What influences forest clearing decisions in shifting cultivation systems? Evidence from Western Amazonia

by

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ABSTRACT

Shifting cultivation systems create disturbances in tropical landscapes by converting forests into agricultural land for a temporary period. These disturbances may induce adverse impacts on not only the ecosystem but also human livelihoods by decreasing biodiversity and aggravating climate change. Since preserving biodiverse old-growth forests has a higher conservative priority than fallows, we are interested in identifying the factors that drive farmers to clear old-growth forests over secondary forest fallows in shifting cultivation systems. Using survey data collected previously as part of the PARLAP project, we conducted exploratory and multivariate regression analyses to examine the factors that influence forest clearing decisions on plot location and forest type. Community-level factors (e.g., community age, initial aquatic endowment, and land availability) as well as biophysical factors (e.g., percentage of Holocene soils, old-growth forests availability) were found to predict the probability of clearing old-growth forests better than the household-level factors. This study provides useful insights for policymakers to design more effective policies for preserving old-growth tropical rainforests.

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1. CHAPTER 1: INTRODUCTION

Shifting cultivation - also known as swidden agriculture or 'slash and burn' agriculture - is common throughout the tropics and subtropics (Cairns, 2015). Shifting cultivation is a system in which small patches of forest are selected, cleared, and burned by farmers to provide nutrients for crop production (Cairns, 2015). Farmers usually cut and burn the vegetation in the dry season and plant crops in the ashes early in the wet season (Angelsen, 1995). Declining soil productivity and increasing weed problems lead farmers to leave their plot in fallow after a few years of cultivation. Once weeding stops, other types of vegetation take over, and eventually secondary forest arises before the cycle is repeated (Angelsen, 1995). As a result, shifting cultivation system is characterized by shifting between forest and cropland, and leads to a mosaic of fields in different stages of recovery from agricultural activities (Cairns, 2015).

1.1 Shifting Cultivation Systems

1.1.1 Geographical Extent and Circumstances

The current extent of shifting cultivation landscape, counting both cultivated fields and secondary forest fallows, is about 280 million hectares worldwide (Heinimann et al., 2017, p. 11). Secondary forests alone account for more than half of the world's tropical forests, and they are expanding in extent (Cairns, 2015). In tropical Asia, almost two-thirds of total forest cover is comprised of secondary forests, and many people rely on the practice of 'slash and burn' to sustain their livelihood (Mertz et al., 2009). It is estimated that some 14 to 34 million people employ shifting cultivation in Asia for subsistence and cash income, contributing food, fibre, and non-timber forest products to the regional and national markets (Mertz et al., 2009, p. 157).

Today, markets and government policies are putting pressure on shifting cultivation systems. Increasing access to markets is reducing the area under shifting cultivation because markets encourage farmers to work on other activities, such as cattle ranching and cash cropping (Angelsen, 1995). In addition, conservation policies and practices also limit shifting cultivation by restricting forest clearing and encouraging agriculture intensification (Jakovac et al., 2017). During the past few decades, shifting cultivation in riverine Amazonia has gone through a process of intensification, as indicated by the decreasing fallow-period length as well as the slowing encroachment into old-growth forests (Jakovac et al., 2017). Consequently, young secondary forests have become the predominant component of the current landscape around communities, and many swiddens are being turned into permanent agricultural plots (Jakovac et al., 2017).

Nonetheless, shifting cultivation remains vital in many frontier areas. It is still the principal livelihood strategy for farmers who have unequal or insecure access to investment as well as those with few opportunities for market access (Palacios et al., 2013). Shifting cultivation is also important in regions where farmers adopt a diversified livelihood strategy to adapt to current ecological, economic, and political circumstances, and thus preserve multi-functionality land uses (Palacios et al., 2013). Indeed, shifting cultivation remains prominent in areas where intensification is not a viable option as population density and/or the food market demand is low (Palacios et al., 2013).

1.1.2 Sustainability of Shifting Cultivation Systems

Shifting cultivation is one of the most extensive and controversial land uses in the tropical world. Some studies argue that shifting cultivation is sustainable, both ecologically and economically, under the conditions of low population density and limited market integration

(Cairns, 2015; Ravikumar et al., 2016). Rather than lead to permanent land conversion, shifting cultivation involves rotational patterns of growth, fallow, and regrowth, and these cycles result in a dynamic landscape that can be relatively stable and sustainable (Ravikumar et al., 2016).

Recent changes in population density and market integration, however, can make shifting system less sustainable. If the population grows quickly, and regional economic participation intensifies, shifting cultivation can experience a rapid transition to commercial agriculture as well as shorter fallow periods (Cairns, 2015; Jakovac et al., 2017). Shorter fallows reduce the productivity of swiddens and the regrowth capacity of subsequent fallows, undermining the resilience of shifting cultivation (Jakovac et al., 2017). Further, shorter fallows have negative impacts on the environment, including limited biomass accumulation and inadequate protection of erodible soils (Takasaki, 2013).

1.2 Deforestation in the Tropics

In this section, we argue for the importance and necessity of preserving forests, especially old-growth forests, by stressing the adverse impacts brought by deforestation as well as emphasizing benefits provided by old-growth forests to ecosystems. Potential adverse impacts of deforestation include biodiversity loss and increasing carbon emission to the atmosphere. However, if forest preservation was successful, these adverse influences would be avoided.

1.2.1 Decreasing Biodiversity

Biodiversity describes the variety and variability of life on Earth, and it is typically a measure of variation at the genetic, species, and ecosystem levels (Sodhi & Ehrlich, 2011). In shifting cultivation, the conversion of old-growth forests into agricultural lands and then into secondary forest fallows decreases biodiversity (Coomes et al., 2017). Old-growth forests are the most important stocks of genetic resources because they are home to many endemic species (Barlow et al., 2016). Secondary forests, however, are inhabited by more homogenous species and thus containing less genetic resources. One study examined the effects of shifting agriculture on species abundance and composition of a tropical forest in Mexico, and found that the conversion from old-growth forests to secondary forest fallows reduces species diversity principally by reducing the presence of woody species with relative abundances of < 1%, favouring species with high relative abundances (Miller & Kauffman, 1998, p. 199). Another study also found that old-growth forests are inhabited by more rare bird species than secondary forests: 12 habitat specialists were found in old-growth forests, whereas only five species were found in fallows (Ramen, 2001, p. 692). Consequently, it is more important to protect old-growth forests since they contain richer biodiversity than secondary forests.

1.2.2 Increasing Carbon Emission and Climate Change

Tropical deforestation is one of the main drivers of increasing carbon dioxide concentrations in the atmosphere. Forests act as carbon sinks because vegetations can store carbon in an organic form; forest clearing, however, destroys the carbon stock and releases carbon into the atmosphere. Further, agricultural production will increase carbon emissions. Kotto-same et al. (1997) analyzed the carbon dynamics under shifting cultivation systems in Cameroon, Central Africa, and found that the conversion from intact forest to agricultural land induced a loss of 220 t C/ha (Kotto-same et al., 1997, p. 249).

Increasing carbon concentrations in the atmosphere fuels global warming, which in turn results in a series of environmental changes and that harm not only humans but also other living organisms. Old-growth forests are crucial regulators on climate change because they store more carbon than secondary forest fallows. One study found that the average carbon stocks in live aboveground biomass debris declined by 64% after conversion from old-growth forests to secondary forest fallows, and the combined aboveground and soil carbon stock declined almost 36% further (Eaton and Lawrence, 2009, p. 954). As a result, the preservation of old-growth forests should be given a higher conservative priority than that of secondary forests.

1.3 Objective and Research Questions

In shifting cultivation systems, farmers must decide between clearing old-growth forests and secondary forest fallows when selecting a new plot. Since the preservation of old-growth forests is of greater significance than that of secondary forests, we propose to investigate what factors drive old-growth forest clearing over secondary forest fallow in shifting cultivation systems by drawing evidence from western Amazonia. To meet this goal, we will examine the following research questions: (1) what factors have been analyzed in deforestation models from previous studies?; (2) what factors are considered by farmers during the plot selection process in shifting cultivation systems?; (3) what factors have the potential of driving farmers to clear old-growth forests over secondary forests in shifting cultivation systems?; and lastly, (4) what recommendations can be made to design better policies for forest conservation in the tropics.

This research will help us to better understand the decision-making process for forest clearing in tropical shifting cultivation systems. By helping understand why some farmers clear old-growth forests instead of secondary forests fallows, this study can provide insights to design more effective policies for preserving tropical rainforests.

2. CHAPTER 2: LITERATURE REVIEW

This chapter presents a review of the literature relevant to this study. The literature review process is divided into two parts: the first part examines the causes of tropical deforestation in a general context; the second part identifies the predictors of plot selection in shifting cultivation systems. By drawing insights from these literatures, we hope to understand the potential factors that influence deforestation and then apply them to understanding shifting cultivation systems. In addition, we seek to investigate the factors that farmers consider when selecting a new forest plot for cultivation. These insights from literature are integrated into a conceptual framework that guides the empirical analyses to be undertaken on forest clearing decisions by farmers in the Peruvian Amazon.

