**CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE**

**Faculty of Tropical AgriSciences**


# Adoption of multistrata agroforestry systems in the Peruvian Amazon

MASTER'S THESIS

Prague 2023

**Author**: Kateřina Čalounová

**Chief supervisor:** prof. Ing. Bohdan Lojka, Ph.D.

# Declaration

I hereby declare that I have done this thesis entitled “Adoption of multistrata agroforestry systems in the Peruvian Amazon” independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague, 21.4.2023

.....

Kateřina Čalounová

# Acknowledgements

I would like to thank my supervisor, Prof. Ing. Bohdan Lojka, Ph.D., for his invaluable guidance, feedback, and suggestions throughout the research and writing of this thesis.

I could not have undertaken this journey without the crucial help of Ing. Goldis Perry Davila. I am extremely grateful for his help on the research site, for his support, patience, and medical care he arranged when needed. Special thanks also go to the Perez Tuesta family for their unceasing support, namely to Cielo Yamileth Perez Tuesta for her tireless assistance and aid.

This endeavour would not have been possible without the help of the National University of Ucayali and the helpful team of the international office. I am aware that without the support and safe background they created, my research could not have been realized. For the useful consultations, I would like to express my gratitude to Jan Bouček Sr.

A big thanks also goes to my friends and family for their love and support during this process.

Finally, I would like to acknowledge all of the participants in my study for their time and willingness to share their experiences. This work would not have been possible without their contributions.

## Abstract

Deforestation in the Amazon rainforest is one of the biggest environmental threats our planet is facing nowadays. More than one-third of the forest loss is caused by local small-scale farmers and their unsustainable slash-and-burn agriculture. A project aiming to bring change in this regard took place in the area of Pucallpa in the Ucayali region of Peru in between 2007 and 2009. Its aim was to promote and apply agroforestry within the community of local farmers and eventually, this way, cease the deforestation in that area. The focus of this thesis was to evaluate the impact of the project, with a focus on the adoption of agroforestry. The aim of the research was to determine how many farmers continue using agroforestry and what the reasons were for why some have dropped out. It was investigated what factors agroforestry adoption was dependent on in the area and what the farmers' perception of agroforestry was. First, by visiting the villages where the project took place, it was found that 22% of the participants continue to use agroforestry. Second, by conducting a survey with 41 respondents, the reasons for the dropout from the project were identified. The causes were uncontrolled human-induced fires, a labour shortage, insufficient financial resources, and farmers' motivation. Agroforestry adoption at the study site is related to the number of workers on the farm, years of experience in agriculture, the cultivation of timber trees, and the motivation of environmental protection to use agroforestry. Farmers' perception of agroforestry was evaluated as positive; they are aware of its various benefits. The factors that are important for them are shading by the trees, food and construction material production, and environmental impacts such as halting deforestation and maintaining biodiversity.

**Key words**: agroforestry, Amazon, Peru, multistrata agroforestry systems, rainforest deforestation

# Contents

# List of tables



# List of figures

## List of the abbreviations used in the thesis

AF = agroforestry

AFS = agroforestry systems

CIDRA = Centro de Investigación y Desarrollo Rural Amazónico

UNU = Ucayali National University

# 1. Introduction

The Amazon rainforest is the largest remaining tropical rainforest on the planet, and naturally, it is considered a biodiversity and cultural diversity hotspot (Silva et al. 2021; Reygadas et al. 2023). Its importance in the global ecosystem is immense, as it provides numerous environmental services. It is responsible for evapotranspiration, which maintains humid tropical conditions in the area; water recycling (Silva et al. 2021); carbon sequestration; oxygen supply; sustenance of biodiversity; genetic resources; and so many others. These ecosystem services are highly affected by the degradation of the Amazon rainforest and its deforestation (Reygadas et al. 2023).

Deforestation of tropical rainforests and loss of vegetation cover are some of the biggest environmental threats our nature is facing nowadays (Steffen et al. 2015). The disappearance of native forests not only decreases biodiversity and leads to the irreversible eradication of a number of species, but also reduces the capacity of the ecosystem to sequester carbon (Chapin et al. 2011). That is becoming a serious problem when the carbon dioxide emissions of humankind continue to increase and there is high pressure to reduce them or store them as carbon to prevent climate change (IPCC 2022).

Forest loss in the Peruvian Amazon is caused by multiple factors, some of which are logging, expansion of the agricultural border, human settlements, and gold mining (Alarcón-Aguirre et al. 2023). A big portion of deforestation and forest degradation is done by local small-scale farmers in the Amazon basin, about one third (Serrao et al. 1996). That is mainly due to shifting cultivation, which is practised by millions of farmers, yet it is blamed for keeping them in poverty (Lojka et al. 2016).

Nowadays, there is a higher pressure on productivity increases in agriculture coming from population growth and its higher demands (Department of Economic and Social Affairs 2021). The higher demand is due to population growth but also to the diet change which includes more calories and more varied and expensive food. It can seem impossible to keep the production sustainable at this pace. Luckily, agroforestry is a solution for both problems, as the system's attributes are productivity and sustainability. There is also a third term, which is adoptability, meaning that it is easy to be adopted by a farming community (Nair 1993).

It has been shown that agroforestry could serve as a solution to problems causing deforestation, but it has not been fully researched how effective the adoption of these alternative land use systems is (Lojka et al. 2016). A number of projects aiming to slow down deforestation rates have been implemented in the Amazon rainforest, one of which is Sustainable Management of Natural Sources in Amazonia, realized by the Czech University of Life Sciences (CULS) and Ucayali National University (UNU) between 2007 and 2009. The aim of this project was to promote and implement agroforestry in the region. The project was meant to work over the long term to be beneficial for both local communities and the environment, but a view of the evolution of the project's outputs over time has been missing. That is why the focus of this thesis is on the adoption of multistrata agroforestry systems by local farmers in the Peruvian Amazon in the region of Ucayali. The research aim was to evaluate the benefits of agroforestry and whether the project had positively impacted its participants. The data were compared to a control group of farmers from the same area who had not been involved in the project.

# 2. Literature review

## 2.1. Multistrata agroforestry systems

"Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land management unit as agricultural crops and/or animals, either in the same form, spatial arrangement, or temporal sequence." (Lundgren & Raintree 1983). Simply put, it is an integration of trees with crops and possibly also livestock (Rosenstock et al. 2019). The specific definition of agroforestry differs depending on the country's legal system. What distinguishes agroforestry from other agricultural systems is that the production is diversified, and the farmer aims to obtain a variety of products in their harvest. It is not only the afforestation of an agricultural land, but there must also be a combination of certain agricultural productions leading to multiple products or benefits from the same management unit (Nair et al. 2021).

There are different ways to classify agroforestry, one of them is based on the type of components of such a system (Nair 1993).

- **Agrisilvicultural system** – combination of crops and woody perennials such as trees or shrubs. An example of such production can be home gardens, multistrata systems, alley cropping, shelterbelts, plantations with crop combinations, etc.

- **Silvopastoral system** - combination of trees and pastures or animals directly. Examples are orchards with pastures, parkland systems, and others.

- **Agrosilvopastoral system** – combination of all the above in one area. Examples are home gardens with livestock, multipurpose woody hedgerows, etc.

This classification is done according to the composition of the components. If focus is given to the vertical stratification of the components, the systems can be differentiated based on how many levels, e.g., strata, they have. It is commonly referred to as agrisilvicultural systems as multistrata systems, because the vegetation is spread on several levels (annual crops on the ground level, shrubs or young woody perennial plants above, and older, taller woody perennials above these, for example). By their structure, multistrata agroforestry systems in the tropics imitate the arrangement of a rainforest (Nair 1993).

The above classifications are within the category of spatial arrangements; they are described by the components spread in an area. Another perspective from which agroforestry can be classified is temporal arrangement, meaning how the components change over time. The most common example of such classification is rotational practice, where crops and other vegetation in one area change during rotational periods. Concomitant temporal arrangement is a system where different components occupy the same parcel for some time. An example of such a practice is *taungya*. An opposite case is the separate or sequential temporal arrangement, which is the case of improved fallow, where different crop components occupy the land at different times (Nair 2021).

"Agroforestry is a relatively new word for an old set of practices" (Nair 1993). It has been ascertained that pre-Columbian civilizations were using agroforestry systems on their land to meet the high demand for timber production while preserving valuable natural resources (Lentz & Hockaday 2009). A specific example from the Peruvian region is the Inca civilization, which practiced agroforestry around AD 1100 (Chepstow-lusty & Winfield 2000). Nowadays, due to agricultural intensification, agroforestry is not commonly implemented in land management. Since 1945, monoculture has become prevalent all around the world, not only in food production but also in non-food crops such as cotton (Balogh 2021). Although it is an example of intensive farming, monoculture leads to a production loss in an area over time, which leads to increased use of inputs. It consequently negatively impacts the environment by polluting water resources, increasing soil erosion, increasing carbon emissions in the atmosphere, and causing loss of biodiversity (Demirdogen et al. 2023).

### 2.1.1. Benefits of agroforestry

Agroforestry seems to offer a solution for the problems the environment is currently facing. It provides a wide range of ecosystem services and benefits the environment and people in various ways (Figure 1). On the biophysiochemical level (in Figure 1, referred to as ecological services), agroforestry is recommended for soil restoration thanks to its positive impact on both the structure and composition of the soil. It fights soil erosion and the creation of soil crust by decreasing the soil bulk density, which changes the ability of the soil to conduct water in the soil (Indoria et al. 2020). Agroforestry physically enforces the soil structure with the roots of trees and shrubs. The

chemical composition of soil can be improved under an agroforestry system thanks to more soil organic matter present under trees from their canopy (Chapin et al. 2011). Shed leaves from the trees work as mulch and fertilizer, provide more matter for soil microorganisms, and thus provide a better environment for matter circulation (Iqbal et al. 2020). It enhances not only more organisms in the soil but also at the canopy level, as the above-ground biomass provides shelter and habitat for various organisms. That is an example of the biological benefit of agroforestry, which brings more biodiversity into the production system. The aboveground biomass of trees and shrubs provides not only shelter for animals but also creates an environment with a specific microclimate or helps to maintain a forest-like microclimate. That seems to be beneficial for the environment thanks to its positive impact on plant regeneration and growth, nutrient cycling, and soil respiration (Chen et al. 1999). The trees can also serve as natural a fence and provide shade for animals in a silvopastoral system or increase pollination possibilities (Nair 2021).

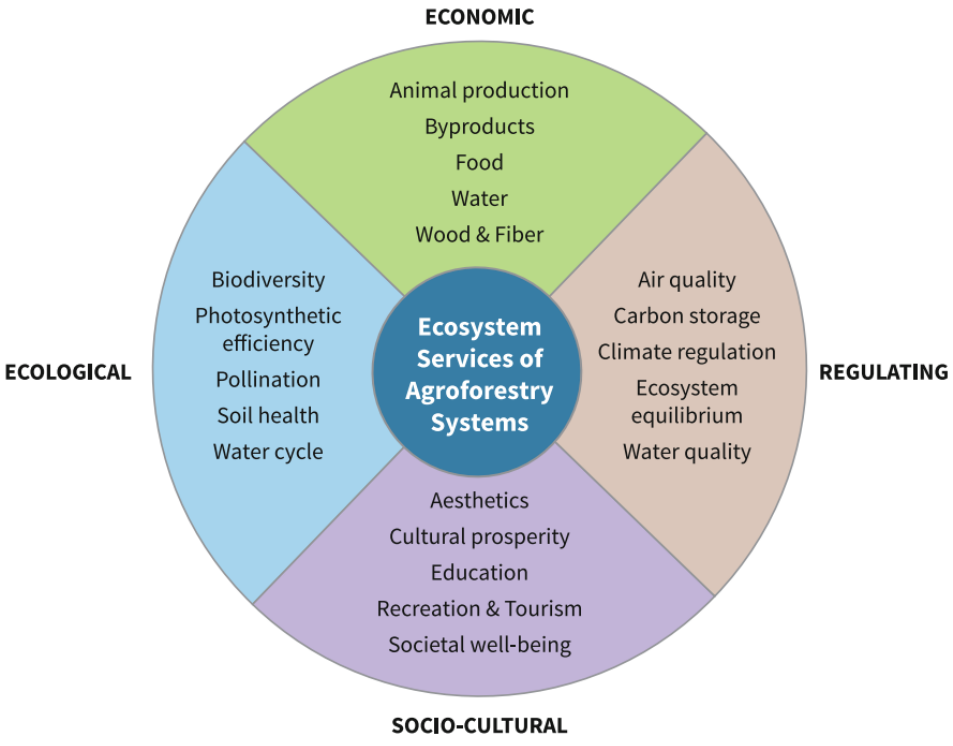


**Figure 1 Ecosystem services (Nair 2021)**

Another level on which agroforestry is beneficial is the environmental one because it provides regulating services. These services are crucial in regard to efforts to decrease the contribution to climate change. "The average global temperature has

increased by about 0.8 degrees Celsius since 1880, and this change is believed to be permanently changing the Earth's climate" (Nair 2021). It is believed that climate change and global warming are caused by an increased concentration of greenhouse gases in the atmosphere. One of these gases is carbon dioxide, $CO_2$, concentration of which has increased from about 280 ppm in the pre-industrial period to more than 400 ppm in the early 2000s. It is alarming that with the knowledge we have nowadays about this problematic, the concentration of $CO_2$ in atmosphere keeps rising faster, instead of decreasing (2.4 ppm per year during 2010 – 2019, compared to 2 ppm per year in early 2000s) (Nair 2021). The two biggest anthropogenic sources of $CO_2$ are fossil emissions and emissions resulting from land use change and land management, such as deforestation, degradation, and others (see Figure 2). One third of this emitted $CO_2$ is stored by vegetation in terrestrial systems (IPCC 2021). But with the continuous deforestation, forests, which have served as carbon sinks, become carbon sources. That is why carbon sequestration as a tool to balance the increasing carbon emissions and thus mitigate the climate change has a high importance.

