its indigenous reserve, because of population growth the amount of area per person is very low and productivity of a field is limited. Furthermore, the changes of the last decades have had a negative impact on other ways of obtaining food from natural resources, because the number of fish and animals for hunting declined (Prieto-Piraquive 2006, Santos, et al. 2013). It is apparent from interviews that the people do not catch as much fish as before. According to the inhabitants, the amount of fruit trees in the whole area has been reduced as well, not only in várzea but also in the communities. Also the disappearance of certain fruit and other tree species of the várzea was mentioned often. To summarize the above: there has been a growth in food demand but a decline in availability of food from natural resources.

However, some positive changes have taken place as well. Parts of the previously deforested areas in the várzea have been recovered again; some parts that were paddocks first are forest again. In those reforested areas locals can extract non-timber forest products. Many different projects have taken place, like a reforestation program of Corpoamazonia in the várzea and a SINCHI project to enhance agricultural productivity. Furthermore the Ticuna elders are trying, with the help of indigenous organisations like Azcaita, to reclaim land that belonged to their parents; some land has been recovered in this way already (Santos, et al. 2013).

5.2.2 Changes in the agricultural system

Soil structure has deteriorated due to cattle tramping. Other factors have influenced soil quality as well. Because of the small amount of hectares available for each family, people are forced to shorten fallow periods of their fields. This is true especially for the chagras on the mainland (Lopez 2009). But also in the várzea, although soils there are more fertile, it was apparent from field visits that the chagras of San Sebastián do not get such a thick layer of sedimentation and a decline in fertility over the past years caused by continuous cultivation is mentioned often by farmers; declining crop sizes are being noticed.

According to Lopez (2009), species diversity in the chagras of the elders is highest and younger generations cultivate monoculture cassava, pineapple or other products which are grown for commercial purposes. In the chagras on the mainland diversity has declined because of a stronger commercial orientation of the farmers. Some farmers mention that in the várzea there has been a decline in diversity in the chagra as well, mostly because stealing was not such a big problem before. Some species mentioned which were grown before and not anymore are squash *(Cucurbita maxima),* groundnut *(Arachis hypogaea)* and yam *(Dioscorea alata),* although it is unclear to what extent crop species diversity in the várzea has changed exactly.

The chagra of the Ticuna people is, apart from being of vital importance for providing food, a symbolic place where knowledge is transferred from generation to generation (Box 1). The urban growth of Leticia and getting in contact with other people partly changed this way of thinking of indigenous people (Santos, et al. 2013). This is linked with loss of traditional knowledge, which has been mentioned several times during interviews as an important change affecting the chagra management. According to literature the little interaction between women of different generations affects the transference of indigenous knowledge about agriculture negatively (Lopez 2009). An example of how the loss of knowledge affects chagra management: every year there are worms that attack the cassava plant. Lucia Gomez (55) explains that they have a ceremony at the beginning of the planting season, where they ask the worms not to eat their harvest, because it is said worms understand humans. Nowadays, most people kill the worms with a machete, although farmers say it is not very effective.

In many aspects chagra management in the várzea is similar compared to the beginning of the last century, for example the methods and tools used for planting and harvesting broadly remained the same. However there are also differences: a decline in soil fertility, a lower diversity of crops in the chagra and the loss of traditional knowledge. An example of an agricultural practice that is not executed nowadays anymore is “enterramiento de yuca”, cassava is buried in a hole in the ground when there is large harvest, where it can be conserved for a whole year. This technique is not used anymore because of the small chagra sizes; harvests are small and therefore this method is considered unnecessary.

Box 1 The chagra as a symbolic place

According to myth, the Ticuna people were nomads, until the gods, Yoi and Ipi gave them a bag with seeds for cultivation. The chagra is seen as symbolizing the cosmos, the Ticuna word for chagra and cosmos are the same (“*na-ane”*), and the chagra is said to follow “the same order as the universe”. The chagra is seen as representing a living being. The house is the central part, or the body, and the fields around the house where the crops are located, are seen as providing alimentation or energy for the body. In return, the house symbolizes a fire that radiates outward and takes care of the surroundings; crops and people (Santos, et al. 2008, Goulard 2009).

5.3 Chagra management

5.3.1 Activities and work division

People generally work 5 to 6 days a week in their chagra dividing the time between the fields on the mainland and the várzea. Some people work on the mainland in the morning and in the várzea in the afternoons, others work 1 or 2 complete days in the várzea and the other days on the mainland. As stated before part of the chagras are on the other side of the Yahuarcaca creek and people reach their fields in canoes.

When the water level has lowered sufficiently the work starts with cutting down unwanted trees especially in fields that have been abandoned for several years. This work is usually done by men with an axe and trees are left in the field or used as firewood. The rest of the field is weeded, occasionally sparing a useful tree or plant. This work is usually done by women with a machete or by hand. Families are often very busy and sometimes a *minga* is held at the beginning of the planting season, meaning other people are invited to do a communal work in the chagra one day in exchange for food and drinks. After the weeding the field is left to dry for about a week before the weeds are burned. In some cases the weeds are left in the field. Part of the woody plant species is used for firewood and some plants or leaves are taken home for medicinal purposes, although only some people have knowledge on how to prepare medicines; usually the elders. When the field is free of weeds the planting begins. Cassava is propagated vegetatively through stem cuttings. A part of the stalk, about 20 cm is cut off from another cassava plant and this is grown into a new plant. Usually planting material is used from the chagra on the mainland. For most other temporary crops seeds are planted, except for sugar cane which is propagated vegetatively as well. For planting farmers often use a planting stick and a hoe is used to loosen the soil. Given the size of the fields planting generally takes a couple of days. After that, weeding usually happens every 2 weeks. The harvesting of the crops happens in September or October. Although often crops are not fully grown harvesting is necessary because of rising water levels.

When permanent crops are planted often stem cuttings are used from trees that grow in the forested border. Most trees have their fruiting period when water levels are rising or high and therefore farmers have to travel to their fields by canoe and cut off an entire branch with a machete to harvest the fruits. Growing trees is generally less labor-intensive than growing temporary crops.

5.3.2 Crop losses, pests and diseases

When managing the chagras of the várzea farmers have to cope with different challenges related to the dynamic environment of a floodplain. Crop losses because of the water are frequent because the water rises earlier than expected or the permanent crops do not survive the flood. This is especially the case with plantain, although a more flood-resistant species is used, in 2011 many plants died during high water levels. Apart from roaming cattle, another important problem is that often crops get stolen; this is one of the reasons why people do not plant many fruits and vegetables anymore.

In the period shortly after planting the cassava the field has to be checked regularly because of a worm that eats the leaves of the plants. Different techniques are used to remove worms, most farmers kill them with a machete and sometimes poison is used. Plants that have died or are damaged are often replanted. Other pests and diseases are common, like cassava tuber rot; however use of pesticides and insecticides is rare.

5.4 Types of crops and direct use

A total of 22 different types of crops are being cultivated consisting of 9 temporary and 13 permanent crops. The permanent crops consist mostly of tree species while the temporary crops consist mainly of tubers, vegetables and fruits.

5.4.1 Temporary crops

Table 4 gives an overview of the temporary crops and their expected and actual frequency, as will be explained below. Annex F shows the 9 crops that are being cultivated. The cropping system of the inhabitants of San Sebastian in the várzea is cassava-based. This means the main crop in the majority of the chagras is cassava *(Manihot esculenta),* a tuber crop of which 2 varieties are being grown: bitter cassava (locally known as *yuca brava* or *yuca amarilla*) and sweet cassava (*yuca dulce* or *yuca blanca*). Other temporary crops frequently cultivated are lulo *(Solanum quitoense)*, long coriander (*Eryngium foetidum)*, maize *(Zea mays)* and watermelon *(Citrullus lanatus)*. Some of the crops were only grown in 1 or 2 fields like sweet pepper *(Capsicum sp.),* papaya *(Carica papaya)*, sugarcane (*Saccharum officinarum)* and melon (*Cucumis melo)*. Figure 5 shows the number of species in 9 fields. 6 out of 9 fields in use contain relatively low temporary crop species diversity; only 1 or 2 types of crops are grown there. General statistics are shown in Table 5: the average amount of temporary crop species grown per chagra is 2.9 with a minimum of 1 and a maximum of 8.

The temporary crops belong to 6 families of which Cucurbitaceae, Solanaceae and Poaceae are the most represented with 2 species each. One species was present of each of the families Apiaceae, Caricaceae and Euphorbiaceae.

Based on interviews with farmers and observations in 13 fields visited at the beginning of the low water period when most people had not cultivated their temporary crops yet, a list was made of the crops and the amount of chagras in which they were grown or planned to be grown (expected frequency). Column 3 of Table 4 shows the amount of chagras in which each crop was supposed to be growing; in this case 100% is 13 chagras. Later all 31 fields were visited and 9 of the fields were being used at that moment; column 5 shows the actual frequency of the crops grown in those fields, so in this case 100% is 9 chagras.

Crops expected that were not found in the fields later are cucumber, tomato, yam, machiche and beans. Beans and machiche were observed growing in the field during first observations but later had died, while tomato, yam and cucumber have never been observed in the field. Furthermore cassava, watermelon, sweet pepper, maize, long coriander and papaya were found in a lower percentage of the fields than expected. Cassava was not planted in only 1 of the fields, maize was planted there. Lulo was found in more fields than expected. The only crop not expected that was found later in the field was melon, however only 1 plant was found.

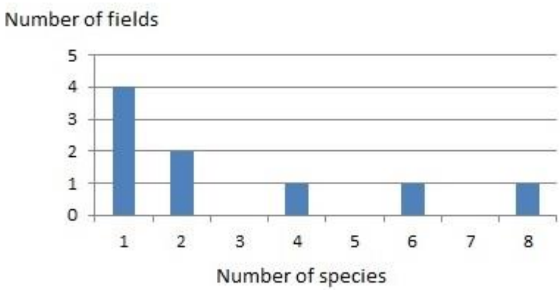

Figure 5 Number of temporary species in 9 fields

Table 4 Temporary crops grown in the várzea and the actual and expected frequency

English name	Scientific name	Amount of chagras Expected	% of total amount of chagras	Amount of chagras Actual	% of total amount of chagras
Cassava	*Manihot esculenta*	13	100	8	88
Sweet cassava		10	77	7	77
Bitter cassava		10	77	6	67
	Solanum quitoense	1	8	4	44
Watermelon	*Citrullus lanatus*	7	54	3	33
Maize	*Zea mays*	6	46	3	33
Long coriander	*Eryngium foetidum*	5	38	3	33
Sweet pepper	*Capsicum sp.*	7	54	2	22
Papaya	*Carica papaya*	3	23	1	11
Sugar cane	*Saccharum officinarum*	1	8	1	11
Melon	*Cucumis melo*	0	0	1	11
Cucumber	*Cucumis sativus*	5	38	0	0
Tomato	*Solanum lycopersicum*	1	8	0	0
Yam	*Dioscorea alata*	1	8	0	0
Beans	*Phaseolus vulgaris*	1	8	0	0
	Cucumis anguria	1	8	0	0

Table 5 General statistics of the amount of crops cultivated (N is the amount of fields)

	N	Min	Max	Median	Average	SD	SE
temporary crops	9	1	8	2	2,9	2,6	0,8
permanent crops	16	0	7	2	2,5	1,8	0,5
permanent + temporary	9	1	10	3	4,5	3,4	1,1

All temporary crops are grown primarily for consumption. Furthermore part of the crops is used medicinally. Among those crops are papaya, of which seeds are used against parasites and sugar cane, of which the juice is used against the flu and coughing. Some crops are not being used medicinally by local inhabitants but, according to literature, have medicinal properties, like melon *(Cucumis melo)* and long coriander *(Eryngium foetidum)* (Saenz, Fernandez and Garcia 1997, Fernandez, et al. 2008).