2.1 Causes of Deforestation

2.1.1 Structure of the framework

Angelson and Kaimowitz (1999) synthesized the results of more than 140 economic models analyzing the drivers of tropical deforestation, and they built a framework to categorize causes of deforestation. They identified five types of variables that are used in models of deforestation: (1) magnitude and location of deforestation — the main dependent variable; (2) agents of deforestation — individuals, households, or companies involved in land-use change and their characteristics; (3) choice variables — decisions about land allocation that determine the overall level of deforestation for the particular agent or group of agents; (4) agents' decision parameters — variables that directly influence agents' decisions but are external to them; and, (5) underlying causes of deforestation — variables that affect forest clearing indirectly through their influence on the decision parameters. These variables can be further categorized into three broad levels: underlying causes, immediate causes, and agents of deforestation. There is a hierarchical relationship between these three levels: underlying causes can shape decision parameters (i.e., immediate causes), and these immediate causes can further influence decisions on land-use changes made by agents of deforestation.

2.1.2 Underlying Causes of Deforestation

The underlying causes of deforestation comprise both macroeconomic-level variables and policy instruments. Macroeconomic-level variables relate to broad economic rules as well as economic relations among countries on a global or national scale. Policy instruments are the rules and regulations used by governments or organizations to overcome problems or to achieve objectives by shaping incentives, technology, infrastructure, markets, and other institutions.

Among macroeconomic-level variables related to deforestation are income level and economic growth, trade liberalization, and foreign debt (Angelsen & Kaimowitz, 1999; Burgess et al., 2011; Jusys, 2016). Economic growth can have opposing impacts on forest clearing (Angelsen & Kaimowitz, 1999). For instance, economic growth can reduce deforestation by providing more off-farm employment opportunities, but it can also increase deforestation by stimulating demand for agricultural and forest products as well as by improving access to forests and markets (Angelsen & Kaimowitz, 1999). Several studies find a U-shaped pattern in the relationship between economic growth and deforestation (Godoy et al., 1996; Jusys, 2016). If a country has a high GDP, economic growth increases deforestation; whereas if a country has a low GDP, economic growth decreases deforestation (Jusys, 2016). Also, trade liberalization that increases agricultural and forest product exports can increase deforestation (Angelsen & Kaimowitz, 1999; Jusys, 2016).

Policy instruments can affect deforestation, such as regulations for protected areas and on-farm soil management (Takasaki, 2006; Takasaki, 2013; Miranda et al., 2014; Jusys, 2016; Jakovac et al., 2017). Policies for protected areas bring different levels of influence to forest preservation, depending on the specific rules (Miranda et al., 2014; Jusys, 2016). For instance, policies that allow sustainable extractive activities are more effective in reducing deforestation than those that prohibit any extractive activities strictly (Miranda et al., 2014). Regulations that improve on-farm soil management bring positive impacts not only for old-growth forest preservation but also for secondary forest fallows (Takasaki, 2013).

2.1.3 Immediate Causes of Deforestation

The immediate causes of deforestation are institutions, infrastructure, markets, and technology. Institutions describe a set of norms and rules which govern the behaviour of people. Infrastructure refers to basic physical and organizational structures and facilities. Markets are a place where exchanges of commodities or services take place, such as local markets where farmers sell their agricultural products. Technology refers to the application of scientific knowledge for practical purposes, such as utilizing fertilizers or machines in agricultural production.

Institutions relevant to deforestation include land tenure, credit access, agricultural price subsidies (Angelsen & Kaimowitz, 1999; Takasaki, 2006; Chibwana et al., 2012; Jusys, 2016). Improving tenure security can encourage farmers to reduce forest clearing (Takasaki, 2006; Jusys, 2016). Whether the availability of credit increases or decreases deforestation depends on the type of investment: if the investment is in forest clearing, then credit will fuel deforestation, whereas if investment is in forest management or agricultural intensification, credit access can decrease deforestation (Angelsen & Kaimowitz, 1999; Jusys, 2016). Some studies find that agricultural price subsidies have an adverse effect on forest protection (Takasaki, 2006); others find that subsidy-induced agricultural intensification of food crops reduces the rate and extent of forest clearing (Chibwana et al., 2012).

Infrastructure refers primarily to the condition of roads in studies about tropical deforestation. The improvements of roads, in terms of both the quantity and quality of them, encourages deforestation by enhancing accessibility to forests as well as to markets (Angelsen, 1999; Babigumira et al., 2014; Sy et al., 2015; Jusys, 2016); however, increasing accessibility to workplaces could decrease deforestation (Angelsen, 1995; Angelsen & Kaimowitz, 1999; Jakovac et al., 2017).

Market conditions include market orientation and demand, market integration, agricultural output and input prices, as well as off-farm wages and employment (Angelsen, 1995; Angelsen & Kaimowitz, 1999; Babigumira et al., 2014; Jakovac et al., 2017). Increasing market orientation can stimulate forest clearance, if forests are accessible and farmers have the means to clear them (Babigumira et al., 2014; Jakovac et al., 2017). Rising agricultural output prices encourage people to shift their resources into more forest clearing activities, whereas higher agricultural input prices (e.g., the fertilizer price) can induce shifts to more land-extensive systems and thus decreasing deforestation (Angelsen & Kaimowitz, 1999; Jakovac et al., 2017). Further, increasing off-farm wages and employment decrease deforestation by making agricultural and forestry activities less profitable (Angelsen, 1995; Angelsen & Kaimowitz, 1999; Takasaki, 2006).

Technology is also closely related to forest clearing. Technological change (e.g., intensification programmes) in frontier areas can increase deforestation (Angelsen, 1995; Takasaki, 2006), whereas new labour-intensive technologies may reduce deforestation if the labour supply is inelastic (Angelsen & Kaimowitz, 1999). Intensification in a subsistence setting reduces forest clearing as people can secure their subsistence income from a smaller land area. The increasing profitability of farming, however, can attract more people to work in agriculture, both through a shift from alternative income-generating activities among those already living in the area, and through immigration (Angelsen, 1995).

2.1.4 Agents of Deforestation

Agents who make decisions to clear forest include individuals, households, companies, and governments. Most articles focused on households as the agent of deforestation, and several studies identify relevant community-level factors including land availability, population density, and migratory movements (Angelsen & Kaimowitz, 1999; Jusys, 2016; Jakovac et al., 2017). With increasing land availability, households in a community are more likely to clear new lands. Increasing population density can also increase deforestation, and the regional population should be considered endogenous to deforestation (Angelsen & Kaimowitz, 1999; Jusys, 2016). Increasing migration puts pressure on forests as well (Jakovac et al., 2017).

Household-level variables found to influence deforestation include labour availability, household assets and financial capital, household demographic factors, livelihood strategy, and local ethnobotanical knowledge (Conklin, 1961; Perz, 2002; Zwane, 2007; Reyes-Garcia et al., 2010; Babigumeria et al., 2014). Labour is one of the main constraints in the expansion of shifting cultivation, and increasing labour availability can fuel deforestation (Conklin, 1961; Zwane, 2007; Babigumeria et al., 2014). Greater financial assets also increase forest clearing, but above a certain threshold, an increase would create no further impact as asset-richer households may have other means and opportunities for income generation (Babigumira et al., 2014). Household demographic factors can have varied effects on land use allocation (Perz, 2002). For instance, younger households are more likely to clear forests, and they clear larger areas (Perz, 2002; Babigumira et al., 2014). The dominant ethnic group, however, may clear smaller areas (Babigumira et al., 2014). Lastly, greater knowledge about the surrounding ecosystem decreases the extent of secondary forest clearing and does not influence the extent of old-growth forests being cleared (Reyes-Garcia et al., 2010). In addition, farmers with more ethnobotanical knowledge clear less old-growth forests per unit of labour as they might engage in more selective and less intensive clearing (Reyes-Garcia et al., 2010).

2.2 Determinants of Plot Selection in Shifting Cultivation

When farmers clear fields in tropical forests under shifting cultivation, the process of plot selection is complex and involves a balancing of biophysical and socio-economic considerations (Sillitoe, 1999). Biophysical factors considered by farmers when selecting a plot include vegetation cover, land availability, topography, proximity to home, the ease of access to the plot, the ease of enclosing the plot, and soil fertility (Sillitoe, 1999; Ducourtieux, 2015; Junqueira et al., 2016).

Variations in vegetation cover provide farmers with different options of forest types and economic opportunities. There exists a trade-off between clearing old-growth forests and clearing secondary forests: plots cleared from old-growth forests provide higher crop yields and have lower labour required for weeding than secondary forest fallows, but they require more work for clearing, accessing the field and harvesting the crops (Ducourtieux, 2015). The economic possibilities offered by vegetation cover of different types also influence farmers' decisions on clearing fields (Ducourtieux, 2015). For instance, maintaining useful species when clearing, can affect secondary successions and lead to the creation of novel ecosystems

(Ducourtieux, 2015). In the extreme, the value of products collected from a fallow can reach a level that dissuades farmers from clearing the field, which then becomes a permanent garden or orchard (Ducourtieux, 2015).

Land availability also plays a vital role in influencing farmers' activities as some farmers confront growing land scarcity by using more fallows (Coomes et al., 2016). In addition, farmers prefer clearing lands closer to their households: the number and area of gardens steadily decline with distance from households (Sillitoe, 1999; Ducourtieux, 2015; Junqueira et al., 2016). The ease of accessing and enclosing plots also affects farmers' selection of land to clear as farmers prefer plots with easier access as well as those with natural barriers (Sillitoe, 1999). Soil fertility is an important factor in farmers' decisions when selecting a plots as farmers value to clear fields on land with fertile soils (Sillitoe, 1999). More fertile soils offer greater opportunities for diversification and intensification of agricultural activities, and as a result, farmers prefer working on plots with higher fertility despite their tedious weeding requirements (Sillitoe, 1999).