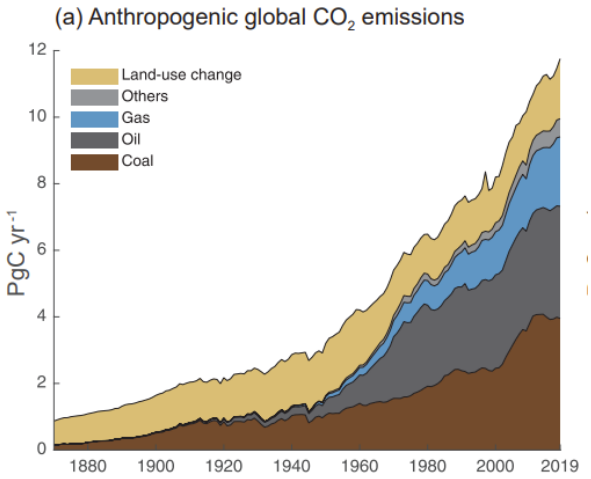


**Figure 2 Global anthropogenic $CO_2$ emissions (IPCC, 2021)**

By planting more trees on agricultural land, agroforestry can be more effective in carbon sequestration thanks to greater capture and resource utilization than monoculture systems (Ghale et al. 2022). When compared to natural forests, agroforestry is certainly less effective in acting as a carbon sink, but needless to say, agroforestry serves as an agricultural production system and provides many benefits for its users that way. If comparisons are made between other agricultural systems, agroforestry seems to be sustainable in this regard.

Among other regulating services, agroforestry provides benefits for water quality, soil protection, ecosystem balance, and nutrient cycling. The last mentioned is often used in soil restoration when leguminous trees are planted to act as natural fertilizer. These trees are able to provide such a service thanks to nitrogen fixing-bacteria living in the root nodules. This can increase the soil mineral nitrogen and improve soil health (Rosenstock et al. 2014). Thanks to lower nitrogen inputs, the system also reduces the overall emissions (Smith et al. 2014).

Agroforestry brings benefits on an economic scale as well; thus, it provides functions to the users, e.g., farmers. By planting trees on their land, farmers diversify their harvest and do not depend on a single product, which secures their income. Fruit trees might bring fruit harvest every year, while timber trees could be harvested in several years for their valuable wood. There are also a large number of non-wood products the trees can provide, such as medicine, fodder, green manure, and others. What is usually most beneficial for the local farmers is the ecological and sociological service of providing shade for other crops and for people, as well as the economic service of augmenting the yield of the shade tolerant crops, which results in a higher farmer's income.

The last sphere in which agroforestry is profitable is socio-cultural services. People often grow trees for their pleasing aesthetics and because they want to surround themselves with nature. There are proven positive effects of spending time surrounded by big trees on human mental health (Nilsson et al. 2011). There are also historical, cultural, and recreational reasons people want to include more trees on their land.

It is shown that agroforestry is an example of ecological intensification, which can be a sustainable solution to society's higher demand for production thanks to the provision of multiple services and benefits to both society and the environment.

## 2.2. Amazon rainforest

Rainforests are sources of the world's richest biodiversity, of both flora and fauna, and the Amazon is no exception. The understanding of the geographical boundaries of Amazonia differs from source to source. Criteria for the area by which it can be measured are at least five: climate, vegetation cover, phenology, hydrology, and altitudinal zones

(Eva et al. 2005). It is often referred to as the Amazon Basin, although the two terms do not fully overlap. The Amazon River basin is an area in South America that is drained by the Amazon River and its tributaries, and "it contains two-thirds of all freshwaters on earth" (Park 1992). From a climatic point of view, the rainforest is in a hot and humid climate with constant temperatures between 20 and 28°C throughout the year and a mean annual rainfall of 1500mm or more. The vegetation cover is a humid lowland (>700a.s.l.) evergreen forest (Eva et al. 2005), although the trees are not evergreen per se; they are deciduous trees that are continuously shedding leaves and growing new ones, so their foliage appears permanent (Park 1992). When these criteria are put together to form the boundaries of the Amazon rainforest, a discontinuous region is obtained (Figure 3).

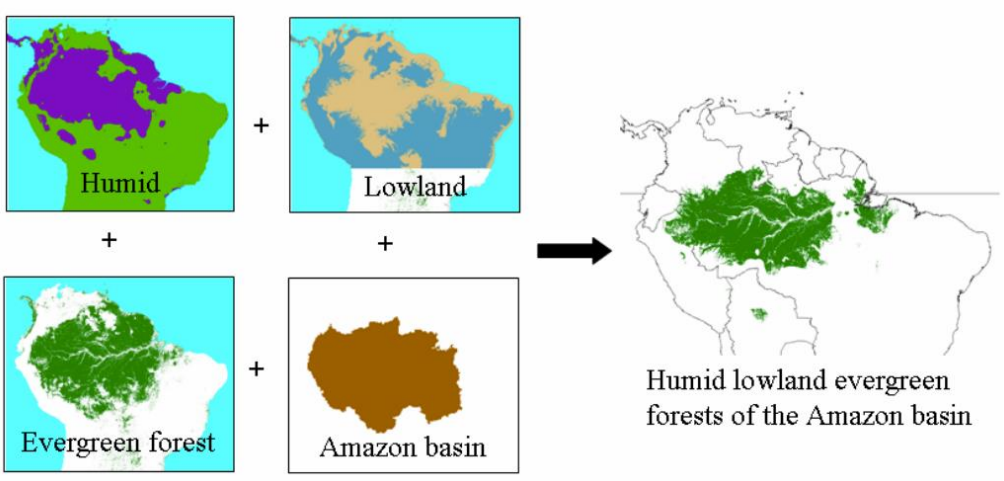


**Figure 3 Cartographic representation of criteria proposed by Eva et al. (2005) to delineate Amazon rainforest's borders**

It shows the importance of global agreement on the criteria by which the boundaries of the Amazon region are delimited. Taking various key elements into account, experts from different fields have agreed on a consensus about the definition of the Amazon region (highlighted in red in Figure 4). It consists of five subregions (Amazonia sensu stricto, Andes, Planalto, Guiana, and Gurupí) which all share the criteria of the lowland rainforest biome. It lays over a vast area of Brazil, southern Venezuela, south-eastern Colombia, eastern Peru, eastern Ecuador, and north-eastern Bolivia. With 8,121,313 $km^2$ (Eva et al. 2005), it is the largest rainforest in the world. The Amazon rainforest is one of the world's most biologically diverse regions, with an estimated 16,000 tree species, 2.5 million insect species, and hundreds of thousands of other animal and plant species (Butler 2022). The Amazon rainforest is also a vital component of the

Earth's climate system. It absorbs and stores large amounts of carbon dioxide, a greenhouse gas that contributes to global warming. The forest's water cycle also plays a significant role in regional and global weather patterns, producing a significant portion of the world's rainfall.


**Figure 4 Map of Amazon rainforest proposed by European Commission in collaboration with the Amazon Cooperation Treaty Organization (Eva et al. 2005)**

The forest is also home to many indigenous communities, whose traditional knowledge and practices have contributed to the forest's conservation. The indigenous peoples' knowledge of local species and understanding of natural processes is immense, and this traditional wisdom should be considered culturally protected. Their ethnobotanical knowledge and skills are often unknown to the western world, yet in so many cases, it has been the traditional medicine that has led to the inventions of today's widely used pharmaceuticals, food supplements, and many others. More than 40 million people, including 350 indigenous and ethnic groups, live in the Amazon and depend on nature for agriculture, clothing, and traditional medicines. Most live in large urban centres, but all residents rely on the Amazon's natural bounty for food, shelter, and livelihoods. People also use the region's waterways for transport, much like those in the Peruvian Amazon next to the river Ucayali (World Wildlife Fund 2022).

### 2.2.1. Deforestation of Amazon rainforest

Deforestation means a long-term reduction of tree canopy cover to less than 10% of the original forest. It is commonly done for the conversion of forest to other types of land use, such as pasture or cropland. A term related to deforestation is forest degradation, which is considered partial deforestation, when more than 10% of the forest remains. Forest degradation is caused by selective logging, for example (Werf et al. 2009). The two terms together are referred to as forest loss or tree loss.

Deforestation of rainforests is one of the biggest environmental issues our planet is facing nowadays. It negatively impacts the state of global ecosystems as they, by consequence, cease to provide ecosystem services. On the environmental level, it leads to reduced carbon storage, reduced precipitation, reduced evaporation, which leads to an increase in surface air temperature, increased albedo in high-latitude systems, increased air temperature and diurnal temperature variation locally and globally, and so many others (IPCC 2021).

In the Amazon region, deforestation for agricultural expansion and the degradation of forests adjacent to deforested areas are very common. Forest loss in the Peruvian Amazon is caused by several factors, some natural and some anthropogenic. Example of natural factors are fires, droughts, or storms. As these disturbances have happened more frequently in recent decades, it has been researched that these events might not be fully natural, because they are a consequence of climate change, which is partly human-driven. Examples of pure anthropogenic factors causing deforestation are the expansion of the agricultural frontier, human settlements, logging, and gold mining (Alarcón-Aguirre et al. 2023). It is surprising that about one-third of the deforestation in the Amazon is caused by the local farmers due to their unsustainable approach to agriculture (Lojka et al. 2016). Humans have always used the natural resources rainforests provide, but why it has become problematic in the last century is because of the rate at which the resources are utilized, or rather exploited. It is far from being sustainable nowadays, and with the increasing number of hectares of deforested and degraded forest land (Figure 5), a loss of resilience in the Amazon rainforest is observed. This has

profound implications for biodiversity, the rainforest's ability to store carbon, and global-scale climate change (Boulton et al. 2022).

The consequences of deforestation in the Amazon are serious; it affects not only the environment but also communities and indigenous people living in the area. It has been proven that it leads to a hotter and drier regional climate. Those are also the two most commonly noticed impacts by local farmers. Extreme droughts occur more often and lead not only to vegetation degradation but also wildfires in the area, although moist humid tropical forests are not adapted to fire (IPCC 2021). It is not only direct logging or

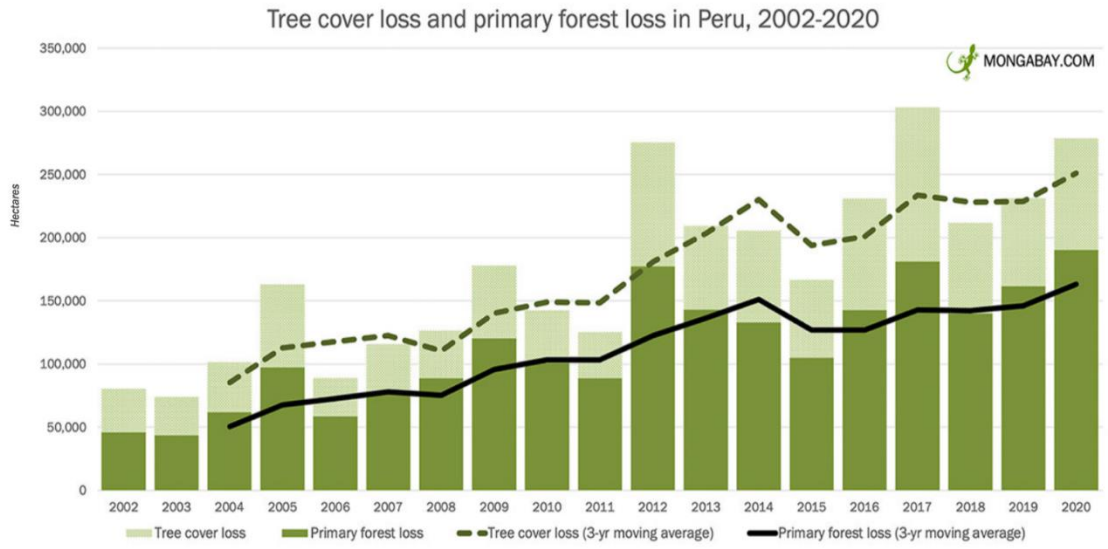


**Figure 5 Deforestation of Peruvian Amazon between the years 2002 and 2020 (Butler, 2021)**

forest clearance that leads to deforested land; also, roads built in the area to make the land more accessible for motorized vehicles cause forest degradation, which facilitates deforestation by fragmenting the rainforest and increasing the dryness and flammability of vegetation (Alencar et al. 2015). From 1973 to 2014, the extent of burned area increased in the Amazon, with one part of the rainforest experiencing a 36-fold increase (da Silva et al. 2018). Furthermore, from 1981 to 2018, deforestation in the Amazon reduced moisture inputs to the lower atmosphere, increasing drought and fire in self-reinforcing feedback (Xu et al. 2020). Increased fire, deforestation, and drought, acting via vegetation–atmosphere feedbacks, increase the risk of extensive forest dieback and potential biome shifts of up to half of the Amazon rainforest to grassland, a tipping point that could release an amount of carbon that would substantially increase global emissions

(Brando et al. 2020). In addition, an annual average temperature increase of 1.2°C from 1950 to 2018 contributed to tree mortality of ~40% from 1983 to 2011 (IPCC 2021).