Although all crops are sold at the market and used for own consumption, bitter cassava is usually cultivated with a commercial orientation and in larger quantities, while all the other crops are grown in smaller quantities aimed at self-subsistence. Products are usually sold at the market in Leticia, although sometimes products are sold near the house in the community or traded with other inhabitants for another product.

5.3.2 Cassava

The main crop, cassava, is the staple food of the people in this region. It is of high importance for Ticunas and other indigenous people in San Sebastián. It is a traditionally grown food crop which is not only the basis of the diet but is of cultural and commercial significance.

The difference between sweet and bitter cassava relates to the content of toxins. Bitter cassava is normally toxic because of high cyanide content, however when prepared properly these toxins are eliminated (Bandna 2012). Bitter cassava is used to make *fariña,* although occasionally sweet cassava is used as well. Fariña consists of grains obtained by a series of operations like grating, drying, fermenting and roasting. When made into fariña the cassava can be stored for a very long time. After harvesting periods, fariña is used as a condiment and side dish with the majority of the meals for the rest of the year. Many people focus on cultivating bitter cassava because it has a high demand and gives a good price at the local market.

Almidón is fermented flour used to make a type of pancakes; called *casabe.* Almidón is made from both varieties of cassava and is used medicinally as well. Sweet cassava can be eaten when cooked only. From this type of cassava 2 types of fermented beverages are made: *masato* and *payawarú.* These beverages are especially important because they are consumed during the *pelazón* (Box 2).

Box 2 The Pelazón ritual

The pelazón is one of the most important traditional ritual ceremonies of the Ticuna people celebrating the transition of women from child to adulthood. Usually the girl has to stay in her room for several days and only the mother can enter, teaching her to make handicrafts from natural materials, like hammocks and baskets. Afterwards all family and community members are invited to celebrate. Nowadays the celebration is usually only one day, but it used to be several days or even a week. Because of the large amount of food necessary for the guests sometimes an entire chagra is planted with sweet cassava for this particular purpose.

5.3.3 Permanent crops

The cultivation of permanent crops can be seen as a part of current agroforestry practices applied by inhabitants of the community. Table 6 gives an overview of the permanent crops grown and their frequency. Of the 13 permanent crop species 11 species are trees, 1 is a palm species and 1 a perennial plant. The most commonly grown permanent crop is guava *(Psidium sp.).* Other frequently grown species are huito *(Genipa americana)*, guamilla *(Inga sp.)* and plantain *(Musa sp.)*. The biggest part of the permanent crops is only found in 1 or 2 chagras: ubo *(Spondias mombin),* capirona *(Calycophyllum spruceanum)*, cacao *(Theobroma cacao)*, totuma *(Crescentia cujete),* timareo *(Laetia corymbulosa)*, invira *(Pseudobombax munguba)*, guanabana de la várzea *(Annona hypoglauca),* amacisa *(Erythrina fusca)* and aguaje *(Mauritia flexuosa)*. Figure 6 shows the number of species in 16 fields. General statistics are shown in Table 5: the average amount of permanent crop species grown per chagra is 2.5 with a minimum of 0 and a maximum of 7.

The permanent crops belong to 10 families of which Rubiaceae, Fabaceae and Malvaceae are the most represented, with 2 species each. One species was present of each of the families Salicaceae, Myrtaceae, Musaceae, Bignoniaceae, Arecaceae, Annonaceae and Anacardiaceae.

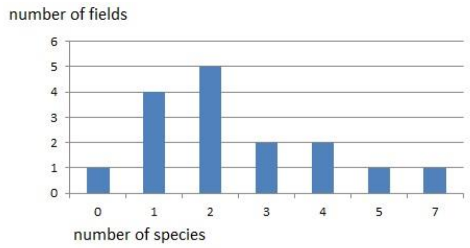

Figure 6 Number of permanent species in 16 fields

Table 6 Permanent crops grown in the várzea and their actual frequency

Local name	Type	Scientific name	Family	Amount of chagras	% of total amount of fields
Guayaba de la várzea	Tree	*Psidium sp.*	Myrtaceae	8	50
Huito	Tree	*Genipa americana*	Rubiaceae	7	44
Guamilla	Tree	*Inga sp.*	Fabaceae	5	31
Plátano sapo	Perennial plant	*Musa sp.*	Musaceae	5	31
Ubo	Tree	*Spondias mombin*	Anacardiaceae	2	13
Capirona	Tree	*Calycophyllum spruceanum*	Rubiaceae	2	13
Cacao	Tree	*Theobroma cacao*	Malvaceae	2	13
Aguaje	Palm	*Mauritia flexuosa*	Arecaceae	2	13
Timareo	Tree	*Laeti corymbulosa*	Salicaceae	2	13
Amacisa	Tree	*Erythrina fusca*	Fabaceae	2	13
Invira	Tree	*Pseudobombax munguba*	Malvaceae	1	6
Guanabana de la várzea	Tree	*Annona hypoglauca*	Annonaceae	1	6
Totuma	Tree	*Crescentia cujete*	Bignoniaceae	1	6

The different use of the permanent crops have been divided into 6 categories according to the uses mentioned by farmers: edible fruits, medicinal use, firewood, timber, handicrafts and cultural use.

The majority of the crops (8 species or 62%) is planted mainly because of their edible fruits. All 4 most commonly grown permanent crops are planted in the first place because of that; other permanent crops grown primarily for fruit consumption are cacao, aguaje, ubo and guanabana de la várzea. Timareo and capirona are grown primarily for timber production, totuma for making handicrafts and Invira for its use as fish bait. However, all permanent crops are used for more than one purpose. In Annex G a complete list of the uses of the permanent crops can be found. 8 crops have edible fruits (62%), 7 crops (54 %) have a medicinal use, 10 crops (77%) serve as firewood, 7 (54%) for timber production, 5 (38%) to make handicrafts and 2 (15%) for cultural purposes. An example of using material from a tree to make handicrafts is totuma, of which the fruits are used for making bowls (used for eating) and an example of the cultural use of a tree is huito of which the juice is used as paint during the pelazón ritual (Box 2).

5.5 Spatial and temporal distribution of crops

5.5.1 Temporal distribution

The annual ecological cycle of the agricultural system in the várzea depends on fluctuations of the water level; the agricultural fields can only be used for temporary crops during a period of 4 to 5 months: from June-July until September-Octobre. This means fields are abandoned for at least part of the year, during a period of 7 to 8 months. Logically the lower lying fields have to be harvested first. Some farmers indicated during interviews that they leave their field fallow for 1, 2 or sometimes 3 years; although the majority of the farmers stated that they cultivate each year. However, as explained before, only 9 out of 31 fields were in use this year. Some farmers divide their fields in parts and leave one part fallow while cultivating the other part and the next year the other way around. According to interviews the same crops are cultivated each year, however this depends on seed and plant material availability. Cassava takes the longest time to mature and therefore is planted first, followed by crops that mature a little bit faster like maize and watermelon. When trees are planted farmers do this at the beginning of the low water period, because in this way the trees have the maximum amount of time to grow before the field floods, increasing the sapling's chances of survival.

5.5.2 Spatial distribution

The agriculture in the area can be seen as traditional, small scale farming; therefore it is not surprising that the spatial distribution of crops in the fields differs significantly from more common commercial or large scale agricultural systems. As can be seen in Figure 7 spatial distribution of crops seems to be random; however it does follow a certain logic. Figure 7 shows a field where relatively many types of temporary crops are grown. Annex H shows a field where only one type of crop is grown. Even in the fields with many different crops the majority of the crops are present in small quantities beside one main crop (mostly cassava).

The main crop, cassava, is planted in two different ways: in triangles, a traditional method as taught from generation to generation, and in rows, a method which is the result of a project to enhance agricultural productivity (from SINCHI). The majority of the field is planted with cassava, although one of the fields is only used partly and one field only contains maize. Maize is either planted in rows near the border or intercropped with cassava, in this case meaning it is grown in the middle of a “cassava triangle” (Figure 7). Planting of crops near the border (close to the forested area) is done because according to farmers soil fertility is higher there and certain crops, like sweet pepper, need a more fertile soil. Sweet pepper is planted in rows at the border of the field, as can be seen on Photo 3, or several plants together as can be seen in Annex H. Watermelon is a creeper that grows in between cassava, as can be seen on Photo 4. Lulo is randomly distributed because it is usually not planted but grows naturally and is spared during weeding; the same accounts for the 2 papaya plants found. Long coriander was planted around a tree stump; tree stumps are more often left in the field to improve soil fertility, as can be seen on Photo 5. The only melon plant found in all fields was planted in the middle of the field, probably to prevent robbing. 4 fields that were being cultivated have not been drawn, those fields showed similar patterns as the ones described.

When visiting fields for the first time in June, a field was visited where beans and cassava were intercropped. Tree stumps were used because beans need support. Another common combination used by farmers was plantain - cassava intercropping, however during the floods of 2011 many plantains died and only one field was found full of plantain, see annex H. One field was found with invira *(Pseudobombax munguba)* - cassava intercropping.

The amount of trees planted in the middle of the field is usually limited because it is said cassava does not grow well with much shade. The amount of trees in a field varies between 0 and 6 and the trees are generally planted somewhere near the side of the field. Exceptions are one abandoned chagra with 18 trees planted and about 35 plantains, and one chagra with about 35 invira trees (annex H).