In addition, farmers consider socio-economic factors, such as labour availability, household needs, land tenure, and distance to their relatives and friends (Sillitoe, 1999; Ducourtieux, 2015; Junqueira et al., 2016). Labour is one of the most important considerations that influence farmers' selection of plots (Junqueira et al., 2016). Households lacking labour will be less likely to establish new plots, as clearing fields and weeding are labour-intensive activities (Junqueira et al., 2016). The pursuit of education, reflected by out-migration of teenagers who abandon agricultural activities, affect farmers' decisions on selecting plots. Besides, in choosing their fields, farmers consider expected yields and the likelihood of stocks or shortages (Ducourtieux, 2015). They also seek to locate their swiddens near to relatives and friends (Sillitoe, 1999).

2.3 Conceptual Framework for Forest Clearing Decisions

A conceptual framework was built following insights from the two bodies of literature reviewed (Figure 1). Angelsen and Kaimowitz (1999) summarized the causes of tropical deforestation in a systematic way by dividing them into three major levels - underlying causes, immediate causes, and agents of deforestation. The determinants of plot selection in shifting cultivation include both biophysical and socio-economic factors, and farmers skillfully draw on their experiential knowledge in balancing various considerations. These findings together inform our analyses the factors driving old-growth forests clearing over secondary forests in shifting cultivation systems.

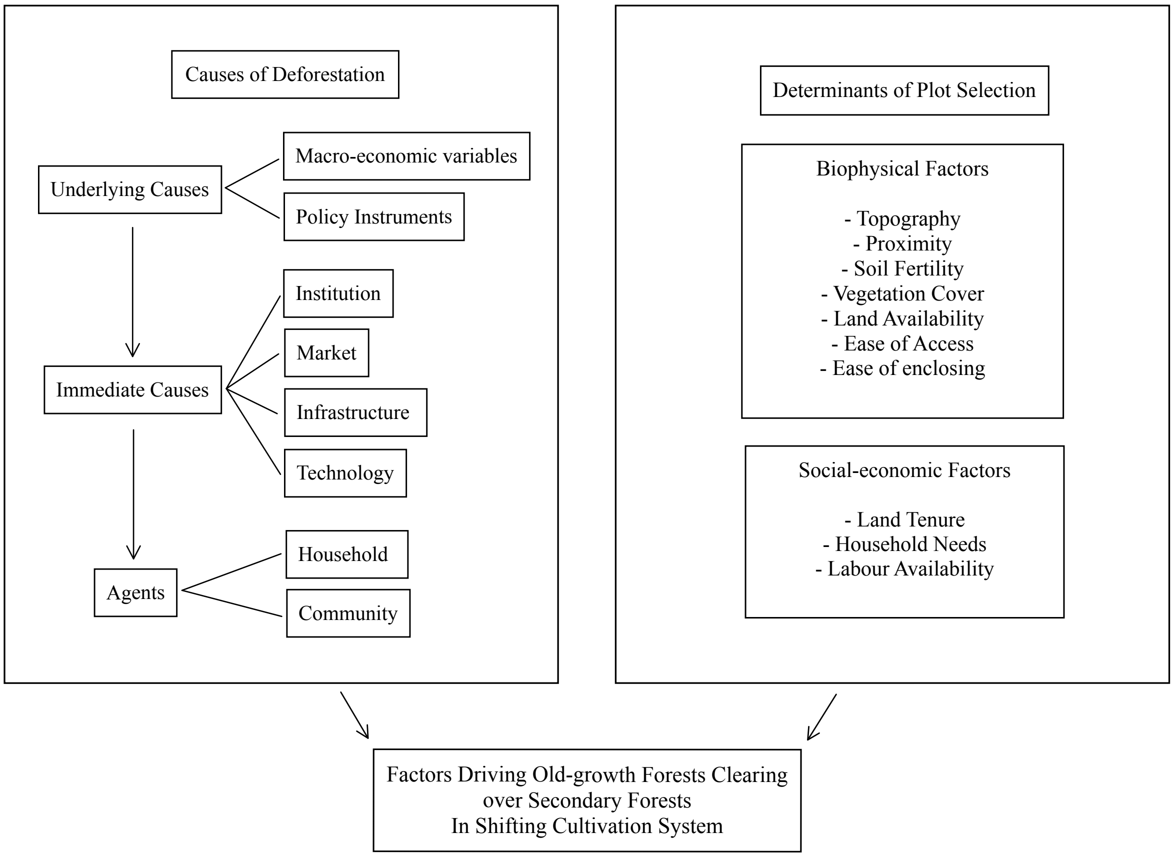

Figure 1. Factors reported in the literature that influence the forest clearing decision among land holders.

3. CHAPTER 3: CONTEXT

This chapter presents the specific context of our study. The first section introduces our study area in the Peruvian Amazonia, and the second section describes people's livelihood strategies in this region.

3.1 Study Area

The study area is located in the administrative regions of Loreto and Ucayali in Peru (Figure 2), covering an area about 85% of the Peruvian Amazon (Coomes et al., 2016). Most land in the study area lies at elevations below 200m and is highly dissected by rivers and extensive wetlands (Coomes et al., 2016). As a result, this study area is described as more 'riverscape' than landscape, with only 5% of land area being >30km from water (Toivonen et al., 2007, p. 1383). The river network is mainly comprised of four major rivers (i.e., the Amazon, Napo, Pastaza, and Ucayali) as well as many tributaries (Coomes et al., 2016). Our analysis focuses on the Amazon-Napo basin. The Napo River is a tributary to the Amazon River, originating from the east Andean volcanoes in Ecuador. It has a length of 1,075 km, draining an area of 100,518 km2, with a mean annual discharge of 6,976 m^3/second (Alain et al., 2009, p. 6).

The total estimated population of the Loreto and Ucayali regions is 1,534,900, with 71% of the population living in urban centres (INEI, 2015, p. 24). Many settlements are concentrated along with the rivers, situated either on the upland (i.e., bluffs overlooking the river) or in the lowland (i.e., floodplains) and are vulnerable to annual floods. The rubber boom, which occurred in the late 19th century, had a profound impact on settlement patterns, with communities being founded during and right after the boom, and new communities formed later in between those older ones (Barham and Coomes, 1997). Today, most native communities are found in areas remote from major cities and towns (Coomes et al., 2016).

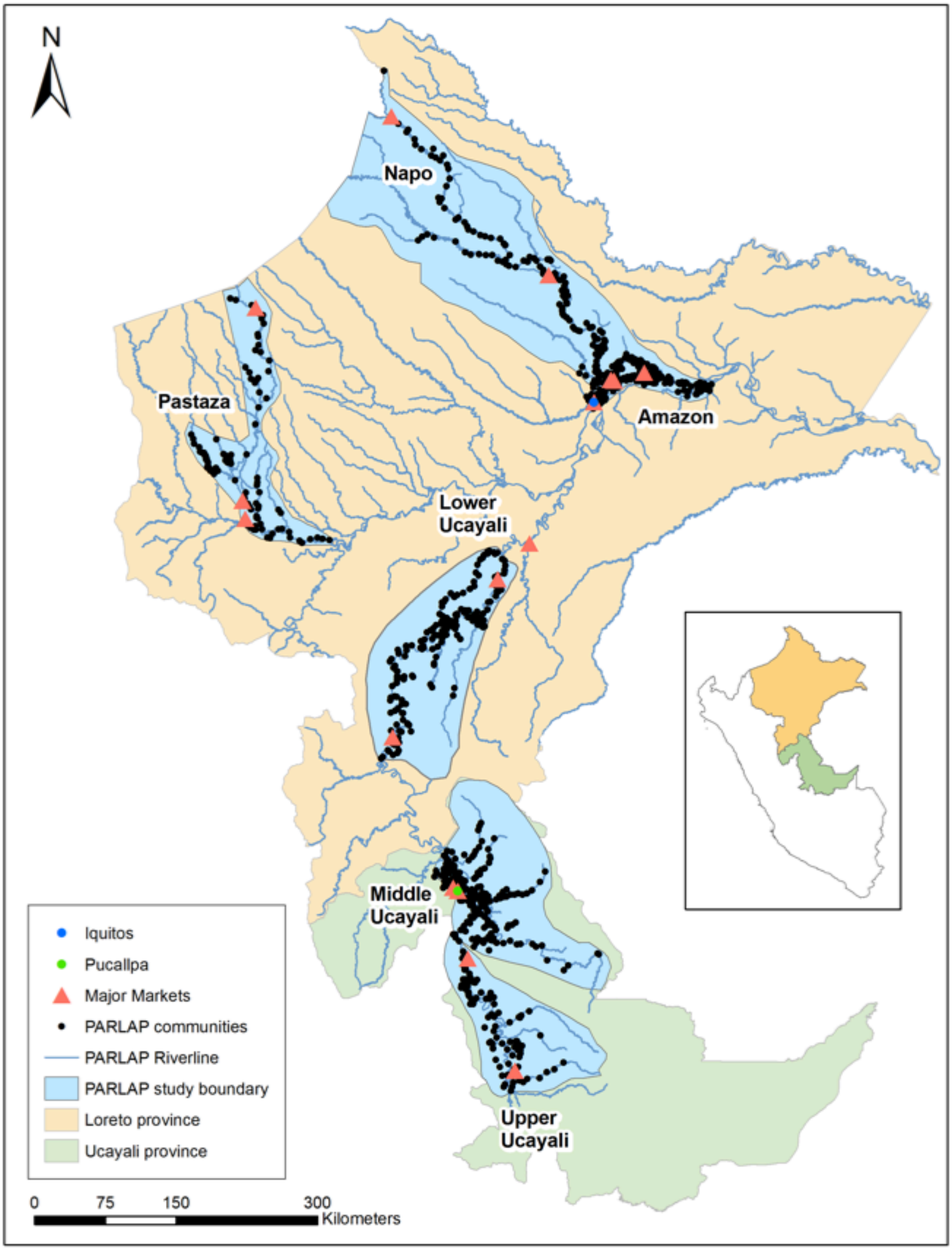

Figure 2. Map of the PARLAP study area in the administrative regions of Loreto and Ucayali, Peru. (source: PARLAP Project, accessed from https://parlap.geog.mcgill.ca/)