Tree planting in historically unforested areas might assist to increased carbon sequestration and can be beneficial for the environment in some ways, however it can also "reduce biodiversity and increase the risks of damage from climate change" (Parmesan et al. 2022). Thus, it is essential to first address the causes of deforestation and prevent losing more of the valuable rainforests we have nowadays to avert loss of biodiversity, droughts, and climate change. Reforestation efforts in combination with agroforestry seem to be a sustainable solution.

### 2.2.2. Agricultural systems in Peruvian Amazon

The Peruvian Amazon comprises an area of 782,880 km² east of the Andes Mountain Range, occupying more than 60% of the Peruvian territory. Agriculture employs about 30% of the country's workforce and accounts for 13% of Peru's GDP (Raihan & Tuspekova 2022). With the focus on Ucayali, nearly 20% of the region's GDP derives from agriculture, livestock, and forestry.

Agriculture in the area is practiced by smallholders and few companies which build their business mainly around palm oil production. The most practiced agricultural system in the region is slash and burn agriculture which is common in all lowland humid areas of the Amazon (Lojka et al. 2008). There is barely any primary forest in the rural areas around the city of Pucallpa as the forest is being cleared for agricultural land use. The soils in a rainforest are not very fertile, as the nutrient cycling is fast in such system due to high amounts of rainfall and fast uptake of nutrients from decomposing organic matter by plants. Together with the fact that smallholders and local farmers cannot usually afford fertilizers or lack the knowledge on how to bring nutrients back to soil naturally, the soil cleared for agriculture becomes after couple of years (even with fallow periods) degraded and unprofitable to be cultivated. It leads to weed proliferation which has an effect of immediate reduction in yields and economic returns. That is the reason for abandonment of the land by a farmer and his search for another area in the rainforest to slash and burn all over again and the cycle continues. The result of such unsustainable agricultural production is abandoned extensive degraded areas in the place where primary rainforest used to be. Because of high population growth around Pucallpa, the pressure

on agriculture production is enormous and the production is highly intensified, therefore the surroundings of Pucallpa are mostly deforested as seen in Figure 6. Logging contributes to the forest degradation and leads to deforestation and thanks to Pucallpa's road connection to other big cities, it is a major industry in the study area (Porro et al. 2015).

Farmers from the area grow staple crops, fruit trees, vegetables, and even medicinal plants in their home gardens. The most important crop from the traditional staples is cassava (*Manihot esculenta*), which is widely grown thanks to its tolerance of the degraded land infested with weeds. It is economically advantageous because it is commonly sold at the local markets, and it also serve for household consumption. Other examples of staple foods are rice (*Oryza sativa*), plantains (*Musa spp.*), maize (*Zea mays*), and beans (*Vigna spp*.) which all require soil with higher fertility compared to cassava (Lojka et al. 2008). There are also other cash crops that have become more relevant in the past decade, particularly cocoa, coffee, papaya, and oil palm. Coca is also widely produced, it is the major economic driver in Ucayali, yet it is not mentioned in the official statistics (Salisbury & Fagan 2011). Livestock is usually owned by wealthier farmers who choose to breed pigs, beef cattle and sheep yet the main meat source is poultry (Lojka et al. 2008).

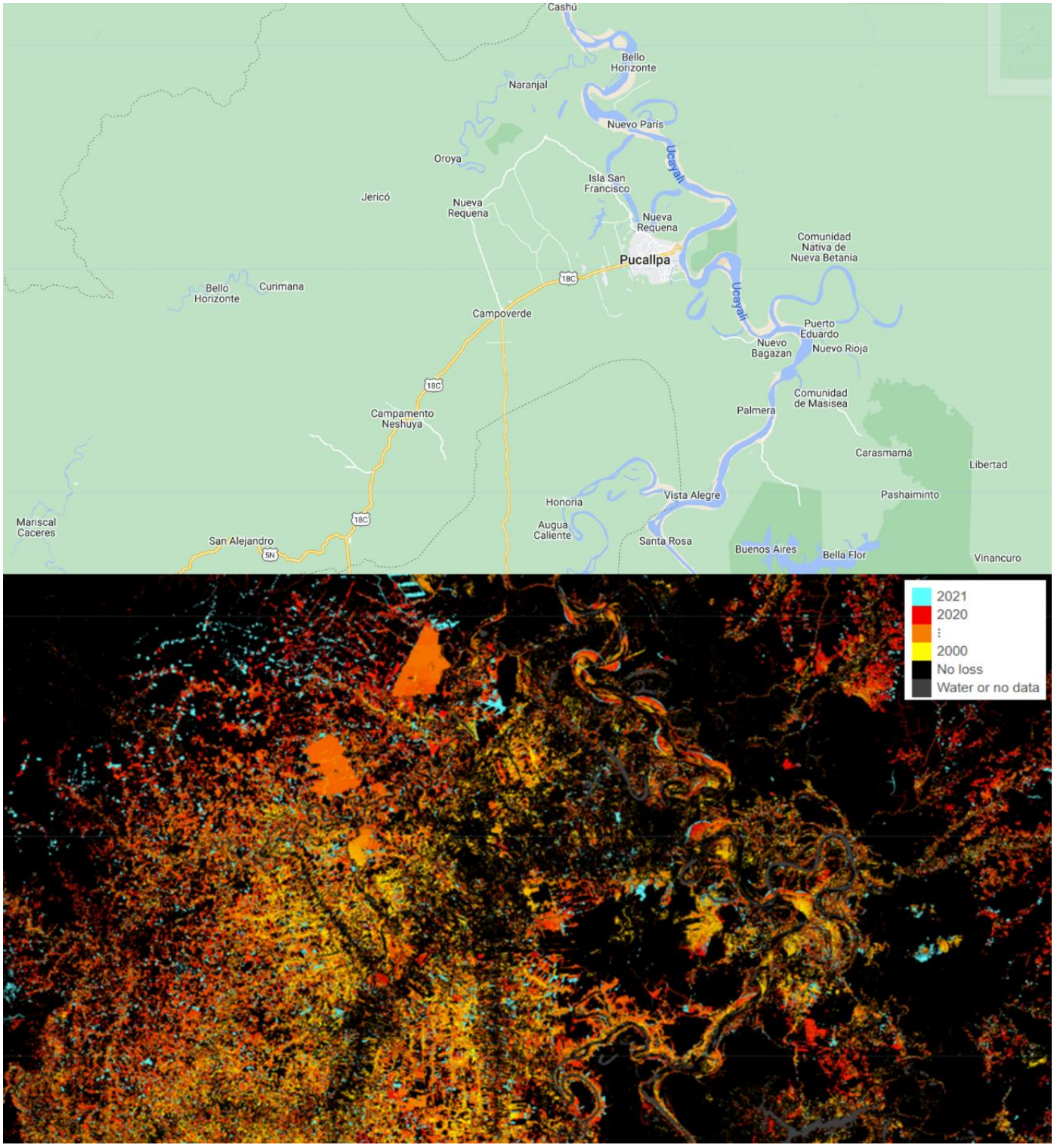


**Figure 6 Deforestation of the study area between years 2000 and 2021 (Hansen et al. 2013)**

## 2.3. Study area & population

### 2.3.1. Study area

The development project coordinated by CZU and UNU and the research for this thesis were both done in the Pucallpa region in Peruvian Amazon. Pucallpa is the capital city of the department Ucayali in the centre-east of Peru, bordering with Brazil to the east. The department covers approximately 102,000 $km^2$ (Willemen et al. 2007) which makes it the second biggest department in Peru. Ucayali has about 496,000 inhabitants and the most represented indigenous groups are Shipibos and Arawaks (Observatorio Socio Económico Laboral 2020). The department is politically divided into four provinces, Coronel Portillo, with the most inhabitants and highest population density (10.3 hab./$km^2$), Atalaya, being the largest province by area, Padre Abad, which is the smallest one and Purús, having the least inhabitants (Ibidem). The city of Pucallpa is in Coronel Portillo, on the Ucayali River, which is the main headstream of Amazon River. The catchment area of Ucayali River is 337,519 $km^2$ and its discharge in Pucallpa ranges between 2,000 $m^3$ and 22,000 $m^3$ (Ettmer & Alvarado-Ancieta 2010). The large differences in the discharge are caused by the two seasons, from December till May the flow rate increases, while between June and November it decreases (Bortl 2011). Flooding directly impacts livelihoods of populations living along the river, forcing many families to migrate to Pucallpa during the rainy season to look for work (Sherman et al. 2015).

The study area belongs to hot and humid climate, characteristic for the tropical rainforest. Its average elevation is 157 m a.s.l. (Observatorio Socio Económico Laboral 2020) and mean annual temperature about 25,7°C. The annual rainfall ranges from 1,500 to 2,000 mm (with higher precipitation to the west of the department towards the rainforest area) and mean annual relative humidity is 80% (Lojka et al. 2016).

Pucallpa is about 860 km from the capital Lima (74°W and 8°S) and has more than 350,000 inhabitants in its seven districts (Callería, Yarinacocha, Manantay, Campo verde, Iparia, Masisea and Nueva Requena) (Observatorio Socio Económico Laboral 2020). The population growth in Pucallpa is very rapid, it tripled in the last four decades, following the construction of a road connection to Lima, in the 1940s (Charette et al. 2020). This rapid growth is blamed for causing the natural resources exploitation and

consequently degraded land resources because of timber extraction and slash and burn clearing of land for agriculture (Goy & Waltner-Toews 2005).

The area around Pucallpa is an example of degraded land in the Peruvian Amazonian lowlands because of over 70 years of continuous deforestation and population growth. The soils are not very fertile, mainly acidic, highly compacted and eroded, with high aluminium (Soudre et al. 2001) and low phosphorus content, about 2ppm (Lojka et al. 2016). These soils are Ultisols with pH around 4.4 and low content of organic matter, they are found in the well drained forest areas, e.g., upland. In the seasonally flooded lowland, in the riverine systems, Entisols can be found with pH about 7.0 and slightly higher content of available phosphorus. “In general, these soils are of low quality for agriculture; but, because of the lack of floodplain soil the upland soils are increasingly used for crop cultivation” (Lojka et al. 2016).

Apart from soil degradation, invasion of weeds causes another problem for the local farmers and has negative impact on their economy. Invading herbaceous and shrub plants (such as *Imperata brasiliensis*) cause a deviation of the natural plant succession and disturbance of the local habitats (Soudre et al. 2001). Farmers often choose to abandon such land infested with weeds and start cultivating the unused land of primary or secondary rainforest. Another approach they opt for is to burn the weedy area to eliminate its propagation, but that frequently leads to fire spread and accidental burn down of the vegetation on their or neighbour’s cultivated land. The income of farmers from this area is on average quite low and their farms are essential for them as they are commonly subsistence farmers so the accidental burn down can have disastrous consequences. It can lead to a relocation of the family or to a change of occupation and abandonment of the cultivated land.

### 2.3.2. Population & socioeconomic situation

Migration, education, and poverty have huge impact on the occupation choice in the study area and influences people’s involvement in agriculture. That is why this chapter focuses on these characteristics of the current population.

The largest registered population of Ucayali is concentrated in the province of Coronel Portillo where the capital is located, mainly in the districts of Callería, Yarinacocha and Manantay. It is considered the urban area of the region and it is where

the commercial force of the entire region is centred. People have a life expectancy of 73 years, and the most represented demographic group is minors under 15 years of age. About 56% of the population is literate; the population over 25 years of age has approximately 9 years of education and the monthly family income is S/. 866 (Observatorio Socio Económico Laboral 2020).

As of 2015, the positive migratory balance was close to 15% of its population, which places it fourth in regions that attracted most inhabitants. (Observatorio Socio Económico Laboral 2020). About 40% of the total emigrants go mainly to Lima in search of better job prospects, health, housing, or technological progress in general. Young people migrate to other cities to access higher education, considering that it is a great opportunity for progress and future career possibilities, among others (Observatorio Socio Económico Laboral 2020).

The poverty threshold is in Peru considered the boundary of spending S/. 352 per month. Anyone who cannot spend more than that is considered poor and extremely poor are those who cannot spend more than S/. 187 per month. (Observatorio Socio Económico Laboral 2020). In 2021 the total poverty in Ucayali department was about 21% and the extreme poverty 2% (Ministerio de Trabajo y Promoción del Empleo 2022).