Photo 3 Sweet pepper planted in rows

Photo 4 A watermelon plant growing in between cassava plants

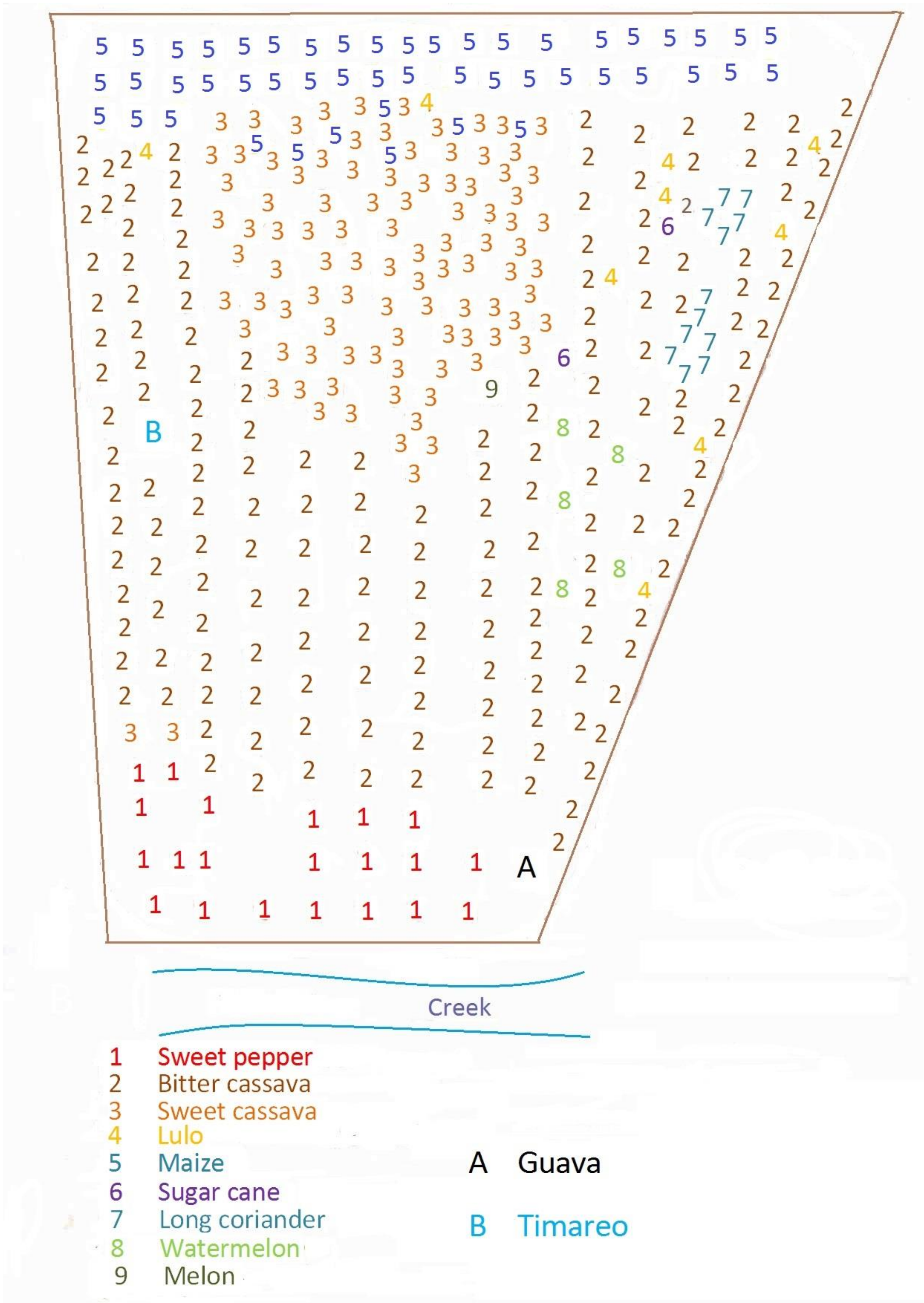

Figure 7 Drawing of a chagra with relatively many types of crops

5.5.3 Buffer zones and vegetation profiles

As mentioned before, adjacent to the agricultural fields are forested areas, which are buffer zones, used for harvesting minor timber products and non-timber forest products. As described in Chapter 3, transects were laid out 5 meters out of the fields, into this buffer zone. 20 different species were found growing in the borders, of which the most frequently encountered tree species were yarumo *(Cecropia sp.),* and matapasto *(Senna reticulata),* fast growing and light demanding *(pioneer)* species. Other frequently encountered species were arapari *(Macrolobium acaciifolium)* and frijolillo (scientific name unknown). No emergent trees were found in those 5 meters, the height varied between 1.7 and 11 meters with an average of 3 ; the DBH varied between 1 and 25.4 cm with an average of 4.65. Other species that, according to observations, frequently grow in the borders, but that were not part of transect measurements are ojé (*Ficus insipida*) and amacisa (*Eryhtrina fusca*). The most represented family is Fabaceae, with 6 species.

Logically, the field structure varies before and during planting season. Figure 8 shows a vegetation profile of a field in the fallow period before cultivation. Figure 9 shows a vegetation profile of a field during cultivation. Other vegetation profiles can be found in Annex I.

Photo 5 In the chagra

Farmer showing a cacao fruit

Plantains in an abandoned field

Tree stumps left in the field

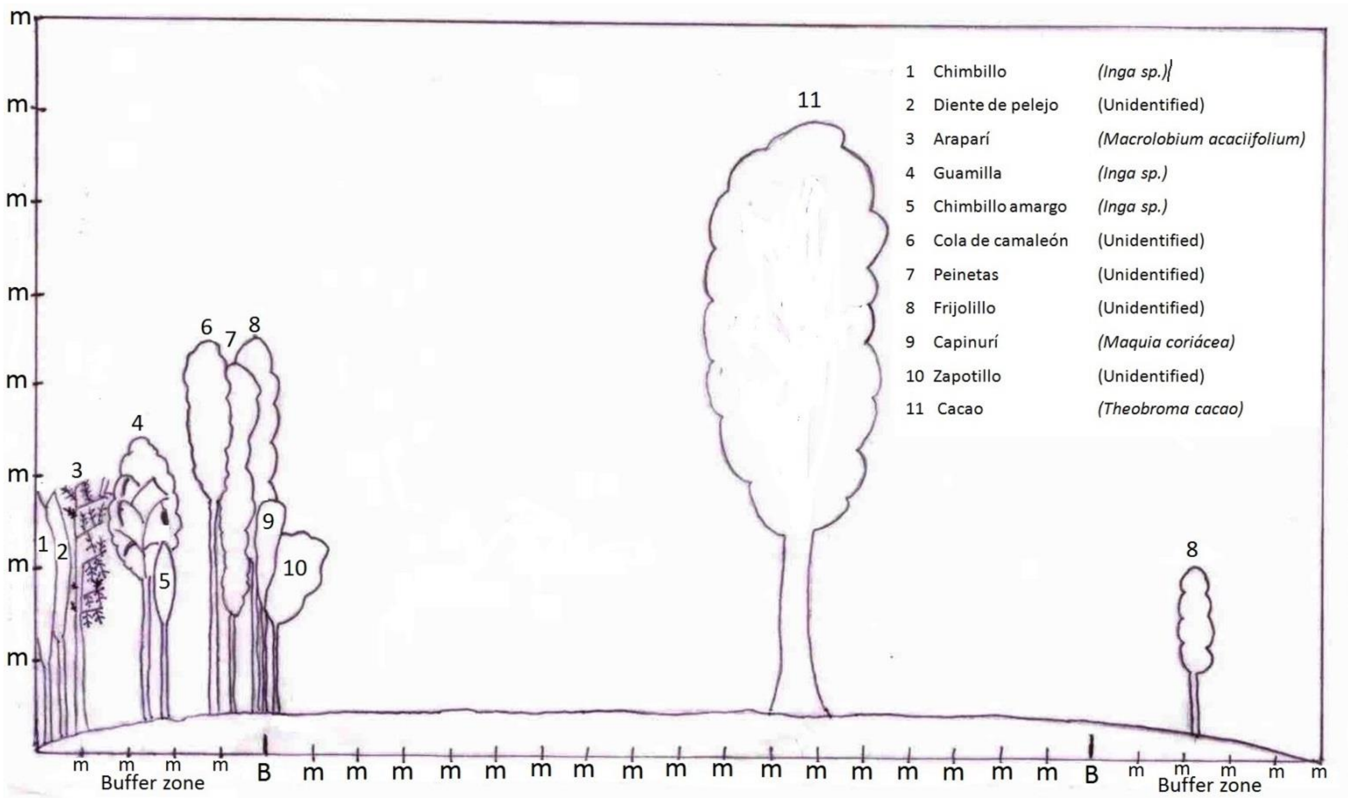

Figure 8 Vegetation profile of a field that lies fallow

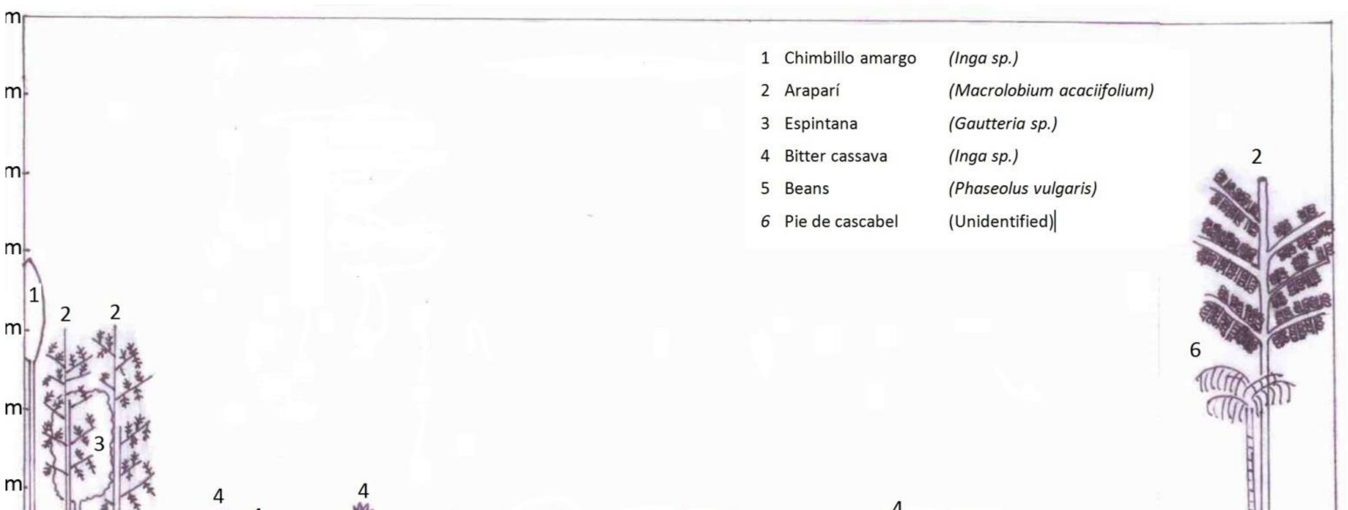

Figure 9 Vegetation profile of a field under cultivation

5.6 Useful species and direct use

As evidenced by the inventories 48 useful species were identified growing in the fields, they represent the majority of the species encountered. Of the useful species 7 belong to the permanent crops. Most inventories were done before the field was under cultivation, and it was noticed that once crop planting had started, almost all useful species had been removed. 6 species were sometimes spared during weeding to provide shade, timber or fruits. It involves the following species: bacurí *(Rheedia sp.)*, catahua *(Hura crepitans)*, ojé *(Ficus insipida)*, cola de camaleón (scientific name unknown), yarumo *(Cecropia sp.)* and cacaoillo (scientific name unknown). These species are thus part of the current agroforestry system. The other 35 species are usually removed from the field during weeding; these plants and trees are partly used as firewood, timber or medicine and partly burned or left in the field. In Annex J a list can be found of the 41 useful species (excluding the 7 species belonging to permanent crops) and their direct use. Of those 41 species, 25 are classified as tree species (60 %), 9 as shrubs (23 %), 2 as palms (5 %), 4 as herbs (10 %) and 1 as grass (2 %).