There are two major cities in the study area - Iquitos in the Loreto region and Pucallpa in Ucayali region - and they act as major markets as well as administrative centres for the Peruvian Amazon (Coomes et al., 2016). Smaller towns serve as secondary markets and often district capitals. Between the towns, small villages with only a few hundred inhabitants line the rivers. Roads are few in the study area, and most transportation is by riverboat (Coomes et al., 2016). Pucallpa has been connected with Lima by road since the 1940s, whereas Iquitos can be reached only by riverboat or air (Coomes et al., 2016). Most communities rely heavily on river transportation, by canoe, small boats, and river launches to convey their products to the market (Coomes et al., 2016).

3.2 Local Livelihood Strategies

Households living in tropical forests are typically active not only in agriculture, but also in fishing, hunting, and other forest-related activities (Takasaki et al., 2001). We describe the residents in our study area as "forest peasants". Forest peasants include both indigenous people and *ribereño*s: indigenous people are native Peruvians who have been living in the forest for thousands of years; *ribereño*s are "river people" who live along the rivers, and are mestizo descendants of Amerindian and Iberian peoples (Hiraoka, 1992; Chibnik, 1994). Unlike colonists on Amazonian frontiers, who claim land for commercial cropping and/or cattle ranching, forest peasants participate in a wide range of activities for their livelihood, including shifting cultivation, floodplain agriculture, fishing, hunting, and various extractive activities from the forests (Coomes et al., 2004).

Among these diverse activities, most forest peasant households focus on agriculture (Coomes et al., 2016). Land around their settlements is held by usufruct (i.e., without title), privately used, and transferred within the kin group network (Takasaki et al., 2001). Young households can, therefore, acquire lands by clearing new plots from old-growth forests or inheriting secondary forest fallows from their parents or relatives. Five types of agricultural land are employed by peasant farmers: upland, high levee, low levee, mudflat, and sandbar. Upland is never flooded; high levee is flooded in some years; and, low levee is flooded every year (Takasaki et al., 2001). Mudflats and sandbars appear when the water level is low, and their extent and edaphic conditions vary from year to year (Takasaki et al., 2001). Forest peasants practice shifting cultivation on upland as well as on the high and low levees, and they practice annual cropping on mudflats and sandbars (Takasaki et al., 2001).

Forest peasant households practice agricultural activities not only to gain sustenance but also to earn cash by selling surplus products in the market (Coomes et al., 2016). These households provide a high diversity of products from agriculture, as well as from livestock production, fishing, timber and non-timber forest products (NTFPs) extraction, and hunting (Coomes et al., 2016). High levels of niche market specialization are found in communities that are closer to major markets and cities (Coomes et al., 2016).

4. CHAPTER 4: METHODOLOGY

This chapter presents information on our data sources and introduces the variables selected for our analyses. The processes of model development are also explicated.

4.1 Data

The data used in this study derives from the Peruvian Amazon Rural Livelihoods and Poverty (PARLAP) Project database. The PARLAP project involves an international collaboration among researchers at McGill University, the University of Tokyo, and the University of Toronto. This project is a large-scale study of rural poverty among both folk and indigenous people in western Amazonia, mainly examining the nexuses between the environment, rural livelihoods, and poverty, as well as their implications for conservation and development.

The PARLAP database has three main components: a community census, a household survey, and a GIS analysis. The community census was conducted by two teams from 2013 to 2014, along four major rivers of the Peruvian Amazon (i.e., the Amazon, Napo, Pastaza, and Ucayali), covering an area of 117,680 km^2 and reaching 919 communities (Coomes et al., 2016). Among the 919 communities, 140 of them are located in the Amazon Basin, 177 in the Napo Basin, 115 in the Pastaza Basin, and 487 are in the Ucayali Basin. Then, from 2014 to 2016, the PARLAP teams returned to a stratified sample of 235 communities and conducted the household survey by interviewing nearly 4000 households (Coomes et al., 2016). The census and survey were designed to capture information, at both the community level and household level, on historical background and current characteristics, livelihood strategies and community economic orientation, as well as resource and land endowments of these settlements. In addition, information derived from remote sensing and GIS analyses on natural resource availability was used to complement the census and survey data.

4.2 Exploratory Analysis

The exploratory analysis in the present study is comprised of two parts: a descriptive analysis and an endogenous variables analysis. For the descriptive analysis, we calculated the percentages of households that cleared forest in different locations (i.e., upland and lowland) as well as the percentages of them that cleared different types of forests (i.e., old-growth forests and secondary forest fallows). In addition, the relationship between old-growth forest availability and the probability of old-growth forest clearance was examined by using a linear regression model.

A second analysis was conducted to better understand the land clearing decisions in which some variables are endogenously correlated with the dependent variable and thus cannot be included in a multivariate regression model. Endogenous variables are the factors that can influence and be influenced by the dependent variate. For instance, household current assets and forest clearance can mutually influence each other because assets are deployed to clear the fields, and at the same time, the forests being cleared and cultivated contribute to household current assets.

The endogenous variable analyses focused on both community-level variables and household-level variables. Community-level variables include community land availability, current terrestrial and aquatic endowments, forest protection, as well as collaboration with neighbouring communities on forest protection. Household-level variables include household current land holdings, incomes, assets, and labour availability. Each of these variables can be divided into multiple levels for comparing their correlation with the probability of clearing old-growth forests. Community land availability has four levels: no land available, little land available, some land available, and lots of lands available. Terrestrial and aquatic endowments are divided into five levels: very low, low, medium, high, and very high endowment. The community forest protection factors both have two levels: communities that protect forests or collaborate with neighbouring communities to protect forests; and, communities that do not protect forests or do not collaborate with neighbouring communities to protect forests. For household landholding, we distinguish they have land holdings on upland and lowland. Household income and assets are divided into multiple levels based on the distribution of data. Lastly, labour availability is analyzed by contrasting the amount of labour (persons*days) used in forest clearance between households that cleared old-growth forests and those that cleared fallows.

A series of t-tests and non-parametric comparison tests were conducted to assess whether these different parameters are related to land clearing decisions. A t-test with unequal variance was applied to assess how variables with two levels would be related to different likelihoods of clearing old-growth forests. For variables that have more than two levels, the Kruskal-Wallis non-comparative test was used.

4.3 Multivariate Regression Analysis

Multivariate regression analyses were conducted to obtain a more structured understanding of land clearing decisions. Two ordinary least squares (OLS) models were developed to answer the research questions. The first model is the basis of the "upland analysis" which examines why farmers clear fields on upland rather than on other types of lands (e.g., high levee, low levee, and mudflats). The second model - the "forest analysis" - explores why farmers clearing on the upland choose to clear old-growth forests over secondary forest fallows. This section presents the variables that are used in the regression models and explains the processes of model selection and sample selection.

4.3.1 Variable Selection

Initially, we used the same set of variables in both models, and then later we adjusted the variable selection based on their statistical significance as well as their correlations with each other. The initial set of variables includes community-level variables, household-level variables, and environmental factors. A framework was built to structure the regression analyses (see Figure 3). Table 1 presents the complete list of variables, and detailed descriptions of the construction of each variable can be found in Appendix A.

Community-level variables depict factors such as community history, accessibility to other places, and initial conditions at the time of community establishment. Community characteristics are described in terms of community size (number of households) and community age (in decades). Community history is captured by community relocation (i.e., the community moved or not) and community ethnicity (i.e., native or non-native). Factors that describe the accessibility of community include access to the main river channel and the distance to city. The distance to city is transformed into a natural log in terms of kilometres. Lastly, community initial conditions are described by terrestrial endowments, aquatic endowments, and the distance to the nearest community. The terrestrial and aquatic endowments are transformed into z-score. The distance in kilometres to the nearest community was transformed using the natural log, and is a proxy for availability of land for the community at establishment in the current location.

Household characteristics include household size (number of adults) and household age (in years), as well as numbers of generations that have lived in the community, for both the head of household and the spouse. Household initial conditions are captured by initial land holdings (hectares) and non-land assets (z-score). Household initial conditions are tested in the model to see if initial differences influence the future land clearing decisions.