Concerning the state of education, 51% of the population aged 15 years and older manages to reach the secondary level, followed by 23% who manage to reach the primary level and only 12% manage to reach the higher university. The education is strongly dependent on the area of residence, there is a higher percentage of illiteracy in the rural area (14%) than in the urban area (3%) and the less populated provinces have higher illiteracy rates (Observatorio Socio Económico Laboral 2020).

In the rural areas, the most common livelihood is agriculture thanks to the proximity of agricultural land but often also because of lack of the variety of needed services which is present in urban areas. For the whole region of Ucayali, workers in the formal private sector were in 2022 mainly concentrated in services, by a participation of 40%, followed by commerce with 27% and agriculture including livestock, hunting, and forestry with 13% (Ministerio de Trabajo y Promoción del Empleo 2022). The sector of agriculture has expanded by 26% in the period 2015 to 2019, which was accompanied by the largest harvested areas of oil palm, paddy rice, cassava, and plantain crops (Observatorio Socio Económico Laboral 2020).

## 2.4. The project "Sustainable Management of Natural Sources in Amazonia"

The base of this study is a developmental project realized by CZU and UNU in between 2007 and 2009. Its aim was to implement sustainable agriculture in Peruvian Amazon specifically in the study area of this research. It was focused on promoting and applying agroforestry within the community of local farmers. It consisted in providing them with trainings and workshops on how to establish and take care of an agroforestry parcel, how to use nature's resources sustainably by composting and other means and it provided the farmers with equipment and seedlings for the parcels as well. Thus, it was meant to overcome both the lack of knowledge or experience and the financial obstacle which might have forestalled some farmers from implementing agroforestry on their land. As lack of available labour might have been a central issue for some farmers, *mingas* (the collective exchange work and help) were organized.

In the framework of the project, a total of 50 trainings were organized to promote agroforestry, explain how it works and what its benefits are, to capacitate farmers how to maintain their own production, how to process and sell it. The workshops also provided information about alternative technologies and motivated farmers to use them.

The established agroforestry parcels were in between 0.5-1 ha and at the end of the project there were 41 functional parcels of a total area of about 30 ha. 9 parcels in Agua Dulce, 10 in Pimental, 2 in San Martín de Mojaral, 3 in Pampas Verdes, 2 in 24 de Diciembre, one in 3 de Diciembre, 4 in Antonio Raimondi, 6 in Tupac Amaru and 4 in Nuevo Belén. The tree seedling promoted and provided by the project were native timber and fruit trees combined with fast growing leguminous tree species guaba (*Inga edulis*) which supplies the soil with nitrogen by acting as a fertilizer, grows very fast so it provides yield in both fruit and wood soon and also suppresses weed proliferation. A total of 55 species were used, some of which are "annona (*Annona muricata)*, bolaina (*Guazuma crinita*), caimito (*Pouteria caimito*), caoba (*Swietenia macrophylla*), capirona (*Calycophyllum spruceanum*), cedro rojo (*Cedrela odorata*), ishpingo (*Amburana cearensis*), lupuna (*Ceiba pentandra*), marupa (*Simarouba amara*), pashaco (*Schizolobium sp*.), shihuahuaco (*Dipteryx odorata*), sangre de grado (*Croton lechleri*),

tahuarí (*Tabebuia sp.*), guanabana (*Annona muricata*), pijuayo (*Bactris gasipaes*) and copoazu (*Theobroma grandiflorum*)" (Bortl 2011).

## 2.5. Adoption of agroforestry in Amazon Basin

Adoption of agroforestry determines whether all the benefits and advantages of such system are implemented in practice, therefore it is a crucial topic in the agroforestry research. Although increasing number of researchers concentrate on agroforestry in general, there is not many studies done on its adoption in Peruvian Amazon, that is why the focus was broaden to whole Amazon region.

Not only the biophysical and ecological aspects of agroforestry must be investigated in connection with its adoption, but socio-cultural aspects are also equally important. It is crucial to understand the livelihoods of farmers using agroforestry, their local communities, their perceptions, and strategies when implementing an agroforestry project (Atangana et al. 2013). Agroforestry has been referred to since 1990' as "very social science" (Pawlick 1989) which shows the importance of acknowledging the social parameters. These important socio-cultural factors that determine the agroforestry adoption are land tenure, labour, demand and marketing, public policies, social acceptability, and many others.

When farmers are not owners of the land they cultivate, it is common that they do not intend to invest in sustainable maintenance of the land both financially and physically. Therefore, farmers who rent the land will be less likely keen on implementing agroforestry practice or continuing with it, because the long-term benefits will not be advantageous for them. Hand in hand with this long-term investment goes labour. When more labour is used for the cultivation and care of agriculture land, the yield might be higher at the end of the season, but not all farmers can afford to hire more workers. They work on the farm together with their family members and do not have enough available labour to establish the agroforestry parcel or to invest more labour in it the first few years before the planted trees grow taller. Understanding what the current demand on the market is and how to promote their products is also very important skill for the farmers to fully benefit from their cultivation (Atangana et al. 2013). FAO claims that together

with difficulties in accessing the markets, a lack of skills in management and organization are amongst the main hindrances to the growth of small-scale agricultural enterprises (FAO 1987). Along with public policies and the legislation of agroforestry, there are numerous other social factors that play a role in agroforestry adoption, such as health, well-being, gender and age of farmers, external and internal on-farm income, local knowledge, cultural and eating habits, etc (Atangana et al. 2013).

In the meta-study of Pattanyak et al. (2003) the studied factors influencing adoption of agroforestry are grouped into five factor clusters.

- Preferences – farmer preference effects, which are difficult to measure, ergo socio-demographic factors are used: gender, age, education, and social status.
- Resources – Assets available to implement change: savings, land, livestock, labour.
- Market incentives – factors which lower costs and higher the benefits of the change: prices, distance to markets, potential income.
- Bio-physical factors – influence the production process, these are soil quality, slope, irrigation, and plot size.
- Risk and uncertainty – factors in the market and institutional environment which affects the change. Examples are land tenure, fluctuation in prices, experience, training, membership of a community organization or cooperative.

It is shown that factors most statistically correlated with the adoption of agroforestry are the risk factors, bio-physical factors, and resources. Specifically, these are training, tenure, soil quality and plot size. Critical determinants which are easy to measure are age, education, labour, and plot size. It is suggested that credit, market constraints, savings, prices, and plot characteristics are potentially important determinants as well but need to be studied adequately (Pattanyak et al. 2003).

The study of Tremblay et al. (2015) has shown that it is usually the implementation costs that impede the widespread adoption of agroforestry. The study has been done in the Brazilian Amazon, but as the conditions of the area are similar to those in Pucallpa, it is applicable to this study. The deforestation rates and population growth have been increasing since the construction of the Trans-Amazonian highway in the 1970s (Tremblay et al. 2015), just like they have been in Pucallpa after the construction of Carretera Federico Basarde. The study proposes to the local households and

communities to convert at least part of their land from slash and burn agriculture to agroforestry systems, as they provide numerous benefits and recover their total implementation and operating costs within 20 years. The agroforestry system takes between three and six years to start providing full benefits. However, local small-scale farmers are more likely to adopt intensive forms of agriculture because they are seen as profitable and economically certain. The initial costs for agroforestry implementation represent about 520 workdays at standard daily wage and farmers do not usually have the labour nor money in the short term to establish the agroforestry parcel (Tremblay et al. 2015). Apart from the initial costs, which are financial constraints, other limiting factors can be structural constraints, such as knowledge, access to markets, lack of regional industry for the transformation of agricultural products. Some products have greater added value when processed (camu-camu, aguaje, cacao etc) but farmers seldom have the means to execute the complete processing. If transportation is too expensive or would take long, the fresh products can only be sold in the local markets where the demand is lower than in bigger cities. "Deficiencies in rural transport networks are often mentioned as a major obstacle to economic development in these areas" (Tremblay et al. 2015).

McGinty et al. (2008) in their research claim that it is age and income that significantly contribute to the adoption or maintenance of agroforestry. It is also said that the adoption decision making is influenced by multidimensional socio-psychological variables which contribute more than socio-economic factors, yet they are less researched in general. These are specifically the "attitudes about conservation and perceived behavioural control" (McGinty et al. 2008).

Mara et al. (2003) explain that adoption of agroforestry is conditioned by the household revenues. These differ among the households based on the distance to the markets, years of residence in that area, size of the farm, technical equipment, soil quality, off-farm work and initial capital (Mara et al. 2003).

A study from Peruvian Amazon points out the importance of study of local community and diversity because of its highly variable results when implemented in different conditions (Coomes & Burt 1997). They claim that farmers with larger portion of land are more likely to practice agroforestry.

# 3. Aim of the thesis

The aim of this thesis was to evaluate the adoption of multistrata agroforestry systems by local farmers in the Pucallpa region, department of Ucayali, Peru. The goal was to assess the impact of the development project called Sustainable Management of Natural Sources in Amazonia realized in the area between 2007 and 2009.

The specific research questions were the following:

- How many farmers from the project have continued practising agroforestry after the end of the project, and what are the reasons they dropped out?
- Did the project have an impact on agroforestry adoption among local farmers?
- What factors is agroforestry adoption dependent on?
- What is the farmers' perception of agroforestry, and what factors do they find important?

It is hypothesised that a high number of participants in the project Sustainable Management of Natural Sources in Amazonia continue using agroforestry systems established during the course of the project. Another hypothesis is that adoption of agroforestry systems is related to the area of their farm, their participation in the trainings during the project, and their membership in an organization or cooperative.

# 4. Methodology

## 4.1. Study site

The study was done in six villages close the city of Pucallpa (8°23' S 74°31' W, 157 m a.s.l.). These villages (Figure 9) are situated alongside the road Carretera Federico Basarde (CFB) which connects Pucallpa with Tingo Maria and other cities on the way to Lima. The villages of this study were rather small with no more than 250 inhabitants.


**Figure 7 Map of study area with localities of interest, and Ucayali region in upper left. source: mapy.cz, https://maps-peru.com/pucallpa-peru-map**

The standard of living in the villages is different than in Pucallpa. People live with their families in small self-made houses which few are made of bricks, majority of wooden planks, some people have canvas or tarpaulin instead of walls in between wooden poles. Most of the houses have metal roof and clay floor. Usually there are several houses closely neighbouring in the centre of the village and if the owners have some agricultural land, it is further away from the house, outside the village centre. On the contrary, the houses further away from the centre are detached and incorporated in the garden or differently maintained land with occasionally a fence around and some animals as pets kept within. The most kept livestock for subsistence is poultry, sporadically few pigs, exceptionally some cattle.

The most common occupation of people living in these villages is in agriculture, whether it is producing fresh products directly (vegetables, fruit, livestock) or producing a commodity which is processed (cane sugar, dried fruits, alcoholic beverages etc). They sell their products in local markets, often they commute to Campo Verde or to Pucallpa where the demand is higher. Some farmers also sell their products at home, which is usually the case of processed products, such as fermented fruit beverages or various products from sugar cane. Farmers also collaborate with organizations who provide them with organic certification or produce and sell their products for them. Certain organizations work as communities who provide farmers with financial or material support and allow them to meet and learn from each other (Ape Pimental for example).

People who do not work in agriculture commute to Pucallpa to work in services like education, commerce, or transportation. Very common job is a driver of *motocar,* a motorized rickshaw which is the prevalent means of transportation in Pucallpa. Some farmers have it as a part time job to provide extra income for the household.

The land used by the inhabitants of these villages is mainly cultivated agricultural systems. Close to their house they keep their home gardens where food for the families is produced, and further away they have a parcel where cash crop and other vegetation is grown. The area of farms differs in between households, on average it is around 10 ha. Seldomly all the farmland is cultivated, some part can be meant for reforestation, some areas are left abandoned to let the soil regenerate, or simply because farmers do not have the capacity to cultivate it all. The actively used land is usually about half of what the farmer owns. Commonly grown crops are cassava, *Manihot esculenta*, plantain and banana, *Musa spp*., maize, *Zea mays*, and sugar cane, *Saccharum officinarum*. From the perennial plants, they are mainly citruses, cacao, *Theobroma cacao*, and various fruit trees. The local farmers use monoculture production systems, agrisilvicultural systems as well as rotational practices where they abandon certain area for revegetation and soil regeneration. To find out to what extent agroforestry is used by these farmers was the aim of this study.

## 4.2. Data collection and evaluation

The data were collected during May and June of 2022. Thanks to interviews with key informants from the local villages (Esau Hidalgo del Aguila, Carlos Ramirez and others), Rober Romero Robledo a former member of CIDRA (Centro de Investigación y Desarrollo Rural Amazónico) and other local association leaders, contacts to farmers were collected. The data collection consisted of two phases. First it was investigated how many farmers, who had been using the established agroforestry parcels at the end of the project, were still practising agroforestry. The 41 participants from the project were aimed to be visited in the 9 villages, where the project took place, and their agroforestry activity was evaluated in an unstructured interview.