To describe the use of these species, the same 6 categories are used as with the permanent crops; edible fruits, medicinal use, firewood, timber, handicrafts and cultural use. The majority of the species, 33 (83 %) are being used as firewood, although some species are not very suitable and are only used when there is no other option. 14 of the species (35 %) are being used medicinally, amongst those are herbs like cat's claw *(Uncaria tomentosa).* 18 species are used for timber (45%), for example catahua *(Hura Crepitans).* 5 species are being used to make handicrafts (13 %), 3 species have a cultural use (8 %) and 3 species have edible fruits (8 %).

The suitability of useful species for improving agroforestry was studied by identifying pepeaderos with edible fruits. The four pepeaderos with edible fruits are pie de cascabel (scientific name unknown), chambira *(Astrocaryum chambira),* bacurí *(Rheedia sp.)* and cacaoillo (scientific name unknown); only the fruits of bacurí have an economic value.

The useful species belong to 17 families; the family with the highest amount of species is Fabaceae, with 6 species. Other important families are Lecythidaceae and Moraceae, containing 3 species each.

5.7 Species providing alimentation for fish

As apparent from interviews, the majority of the permanent crops, 10 out of 13 species, are pepeaderos, or species of which the fruits, seeds or flowers are eaten by fish. The only permanent crops not eaten by fish are plantain *(Musa sp.),* amacisa *(Erythrina fusca)* and totuma *(Crescentia cujete).* Of the other useful species, described in Chapter 5.6, the majority are pepeaderos as well, 34 out of 40. However, as mentioned already, only 6 of those species were sometimes spared during weeding, while the other species are mostly removed. Of those 6 species, 5 are pepeaderos, only cola de camaleón is not (scientific name unknown). Thus it can be concluded that 15 species are providing alimentation for fish (the 10 permanent crops and 5 species spared during weeding).

In Table 7 those 15 pepeaderos are described in terms of flowering and fruiting period and the part on which the fish feed. The table is partly based on literature (Van Vliet 2012) and partly on interviews. The fish eat seeds, fruits and flowers during the high water period. In most cases fruits and/or seeds are eaten, like with guava (*Psidium sp.)* and guanabana de la várzea *(Annona hypoglauca).* Of only 3 species the flowers are eaten, for example of invira *(Pseudobombax munguba)* and capirona (*Calycophyllum spruceanum)*.

Some fruit-eating fish in the area are the tambaqui *(Colossoma macropomum),* lisa (*Anostomus teaniatus)* and sábalo *(Brycon sp.).* Although fish have preferences, they often eat any fruit available (Van Vliet 2012).

The flowering and fruiting period of the pepeaderos is related to the flood pulse, most trees start flowering when the water level is rising, the fruits start to mature in January and February and during high waters most fruits are mature and fruit production is at its peak; this can be seen in Table 7. Species with early flowering and fruiting are guamilla *(Inga sp.),* timareo *(Laetia Corymbulosa)* and catahua *(Hura crepitans).* A species with late flowering and fruiting is invira *(Pseudobombax munguba).* Two exceptions are cacaoillo (scientific name unknown) and cacao (Theobroma cacao), with flowering and fruiting throughout the year in an unpredictable way.

Table 7 Species providing alimentation for fish, their flowering and fruiting period and the part on which the fish feed (dark green indicates flowering while light green indicates fruiting)

	Water level														
	Rising			High		Descending			Low	Rising			Part eaten		
Tree	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Seeds	Fruit	Flower
Huito														+	
Guanabana													+	+	
Bacurí													+	+	+
Timareo													+		
Ojé													+		
Yarumo													+	+	
Aguaje														+	
Invira													+		+
Catahua													+	+	
Ubo														+	
Capirona															+
Guamilla														+	
Guava													+	+	
Cacaoillo	Flowering and fruiting throughout the year													+	
Cacao	Flowering and fruiting throughout the year													+	

5.8 Potential agroforestry species

5.8.1 Selection of species

To select species with a potential for improving agroforestry in the várzea the most important criteria were that the trees should have edible fruits that can be sold at the market and the fruits should serve as alimentation for fish. From the species inventories as described in Chapter 5.6, and trees cultivated by farmers as described in Chapter 5.4, in total 11 species were found that have edible fruits and serve as alimentation for fish. However not all of those species seem suitable for agroforestry. Aguaje *(Mauritia flexuosa)* and bacurí *(Rheedia sp.)* take up a lot of space. Cacao *(Theobroma cacao),* guamilla *(Inga sp.)* and cacaoillo (scientific name unknown) are only rarely eaten by fish because of the hard shell. Guanabana de la várzea *(Annona hypoglauca)* is said to have a low fruit production. Pie de cascabel (scientific name unknown) does not have a market value and chambira *(Astrocaryum chambira)* grows better on the mainland. The remaining 3 species species with edible fruits are suitable for agroforestry in the várzea of the Yahuarcaca floodplain, providing alimentation for fish and providing food for local people: huito *(Genipa americana),* ubo *(Spondias* *mombin)* and guava *(Psidium sp.).* Furthermore, 2 other species are currently not a part of the agricultural system but are mentioned several times in literature for providing alimentation for fish and for their consumptive value as well: camu-camu *(Myrciaria dubia)* and acaí *(Euterpe oleraceae)* (Penn 2006, Van Vliet 2012, Reys, Sabino and Galetti 2008). These are species that grow naturally in the várzea of the Yahuarcaca floodplain and their fruits are being harvested from the forest.

Climatic requirements and fruit production data can be found in Table 8; the information is derived from literature (ICRAF 2009, FAO 2011). Tree descriptions as found below are derived from the Agroforestree Database (ICRAF 2009). Information about indirect and direct use is derived from interviews and from Van Vliet (2012), unless otherwise mentioned.

5.8.2 Alimentation for fish

Fish consume the fruits of huito, acaí and ubo but the seeds are too big to consume for most fish. Guava, however, has very small seeds therefore both the fruits and seeds can be consumed by fish; the same accounts for camu-camu. Fish like lisa *(Leporynus sp.),* paco *(Piaractus brachypomus)* and palometa (*Mylossoma duriventre*) eat the fruits of huito. Fish like shuyo *(Hoplerythrinus unitaeniatus*), sabaleta *(Brycon melanopterus)* and sábalo *(Brycon sp.)* eat acaí. Fish like tambaqui *(Colossoma macropomum)*, paco and sábalo eat Camu-camu. Fish like lisa, sábalo and shuyo eat ubo. Fish like picalón *(Pimelodus blochii Valenciennes*), lisa and palometa eat guava (Van Vliet 2012).

5.8.3 Tree descriptions and direct use

Genipa americana – huito

This is a deciduous tree in the Rubiaceae family with an average height of 8 to 20 meters and an average diameter of 30 to 80 centimeters. Its trunk is tall and straight and the crown is quite dense with the lower branches growing horizontal. Its flowers are yellow-white and it has large yellow-brown fruits.

Direct use

Because of the many different uses of huito it is not surprising that this tree is rated as most useful in terms of provided goods and services by people of San Sebástian and other communities surrounding Leticia; it is highly valued by local people in a floodplain area in Peru as well (Kvist, et al. 1995). Local people sell the fruits of this tree at the market and make a juice from it, which is used during the pelazón as well as natural body paint. The fruit juice is used medicinally. Besides, the tree is used for timber production, as construction material and as firewood.

Spondias mombin-ubo

The average height of this semi-evergreen tree in the Anacardiaceae family is about 15 to 22 meters, although sometimes it reaches a height of 30 meters. Average diameter of a mature individual is 60 centimetres. It has small yellow flowers and yellow fruits the size of a plum. The bark is often deeply grooved. Depending on the individual the canopy can be open or somewhat closed.

Direct use

Local people eat the fruits or make a juice from it; the fruits are also sold at the market. The roots, when cooked, are edible as well. Apart from that it is used for timber production, as firewood and it is used medicinally. This tree is also in the list of species which are highly valued by local people in the Peruvian Amazon (Kvist, et al. 1995). Furthermore it is mentioned for its commercial importance (Junk, et al. 2010).

Psidium sp. - guava

This is a small evergreen tree in the Myrtaceae family growing 3 to 8 meters high, with a crooked stem and many branches. The diameter normally does not exceed 25 centimetres. The fruit is a 4 to 12 cm long berry, which is yellow when ripe and has red pulp. Its crown is light and the tree produces little shade (Corpoamazonia 2006).

Direct use

This tree is already grown in many chagras in the várzea. Apparent from interviews it is preferred because of its extreme flood tolerance, because of its small size and because fruits are tasty, can be sold at the market and according to farmers, production is high. The tree is being used for firewood, as timber and medicinally as well.

Myrciaria dubia- camu-camu

This is a small evergreen tree or shrub in the Myrtaceae family with an average height of 3 to 4 meters. It has a smooth trunk of 10 to 15 cm in diameter. Fruits are round and orange and have about the size of a lemon. The fruiting period of camu-camu is from February until May.

Direct use

In San Sebástian and other communities near the Yahuarcaca lakes, the tree is highly valued for delivering goods and services, especially for fruit consumption and selling at the market. Furthermore it is used for firewood, timber and medicine. Because of its nutritional value and commercial potential there have been agroforestry projects that consisted of planting the tree in the floodplains of the Peruvian Amazon (Penn 2006).

Euterpe oleraceae- acaí

This is a palm tree in the Arecaceae family that can grow 12 to 18 meters tall. The average diameter is 20 to 30 centimetres. It has a very straight stem and the fruits are small and black. The fruiting period is from May until June.