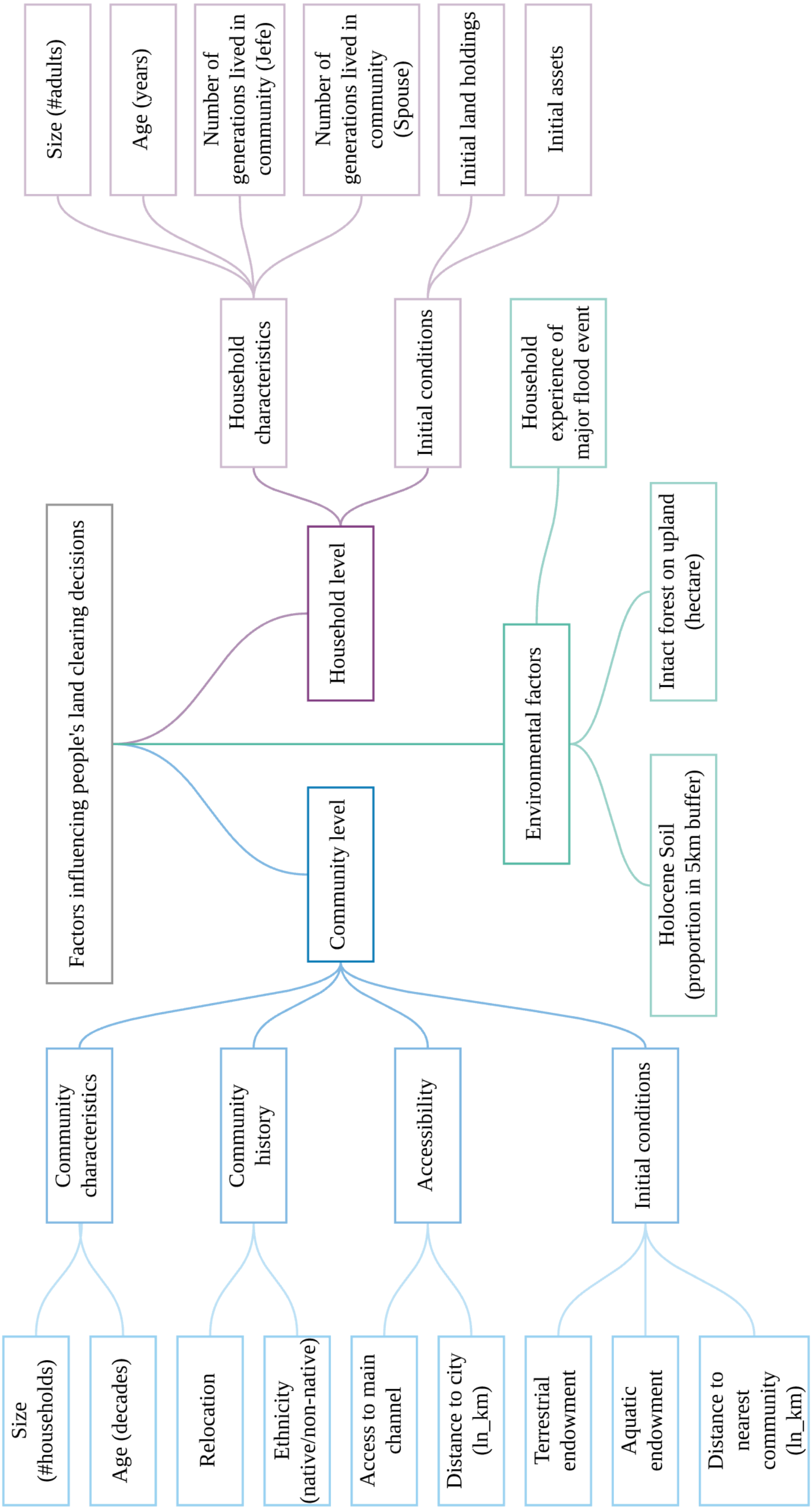

Figure 3. Conceptual Framework showing the variables that are used in the regression models.

Table 1. List of independent variables used in the regression models.

Variables	**Type**	**Unit**
Community size	Quantitative	number of households
Community age	Quantitative	decades
Community relocation	Qualitative	1 = moved; 0 = not moved
Community ethnicity	Qualitative	1 = native; 0 = non-native
Accessibility to main river channel	Qualitative	1 = have access; 0 = no access
Distance to city	Quantitative	log_km
Proportion of Holocene soils in 5km buffer	Quantitative	%
Area of intact upland forest in voronoi	Quantitative	hectares
Initial terrestrial endowment (z-score)	Quantitative	z-score
Initial aquatic endowment (z-score)	Quantitative	z-score
Initial distance to the nearest community (log_km)	Quantitative	log_km
Household size	Quantitative	number of adults
Household age	Quantitative	years
Number of generations lived in community : Jefe	Quantitative	#
Number of generations lived here in community : Spouse	Quantitative	#
Household experience of major flood event	Qualitative	1 = yes; 0 = no
Household initial land holdings	Quantitative	z-score
Household initial assets	Quantitative	z-score
Household fallow holding	Qualitative	1 = yes; 0 = no
Basin control: community location	Qualitative	1 = Napo; 0 = Amazon

Environmental factors include the proportion of young and fertile Holocene soils found in a 5km buffer (%), the area of intact forests available in the upland (hectare), and whether the household experienced the major flood of 2011/2012.

Lastly, we include two variables that control for household fallow holding and the basin in which the community is located. The fallow holding control variable signals if the household held fallows in their land portfolio before the clearing of their most recent field. The basin control variable distinguishes between communities that are located along the Amazon River or Napo River.

4.3.2 Model Selection

Ordinary least squared (OLS) regression models were built to examine factors that influence the decision to clear upland forests and to clear old-growth forests on the upland. For each regression model, the full list of variables was applied initially, and standard errors were clustered by community. The result was retained as the global model; then one or several variables were taken out from the list, and their results were recorded as individual nested models.

We applied two statistical methods to compare the models and to select the most suitable one: the F-test and the Akaike information criterion (AIC). F-tests were applied between the models based on a backward selection rule: one variable was taken out from the global variable list at each time, and the nested model was compared with the global model to detect the statistical significance of the variable that has been taken out. This process allows us to see if the variable has an efficient explanatory power on the dependent variable. In addition, the AIC was calculated for each model to test the relative quality of the model for a given set of data, assessing the risks of overfitting and underfitting (Akaike, 1974). Generally, a smaller value of AIC means that the model has a higher experimental quality in explaining the dependent variable than the others for a given set of data. The AIC values of various models were compared to select the most powerful one.

4.3.3 Sample Selection

Before running the OLS models, we set restrictions to select our sample from the PARLAP database, related to the study area, year of forest clearance, years of household and community founded, and the parcel size. Regarding the study region, we decided to focus on the Amazon-Napo river basin and excluded the Pastaza and Ucayali basins. We did this for two reasons: (1) we are not sure about the accuracy of the Holocene data in the Ucayali basin; (2) and we are uncertain about the availability of upland in the Pastaza and Ucayali basins. Since we will investigate which factors would affect the forest clearing decision between upland versus the other lands, we needed to be sure that upland is available in the communities; otherwise, people cannot make a choice between clearing upland and lowland. In addition, we restricted on the year when households cleared their last field. Since we are interested in more recent conditions, households that cleared their last fields before the year 2012 were excluded. Another reason for setting this restriction is that our model includes a variable to account for whether or not a household experienced the major flood event in 2011/2012. Since we want to know the impacts of experiencing flood event on forest clearing decisions, it is necessary to exclude households that cleared their fields before the flood. The sample was restricted, therefore, to households and communities founded only after 2011. Lastly, we set the size of the field that was cleared most recently to be less or equal to five hectares because larger fields are not likely to have been created by shifting cultivation.

5. CHAPTER 5: RESULTS

This chapter reports the results from our exploratory and multivariate regression analyses. The first part presents the findings of the exploratory analysis, including general observations from descriptive analyses of the dataset and the effects of endogenous variables on the decision between clearing old-growth forests and secondary forest fallows. The second part describes variables that influence the land clearing decisions on forest type and plot location.

5.1 Exploratory Analysis

5.1.1 Descriptive Analysis

About one-half of the households in the Amazon-Napo basin cleared their most recent field in the lowland: 51.3% of households (n = 965) cleared their last fields on high levee, low levee, and mudflat. Among those farmers that cleared their last field on the upland (48.7%) rather than in the lowland, 30.6% of them cleared old-growth forests and 69.4% cleared forest fallows (Table 2). The size of upland fields and the labour used in forest clearing, for farmers that cleared old-growth forests, are greater than those for farmers that cleared secondary forest fallows (Table 3). The descriptive statistics of all variables used in our multivariate regression analyses are presented in Table 4 and Table 5.

We found a positive relationship between the availability of intact upland forest in the community and the percentage of households in each community that cleared old-growth forests (Figure 4). Having old-growth forests available in the community is a necessary but not sufficient condition for predicting if farmers will clear intact forests. Though a greater proportion of available old-growth forests is related to a higher likelihood of clearing old-growth forests, some communities with limited old-growth forests available are still highly likely to clear old-growth forests.

Table 2. Characteristics of most recently cleared fields, Amazon-Napo basin.

Description	Proportion	No. Obs
Field Location		
Upland	48.7%	470
Lowland	51.3%	495
Type of Upland Field Cleared		
Old-growth Forests	30.6%	143
Secondary Forest Fallows	69.4%	325

Notes: Lowland includes high levee, low levee, and mudflat.

Table 3. Characteristics of upland fields, Amazon-Napo basin.

Description	Mean	Std. Dev.	No. Obs
Area of upland field (hectare)			
Old-growth Forests	0.8991	0.7885	143
Secondary Forest Fallows	0.6917	0.6306	325
Total	0.7550	0.6886	468
Labour to clear upland field (persons*days)			
Old-growth Forests	66.5280	108.7694	143
Secondary Forest Fallows	50.4431	126.8461	325
Total	55.3579	121.7187	468

Table 4. Descriptive statistics for variables in the upland multivariate regression analysis.