The second phase of the study consisted of revisiting the active farmers as well as other farmers from the area with a questionnaire investigation. Some participants from the first phase of the study were involved in the second phase as well, but not all of them were willing to fill the questionnaire. A total number of 41 respondents were questioned from following villages: Antonio Raimondi (n=6), Pimental (n=17), Tupac Amaru (n=3), Agua Dulce (n=9), Nuevo Belén (n=3), and San Martín de Mojaral (n=3). About a half (n=19) of these respondents were chosen based on the former participation in the project called "Sustainable Management of Natural Sources in Amazonia". They were compared with a control group of 22 farmers from the same area who have not been part of the project. Farmers in the control group were selected by snowball effect when interviewing key informants.

In the second phase of the study, farmers were interrogated with a semi-structured questionnaire (Appendix 1). The questionnaire consisted of 91 questions of which majority was open-ended questions, some were multiple choice questions and some close-ended questions. Apart from collecting the basic socio-demographic data, such as age, education, and family situation, the questionnaire focused on the farmers' socioeconomic background, for example their income, parents' occupation, or number of years of activity in that area. It was also essential to determine the state of their farm, including the size of the farm, number of workers, distance from their house to the farmland, main grown crops, and yields. Some questions were aiming on farmers' feelings of environmental responsibility, the importance of nature preservation and their understanding of the consequences of deforestation. The fundamental part of the questionnaire was focused on

their attitude towards agroforestry, its implementation, their participation in the former project, its benefits and the reasons that lead to their drop out and abandonment of agroforestry plots or their continuation of the agroforestry practice. One part of the questionnaire was aimed on their future vision, wishes, and family involvement in the field of agriculture. The questionnaire was translated in Spanish and tested on two farmers to ensure understandability and exact aim of the questions. Before the data collection, slight modifications were made in the questions.

Out of all respondents, 34% were women, 66% men. The mean age was 57 years and on average they have lived in the area for 32 years. Most of them reach secondary education (41%), primary 39% and superior 15%. The most frequent civil status within the respondents is cohabiting (59%), 29% are married and 5% widowed.

**Table 1 Respondents' general characteristics**

| | Number or mean | Percentage or SD |
|---|---|---|
| Sex | | |
| Male | 27 | 66% |
| Female | 14 | 34% |
| Age (y) | 56.7 | 15.7 |
| Years living in area | 32 | 15.9 |
| Total area of farm (ha) | 10 | 10.6 |
| Total cultivated area (ha) | 5.5 | 5.8 |
| Civil status | | |
| Married | 12 | 29% |
| Cohabiting | 24 | 59% |
| Widowed | 2 | 5% |
| Other | 3 | 7% |
| Children | 4.4 | 2.8 |
| Household size | 4 people | 1.9 |
| Education | | |
| Primary | 16 | 39% |
| Secondary | 17 | 41% |
| Superior | 6 | 15% |
| Other | 2 | 5% |

Almost all the respondents (95%) come from a family of farmers, and they want to pass on the tradition to their children (average 4 children). The functioning of 59% of the households is not supported by the children as they live independently and do not participate on the family income. On average there are 4 people living in one household.

The mean area of the farm is 10 ha, and the cultivated land is on average 870 m away from the house. Majority (76%) of farmers owns the land they cultivate, 24% rents it or has it borrowed. There are 2 workers on a farm on average and a minority (46%) hires some other workers to help. *Mingas,* the collective help of neighbouring farmers to each other for free, are used by 22% of respondents. Nearly two thirds (63%) of farmers use a separate area to produce food for their household and 27% of respondents have livestock.

The qualitative data obtained from open questions in the survey were analysed by the content analysis and thematic analysis. The answers were sorted into usually four groups of commonly occurring word or topic and their frequency was counted.

# 5. Results

## 5.1. First phase of study – dropout from the project

The information about the agroforestry activity (whether farmers continue using agroforestry or have stopped) was found for a majority (61%) of the 41 farmers that were actively using agroforestry at the end of the project in 2009. About 39% of farmers were not reached, and thus their agroforestry activity is impossible to detect. From the found data, 22% of farmers use agroforestry nowadays. It can be said that the dropout rate for the project is at least 39%.

**Table 2 Numbers of farmers regarding their agroforestry activity**

| | AF in 2009 | Use AF now | Do not use AF | N/A |
|---|---|---|---|---|
| Total | 41 (100%) | 9 (22%) | 16 (39%) | 16 (39%) |
| Nuevo Belén | 4 | 0 | 3 | 1 |
| Tupac Amaru | 6 | 1 | 5 | 0 |
| Antonio Raimondi | 4 | 0 | 2 | 2 |
| 3 de Diciembre | 1 | 0 | 1 | 0 |
| 24 de Diciembre | 2 | 0 | 1 | 1 |
| San Martin de Mojaral | 2 | 2 | 0 | 0 |
| Pimental | 10 | 3 | 2 | 5 |
| Agua Dulce | 9 | 3 | 2 | 4 |
| Pampas Verdes | 3 | 0 | 0 | 3 |

N/A – number of farmers who were not reached.

## 5.2. Comparison of agroforestry adopters with agroforestry non-adopters

In the second part of the study, two major groups of farmers were formed. Farmers who practice agroforestry nowadays are called agroforestry adopters, and these who do not (even if they used to practice agroforestry in the past) are called agroforestry non-adopters.

In the group of respondents practising agroforestry, majority has been part of the project (68 %), whereas the in the group of farmers who do not use agroforestry, majority has not participated in the project (59 %). Men and women are represented similarly in both groups with the majority of men (around 65 %). It is shown that the difference in age between the groups is not significant. What seems to be significant, on the contrary, are years of residence in the area and experience in agriculture. In both variables, the agroforestry adopters have higher values. Although they seem to have bigger farms, their area of cultivated land does not differ significantly from the non-adopters. The differences in numbers of children and numbers of people living in households are not significant across the groups. Farmers from both groups come from families where parents were farmers as well.

As seen in Table 4, the differences between the two observed groups are not significant across the various characteristics. The two only exemptions are the data showing number of farmers who use the techniques learned in the project and data explaining who used agroforestry in the past. It can be assumed that farmers who use agroforestry are using more of the techniques learned in training of the project than farmers who are not agroforestry adopters. The answers for a question about using agroforestry in the past are clearly significant because farmers who use agroforestry nowadays must have used it in the past.

**Table 3 Socio-demographic information about respondents**

| | Agroforestry adopters | Agroforestry non adopters | p-value |
|---|---|---|---|
| Villages of residence | | | |
| Agua Dulce | 5 | 4 | |
| Antonio Raimondi | 1 | 5 | |
| Nuevo Belen | 1 | 2 | |
| Pimental | 9 | 8 | |
| San Martin de Mojaral | 2 | 1 | |
| Tupac Amaru | 1 | 2 | |
| Total | 19 | 22 | |
| Farmers participating in the project | 68% (13) | 41% (9) | 0.118 |
| Farmers not participating in the project | 32% (6) | 59% (13) | 0.118 |
| Women | 37% (7) | 32% (7) | 0.754 |
| Men | 63% (12) | 68% (15) | 0.754 |
| Mean age (y) | 57.5 ± 16.1 | 55.9 ± 15.7 | 0.784 |
| Mean years living in area | 37.7 ± 14.7 | 27.1 ± 15.5 | 0.014 |
| Mean years of farming | 30.4 ± 12.4 | 19 ± 13.1 | 0.007 |
| Total mean area of farm (ha) | 13.5 ± 12 | 6.8 ± 8.2 | 0.025 |
| Total mean cultivated area (ha) | 5.5 ± 2.9 | 5.4 ± 7.5 | 0.077 |
| Civil status | | | |
| Married | 26% (5) | 25% (7) | 0.744 |
| Cohabiting | 53% (10) | 70% (14) | 0.537 |
| Widowed | 5% (1) | 5% (1) | 1 |
| Single | 16% (3) | 0 | 0.091 |
| Mean number of children | 4 ± 3 | 5 ± 2.5 | 0.248 |
| Mean number of people in household | 3.7 ± 1.8 | 4.2 ± 2 | 0.413 |
| Education | | | |
| Primary | 32% (6) | 50% (10) | 0.522 |
| Secondary | 42% (8) | 35% (9) | 1 |
| Superior | 16% (3) | 15% (3) | 1 |
| Other | 11% (2) | 0 | 0.209 |
| Parents farmers | 95% (18) | 95% (21) | 1 |

**Table 4 Farmers' characteristics**

| | Agroforestry adopters | Agroforestry non adopters | P value |
|---|---|---|---|
| Mean distance house - agriculture area (m) | 882 ± 1388 | 861 ± 1001 | 0.564 |
| Mean number of workers on farm | 2.5 ± 1.2 | 2 ± 0.9 | 0.195 |
| Owners of the land | 84% (16) | 68% (15) | 0.292 |
| Have livestock | 36% (7) | 18% (4) | 0.290 |
| Use slash and burn method | 32% (6) | 23% (5) | 0.725 |
| Used AF in past | 100% (19) | 64% (14) | 0.004 |
| Used AF before the project | 32% (6) | 14% (3) | 0.260 |
| Farmer's neighbours use AF | 32% (6) | 36% (8) | 1 |
| Received help from CIDRA | 47% (9) | 18% (4) | 0.091 |
| Participated in trainings and workshops in the project | 53% (10) | 32% (7) | 0.216 |
| - Of these: use the techniques nowadays | 90% (9) | 71% (5) | 0.031 |
| Members of organization or cooperative | 53% (10) | 36% (8) | 0.355 |
| Not members now but have been in the past | 50% (5), (10=100%) | 64% (9), (14=100%) | 0.679 |
| Think being a member of organization is financially beneficial | 74% (14) | 41% (9) | 0.062 |
| Farmers whose living costs are covered by agriculture easily | 57% (11) | 27% (6) | 0.063 |
| Have other income apart from agriculture | 42% (8) | 45% (10) | 1 |

There were 28 open questions analysed separately. Question about the reason for moving to this area was split into 5 categories – born there, work, family reasons, better life (under which are economic reasons, terrorism in other areas, healthy life on countryside etc), and others. The reason for work was mostly answered by the group of adopters (36%), whereas for non-adopters it was family reasons (41%). Question "how have the area looked when you started farming here?" was answered similarly by all the respondents, either tall forest or weedy area. Answers to the question discovering what their attitude was to make it an arable land were put these categories – slash and burn, fertilize and manual work. Few answers covered several categories, as these were not

exclusive. Manual work was prevalent in both research groups, in adopters it was the answer for 53% and in non-adopters for 59%.

The next question was asking where and how often slash and burn method was practiced. It commonly answered by these, who use it, that few times a year on their land before they sow or to eradicate weeds. The same situation was with the question searching for reason why farmers abandon their land. It is usually to let the soil regenerate because it is degraded. Few respondents state family or financial reasons.

Question "Why do they not use chemical fertilizers" was answered by majority of both groups that it is unhealthy for the soil or to the environment as a whole. Two other commonly given answers were for the economic reasons, chemical fertilizers are too expensive. Another answer was due to the organization which the farmer is part of. The organization does not support farmers when they use it by not providing them with a certificate of organic origin which means farmer looses his/her profit. Similar answers were obtained for the same question focused of pesticides. The question about the way farmers control weed on their land was meant to find together with the two previous questions, the environmental responsibility farmers might feel. That is why it was in this analysis converted into – do you use herbicides? Only 11% of farmers who are agroforestry adopters replied positively, from non-adopters it was 27% which is not a significant difference ($p=0.25$).

Although answers to the question about species grown in agroforestry system were very various, they were split into four classes – cacao, citruses, timber trees, and other fruit trees. These categories were not exclusive. The group of adopters had a prevalent answer of timber trees (89%), and 37% of them also grow cacao. For non-adopters this question was not relevant. The same happens in the next three questions "What do you grow the trees for", "When do you plan to cut the trees down", "What is your motivation to use agroforestry", they were answered only by the adopters. The first one was divided in 5 categories – production (both wood and fruits), construction of a house, shade, aesthetics, environmental reasons. Nearly half of adopters (47%) grow trees for environmental reasons and 32% for future construction. Answers for the second question differed a lot, some respondent claimed they do not plan to cut the trees down, some said they would do so when the trees grow older, and some provided exact time determination as in 10 years, or 2-3 years. The last of the three questions was understood

by farmers similarly as the first one, thus the answers were split in 3 groups – environment, shade, income. Majority, this time 89%, said for environmental reasons. A lot of farmers were answered "to improve the environment", motivation of others is to stop global warming, or to provide fresh air. One farmer from Agua Dulce was very precise in his answer, "The motivation is to capture the carbon from atmosphere and purify our environment".

Next question which was common for both research groups was "Why is deforestation an environmental problem". Some farmers stated that it killed animals, or their habitat which leads to lower biodiversity, others said it decreased the temperature, fresh air was also stated few times together with rainforest being the lungs of the Earth.