Direct use

In San Sebástian and other communities near the Yahuarcaca lakes, the tree is highly valued for delivering goods and services, especially for fruit consumption and selling at the market. It is used medicinally as well. It has been planted throughout the Amazon for its fruits and because it has economic potential (Brondizio 2003). In Brazil they extract the palm heart, the edible inner core of the tree (Pollak, Mattos and Uhl 1995).

Table 8 Climatic requirements and fruit production of five agroforestry species

	Requirements			Fruit production	
Tree	**Annual Rainfall**	**Annual temperature**	**Shade tolerance**	**Production per tree per year**	**Start production**
Huito	1200-4000mm	18-28°C	Intermediate	Up to 80 kg	After 6 to 8 years
Ubo	> 1500 mm	23-28°C	Intolerant	Up to 100kg	After 5 years
Guava	1700-3000 mm	20-30°C	Intermediate	30 to 70 kg	After 2 to 4 years
Camu-camu	1500-3000 mm	20-30°C	Intolerant	5 to 10 kg	After 3 years
Acai	2300-3300 mm	Optimally 26°C	Intermediate	16 to 32 kg	After 4 to 6 years

6 Discussion

6.1 Methodology

To put the results of this thesis into perspective some methodological considerations are important.

Since the fieldwork was done from June until September I have not been present during the harvesting period. When doing research about agriculture in the várzea it would be best to do fieldwork starting before the planting season and continue until after harvesting season to be able to observe changes in the field and agricultural activities in relation with fluctuating water levels. Besides, as noticed while doing this research, reality often differs from expectations one has in the beginning.

Considering the social part of the research: during interviews communication was sometimes a bit difficult. This was due to language, because of working with translations or because both the interviewer and interviewed were speaking in a language that was not their native language. However, also cultural differences played a role. For example, when asking questions about which crops are currently being grown in their chagra in the várzea, people replied by saying which crops are being grown by everybody in the community, or which crops they grow in chagras in on the mainland. This is maybe because of a different way of thinking of people; they seem less individualistic and not categorizing everything. Interviewing in the chagras instead of houses appeared to be a good method because people find it easier to talk about what they see.

Considering the ecological part of the research: the results about types of temporary crops grown and their spatial distribution are based on 9 fields only. However, those were all the fields of the community that were in use at the time of the research. Therefore some fields were visited of other communities in the várzea, where similar annual crops and trees were being grown. The method used for understanding the spatial distribution of crops, as described by Van der Hammen, et al. (2012) is very useful, especially with these small scale traditional farming systems and it is not very time consuming. Although not often encountered in literature it is useful for looking at current agroforestry practices and possibilities for the future.

Making vegetation profiles was very time consuming and because only in a very small part of the chagra measurements were done, results do not show a complete representation of the structure of the whole chagra. However a general picture of the structure of the chagra and the vegetation in the chagra and adjacent buffer zones was obtained.

6.2 Changes over the last decades

There are many factors that have had influence on food security and sustainability of the várzea. The information on changes that took place in the last decades is derived from the limited literature available and few interviews with elders. This means that there have most likely been other changes that fall outside the scope of this research. However some important changes became clear and this is important when looking at future prospects.

As is the case in the Yahuarcaca floodplain, clearing floodplain forests for cattle pasture is a very important cause of deforestation in many regions (Goulding, Smith and Mahar 1993). In the study area, the process of internal colonization since the 1930’s has resulted in deforestation (for cattle ranching) and the loss of land of indigenous people. This process continued until the 1970’s and

1980's, when commercialization of natural resources caused a further degradation of the várzea's ecosystem and natural resources were overexploited due to timber extraction, fishing and hunting. Because of the people's (partial) dependence on natural resources for food supply, a decrease in availability of ecosystem goods and services has important consequences for local livelihoods.

In the 1980's an indigenous reserve for San Sebastián was created, but this was only 58 hectares. Population growth caused a decrease of land available per person, and pressure on the várzea increased as well. Dos Santos Baitz and Uibrig (2005) describe that a characteristic of the households in the várzea is the small resource base on which people operate; furthermore there is often little land available and land tenure is insecure.

In the agricultural system changes took place as well, although the agricultural practices have broadly remained the same. According to farmers, a decline in soil fertility that took place over the years has resulted in smaller crop sizes. Some species that have been cultivated in the past are currently not being grown anymore, like groundnut (*Arachis hypogaea).* Another change that has taken place is that farmers have a greater commercial focus; this is true especially for the chagras on the mainland and has resulted in more monoculture fields instead of the previous higher diversity agroforestry systems. This is more often the case with the chagras of Ticuna people (Hammond, Dolman and Watkinson 1995). Although the focus of this research is on the chagras in the várzea, changes in chagras on the mainland are important from the perspective of health, nutrition and availability of food.

Loss of traditional knowledge is seen as a problem by many farmers and influences not only chagra management but also management of other natural resources. Although sometimes ideas about indigenous knowledge are being romanticized, the amount of knowledge people often have is impressive, as shows for example from the large amount of medicinal plants and trees local people can recognize and know how to use. Loss of this knowledge is not just a cultural loss; it can have negative consequences for food security, agricultural diversity and sustainability of ecosystems (FAO, 2009).

As described in Chapter 1.3, people in the communities surrounding Leticia are less self-sufficient than before. This is not surprising in the light of the changes as described above. According to Peña-Venegas (2009) the food obtained from natural resources is generally high-quality food, while the food bought in Leticia is often of lower quality. Therefore a reduction in the possibilities for obtaining food from natural resources is said to negatively affect people's health and wellbeing.

6.3 The floodplain agricultural system

The agricultural system of the inhabitants of San Sebástian de los Lagos in the várzea is small-scale and labour-intensive. It is mainly subsistence agriculture, but contributes to income generation as well. The system is characterized by the cultivation of annual crops cultivated during the flood free period of 4 to 5 months, the fallow period is during the rest of the year. The cropping system is cassava-based. Cassava is the staple food of the people, it forms an important part of the diet and fariña is made for consumption and selling. All annual crops are cultivated for food production, and some crops are used medicinally as well. Apart from the annual crops a variety of permanent crops (mainly trees) are cultivated, although mostly in low amounts. The majority of those are fruit trees, which can be used for other purposes as well, like for firewood and as medicine. Some trees are cultivated for other purposes, for example for timber production or to use the fruits as fish bait.

The agricultural activities start when the water level has lowered sufficiently with the removal of unwanted trees with an axe. Afterwards the whole field is weeded, which is done by hand or with a machete, and the weeds, after they have dried, are usually burned. Sometimes a hoe is used for loosening the soil. Then the crops are planted with a planting stick or manually. After that, weeding has to be done regularly. At the end of the growing period, before water levels have risen, crops are harvested. The field is then abandoned; the only agricultural activity during high waters in the várzea is the occasional harvesting of fruits from trees.

The agricultural system as applied by inhabitants of San Sebástian de los Lagos in the várzea, as described above, is typical for agriculture in the várzea, when comparing agricultural practices with other areas (Schmidt 2003, De Jong 1995, WrinklerPrins and McGrath 2000). A difference is that certain types of crops that are suitable for cultivation in the várzea are not being grown, as described in Chapter 6.4. A method not practiced in this region, used by farmers in other floodplain regions is that of raised beds for producing vegetables, herbs and spices. In this way cultivation can continue even when water levels rise (Goulding, Smith and Mahar 1993, WrinklerPrins and McGrath 2000).

Apart from that, the duration of the growing period differs per region; the growing period can last from 4 to 8 months and there are even areas not flooded every year, for example in some areas it is possible to cultivate maize two times in a row in one season. Often a distinction is made between high levees *(restinga alta),* low levees *(restinga baja),* mudflats and beaches; a distinction which is made mainly on the basis of altitude, and thus the degree to which the habitats are subject to flooding. The fields of San Sebastián are located on the levees, but since there is no strict division between habitats I was unable to determine if the fields are considered high or low levees. According to Schmidt (2003) however, high levees are areas flooded only during some months and years can pass without flooding, which is not the case in the study area.

The agricultural system in the várzea differs significantly from agriculture on the mainland; this is generally the case and applies for San Sebastián as well. Although cassava is an important crop in upland areas as well, other varieties are used there which take longer to mature. The main difference however is that because soils are less fertile in upland areas, after a few years cultivation has to be interrupted. After the cultivation of temporary crops has stopped, the cultivation of trees is continued, making the chagras dynamic agroforestry systems (CIFISAM; PRONATTA 2006). Although, as described before, this is starting to change now because of a bigger focus on income generation.

6.4 Temporary crops

In the chagras in the várzea most fields are dominated by cassava. 9 temporary crops are being grown, of which the most frequently encountered are: cassava *(Manihot esculenta),* lulo *(solanum quitoense),* watermelon (*Citrullus lanatus*), maize *(Zea mays)* and long coriander *(Eryngium foetidum).* In most of rural Amazonia, cassava is the primary staple crop, and it is often the most important crop grown in the várzea. Watermelon and maize are often grown on floodplains in other areas in South America as well (Kawa 2011, Schmidt 2003), but lulo and long coriander are rarely mentioned. Other crops grown by farmers like sugarcane, papaya and sweet pepper, are also grown by farmers on a floodplain in Brazil but, as is the case in San Sebastián, are not the main crops (Schmidt, 2003).

In most fields only one or two temporary crops are grown. This is common in várzeas (Schmidt 2003, De Jong 1995). However, there are crops currently not cultivated by farmers that are cultivated in the várzea in other regions, like: cowpea, jute, tobacco, rice and okra (Schmidt 2003, Gonçalves, et al. 2010). According to farmers, and affirmed by literature, other crops can be grown in the chagras on the Yahuarcaca floodplain, like: yam, squash, tomato, cucumber, beans, groundnut, sweet potato, onions and machiche (De Jong 1995, Schmidt 2003). Squash and rice are already grown in the area by farmers from other communities, El Castañal and La Playa. It should be noted that which crops are ideally cultivated depends on the floodplain geomorphology; there are differences in soil quality, soil fertility, inundation period and length of inundation (De Jong 1995).

When looking at the results of this research there was a difference between crops that were expected to be grown, and crops that were actually grown. Many crops that were expected according to interviews and field observations in the beginning of the research did not grow in the fields later. Some plants died, but mostly the crops were never planted. Farmers mentioned this is because of the cows and because crops get stolen. However, also pests and diseases on certain vegetables play a role. Farmers say for example it is hard to grow tomato because of its vulnerability.