Description	Mean	Std. Dev.	Min	Max	No. Obs
Dependent variable					
Probability of clearing upland forests (%)	0.487	0.500	0.000	1.000	965
Independent variables					
Community size (number of households)	45.808	33.171	7.000	256.000	965
Community relocation (1 = moved; 0 = not moved)	0.270	0.444	0.000	1.000	965
Community ethnicity (1 = native; 0 = non-native)	0.505	0.500	0.000	1.000	965
Accessibility to main river channel (1 = yes; 0 = no)	0.679	0.467	0.000	1.000	965
Distance to city (log_km)	4.907	0.819	3.442	6.253	965
Proportion of Holocene soils in 5km buffer (%)	0.416	0.157	0.132	1.000	965
Initial terrestrial endowment (z-score)	0.440	0.790	-2.548	1.189	965
Initial aquatic endowment (z-score)	-0.302	1.061	-2.636	1.831	965
Initial distance to the nearest community (log_km)	2.071	1.236	-0.174	5.219	965
Household size (number of adults)	5.335	2.391	0.000	15.000	964
Household age (years)	19.321	12.819	0.000	65.000	947
Number of generations lived in community : Jefe	4.516	3.333	1.000	9.000	957
Number of generations lived here in community : Spouse	4.098	3.339	1.000	9.000	948
Household experience of major flood event (1 = yes; 0 = no)	0.634	0.482	0.000	1.000	965
Household initial land holdings (z-score)	1.310	3.190	0.000	58.000	965
Household initial assets (z-score)	-0.387	0.571	-0.629	5.004	965
Basin control: community location (1 = Napo; 0 = Amazon)	0.785	0.411	0.000	1.000	965

Table 5. Descriptive statistics for variables in the forest multivariate regression analysis.

Description	Mean	Std. Dev.	Min	Max	No. Obs
Dependent variables					
Probability of clearing old-growth forests on the upland (%)	0.306	0.461	0.000	1.000	468
Independent variables					
Community size (number of households)	50.216	33.313	7.000	256.000	468
Community age (decades)	6.370	6.099	1.000	47.000	468
Community relocation (1 = moved; 0 = not moved)	0.271	0.445	0.000	1.000	468
Community ethnicity (1 = native; 0 = non-native)	0.504	0.501	0.000	1.000	468
Accessibility to main river channel (1 = yes; 0 = no)	0.566	0.496	0.000	1.000	468
Distance to city (log_km)	4.722	0.771	3.442	6.253	468
Proportion of Holocene soils in 5km buffer (%)	0.380	0.126	0.132	0.755	468
Area of intact upland forest in voronoi (hectares)	1692.933	1418.747	0.000	4400.062	468
Initial terrestrial endowment (z-score)	0.388	0.665	-2.548	1.189	468
Initial aquatic endowment (z-score)	-0.666	1.186	-2.636	1.831	468
Initial distance to the nearest community (log_km)	2.016	1.271	-0.174	4.512	468
Household size (number of adults)	5.278	2.315	0.000	14.000	467
Household age (years)	19.133	12.338	0.000	60.000	457
Number of generations lived in community : Jefe	4.356	3.338	1.000	9.000	463
Number of generations lived here in community : Spouse	4.159	3.337	1.000	9.000	459
Household experience of major flood event (1 = yes; 0 = no)	0.605	0.489	0.000	1.000	468
Household initial land holdings (z-score)	1.329	2.911	0.000	35.000	468
Household initial assets (z-score)	-0.366	0.604	-0.629	5.004	468
Household fallow holding (1 = yes; 0 = no)	0.818	0.386	0.000	1.000	468
Basin control: community location (1 = Napo; 0 = Amazon)	0.701	0.458	0.000	1.000	468

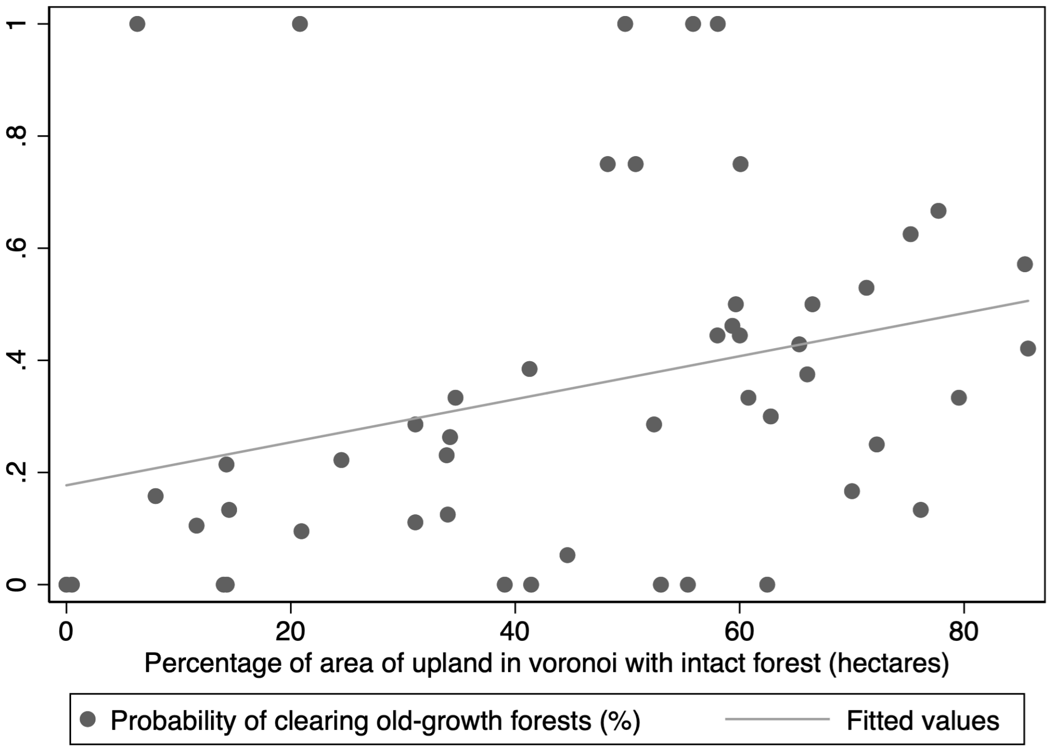

Figure 4. Relationship between old-growth forests endowment (%) and the probability of clearing old-growth forests (%) for communities in the Amazon-Napo basin.

5.1.2 Endogenous Variables Analysis

The influence of the community-level endogenous factors on old-growth forest clearing is summarized in Table 6. Community land availability plays an important role in shaping households' decisions on forest clearance. Households in communities with abundant land on the upland, low levees, and mudflats are most likely to clear old-growth forests. Community terrestrial endowment is also strongly related to the dependent variable: increasing terrestrial endowment is correlated with a higher probability of clearing old-growth forests. Further, regulations on forest protection affect the decision between clearing old-growth forests and secondary forests. Households in communities with forest protection regulations have a slightly higher probability of clearing old-growth forests, but the difference is not statistically significant. Households in communities that collaborate with neighbouring communities to protect forests, however, are significantly less likely to clear old-growth forests.

Certain household characteristics are also related to the likelihood of clearing old-growth forests (Table 7). Households with landholding on the upland are less likely to clear old-growth forests, but the difference is not statistically significant. Households with fields in the lowland, however, have a significantly higher probability of clearing upland old-growth forests. Further, household incomes and assets are not related statistically to the likelihood of clearing old-growth forests or secondary forests fallows. Households with higher income from the collection of non-timber forest products (NTFPs) are more likely to clear old-growth forests, though the statistical significance is weak ($p < 0.12$). Lastly, households that used more labour (persons*days) when clearing fields are significantly more likely to clear old-growth forests ($t = 2.0267$, $p < 0.0001$).

Table 6. Community-level endogenous variables with their effects on the probability of clearing old-growth forests.

Variable	Level	Probability of Clearing Old-growth Forests (95% Confidence Interval)	Test Statistics	p-value
Community upland availability	No land available	0.18 (0.12,0.25)	K-Wallis 13.734	0.033
	Little land	0.33 (0.21,0.47)		
	Some land	0.24 (0.09,0.39)		
	Lots of land	0.33 (0.30,0.36)		
Community high levee availability	No land available	0.28 (0.23,0.33)	K-Waliis 4.276	0.2886
	Little land	0.35 (0.29,0.41)		
	Some land	0.33 (0.23,0.44)		
	Lots of land	0.29 (0.24,0.34)		
Community low levee availability	No land available	0.24 (0.19,0.30)	K-Wallis 9.691	0.0214
	Little land	0.29 (0.23,0.35)		
	Some land	0.30 (0.21,0.38)		
	Lots of land	0.36 (0.31,0.40)		
Community mudflat availability	No land available	0.29 (0.26,0.32)	K-Wallis 16.834	0.0008
	Little land	0.36 (0.28,0.43)		
	Some land	0.23 (0.11,0.35)		
	Lots of land	0.60 (0.41,0.79)		
Community terrestrial endowment	Very low	0.26 (0.20,0.32)	K-Wallis 10.161	0.0378
	Low	0.31 (0.24,0.37)		
	Medium	0.36 (0.30,0.43)		
	High	0.25 (0.19, 0.31)		
	Very high	0.35 (0.29,0.42)		
Community aquatic endowment	Very low	0.25 (0.19,0.31)	K-Wallis 6.243	0.1817
	Low	0.31 (0.25,0.38)		
	Medium	0.31 (0.24,0.37)		
	High	0.36 (0.30,0.42)		
	Very high	0.30 (0.24,0.37)		
Community forest protection	Yes	0.32 (0.28,0.35)	t-test 0.953	0.3411
	No	0.28 (0.23,0.34)		
Forest protection: collaboration	Yes	0.26 (0.21,0.30)	t-test 3.5099	0.0005
	No	0.38 (0.33,0.43)		

Table 7. Household-level endogenous variables with their effects on the probability of clearing old-growth forests.