The most repeated answer to a question about which organization they are members of, was Ape Pimental (Asociación de Productores Ecológicos El Pimental). The following question was searching for a reason why some of them were not members of any organization anymore. The most prevalent answer was "because it stopped working". "Why did they stop using AF on their land" was most often answered because it burned down in a fire. Some of the respondents sold their parcels, one said that the trees had took all the space and nothing could be grown under them. The biggest obstacle when using AF was seen as fires, a repeated answer to this question was also "nothing" and also "too much work". It was only answered by those who stopped using agroforestry. Question asking if they would do anything differently if they had the chance to establish agroforestry parcels again, was answered several times by "no", multiple farmers would grow more timber trees, and some say, they would have taken better care of it. The last question aimed only on farmers who abandoned agroforestry was asking what was the land of former agroforestry parcel used for at that time. Answers varied from monoculture, reforestation purposes, sold, to abandoned weeds overgrown area.

Oppositely to the previous questions, the following ones were asked only to farmers who continue with establish agroforestry parcels. The questions were: "What is your motivation to continue with the settled agroforestry system? ", „Why do or do not you have better status than your neighbouring farmers. ", "What benefits does AF bring you personally", "What disadvantages does it bring?". The first one was answered in different ways, the motivation is for wood in the future, nature conservation, protect land against deforestation, cooling and shading the environment. One respondent wanted to

preserve the system so it could be used in the future. If farmers did not agree that they would have better status than their neighbours, they stated the reason for that being less income as they do not have livestock or have small farmland. If they agreed, they claimed it is thanks to wood they can sell and also healthy food the system provides them with. The benefits that AF brings them personally are grouped in 3 categories – financial benefits, shade and environmental improvement. Majority of answers were from the last category (47% of adopters). One specific answer was "It gives me experience I can pass on to my sons". Concerning the disadvantages, the categories of answers were – fire, work, none, and others. Again 47% claimed there are no disadvantages, 16% finds the abundant work to be a disadvantage and 26% of them stated some other individual reason. One farmer said that the crops were dehydrated the as it did not rain under the trees which lead to smaller production.

Another question pinpointed the crop that brings the farmer the most profit on his farm. The answers which occurred repeatedly were yuca, cacao and citruses. If farmers have also other income than from farm, it comes from helping in a construction from time to time, driving motorcar or fish farming.

Last two open questions were focused on farmers' future vision. Answers to the question "What are your plans on the farm" were grouped in categories – enlarge the agriculture land, tourism, continue the same way and fish industry. In between adopters the most common answers were continue, enlarge the land and others, each with 26% of respondents. In the group of non-adopters the most prevalent answers were enlarge the land and continue, both with frequency of 32%. When asked what do the farmers want to focus on in the future, they were repeating answers about fish farming, livestock and cacao production.

The multiple-choice questions that were based on Likert scale were evaluated separately (Figure 8). Part a) contains two extra questions which do not appear in part b), because these questions were aimed on farmers who practise agroforestry. These two questions were whether they feel they work more and if they have better status than farmers who do not use agroforestry. Around one third (32%) thinks they work more, about 42% does not agree and 26% is neutral. Concerning the status, about 68% would say they have better status than farmers who do not practise agroforestry. From the questions that were common for both groups of farmers, majority of both groups answered the question about benefit of agroforestry positively, only 13% of non-adopters was neutral. About 95% of farmers who practise agroforestry strongly agree that deforestation is an environmental problem, remaining 5% agree, whereas it is only 75% and 15% respectively for non-adopters. Only 5% from the same group disagrees and another 5% even strongly disagrees with the claim that deforestation is a problem. Answers for the question about importance of being part of an organization differed mainly in the frequency of answer "strongly agree". Agroforestry adopters show retrospectively strongly belief in the project, but less of them find the training of the project useful compared to non-adopters. More respondents from the group of adopters than non-adopters strongly agree with continuing their career in agriculture, but it is also bigger portion of farmers from this group who reply negatively (disagree and strongly disagree) and neutral. The last question evaluated in the stacked bar charts is if farmers want their children to take over the farm and continue working in agriculture after them. The answer "strongly agree" was more represented by adopters. In non-adopters' group, there were more farmers replying neutrally or who disagreed with it compared to adopters.

As shown in the Table 5, most farmers perceptions do not differ significantly between the groups of farmers who adopted agroforestry (adopters) and these who did not (non-adopters). To be able to claim that values on the scale 1-5 have been attributed to farmers' answers strongly disagree – strongly agree. The more positive the answer was, the more conceptual points it got (Strongly disagree – 1, disagree – 2, neutral – 3 and so on). There are two statements for which the difference has shown to be significant. The statement that agroforestry systems are beneficial is assessed by the farmers who use agroforestry more positively than by the farmers who do not use AF. Also, the statement

about farmers' wishes for the future differ. More adopters than non-adopters want their children to continue working on their farm after them.


**Figure 8 Perceptions of a) agroforestry adopters, b) agroforestry non-adopters**

**Table 5 Mean, standard deviation and p value for the Likert scale questions**

| | Adopters | Non-adopters | p value |
|---|---|---|---|
| AFS are beneficial | 4.7 ± 0.5 | 4.2 ± 0.9 | 0.046 |
| Deforestation is a problem | 4.9 ± 0.2 | 4.6 ± 1 | 0.115 |
| Being member of organization is beneficial | 4.2 ± 1.2 | 3.9 ± 1 | 0.250 |
| Belief in the project to be functional in long term | 4.5±0.7 | 4.4 ±0.7 | 0.789 |
| Trainings were useful | 4.4±0.7 | 4.7±0.5 | 0.369 |
| Farmer in future | 3.9 ± 1.3 | 4.2 ± 1.0 | 0.573 |
| Wants children to continue | 4.5 ± 1 | 3.7 ± 1.3 | 0.012 |

## 5.3. Variables affecting agroforestry adoption

To investigate what variables play a role in agroforestry adoption and to what extent, the Pearson correlation coefficient was calculated. It is shown for the 8 most correlated questions (Figure 9). The first three have coefficients above the 0.5 threshold, which makes them highly correlated; the remaining have a moderate degree of correlation. Other factors which fall into the degree of moderate correlation (the coefficient is bigger than 0.3) are the cultivation of cacao, years of farming in the area, moving to the area for work, growing trees to be used in construction, and the distance to the city.

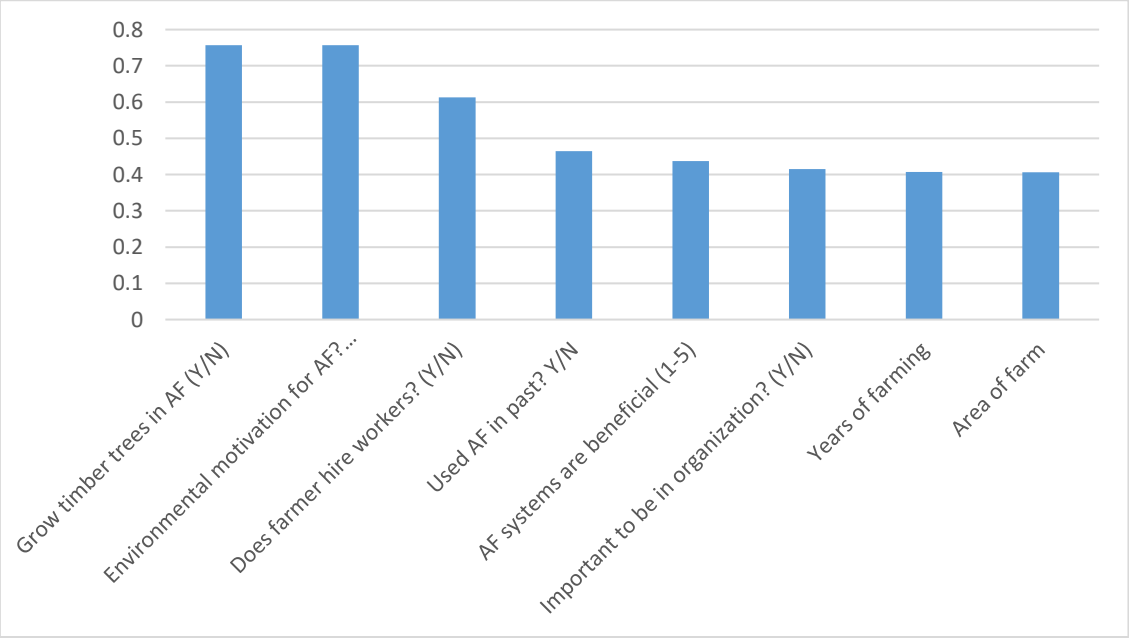


**Figure 9 Questions correlated to agroforestry adoption**

# 6. Discussion

## 6.1. Limitations of study

Before discussing the results and outcome of the study, several limitations need to be reviewed. They can be grouped into 3 categories: study design, data collection, and data analysis.

The study design had its limitations in the questionnaire arrangement, especially in the sequence of questions. A question-order bias might occur in the section on environmental awareness. First, there is a question about whether farmers have heard of deforestation as an environmental problem, followed by a question about how much they see it as a problem. That is why awareness was tested by other questions as well, such as the use of chemical fertilizers, pesticides, and compost, and the focus was given on the respondent's explanation of why they do not use them. Related to the study design is also a limitation of the respondents' selection. The sampling bias was not prevented as the fact that farmers were chosen by a snowball effect. It might have led to obtaining more respondents who were actively using agroforestry or more inclined to use it.

Data collection was the phase where the most limitations occurred. When investigating the dropout rate of the project, not all the participants were reached. That is due to several reasons. One of the villages, Pampas Verdes, was not visited because of transportation difficulties and hindrance of reaching the village in the bad weather conditions. A car was borrowed from the university (UNU) to access all the remote villages, but that required dry conditions the same day and the day before; otherwise the dirt road was inaccessible. The author of the thesis was not allowed to drive the car, so a driver had to be arranged, who also was not available permanently. Last but not least, because of high criminality rate, there was a state of emergency in Ucayali declared by the Peruvian government (Andina 2022). It was highly recommended to visit the remote areas with a guide or an accompanying person which obliged the researcher to arrange another person for all the field work. That brought another factor into the organization of data collection. Apart from transportation, the second reason for not reaching all the farmers was the timing of arrival to the villages. It happened that after arrival to a village, the interviews with local key informants did not provide directions how to reach the

desired project participants. They did not know them, which might have been from various reasons such as the participant's departure from the village etc. Unless it was explicitly found that the participants have left their farms, sold them or for any reason do not continue with agroforestry parcel, they were counted as not reached. Limitations connected to the questionnaire data collection seem countless. Another big factor is certainly Spanish language level of the researcher, which might have influenced the interviews with farmers. Another would be nonresponse bias, as some questions were not answered by the farmer because he/she was avoiding it or avoided getting precise in their answer (such as income, investment). Farmers might also have been affected by the study itself by giving expected answers rather than true ones. They might have wanted the study to turn out positive, so they influenced their answers in a certain way; thus, demand characteristics bias was not excluded. This might have been the case for the question of slash-and-burn method utilization.

Data analysis is affected on several levels. Open questions allowed the respondent to answer freely, but in quantitative analysis, they were converted into categorical data. This must have led to the omission of certain answers that have not occurred several times, so they were counted into the category "others". Qualitative analysis balances it out, especially with the feedback and remarks some farmers gave. In the analysis of farmers' perceptions, some questions were answered only by a few respondents because not all of them were part of the project. Therefore, analysis of questions about the usefulness of the trainings, and belief in the project at its beginning was done from smaller samples (13 for adopters and 9 for non-adopters). In the follow-up question about feeling like they had better status than neighbours, farmers were asked "Why do they have better or worse status". Some respondents explained that trees create a better environment for their lives, or consume healthier food from their own production, which is why they consider their status to be better. The question was asked in an economic context; however, it shows that farmers' approaches do not have to be focused solely on financial prosperity and that researcher might be biased in that regard.

## 6.2. Discussion

It has been shown that the dropout rate of the project "Sustainable Management of Natural Sources in Amazonia" is 9%. There are 22% of farmers from the project who

continue practising agroforestry nowadays. Both of these numbers might rise because of the number of farmers who were not reached. The overall success rate of the project is questionable. In the final report of the project (Lojka 2009), it is said that a 60% success rate is adequate since the majority of established parcels were on degraded land. For such a success rate in the long term, after 15 years of the project, all the farmers who were not reached in this study would need to be actively using agroforestry nowadays. It can also happen that some farmers who participated in the project and stopped using agroforestry before its end will establish an agroforestry parcel again. This is the case of one farmer interviewed in the second phase of this study, where also farmers who dropped out of the project before its end were included. Apart from soil degradation, it should be taken into consideration that the study site is in an active migratory area, where a lot of young people leave for other cities because of job or education opportunities (Observatorio Socio Económico Laboral 2020). Only about half of the population reaches secondary education, and 21% are considered poor (Ministerio de Trabajo y Promoción del Empleo 2022). These might be reasons for economic instability and work-field fluctuations that affect people involved in agriculture and have an impact on agroforestry adoption.