6.5 Permanent crops

In the chagras in the várzea, 13 permanent crop species are being grown of which 11 are trees, 1 is a palm species and 1 a perennial plant. The most commonly grown tree is guava *(Psidium sp.).* Other frequently grown species are huito *(Genipa americana)*, guamilla *(Inga sp.)* and plantain *(Musa sp.)*. Species encountered in 1 or 2 fields are ubo *(Spondias mombin*), capirona *(Calycophyllum spruceanum),* totuma *(Crescentia cujete),* cacao *(Theobroma cacao),* aguaje *(Mauritia flexuosa),* timareo *(Laetia corymbulosa)*, invira *(Pseudobombax munguba),* amacisa *(Erythrina fusca)* and guanabana de la várzea *(Annona hypoglauca).*

Including agroforestry practices in the várzea is not uncommon. Just like it is done by the farmers of San Sebastián, trees are often planted at the side of the field and not so much in the middle (Schmidt 2003). This is probably because the land is used for more intensive cropping of annuals, which is also the reason why agroforestry is not as common in the várzea as it is on the mainland (where continuous cropping of annuals is not possible) (De Jong 1995).

De Jong (1995) found a total of 40 different agroforestry species grown by farmers in the várzea in Brazil. Fields were found with trees only and fields where trees were combined with annual crops. Many of the same species that are being grown by farmers from San Sebastián are being grown there: capirona, totuma, huito, guamilla, aguaje, plantain, ubo and cacao. Other species that were part of the agroforestry system in the area were cedro *(Cedrela odorata),* chontaduro *(Bactris gasipaes)* and vacavilla *(Oenocarpus mapora).* Just like with the temporary crops, the trees that can be grown in a specific area of the várzea depends on the periodicity and height of flooding.

Schmidt (2003) found 25 agroforestry species on low levees in the várzea in Brazil of which ubo, huito, cacao, guava and capirona were also found in the fields in this research. Other species grown there are inamui (*Ocotea cymbarum)*, acaí *(Euterpe oleraceae)* and castaña de várzea *(Couroupita guianensis).* The intercropping of plantain with cassava is also described as a common practice; it used to be very common in San Sebastián as well before many plantains died because of the floods.

Another agroforestry practice described by Schmidt (2003) is the creation of a fruit orchard, a fallow field with relatively dense planting of fruit trees and high diversity of species. Some species common in the fruit orchards in the várzea are acaí *(Euterpe sp.),* bacurí *(Rheedia sp.)* and cacao *(Theobroma cacao).*

6.6 Useful species

An interesting finding was that almost all plants growing in the chagras are considered useful by local inhabitants. 48 useful species were found growing in the chagras, of which 7 are permanent crops. The majority of the useful species are normally removed during weeding, but 6 species sometimes get spared during weeding, including bacurí *(Rheedia sp.)*, catahua *(Hura crepitans)* and ojé *(Ficus insipida)*. These species are used for timber, fruit production and for providing shade. These species are thus a part of current agroforestry practices of the community, just like the permanent crops that are being grown. Sparing certain species during weeding is also a practice in the várzea in Brazil; it is for example described by Schmidt (2003), however there it concerned timber species like muiratinga *(Maquira spruciana),* virola *(Virola surinamensis),* and the kapok tree *(Ceiba pentandre).* De Jong (1995) mentions the sparing of cedro *(Cedrela odorata),* also a timber species. Bacurí and catahua are part of other agroforestry systems in the várzea, but there they are planted (Schmidt 2003, De Jong 1995).

An important reason for looking at useful species was to see if there were species with agroforestry potential that are not yet cultivated a lot by farmers. There were, however only 4 species with edible fruits: pie de cascabel, chambira, bacurí and cacaoillo that, as explained in Chapter 5.8 are not so suitable.

6.7 Species providing alimentation for fish

It is notable that the majority of the trees growing in the chagras are pepeaderos. 10 out of 13 permanent crops are pepeaderos, 34 out of 40 other useful species and 5 of the 6 species spared during weeding. Van Vliet (2012) also describes that the majority of species in the várzea are pepeaderos.

Sometimes there is a discussion among fishermen about which species are not and are eaten by fish. This is not surprising since their knowledge is based on their own observations. For example with cacao, some people said it is not a pepeadero because most fish cannot consume the fruit because of the hard shell. However, another person has seen a larger fish eating the fruit. The majority of the 15 pepeaderos seen in Table 7 are confirmed by literature for their consumption by fish: huito, guanabana, ojé, yarumo, aguaje, invira, ubo, guamilla and guava (Goulding 1980, Banack and Horn 2002). Walschburger et al. (1990) investigated stomach contents of fish and concluded that almost all fish species consume materials from plants and trees (fruits, seeds or flowers), showing the importance of the várzea for fishery resources.

Regarding the part on which the fish feed, mostly the seeds and fruits are eaten, sometimes the flowers. According to Gottsberger (1978) leaves are sometimes consumed as well. By consuming the seeds, fish play a role in seed dispersal as well (called *ichtyochory*).

Although there are some exceptions, flowering of the pepeaderos generally starts at the beginning of the aquatic phase, when water levels are rising. Fruiting is mostly during rising and high water levels, which is confirmed by Wittmann and Parolin (1999). However some findings of this research are not consistent with that literature, for example they describe that the fruiting of guava already stops before the high water period, while in this region it was observed that fruiting lasts longer. Differences could be due to the fact that research has been done in another region.

6.8 Potential agroforestry species

The following 5 species were selected for improving agroforestry as described in Chapter 5.8: huito *(Genipa americana),* ubo *(Spondias mombin),* guava *(Psidium sp.),* acaí *(Euterpe oleraceae)* and camu-camu *(Myrciaria dubia).* The most important criteria were that they have edible fruits and serve as alimentation for fish; however other aspects were taken into account like whether the fruits can be sold at the market and the size of the tree. The importance of fruits for the inhabitants of San Sebastian and other communities living near the Yahuarcaca lakes is also described by van Vliet (2012); all species most highly valued by the local population have fruits that can be eaten and sold. As apparent from interviews, the selected species also contribute to biodiversity because monkeys, birds and bats consume the fruits of these trees as well.

Also in other regions, acaí and camu-camu are being applied to improve agroforestry. Acaí has been planted a lot in the várzea of Brazil due to the increased demand for the fruits and the strong and growing local, national and international market. Smallholders convert their agricultural plots to acaí-dominated agroforests (Steward 2013).The fruits of acaí are shown in Photo 6. Camu-camu has been planted often in Peru, the government also promoted cultivation of camu-camu to provide income for rural households. The tree is often intercropped with cassava and planted in reforestation projects for the conservation of fishery resources (Penn 2006).

Photo 6 Fruits of the acaí palm (www.skyfieldtropical.com)

7 Conclusion

Details of the findings with regard to the main question and sub-questions are described in Chapter 5 and discussed in Chapter 6. From these, the following can be concluded.

Currently, agroforestry is already a part of the agricultural system of the inhabitants of San Sebastián in the várzea. The agroforestry practices consist partly of planting permanent crops, mainly trees, and partly of sparing certain trees during weeding. In most of the fields, the trees are present in low quantities and grow near the borders. A large part of the species planted and spared during weeding are cultivated because of their fruit production. This shows the importance of fruits for local people, something that is confirmed by literature as well. Taken into consideration the current vegetative structure of the field and the spatial distribution of crops it can be concluded that agroforestry practices can be improved by planting more trees. This should be done adjusting to the current traditional agricultural system and the small field size.

To increase fruit production and provide alimentation for fish, five species have been selected that are expected to be most suitable to contribute to food security and sustainability of várzea: huito *(Genipa americana),* ubo (*Spondias mombin),* guava (*Psidium sp.)* acaí (*Euterpe oleraceae)* and camu-camu (*Myrciaria dubia).* Current agricultural and agroforestry practices should not be replaced; rather the recommendations should be seen as complementing the current system, and maintaining diversity of trees and crops grown.

The chosen species are known to have a high fruit production, according to both farmers and literature. The production of the field will increase, thereby contributing to food security. Since the harvesting of the annual crops is only in September and October, increasing the amount of trees is beneficial because the fruiting period of the trees is approximately from February until August. This means the field will yield during two periods of the year instead of one, meaning there is a better distribution of food from the chagras throughout the year.

The selected tree species are all very nutritious and can therefore contribute to counteracting malnutrition; the fruits contain for example vitamins that are known to be of shortage in the region.

Apart from the direct effects agroforestry can have on food security an indirect effect is expected as well because people consume fish. The fruits of the recommended tree species are consumed by fish species that are most preferred and captured by locals.

Planting more pepeaderos increases food availability for fish and therefore contributes to sustainability of the várzea. Apart from that, improving agroforestry contributes to maintaining biodiversity, since bats, birds and monkeys eat the fruits as well. Furthermore an indirect effect is expected on the sustainability of the várzea because trees can deliver goods and services, lowering pressure on the várzea. For example huito, guava and ubo can be used medicinally, for timber production and as firewood.

Often shifting cultivation is thought of as ecologically unsustainable because of the clearing of rainforest that goes along with slash and burn techniques. In the várzea, however, this is different because cultivation on one plot can continue for a longer period. However, the agricultural system is somewhat unsustainable in a sense that agricultural production is not sufficient for maintaining households.

The agricultural system has not reached its full potential, which is partly due to the low production per field and improving agroforestry can play a role in increasing production. Notably soil fertility has declined during the last decades despite the high fertility of várzea soils. That is why the inclusion of other sustainable agricultural practices, like the use of chicken manure, is recommended as well. These sustainable practices can also contribute to increased food production.

When looking at the changes that took place over the last decades in the area, it can be concluded that time and again there is less space for the cultivation of crops and that the quality of the ecosystem of the várzea has diminished as well, limiting possibilities for natural resource use. That is why it is important to use the remaining land optimally.

Studying the agricultural system of the inhabitants of San Sebastián de los Lagos in the várzea shows the vast knowledge that farmers have and the fact that they are able to cultivate crops in a difficult environment like the floodplain. The chagra is a symbolic place for Ticuna people where this knowledge is transferred from generation to generation. Cultural values of the Ticuna are interwoven in chagra- and natural resource management. This shows for example from the importance of cultivating cassava for the pelazón ritual as well as for their diet.

Thus on the one hand there are aspects of the current agricultural and agroforestry systems that should be maintained but on the other hand improvements are needed as well. Farmers have shown that they are open to change, especially now that many people perceive their own situation as difficult. This is not a theoretical problem description in a thesis, but reality as people told me they sometimes do not have enough food.

The agricultural system of San Sebastián in the várzea has many similar characteristics with what was seen from agriculture of other nearby communities and with floodplain agriculture as described in literature. Therefore the recommendations as described below could contribute to improving other agricultural systems as well.

The decrease in land availability and scarcity of natural resources as a consequence of population growth is a global problem. To ensure food security it is important to come up with creative ideas to increase food supply while at the same time paying attention to nature conservation and sustainability of ecosystems. Agroforestry has received world-wide attention because of that and many projects are going on already and successes were obtained.