Variable	Level	Probability of Clearing Old-growth Forests (95% Confidence Interval)	Test Statistics	p-value
Household land holding on the upland	Yes	0.30 (0.27,0.33)	t-test 0.6282	0.5323
	No	0.35 (0.22,0.48)		
Household land holding on the lowland	Yes	0.38 (0.33,0.43)	t-test 3.7651	0.0002
	No	0.27 (0.23,0.30)		
Household total income	Very Low	0.28 (0.22,0.35)	K-Wallis 5.269	0.2607
	Low	0.35 (0.29,0.42)		
	Medium	0.27 (0.21,0.33)		
	High	0.34 (0.27,0.40)		
	Very High	0.29 (0.22,0.35)		
Household FNTP income	None	0.28 (0.24, 0.32)	K-Wallis 5.780	0.1228
	Low	0.32 (0.24,0.39)		
	Medium	0.32 (0.25,0.39)		
	High	0.37 (0.30,0.44)		
Household assets	Very Low	0.27 (0.23,0.33)	K-Wallis 2.112	0.7152
	Low	0.31(0.22,0.39)		
	Medium	0.31 (0.25,0.37)		
	High	0.32 (0.26,0.39)		
	Very High	0.33 (0.26, 0.39)		

5.2 Multivariate Regression Analysis

5.2.1 Upland Analysis

The first regression model seeks to identify the factors that influence farmers' decisions to clear fields on the upland (Table 8). The sample is comprised of all households that have cleared their most recent fields in the Amazon-Napo basin (n = 942). The model explains 23% of the variation in the dependent variable, and the global p-value indicates that this model is statistically efficient in predicting the land clearing decision regarding plot location.

Several community-level and environmental variables were found to be statistically significant in this model: the proportion of Holocene soils in a 5km buffer, community ethnicity, distance to city, initial aquatic endowment, and community size. With more young and fertile (Holocene) lowland soils available in surrounding area, households are significantly less likely to clear fields on the upland (-57.1%**). Native communities are more likely (+18.5%**) to clear fields on the upland compared to non-native communities. Increasing remoteness from city decreases the probability of clearing fields on the upland (-16.8%***), which means that if households are located in a community that is closer to city, they are more likely to work on the upland. Households in communities initially richer in aquatic endowments, but not terrestrial endowments, are less likely to clear fields on the upland (-11.0%***). Households in larger communities are somewhat more likely to clear upland forest although the relationship is statistically weak (p = 0.10). All household-level variables, however, had no statistically significant impacts on the decision regarding plot location.

Table 8. Results of OLS regression model in the upland analysis.

Variables	Coefficient (Std. Err)
Community size (number of households)	0.0018 (0.0011)
Community relocation (1 = moved; 0 = not moved)	-0.1225 (0.0935)
Community ethnicity (1 = native; 0 = non-native)	0.1846* (0.0962)
Accessibility to main river channel (1 = yes; 0 = no)	-0.1321 (0.0838)
Distance to city (log_km)	-0.1682** (0.0704)
Proportion of Holocene soils in 5km buffer (%)	-0.5712** (0.2630)
Initial terrestrial endowment (z-score)	0.0230 (0.0528)
Initial aquatic endowment (z-score)	-0.1097*** (0.0398)
Initial distance to the nearest community (log_km)	-0.0186 (0.0396)
Household size (number of adults)	0.0023 (0.0115)
Household age (years)	-0.0002 (0.0011)
Number of generations lived in community : Jefe	-0.0057 (0.0044)
Number of generations lived here in community : Spouse	0.0004 (0.0040)
Household experience of major flood event (1 = yes; 0 = no)	-0.0382 (0.0439)
Household initial land holdings (z-score)	0.0040 (0.0057)
Household initial assets (z-score)	0.0170 (0.0242)
Basin control: community location (1 = Napo; 0 = Amazon)	-0.0213 (0.0817)
Constant	1.5532 (0.3384)
F	7.52
P(F)	< 0.0001
Number of observations	942
Adjusted R-squared	0.2300

Note: *p ≤ 0.10, **p ≤ 0.05, ***p ≤ 0.01

Standard errors clustered by community.

5.2.2 Forest Analysis

The second regression model seeks to identify those factors that influence farmers' decisions to clear old-growth forests or secondary forest fallows on the upland. The sample comprises all households that worked on upland in the Amazon-Napo basin (n = 468). A series of models were built to assess variations in factor coefficients by modifying the variable selection (Appendix B). The most parsimonious model will be used to present the quantitative results, and the other models will be used for qualitative discussion. The simplest model explains 53.3% of the variance in the outcome of the dependent variable, i.e., whether the households cleared old-growth forests or secondary forests. The global p-value indicates that this model is statistically efficient in predicting the land clearing decision regarding forest type.

Five variables are shown to be statistically significant across the models: the proportion of Holocene soils in a 5km buffer, community initial aquatic endowments, initial distance to the nearest community, community age, and the area of intact forests on the upland. The proportion of Holocene soils in the surrounding region is related to the probability of clearing old-growth forests in a positive and statistically significant way (+51.2%***). In communities with higher initial aquatic endowments and with greater distance to the nearest community (i.e., more land available in early expansion period), households are less likely to clear old-growth forests (-5.3%*** and -4.9%***, respectively). Community age has a positive effect on the dependent variable, which means that households in older communities are more likely (+0.6%***) to clear old-growth forests. Besides, with greater old-growth forests available, households are more likely (+0.01%***) to clear old-growth forests.

The two control variables - household possession of secondary forest fallow and the basin location - both have a significant influence on the probability of clearing old-growth forests. Households with fallow holdings are significantly less likely to clear old-growth forests (-83.0%), and households in the Napo basin are more likely to clear old-growth forests than those in the Amazon basin (+13.6%). Household-level variables, however, have little effect on the land clearing decision regarding forest type.

When the OLS model was run without the fallow holding variable (i.e., the Partial Model), two household variables became statistically significant: household age and whether the household experienced a major flood shock (Table 9). Older households tend to clear less old-growth forest than young households. Overtime households build up a stock of secondary forest fallows that they can use in farming. Households that experienced a flood shock are more likely to have cleared their most recent field in old-growth forest, presumably to cultivate crops on the high ground of the upland.

Table 9. Results of OLS regression model in the forest analysis.

Variables	Global Model	Partial Model
Community size (number of households)	-0.0005 (0.0008)	-0.0023* (0.0012)
Community age (decades)	0.0084* (0.0049)	0.0299*** (0.0065)
Community relocation (1 = moved; 0 = not moved)	0.0249 (0.0421)	0.1456** (0.0606)
Community ethnicity (1 = native; 0 = non-native)	0.0304 (0.0472)	-0.0479 (0.0676)
Accessibility to main river channel (1 = yes; 0 = no)	-0.0512 (0.0334)	-0.0681 (0.0423)
Distance to city (log_km)	0.0125 (0.0412)	0.0879 (0.0547)
Proportion of Holocene soils in 5km buffer (%)	0.4270*** (0.1274)	0.2946 (0.3001)
Area of intact upland forest in voronoi (hectares)	0.0001** (0.0000)	0.0001 (0.0000)
Initial terrestrial endowment (z-score)	0.0001 (0.0293)	-0.0026 (0.0552)
Initial aquatic endowment (z-score)	-0.0529*** (0.0175)	-0.0514 (0.0326)
Initial distance to the nearest community (log_km)	-0.0393*** (0.0118)	-0.0448* (0.0267)
Household size (number of adults)	-0.0030 (0.0088)	-0.0099 (0.0140)
Household age (years)	0.0004 (0.0013)	-0.0032* (0.0017)
Number of generations lived in community : Jefe	0.0019 (0.0040)	-0.0021 (0.0055)
Number of generations lived here in community : Spouse	-0.0052 (0.0047)	-0.0068 (0.0064)
Household experience of major flood event (1 = yes; 0 = no)	0.0047 (0.0248)	0.0701* (0.0391)
Household initial land holdings (z-score)	0.0048 (0.0079)	-0.0037 (0.0087)
Household initial assets (z-score)	0.0082 (0.0362)	0.0197 (0.0383)
Household fallow holding (1 = yes; 0 = no)	-0.8294*** (0.0244)	NA
Basin control: community location (1 = Napo; 0 = Amazon)	0.1367*** (0.0399)	0.1693* (0.0929)
Constant	0.6137*** (0.1795)	-0.3372* (0.1840)
F	151.50	9.50
P(F)	< 0.0001	< 0.0001
Number of observations	455	455
Adjusted R-squared	0.5360	0.1158
AIC	278.4072	569.8370

Note: *p ≤ 0.10, **p ≤ 0.05, ***p ≤ 0.01
Standard errors clustered by community.