The reasons for dropout might also be other than socio-economic. According to Vázquez-Rowe et al. (2019), the deforestation caused by wildfires in the area has had an increasing trend over the last years because of drier conditions. Fire is not an enemy only to rainforests but also agroforestry systems, as was often reported by farmers in the questionnaire. It was the most commonly cited reason for abandoning agroforestry parcels. Farmers frequently experience accidental burning of their vegetation caused by uncontrolled burning of weeds by themselves or their neighbours. Few respondents referred to the trainings of the project where precautionary measures to prevent losing their production were taught (2m of buffer zone, no dry matter to burn, etc.). Apart from not partaking in the trainings, the reasons why some farmers do not implement these measures are individual. Other reasons why farmers might have dropped out are unrealistic expectations from the project and, consequently, from the established parcels. A farmer from Agua Dulce commented on the project with these words: “The help was insufficient because the Czechs only provided the plants, and then the farmers had to do all the work. Also, they should help directly and not through any organization, because due to corruption, the money will be lost and will not reach the farmers. The project people should come back, sometimes farmers are in debt and they need help.” This raises

a question which might also affect the outcome of the project. There were no specific criteria for how the farmers were chosen to take part in the project except their agricultural activity and willingness to participate in it. The farmers' motivation as well as their eagerness to invest their work in the agroforestry parcel in the long term might differ a lot across the participants.

Considering the impact of the project on the adoption of agroforestry among local farmers, it is difficult to pinpoint it. About 64% (14) of those who do not practice agroforestry nowadays had been practising it in the past, and 79% (11) of these started using agroforestry after the project ended. But as none of these farmers practice agroforestry nowadays, it cannot be counted as an impact of the project. However, there are 21% (4 farmers) of these who use agroforestry, started after the project and had not been part of it. There certainly is a positive impact of the project on the local population; however, its effect cannot be counted only based on the number of farmers using agroforestry. Spreading knowledge and experience among farmers is impossible to research within the scope of this study. The same goes for raising awareness about unsustainable agricultural methods and their risks (the slash and burn approach).

It is shown that agroforestry adoption is dependent on various factors. As suggested by Atangana et al. (2013), understanding farmers' perceptions and strategies for the future has been shown to be crucial for that. It was proven within this research group that agroforestry adoption is significantly dependent on available labour on the farm, which confirms the findings of Atangana et al. (2013). Hiring more workers for help on the farm is correlated with practising agroforestry. It validates the claim that agroforestry is labour demanding, although one farmer mentioned in the interview that agroforestry allows him to work less because the shading trees reduce the thriving of weeds. Contrary to what Atangana et al. (2013) propose, it was not proven in this study that land tenure would be an important determinant for agroforestry adoption.

McGinty et al. (2008) claim that age and income contribute to both the maintenance and adoption of agroforestry. This has not been found in our case. Income was not included in the calculations because of inadequate data. Age did not show any correlation, but by contrast, the years of farming did. The mentioned research also indicates that multidimensional socio-psychological variables, such as conservation attitudes or behavioural control, influence adoption decision-making, but they are less

studied (McGinty et al. 2008). The findings of this study support this statement. Environmental motivation to use agroforestry was found to be strongly correlated with its adoption. The environmental motivation stated by farmers was, for example, maintaining the natural environment to prevent global warming, to be surrounded by nature and life, etc. Another factor from the socio-psychological variables was confirmed in this study to be related to agroforestry practice, and that is farmers' belief that agroforestry systems are beneficial.

The decision to practice agroforestry seems to be dependent on the area of farmland (Coomes & Burt 1997). This statement is supported by the results of this study, where the area of a farm shows a moderate correlation with agroforestry adoption.

Trembley et al. (2015) mention transportation in rural areas as a major constraint for the economic development to which agroforestry should lead. Thus, indirectly, it is a burden for agroforestry adoption as well. This assumption is also supported by Pattanyak et al. (2003). It has been detected in this study that distance from markets is another factor that conditions the practise of agroforestry, although its correlation is rather low. Membership in an organization or cooperative and participation in trainings are two factors that are correlated to agroforestry adoption. However, the coefficient values are very low (around 0,15), which shows a low degree of correlation. Considerably more correlated is the farmers' assessment of the importance of being in an organization, which shows moderate correlation. It means that seeing membership in an organization as important is related to the practice of agroforestry.

Concerning the last research question, farmers are aware of the benefits of agroforestry and its positive impact on the environment. They do not think they would have to work more compared to farmers who do not practice agroforestry. Yet the adoption of agroforestry is not happening naturally in the area on its own. In accordance with findings from the literature review, the economic situation, the impossibility to invest more means into the establishment of agroforestry parcels, a short-sighted business plan, and a lack of labour are blamed as the reasons for low agroforestry adoption.

# 7. Conclusions

The study aimed to evaluate the adoption of multistrata agroforestry systems by local farmers in the Pucallpa region, department of Ucayali, Peru. The objective was to examine the impact of the development project called Sustainable Management of Natural Sources in Amazonia. Based on quantitative and qualitative analysis of farmers' survey answers, it can be concluded that the outcome of the project is multifaceted and cannot be assessed simply as a success or a failure. About 22% of the former project participants who were practising agroforestry at the end of the project continue using it nowadays. The reasons for the dropout of the project are uncontrolled human-induced fires, a labour shortage, insufficient financial resources, and farmers' motivation. The project had a positive impact on local farmers, but more research is needed to claim with certainty that it had an impact on their adoption of agroforestry.

The research clearly illustrates that agroforestry adoption is related to growing timber trees, environmental motivation to use it, experience in agriculture and also with agroforestry in the past as well, number of workers, and area of their farm. Farmers' perception of agroforestry is positive; they acknowledge its benefits. The factors that are important for them are shading by the trees, food and construction material production, and environmental impacts such as halting deforestation and maintaining biodiversity.

The first hypothesis was rejected because the available data does not show a high number of participants continuing with the established agroforestry parcels. Nevertheless, it cannot be stated with certitude due to a lack of information about some of the project's participants. The second hypothesis was partly accepted because it was shown that the adoption of agroforestry is related to the area of farms. Since the adoption is not related to farmers' participation in the trainings during the project, nor is it directly linked to the membership of organizations or cooperatives, the second hypothesis is partly rejected.

Within the study, a great deal of data was collected, which can serve as a base for future research and a deeper analysis of the respondents. Subsequent research should examine the impact of the project on all its participants. On this basis, the research can also focus on finding ways to make developmental projects self-supporting, independent, and efficient over a long period of time.

# 8. References


Alarcón-Aguirre G, Sajami Quispe E, Vásquez Zavaleta T, Ponce Tejada LV, Ramos Enciso D, Rodríguez Achata L, Garate-Quispe J. 2023. Vegetation dynamics in lands degraded by gold mining in the southeastern Peruvian Amazon. Trees, Forests and People **11**:100369.

Alencar, A. A., P. M. Brando, G. P. Asner and F. E. Putz, 2015: Landscape fragmentation, severe drought, and the new Amazon forest fire regime. Ecological Applications, 25(6), 1493–1505, doi:10.1890/14-1528.1.

Andina A. 2022. Peru: Gov't declares state of emergency in Ucayali Region Provinces. Available from https://andina.pe/agencia/noticia-peru-govt-declares-state-of-emergency-in-ucayali-region-provinces-891583.aspx (accessed April 19, 2023).

Atangana A, Khasa D, Chang S, Degrande A. 2014. Socio-Cultural Aspects of Agroforestry and Adoption. Pages 323–332 in Atangana A, Khasa D, Chang S, Degrande A, editors. Tropical Agroforestry. Springer Netherlands, Dordrecht. Available from https://doi.org/10.1007/978-94-007-7723-1_17 (accessed April 8, 2023).

Balogh, A. 2021. *The rise and fall of monoculture farming*. Horizon Magazine. Retrieved February 4, 2023, from https://ec.europa.eu/research-and-innovation/en/horizon-magazine/rise-and-fall-monoculture-farming

Bortl L, 2011. *Adoption and socioeconomic evaluation of multistrata agroforestry systems in the Peruvian Amazon.* [Master's thesis]. Czech University of Life Sciences Prague, Institute of tropics and subtropics.

Boulton CA, Lenton TM, Boers N. 2022. Pronounced loss of Amazon rainforest resilience since the early 2000s. Nature Climate Change **12**:271–278. Nature Publishing Group.
Brando, P. M. et al., 2020: The gathering firestorm in southern Amazonia.

Butler RA. 2022. Facts about the amazon rainforest for 2022. Mongabay. Available from https://rainforests.mongabay.com/amazon/amazon-rainforest-facts.html (accessed February 20, 2023).

Coomes OT, Burt GJ. 1997. Indigenous market-oriented agroforestry: dissecting local diversity in western Amazonia. Agroforestry Systems **37**:27–44.

da Silva, S.S., et al. 2018. Dynamics of forest fires in the southwestern Amazon. For. Ecol. Manag., 424(September), 312–322, doi:10.1016/j. foreco.2018.04.041.

Demirdogen A, Guldal HT, Sanli H. 2023. Monoculture, crop rotation policy, and fire. Ecological Economics **203**:107611.

den Herder, M., et al. 2015. Preliminary stratification and quantification of agroforestry in Europe. Milestone Report 1.1 for EU FP7 Research Project: AGFORWARD 613520: 57 pp.

Department of Economic and Social Affairs. 2021. *UN/DESA Policy brief #102: Population, Food Security, Nutrition and Sustainable Development | Department of Economic and Social Affairs*. United Nations. Retrieved February 6, 2023, from https://www.un.org/development/desa/dpad/publication/un-desa-policy-brief-102-population-food-security-nutrition-and-sustainable-development/

Ettmer, B., Alvarado-Ancieta, C., A., 2010. Morphological development of the Ucayali River, Peru without human impacts, Waldökologie, Landschaftsforschung und Naturschutz (Forest Ecology, Landscape Research and Nature Conservation) 10

European Agroforestry Federation.(n.d.). *Agroforestry fact sheet* [Fact sheet]. National Research Institute for Agriculture, Food and the Environment. https://euraf.isa.utl.pt/sites/default/files/pub/docs/agroforestry_fact_sheet.pdf

Eva H et al. 2005. A proposal for defining the geographical boundaries of Amazonia. Journal of Organic Chemistry - J ORG CHEM.

FAO. 1987. Small-scale forestry-based processing enterprises. FAO, Rome

Ghale B, Mitra E, Sodhi HS, Verma AK, Kumar S. 2022. Carbon Sequestration Potential of Agroforestry Systems and Its Potential in Climate Change Mitigation. Water, Air, & Soil Pollution **233**:228.

Goy J, Waltner-Toews D. 2005. Improving Health in Ucayali, Peru: A Multisector and Multilevel Analysis. EcoHealth **2**:47–57.

Hansen MC et al. 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change. Science **342**:850–853. American Association for the Advancement of Science.

Chapin, F. S., Matson, P. A., & Vitousek, P. M. 2011. Principles of Terrestrial Ecosystem Ecology. https://doi.org/10.1007/978-1-4419-9504-9

Charette M, Berrang-Ford L, Coomes O, Llanos-Cuentas EA, Cárcamo C, Kulkarni M, Harper SL. 2020. Dengue Incidence and Sociodemographic Conditions in Pucallpa, Peruvian Amazon: What Role for Modification of the Dengue–Temperature Relationship? The American Journal of Tropical Medicine and Hygiene **102**:180–190.

Chen J, Saunders SC, Crow TR, Naiman RJ, Brosofske KD, Mroz GD, Brookshire BL, Franklin JF. 1999. Microclimate in Forest Ecosystem and Landscape Ecology: Variations in local climate can be used to monitor and compare the effects of different management regimes. BioScience **49**:288–297.

Chepstow-lusty A, Winfield M. 2000. Inca agroforestry: Lessons from the past. Ambio **29**:322–328.

Indoria AK, Sharma KL, Reddy KS. 2020. Chapter 18 - Hydraulic properties of soil under warming climate. Pages 473–508 in Prasad MNV, Pietrzykowski M, editors. Climate Change and Soil Interactions. Elsevier. Available from

https://www.sciencedirect.com/science/article/pii/B9780128180327000187 (accessed March 16, 2023).

IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2391 pp. doi:10.1017/9781009157896.

IPCC, 2022: *Climate Change 2022: Impacts, Adaptation, and Vulnerability*. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 pp., doi:10.1017/9781009325844.

Iqbal R, Raza MAS, Valipour M, Saleem MF, Zaheer MS, Ahmad S, Toleikiene M, Haider I, Aslam MU, Nazar MA. 2020. Potential agricultural and environmental benefits of mulches—a review. Bulletin of the National Research Centre **44**:75.

Lentz DL, Hockaday B. 2009. Tikal timbers and temples: ancient Maya agroforestry and the end of time. Journal of Archaeological Science **36**:1342–1353.

Lojka B, Lojkova J, Banout J, Polesny Z, Preininger D. 2008. Performance of an improved fallow system in the Peruvian Amazon—modelling approach. Agroforestry Systems **72**:27–39.

Lojka B. 2009. Pages 4–9 Závěrečná zpráva projektu Udržitelné nakládání s přírodními zdroji v oblasti Amazonie (Peru) . rep. Czech University of Life Sciences, Prague, Czech Republic.