8 Recommendations for agroforestry

8.1 Prerequisites and general guidelines

For successful implementation of agroforestry practices the following recommendations should be followed up.

- Solving the problem with roaming cattle and the stealing of crops are prerequisites for any improvement to be made in the agricultural system.

- In the past there have been projects aimed at sustainable agriculture, agroforestry and reforestation of the várzea. These projects have been partly successful, because parts of the várzea have been reforested, some trees have been planted on agricultural plots and different agricultural techniques have been applied, like planting cassava in rows instead of triangles. However these projects have been partly unsuccessful, for example because trees were planted in the várzea that were not flood-resistant; furthermore trees were planted at the end of the growing season just before water levels were rising. Local inhabitants already stated that "those trees cannot swim". An important lesson that can be learned from this is that the incorporation of traditional ecological knowledge is crucial for the implementation of projects. In line with this it should be kept in mind that projects should have a bottom up instead of top down approach.

- Different organisations have experience with working with indigenous communities in the area, like SINCHI and Corpoamazonia. These organisations could be involved in an agroforestry project in the study area and provide technical assistance when necessary.

- Interaction between components of crops and native trees is often unknown, for example the degree of root competition. This is also the case with the selected species and therefore on farm trials can be held to test this. On farm trials are observational trials carried out by farmers in agricultural plots. This can be done with farmers willing to try out new methods, so these recommendations can be an opening for experimentation. Farmers in the region have shown to be open to new opportunities and were willing to participate in other projects as well.

- Setting up a local knowledge exchange system would be advisable. Exchanging local agricultural knowledge is a way to increase agricultural production on the long term (WrinklerPrins and McGrath 2000). Not only knowledge about agriculture and tree farming could be exchanged, but also knowledge on other subjects. For example exchanging knowledge on the use of medicinal plants will counteract the loss of traditional knowledge and contributes to the health of people. Also, knowledge on other health and nutrition issues could be shared in this way. Knowledge exchange meetings could be combined with meetings of the council of village elders.

-Maintaining the forested buffer zone between agricultural plots and the creek is important because of the flora and fauna in those areas, the role these buffer zones play in erosion control and because they provide other environmental goods and services.

8.2 Agroforestry systems

The five species that are selected for agroforestry, as described in chapter 5.8, are all multipurpose fruit trees that are flood-resistant, have edible fruits that can also be sold at the market and serve as alimentation for fish. Apart from increasing food production and providing alimentation for fish, agroforestry can serve additional goals, two examples are given below.

1. Goal: agricultural production aimed at improving nutrition

Species and spatial distribution

Ubo, guava and huito can be planted with the aim of improving nutrition. Since Huito is a large moderately shade-tolerant tree, it is best planted along the borders of the agricultural field, like in Figure 10. Ubo can be planted ìn the field on the side, where it can grow with somewhat shade-tolerant annual crops, like sweet pepper *(capsicum sp.)* or lulo *(solanum quitoense).* In the middle of the field some guava trees can be planted, at low densities so that the cultivation of cassava and other light-demanding annual crops can continue. Considering the traditional farming methods and the small field size, it seems best not to plant trees in rows, but rather in a random mixture, as shown in Figure 10. Since the goal is improving nutrition, high temporary crop species diversity is recommended as well (see also Chapter 8.4).

Guava is a good source of vitamin C, Ubo contains vitamin A and Huito is a source of calcium; as described in the problem analysis those are nutrients people in the Amazonas region often lack. Huito also contains iron, which children often lack (Pandya and Nidhi 2013, ICRAF 2009, United Nations 2005).

Farmers can choose to plant trees at somewhat higher densities and stop cultivation of annual crops after two or three years and in this way create a fruit orchard. This would be a good option for elders or people who do not have a lot of time to work in the chagra. In very small fields only planting huito at the borders is an option.

2. Goal: agricultural production aimed at increasing income

Species and spatial distribution

Acaí and Camu-camu can be planted with the aim of increasing income. Camu-camu requires full sun so it can be planted within the field in a random mixture while acaí can be planted along the borders of the field. Cassava can be planted in the field as the main annual crop.

These fruits give a good price at the market according to farmers and this is confirmed by van Vliet (2012). Furthermore, in San Sebastián there is a fruit pulper where farmers can sell camu-camu fruits. Beside the fariña made from cassava can be sold for a good price as well.

It is said that the acai and camu-camu fruits have certain health benefits: acaí contains anti-oxidants and healthy fatty acids and camu-camu has a very high concentration of vitamin C (Alves, et al. 2002, Strauss, et al. 2006).

Establishment and maintenance

All trees should be planted at the beginning of the growing season in June or July, considering the flood risk. Ubo, huito and guava are usually propagated vegetatively through stem cuttings; since these tree species are already cultivated by farmers planting material availability will probably not be a problem. Acaí and Camu-camu are propagated by seeds; those are species that grow in the area. When, however, the availability of planting material would be a problem a nursery could be set up by a group of people. An advantage is that farmers already have experience with tree planting. All selected trees require low maintenance; only weeding should be done regularly, especially with camu-camu (Penn 2006). Pruning is not necessary but can be done to make sure a tree does not provide too much shade for annual crops. Branches that are removed can be used as firewood and the leaves of huito can be used as a soil improver.

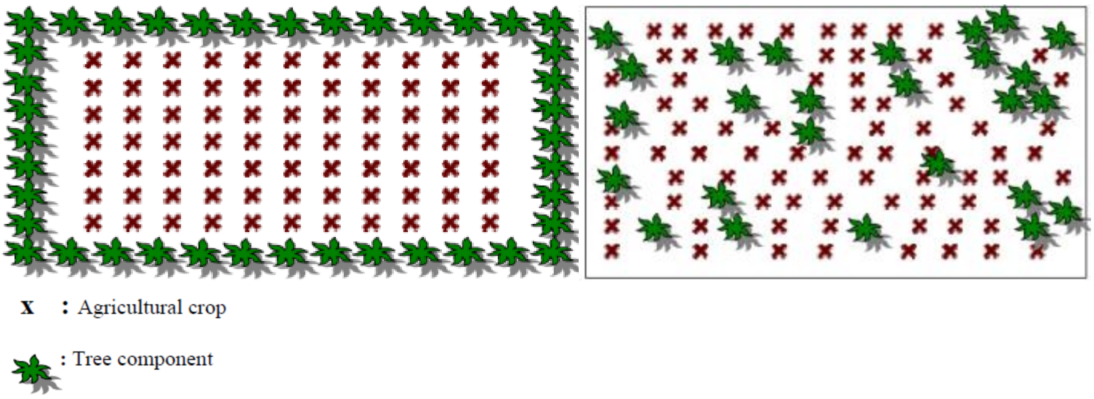

Figure 10 Trees along the borders of the field (left) and in a random mixture (right)

8.3 Other sustainable agricultural practices

Apart from agroforestry practices as described above, there are several techniques that can be used to improve sustainability of the agricultural system: increasing the supply of organic matter through addition of manure, nutrient recycling mechanisms through using intercropping with legumes, and increasing temporary crop species diversity. Techniques that together can result in effective use of local resources, a varied diet, enhanced pest control and soil conservation (Altieri 1987).

Although soil fertility generally is higher in várzeas than in upland areas, as described in the results the soil is not that fertile in some chagras and crop sizes are smaller than before. Therefore increasing soil fertility would be a good option to benefit crop yields. A method used already by some farmers, especially in upland areas, is through the use of chicken manure, combined with sawdust. Since many people have chickens this is an easy applicable method. According to Kreibich and Kern (2000), when there is a shortage of nutrients in the várzea, it is mostly nitrogen, because white-water does not contain much nitrogen. Chicken manure contains a lot of nitrogen.

Adding wood chips as mulch is good for retaining nutrients and maintaining soil moisture; during the growing season there are months with a lot of sun and relatively little rainfall, this makes the soil dry. Apart from that, burning weeds, a practice often applied currently, causes high aboveground loss of nutrients (Giardina et al., 2000). Weeds could thus be composted, and after that left in the field to conserve soil moisture and add organic material. Some farmers do this and confirm it is better than burning.

Cassava, when intercropped with legumes like beans, groundnut or cowpea, has a yield somewhat lower than cassava planted in monoculture. However, with this intercropping system land use efficiency increases and this is important since available arable land in the area is limited. Furthermore an increase in economic return has been reported and legumes are known to improve soil fertility through nitrogen fixation (Polthanee et al., 2001). Besides, legumes do not grow well in upland areas and can serve as a source of protein.

It should be kept in mind that in order to decrease vulnerability to pests and diseases it is best not to grow the same crop on the same part of the field every year, but instead use crop rotation: growing different crops in succession on the same land, preferably crops from a different family (Altieri 1987).

8.4 General recommendations

It is recommended to diversify temporary crop production, however more research is needed to determine which exact crops farmers prefer and are best suitable, also in combination with trees. Apart from continuing the crops that already are being grown, some of the crops mentioned in Chapter 6.4 could be cultivated as well like squash, tomato, cucumber and yam. Some crops that grow in the várzea cannot be cultivated in the chagras on the mainland. It would be advisable to provide technical assistance on how to cultivate vegetables since farmers have indicated they find it difficult to grow vegetables due to pests and diseases.

A technique used in a Brazilian várzea agricultural system as described by WrinklerPrins and McGrath (2000) is worth trying out seen the risk of flooding of crops. When water levels are still high seeds (mainly of watermelon) are planted in a cup made of a cacao leaf filled with a mixture of manure and the rotting bark of Invira *(Pseudobombax munguba).* Apart from adding organic matter to the soil, in this way seedlings are ready as soon as the water level has lowered sufficiently and the growing season begins. Another option to minimize flooding risk is making use of raised beds. This happens especially in floodplain gardens in other várzea regions and might be an option here as well.

I found several documents in which no distinction was made between mainland and várzea agriculture and ecosystems. Because the systems are intrinsically different and ask for a different approach making this distinction would indeed be useful.

There is not much information available about how to improve agroforestry systems and the information that exists is often very general. Examples can be found of improved agroforestry systems, however very little more detailed information exists about, for example, the spatial distribution of crops and trees. Usually the spatial distribution of crops is only described in research where the aim is calculating exact yields under different planting patterns. More detailed information on spatial distribution would be useful because in agroforestry the arrangement of components plays an important role.

Directing agricultural research in the tropics aimed at its practical application would be beneficial for many people.

References

Altieri, M.A. *Acroecology: the science of sustainable agriculture.* Boulder: Westview Press, 1987.

Altieri, M.A., and L.C. Merrick. “In-Sity conservation of crop genetic resources through maintenance of traditional farming.” *Economic Botany*, 1987: 86-96.