Lojka, B., Bortl, L., Riva Ruiz, R., Banout, J., Lojková, J., Polesný, Z., Preininger, D. , Ugarte Guerra, J., Espinoza Linares, M., Verner, V. *Agroforestry Research Development.* New York : Nova Science Publishers Inc., 2016, 578s. ISBN 978-1-63485-046-9. Multistrata agroforestry as an alternative to slash-and-burn farming in the Peruvian Amazon, s. 383-398.

Lundgren, B.O.; Raintree, J.B.(1983). Sustained Agroforestry. In *Agricultural Research for Development: Potentials and Challenges in Asia*; Nestel, B., Ed.; ISNAR: The Hague, The Netherlands; pp. 37–49.

Marra M, Pannell D, Abadi Ghadim A. 2003. The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: Where are we on the learning curve? Agricultural Systems **75**:215–234.

McGinty M, Swisher M, Alavalapati J. 2008. Agroforestry adoption and maintenance: Self-efficacy, attitudes and socio-economic factors. Agroforestry Systems **73**:99–108.

Ministerio de Trabajo y Promoción del Empleo. 2022. *REPORTE DEL EMPLEO FORMAL EN LA REGIÓN UCAYALI*. Dirección de Supervisión y Evaluación de la Dirección General de Políticas para la Promoción de la Formalización Laboral e Inspección del Trabajo. Retrieved March 24, 2023, from https://cdn.www.gob.pe/uploads/document/file/3444966/25.%20Ucayali%20-%20Febrero%202022.pdf

Nair PKR, Kumar BM, Nair VD. 2021. Definition and Concepts of Agroforestry. Pages 21–28 in Nair PKR, Kumar BM, Nair VD, editors. An Introduction to Agroforestry: Four Decades of Scientific Developments. Springer International Publishing, Cham. Available from https://doi.org/10.1007/978-3-030-75358-0_2 (accessed March 20, 2023).

Nair, P., K., R. (1993). Introduction to Agroforestry, Kluwer Academic Publishers, Netherlands

Nilsson K, Sangster M, Konijnendijk CC. 2011. Forests, Trees and Human Health and Well-being: Introduction. Pages 1–19 in Nilsson K, Sangster M, Gallis C, Hartig T, de Vries S, Seeland K, Schipperijn J, editors. Forests, Trees and Human Health. Springer Netherlands, Dordrecht. Available from http://link.springer.com/10.1007/978-90-481-9806-1_1 (accessed March 30, 2023).

Observatorio Socio Económico Laboral. (2020). DIAGNÓSTICO SOCIOECONÓMICO LABORAL 2019 REGIÓN UCAYALI. Pucallpa; DIRECCIÓN REGIONAL DE TRABAJO Y PROMOCIÓN DEL EMPLEO DE UCAYALI.

Park CC. 1992. Tropical Rainforests. Routledge Press, London, UK.

Parmesan, C., M.D. Morecroft, Y. Trisurat, R. Adrian, G.Z. Anshari, A. Arneth, Q. Gao, P. Gonzalez, R. Harris, J. Price, N. Stevens, and G.H. Talukdar (2022). Terrestrial and Freshwater Ecosystems and their Services. In: *Climate Change 2022: Impacts, Adaptation, and Vulnerability*. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 197-377, doi:10.1017/9781009325844.004.

Pattanayak S, Mercer D, Sills E, Yang J-C. 2003. Taking stock of agroforestry adoption studies. Agroforestry Systems **57**:173–186.

Pawlick T. 1989. Agroforestry: a very social science. Agroforestry Today **1**:2–5.

Porro R, Lopez-Feldman A, Vela-Alvarado JW. 2015. Forest use and agriculture in Ucayali, Peru: Livelihood strategies, poverty and wealth in an Amazon frontier. Forest Policy and Economics **51**:47–56.

Raihan A, Tuspekova A. 2022. The nexus between economic growth, renewable energy use, agricultural land expansion, and carbon emissions: New insights from Peru. Energy Nexus **6**:100067.

Reygadas Y, Spera SA, Salisbury DS. 2023. Effects of deforestation and forest degradation on ecosystem service indicators across the Southwestern Amazon. Ecological Indicators **147**:109996.

Rosenstock T, Tully K, Arias-Navarro C, Neufeldt H, Butterbach-Bahl K, Verchot L. 2014. Agroforestry with N2-fixing trees: sustainable development's friend or foe? Current Opinion in Environmental Sustainability **6**:15–21.

Rosenstock TS et al. 2019. Making trees count: Measurement and reporting of agroforestry in UNFCCC national communications of non-Annex I countries. Agriculture, Ecosystems & Environment **284**:106569.

Salisbury DS, Fagan C. 2011. Coca and conservation: Cultivation, eradication, and trafficking in the Amazon borderlands. GeoJournal **11**:1–20.

Serrao EAS, Nepstad D and Walker R. 1996. Upland agricultural and forestry development in the Amazon: sustainability, criticality and resilience. Ecological Economic 18: 3-13.

Sherman M, Ford J, Llanos-Cuentas A, Valdivia MJ, Bussalleu A, Indigenous Health Adaptation to Climate Change (IHACC) Research Group. 2015. Vulnerability and adaptive capacity of community food systems in the Peruvian Amazon: a case study from Panaillo. Natural Hazards **77**:2049–2079.

Silva IMS, Calvi GP, Baskin CC, dos Santos GR, Leal-Filho N, Ferraz IDK. 2021. Response of central Amazon rainforest soil seed banks to climate change - Simulation of global warming. Forest Ecology and Management **493**:119224.

Silva RM da, Lopes AG, Santos CAG. 2023. Deforestation and fires in the Brazilian Amazon from 2001 to 2020: Impacts on rainfall variability and land surface temperature. Journal of Environmental Management **326**:116664.

Smith P., M. Bustamante, H. Ahammad, H. Clark, H. Dong, E.A. Elsiddig, H. Haberl, R. Harper, J. House, M. Jafari, O. Masera, C. Mbow, N.H. Ravindranath, C.W. Rice, C. Robledo Abad, A. Romanovskaya, F. Sperling, and F. Tubiello, 2014: Agriculture, Forestry and Other Land Use (AFOLU). In: *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Soudre, M., Ricse, A., Carbajal, Y., Kobayashi, S., Sabogal, C., Alegre, J., (2001) Adaptability of Six Native Forest Tree Species to Degraded Lands in Pucallpa, Peruvian

Amazon, In: Southgate, D., (ed.), 2001, Tropical Forest conservation: An economic assessment of the alternatives in Latin America, Oxford Press, UK

Steffen W et al. 2015. Planetary boundaries: Guiding human development on a changing planet. Science **347**:1259855. American Association for the Advancement of Science.

Tremblay S, Lucotte M, Revéret J-P, Davidson R, Mertens F, Passos CJS, Romaña CA. 2015. Agroforestry systems as a profitable alternative to slash and burn practices in small-scale agriculture of the Brazilian Amazon. Agroforestry Systems **89**:193–204.

Vázquez-Rowe I, Kahhat R, Larrea-Gallegos G, Ziegler-Rodriguez K. 2019. Peru's road to climate action: Are we on the right path? The role of life cycle methods to improve Peruvian national contributions. Science of The Total Environment **659**:249–266.

Werf GR, Morton D, Defries R, Olivier J, Kasibhatla PS, Jackson RB, Collatz GJ, Randerson J. 2009. CO2 emissions from forests. Nature Geoscience **2**.

Willemen L, Scheldeman X, Soto Cabellos V, Rafael Salazar S, Guarino L. 2007. Spatial patterns of diversity and genetic erosion of traditional cassava (Manihot esculenta Crantz) in the Peruvian Amazon: An evaluation of socio-economic and environmental indicators. Genetic Resources and Crop Evolution **54**:1599–1612.

World Wildlife Fund. (2022). *Amazon*. WWF. Retrieved March 26, 2023, from https://www.worldwildlife.org/places/amazon

Xu, X. Y. et al., 2020: Climate regime shift and forest loss amplify fire in Amazonian forests. Global Change Biology, 26(10), 5874–5885, doi:10.1111/gcb.15279.

# Appendices

# Appendix 1: Questionnaire

Farmers questionnaire

Thank you very much for your time and will to complete my questionnaire. I appreciate your help a lot. All the information you provide will be used only for the purpose of my research and presented anonymously.

Personal info:

1 Name:

2 Phone number:

3 Age:

4 Address:

5 How many years have you lived here?

6 (Why did you move to this area)

7 Area (ha):

8 Area used for farming:

9 Years of farming:

10 Years of farming in this area:

11 Are you: a) married b) cohabiting c) widowed d) single

12 How many sons/daughters do you have: (where do they live? What do they do? Do they participate in any way in the family income?)

13 How many people live in your household?

14 Did you finish school: a) primary b) secondary c) superior d) other / how many years of studies?

15 Were your parents farmers?

---

Farm:

16 How far is your agriculture area from your house?

17 How many people work on your farm?

18 Do you use neighbour cooperation = mingas? How often and for what work?

19 Do you hire workers?

20 Do you own the land? Do you have any certificate of ownership and for how long is it valid?

21 How have the area looked when you started farming here?

22 What have you done to make it an agriculture land?

23 Do you use a separate area to produce food for your own household?

24 Do you have any livestock? What and how many?

25 Do you use slash and burn? Where and how often?

26 Have you ever abandoned = stopped using any part of your land? Why?

27 What do you produce on your farm? How many kg per year?

28 Do you use chemical fertilizers? If not, why?

29 Do you use pesticides? If not, why?

30 How do you control weed?

31 Do you use any composting technique?

---

Agroforestry:

32 Do you know the term multistrata agroforestry system?

Agroforestry combines cultivation of crops with trees. Both can be for profit, trees can give fruit or timber in the future and crops provide yield. Multistrata means the system works on several levels just like the natural forest.

33 Do you use any agroforestry systems on your land?

34 If no, have you ever used any in the past? Why did you use them?

35 Give your opinion to the following statement. Agroforestry systems are beneficial.

- Strongly agree – agree – neutral – disagree – strongly disagree

36 What species do you grow in such system?

37 Do you switch to different crops every year? What did you grow under the trees last year?

38 How many kg do you produce per year?

39 What do you grow the trees for?

40 When do you plan to cut down the trees? Will you replace them by some other trees? Which ones?

41 Have you extended the agroforestry parcel since the project?

42 Have you been using agroforestry systems before the Czech project started here?

43 What is your motivation to use agroforestry system?

44 Do your neighbours use multistrata agroforestry systems?

45 Have you heard of deforestation of the rainforest being an environmental problem? Do you see it as a problem? - Strongly agree – agree – neutral – disagree – strongly disagree

Why?

---

Project:

46 Have you ever received any support from CIDRA? (of which kind and when)

47 Did you participate in any workshops and trainings in the project 15 years ago?

48 If yes, give your opinion to following statement. The workshops and trainings were useful.

- Strongly agree – agree – neutral – disagree – strongly disagree

49 Do you nowadays use anything what you have learned there?

50 Have you received any seedlings during the project? What species:

51 Have you harvested the trees for any product? For which?

52 Do you use your own seeds now? Where do you get seedlings from?

53 Are you a member of any community organization or cooperative? Which one?

54 Have you been a member of any in the past? Why aren't you anymore?

55 Give your opinion to following statement. Being part of an organization is important for the functioning of my farm.

- Strongly agree – agree – neutral – disagree – strongly disagree

56 Is it financially beneficial for you to be a member of the organization?

---

Limitations:

57 Give your opinion to the following statement. At the beginning of the project (establishment of agroforestry parcel), I believed in its long-term functioning.

- Strongly agree – agree – neutral – disagree – strongly disagree

58 Did your vegetation burn down by accident at any point?

If you continue using agroforestry systems, go to question 64

For these who dropped out:

59 Why did you stop using the agroforestry systems on your land?

60 What did you find as the biggest obstacle?

61 Would you start it again if you had the means for it?

62 Would you do anything differently? What?

63 What do you use the land which used to be Agroforestry systems for?

For these who continue:

64 What is your motivation to continue with the settled agroforestry system?

65 Give an opinion to the following statements. “I work more than other farmers who don’t use agroforestry.”

- strongly agree – agree – neutral – disagree – strongly disagree

66 “I have better status than my neighbouring farmers.”

- strongly agree – agree – neutral – disagree – strongly disagree

- Why?

67 What benefits does agroforestry bring you personally?

68 What disadvantages does it bring?

---

Income:

69 How much income does your farm provide you monthly?

70 What brings you the most profit on your farm?

71 Where do you sell your products? Is there any mediator?

72 For how much do you sell them?

73 If you go by yourself, how far do you go to the markets?

74 Does farming cover your living costs easily?

75 How much do you have to invest yearly into maintenance of your farm?

76 Do you have other income than that from your farm? Which one?

---

Future:

77 What are your plans on the farm?

78 What do you want to focus the most on?

79 Give an opinion to the following statements. “I see myself as a farmer in the future.”

- strongly agree – agree – neutral – disagree – strongly disagree

80 “I want my children to continue working on my land.”

- strongly agree – agree – neutral – disagree – strongly disagree

---