Alves, R.E., H.A.C. Figuieras, C.F.H. Moura, N.C.C. Araujo, and A.S. Almeida. “Camu- Camu (Myrciaria dubia): a rich natural source of vitamin c.” *Journal of the Interamericans Society For Tropical Horticulture*, 2002: 11-13.

Ayres, J.M. *Flooded forests in the Mamirauá: Middle Solimões River.* Sociedade Civil Mamirauá, 2006.

Banack, S.A., and M.H., Gawlicka, A. Horn. “Disperser- vs. establishment-limited distribution of a riparian fig tree (Ficus insipida) in a Costa Rican tropical rainforest.” *Biotropica*, 2002: 232-243.

Bandna, C. “Effect of processing on the cyanide content of cassava.” *Journal of Microbiology, Biotechnology and Food Sciences*, 2012: 947-958.

Brondizio, E.S. “The urban market of Acaí fruit and land-use change.” *Urban ecosystems*, 2003: 67-97.

CIFISAM; PRONATTA. *La chagra: un espacio de roles, aprendizajes y autoebastecimiento.* Puerto Legizamo: Centro de investigación, formación e información para el servicio Amazónico, 2006.

Corpoamazonia. *Plan de ordenación y manejo de la microcuenca de la quebrada Yahuarcaca.* Leticia: Corpoamazonia, 2006.

De Jong, W. *Diversity, variation and change in ribereño agriculture and agroforestry.* PhD Thesis, Wageningen: University of Wageningen, 1995.

Dufour, D.L. “Uso de la selva tropical por los indígenas Tukano del Vaupés.” In *La selva humanizada: ecología alternativa en el trópico húmedo colombiano*, by F. Correa. Bogota: Instituto Colombiano de Antropologia, 1993.

Eden, M.J., and A. Andrade. “Ecological aspects of swidden cultivation among the Andoke and Witoto Indians of the Columbian Amazon.” *Human Ecology*, 1987: 335-356.

FAO. *The community's toolbox.* Rome: Food and Agriculture Organization of the United Nations, 1990.

FAO. *Tree crops- guidelines for estimating area data.* Food and Agriculture Organisation of the United Nations, 2011.

Fernandez, G.A., I.E. Rodriguez, M.A. Araujo, and E.E. Camarillo. “Efecto diurético del extracto acuoso de pericarpio de melón (Cucumis melo) en ratas.” *Revista Cubana de Plantas Medicinales*, 2008.

Gonçalves, J.R., J.R. Fontes, R. de Morais, M. Rocha, and L.J. Guimarães. *Sustainable production of grains in Amazonian floodplain.* Brisbane: Brazilian Agricultural Research Cooperation, 2010.

Gottsberger, G. "Seed dispersal by fish in the inundated regions of Humaita, Amazonia." *Biotropica*, 1978: 170-183.

Goulard, JP. *Entre mortales e inmortales: El Ser según los Ticuna de la Amazonia.* Lima: IFEA, 2009.

Goulding, M. "Introduction to the Section 1: Fish and Fisheries. Várzea:diversity, development, and conservation of Amazonia's whitewater floodplains." *The New York Botanica*, 1999: 3-6.

Goulding, M. *The fishes and the forest. Explorations in Amazonian natural history.* Berkeley: University of California Press, 1980.

Goulding, M., N.J.H. Smith, and D.J. Mahar. *Floods of fortune: ecology and economy along the Amazon.* New York: Columbia University Press, 1993.

Hammond, D.S., P.M. Dolman, and A.R. Watkinson. “Modern Ticuna swidden- fallow management in the Colombian Amazon: ecologically integrating market strategies and subsistence-driven economies?” *Human Ecology*, 1995: 335- 356.

ICRAF. *Agroforestree Database: a tree reference and selection guide version 4.0.* World Agroforestry Centre, 2009.

IDEAM. *Temperatura y otros valores. Cartas climatologicas – medias.* Leticia: El Instituto de Hidrología, Meteorología y Estudios Ambientales, 2000.

Inglis, J.T. *Traditional ecological knowledge: concepts and cases.* Ottawa: International Development Research Centre, 1993.

Jamnadass, R., F. Place, E. Torquebiau, E. Malézieux, M. Iiyama, and GW. Sileshi. *Agroforestry, food and nutritional security.* Nairobi: World Agroforestry Centre, 2013.

Junk, W.J., M.T.F. Piedade, F. Wittmann, J. Schöngart, and P. Parolin. *Amazonian floodplain forests: ecophysiology, biodiversity and sustainable management.* Dordrecht: Springer, 2010.

Kawa, N.C. *The social nature of agrobiodiversity in central Amazonia.* PhD Thesis, University of Florida, 2011.

Kvist, L.P., M.K. Andersen, M. Hesselsoe, and J.K. Vanclay. “Estimating use-values and relative importance of Amazonian floodplain trees and forests to local inhabitants.” *Commonwealth Forestry Review*, 1995: 293-300.

Lopez, V.A. “Chagras y mujeres indígenas: significado y función del trabajo femenino en la comunidad indígena Ticuna San Sebastián de los Lagos.” Thesis, Leticia, 2009.

Lucas, C.M. “Within flood season variation in fruit consumption and seed dispersal by two characin fishes of the Amazon.” *Biotropica*, 2008: 581-589.

Municipality of Leticia. *Plan de Desarollo Municipal 2005-2007.* Leticia: Municipio de Leticia, 2004.

Nair, P.K. *An introduction to agroforestry.* Dordrecht: Kluwer Academic Publishers, 1993.

National Research Council. *Sustainable agriculture and the environment in the humid tropics.* Washington D.C.: National Academy Press, 1993.

Omacha Foundation. *Conservation of river dolphins in South America.* Bogota: Omacha Foundation, 2009.

Pandya, A., and D. Nidhi. “Analysis of ascorbic acid contents in white guava and red guava.” *Journal of chemical, biological and physical sciences*, 2013: p. 2644-2648.

Peel, M.C., B.L. Finlayson, and T.A. McMahon. “Updated world map of the Köppen-Geiger climate classification.” *Hydrology and Earth System Sciences*, 2007: 1633-1644.

Peña-Venegas, C.P., A. Mazorra Valderrama, L.E. Acosta Muñoz, and M.N. Pérez Rúa. *Seguridad alimentaria en comunidades indígenas del Amazonas: ayer y hoy.* Bogota: SINCHI, 2009.

Penn, J.W. “The cultivation of camu camu (Myrciaria dubia): a tree planting programme in the Peruvian Amazon.” *Forests, Trees and Livelihoods*, 2006: 85-101.

Pinedo-Vasquez, M., M.L. Ruffino, C. Padoch, and E.S. Brondízio. *The Amazon Várzea: The decade past and the decade ahead.* Dordrecht: Springer, 2011.

Pollak, H., M. Mattos, and C. Uhl. “A profile of palm heart extraction in the Amazon estuary.” *Human Ecology*, 1995: 357-363.

Prance, G.T. “Notes on the vegetation of Amazonia III. The terminology of Amazonian forest types subject to inundation.” *The New York Botanical Garden*, 1979: 26-38.

Prieto-Piraquive, E. *Caracterización de la pesquería en las lagunas de Yahuarcaca (Amazonas, Colombia) y pautas para su manejo sostenible.* PhD Thesis, Guanare: Universidad Nacional Experimental de los Llanos Occidentales, 2006.

Reys, P., J. Sabino, and M. Galetti. “Frugivory by the fish Brycon hilarii (Charicadae) in Western Brazil.” *Elsevier*, 2008: 1-6.

Rodrigues, R.B., H.C. De Menezes, L.M.C. Cabral, M. Dornier, and M. Reynes. “An Amazonian fruit with a high potential as a natural source of vitamin C:the camu-camu.” *Fruits*, 2001: 345-354.

Saenz, M.T., M.A. Fernandez, and M.D. Garcia. “Antiinflammatory and alnalgesic properties from leaves of Eryngium foetidum L. (Apiaceae).” *Phytotherapy Research*, 1997: 380-383.

Santos, A., E. Camps, M. Perez, and S.R. Duque. "Historia ambiental de los Ticuna en los lagos Yahuarcaca." Leticia, 2013.

Santos, A.A., E.C. Arroyo, J. Dámaso Yoni, T. Mendoza Salamanca, S.R. Duque, and C. Rodríguez. *Diálogo de saberes y conocimiento local en los ciclos de agua: los lagos de Yahuarcaca.* Leticia: Universidad Nacional de Colombia- Sede Amazonia, 2008.

Schmidt, M.J. *Farming and patterns of agrobiodiversity on the Amazon floodplain in the vicinity of Mamiraua, Amazonas, Brazil.* Thesis, University of Florida, 2003.

Smith, N., J. Dubois, D. Current, E. Lutz, and C. Clement. *Agroforestry experiences in the Brazilian Amazon: constraints and opportunities.* Brasilia: World Bank, 1998.

Smith, N.J.H. "Homegardens as a springboard for agroforestry development in Amazonia." *International Tree Crops Journal*, 1996: 11-30.

Steward, A. *Changing lives, changing fields: diversity in agriculture and economic strategies in two caboclo communities in the Amazon Estuary.* PhD Thesis, New York: The City University, 2008.

Steward, A. "Reconfiguring agrobiodiversity in the Amazon Estuary: market integration, the acaí trade and smallholders' management practices in Amapá, Brazil." *Human Ecology*, 2013: 827-840.

Strauss, A.G., R.L. Prior, B. Ou, D. Patel, D. Huang, and J.P. Kababick. "Phytochemical and nutrient composition of the freeze-dried Amazonian palm berry, Euterpe oleraceae Mart. (Acai)." *Journal of Agricultural and Food Chemistry*, 2006: 8598-8603.

United Nations. "Market Brief in the European Union for selected natural ingredients from native species." 2005.

van der Hammen, M.C. *El manejo del mundo: naturaleza y sociedad entre los Yukuna de la Amazonia Colombiana.* Bogota: Tercer Mundo Editores, 1991.

Van der Hammen, M.C., S. Frieri, N. Zamora, and P. Navarette. *Autodiagnóstico: reflexionar para conocer el territorio.* Bogota: Tropenbos International, 2012.

Van Vliet, K. "La relación entre los peces vegetación de la várzea y usos directos." Thesis Report, 2012.

Walschburger, T., C. Monje, and D. Munoz. *Importancia de los bosques inundados para el recurso pesquero en la Amazonia Colombiana.* Bogota: Fundación Puerto Rastrojo, 1990.

Wittmann, F., and P. Parolin. "Phenology of six tree species from central Amazonian várzea." *Ecotropica*, 1999: 51-57.

WrinklerPrins, M.G.A., and D.G. McGrath. "Smallholder agriculture along the lower Amazon floodplain, Brazil." *Plec news and views*, 2000: 34-42.