6. CHAPTER 6: DISCUSSION

This chapter discusses the implications of the findings from our statistical analyses. The first section reviews results from the multivariate regression model in the upland analysis, explaining why farmers cleared fields on the upland rather than in the lowland. The second part describes findings of both the endogenous variables analysis and the multivariate regression modelling, analyzing why farmers chose to clear old-growth forests instead of secondary forest fallows. The third section provides suggestions for future improvements. In the last section, we offer advice for policymakers to design better policies and regulations to preserve old-growth forests.

6.1 Land Clearing Decisions: Upland or Lowland?

Four variables had statistically significant impacts on the forest clearing decision between upland and lowland (Table 8). Three of them are community-level variables, describing the community background, initial conditions, and the current accessibility to major cities, respectively. The other variable is a biophysical factor, and it describes soil fertility as well as community's relative location to the river.

Among the three community-level factors, community ethnicity plays an important role in affecting the likelihood of clearing forests on the upland. Native communities are about 20% more likely than non-native communities to work on the upland, and this difference may be attributed to their history. Since the 18th century, native people have withdrawn from the rivers and lowlands to the uplands in order to escape disease, slave trader, and persecution. Their cultural preferences may also account for this difference as native communities are more accustomed to working and living in forests on the upland, and most practice sustenance-oriented shifting cultivation. In non-native communities, however, residents prefer performing market-oriented and more intensive agriculture.

The distance to major cities is inversely related to the probability of working on the upland, which means that with increasing remoteness, households are less likely to clear upland forests. Usually, communities are first established along the river, and many households work in the nearby lowlands. As communities develop, more land needs to be cleared and cultivated to support the increasing population. Consequently, households move to work deeper into the forests on the upland. Communities closer to major cities are better developed and are more populated, so their expansion on the upland is greater than communities that are further away from the city. For this reason, households in communities that are closer to cities are more likely to clear upland forests.

The initial endowment of aquatic resources is also negatively associated with the likelihood of working on the upland. Communities that had higher aquatic endowments in their early stages of development are less likely to work today on the upland. The initial resource endowments around a community are likely to have shaped people's early livelihood choices. Households in communities with higher aquatic endowments devote greater time and labour in using floodplain resources, such as in fishing. Further, aquatic endowments also reflect the communities' relative location within the river network. Communities with greater aquatic endowments are closer to rivers, mainly located in the lowland, and households there prefer working nearby in the lowlands due to the close proximity. Also, these households have better river travel access, which allows people to move more efficiently to cities and thus increase their degree of market integration. Increasing integration to market may push households to work their surrounding lands more intensively (i.e., clearing fields on lowland) instead of working more extensively on the upland.

Lastly, the percentage of Holocene soils nearby a community is also negatively associated with the likelihood of clearing fields on the upland: if the area of Holocene soils increases by ten percent in surrounding areas, then households are 5.7% less likely to work on the upland. The proportion of Holocene soils is an indicator of soil fertility. In western Amazonia, young soils (i.e., Holocene soils) are more fertile than soils formed in previous geological epochs, such as the Oligocene or Pliocene. As a result, households are less likely to work on the upland when there are more fertile soils in their surrounding environs. Again, the proportion of Holocene soils may also reflect the relative location of a community within the river network (i.e., closer to lowland or upland) because Holocene soils are common in the lowlands. As a result, households in communities that have a greater proportion of Holocene soils (i.e., closer to lowland) are more likely to work on the lowland.

6.2 Forest Clearing Decisions: Upland Old-Growth or Secondary Forest Fallows?

Insights from both the endogenous variables analysis and the multivariate regression model in the forest analysis help us to understand the decision-making process regarding the choice to clear old-growth forests or secondary forest fallows. In this section, we contrast the expected and observed impacts of each variable analyzed on the forest clearing decision, and discuss the implications.

6.2.1 Insights from the Endogenous Variable Analysis

Community-level factors, including land availability on both upland and lowland as well as the forest protection regulation, influence the probability of clearing old-growth forests. With greater forest land availability, we found more clearance of old-growth forests, and this observed impact is consistent with expectations. In addition, forest protection regulation plays an interesting role in predicting forest clearance: forest protection by individual communities does not have significant impact on reducing old-growth forest clearing; however, forest protection in collaboration with other communities has statistically significant impact on decreasing deforestation. It is possible that, when communities are not collaborating, they prefer expanding into their intact forests to claim their rights over these lands. Also, community collaboration may reflect a generalized perception of land and forest scarcity which promotes conservation and dampens clearing of old-growth forests.

Household-level factors including land holdings (either on the upland or in the lowland), incomes and assets, as well as labour availability can also influence the probability of clearing old-growth forests. We found that households with land holdings in the lowland are more likely to clear old-growth forests on the upland, whereas household landholding on the upland has no significant impact on the dependent variable. Households that work in the lowland (i.e., having landholdings there) may choose to clear a new plot on the upland as a security to prepare for major floods that may destroy their fields in the lowland. And in this case, households are more likely to clear old-growth forests as they may not have fallow holdings on the upland.

Household income and assets were found to be not related to forest clearing decision between old-growth forests and secondary forests fallows. Findings from previous studies on the relationship between income and deforestation show mixed effects: some studies find that the link between income and deforestation resembles an inverted U, whereas some others find a weak link between these two variables (Godoy et al., 1996). One reason for the inverted U-shape relationship between total household income and deforestation may have to do with the different roles that farm and non-farm income play as households become part of market economies (Godoy et al., 1996). At high levels of income, households appear to be relying more on income from off-farm labour, whereas poorer households rely more on income from the forest and the farm. As such, farm and off-farm income offset each other, causing the relationship between total income and deforestation to resemble an inverted U. The observed influence of income in our study, however, only displays a less pronounced inverted U shape: households with low income and with high income have a lower probability of clearing old-growth forests, whereas households with middle income are more likely to clear old-growth forests. This trend was not statistically significant but might be more pronounced after controlling for other factors.

Finally, greater household labour availability is related to the clearance of old-growth forests. Plots created by clearing old-growth forests are more fertile than those created by clearing secondary forest fallows, so farmers prefer clearing old-growth forests when there are enough labour to do so. Clearing old-growth forests, however, is a more difficult task than clearing secondary forest fallows because trees are much bigger, and thus requires more labour. Consequently, the probability of farmers clearing old-growth forests is higher when households have more labour available.

6.2.2 Insights from the Multivariate Regression Analysis

The multivariate regression models also provide insights into the factors that drive farmers to clear old-growth forests. Community age was expected to have a negative impact on the probability of clearing old-growth forests because this variable would proxy for the availability of secondary forests as well as for the security of land tenure. For communities that have been established for a longer time, more surrounding intact forests would have already been cleared and transformed into secondary forest fallows, so households would have more fallows to work. Older communities should also have land rights more firmly established. Further, households in older communities can pass their cumulated fallow holdings to the next generation as a heritage, so the probability for later generations to clear intact forests would decrease. Therefore, community age was expected to lower old-growth forest clearance. The results of our analysis, however, do not confirm expectations: households in older communities are more likely, not less so, to clear old-growth forests. One potential explanation is that older communities might have less land available, and households prefer to claim and clear the remaining remnants before all of the intact forest land is claimed.

The proportion of Holocene soils in surrounding areas is positively associated with the likelihood of clearing old-growth forests. Communities that have a greater proportion of Holocene soils nearby possess more lowland than upland. Since households in these communities have more landholdings in the lowland, they work less frequently on the upland; therefore they only clear old-growth forests on the upland as a safety net.

Community initial aquatic endowments are strongly associated with the current probability of clearing old-growth forests. Rich aquatic endowments reflect the relative location of a community within the river network as communities with greater aquatic endowments are usually closer to rivers. A rich endowment of aquatic resources in their early stage of community settlement would have shaped the household livelihood strategies as well as their preferences. For instance, these households may devote more time and labour into fishing rather than into agricultural activities. As a result, there is no need for them to expand deep into the intact forests for clearing new fields.

The initial distance to the nearest community is also related to the recent likelihood of clearing old-growth forests in a negative and statistically significant way. This factor reflects the land availability in the early period when communities were first established in their current location. With greater distance to other settlements, communities are able to claim greater areas of forest land. Since these communities have already acquired considerable land early on, there would be more fallows available for the current generation, thus decreasing the need to clear old-growth forests.

Household fallow holding is an important predictor of the probability of farmers clearing old-growth forests. A household with extant fallow holding would be much less likely to clear old-growth forests (-83%***) than a household without fallows. When fallow holding is excluded from the model (i.e., the Partial Model in Table 9), then community size, relocation, as well as two household features (i.e., household age and whether they experienced a major flood in 2011/2012) become influential.

According to previous studies, community size has an ambiguous effect on forest clearing - some researchers found a positive link between population growth or population size and deforestation, whereas others find only a weak or lagged effect (Godoy et al., 1996). The results of our analysis, however, showed a negative relationship between old-growth forest clearance and the community size. One possible reason is that households in more densely populated communities have restricted access to old-growth forests since they are reaching full enclosure; consequently, they are more likely to clear fallows due to the lack of available intact forest.

Communities that have moved location between their foundation and today are more likely to clear old-growth forests, and the observed effect is in accordance with the our expectation. When a community moves to a new place, households need to clear forests and accumulate land, and this process requires them to expand into old-growth forests since they do not have any fallow holdings in their new location. As a result, community relocation fuels the clearance of old-growth forests.

Household age is related to the old-growth forest clearance in a negative and statistically significant way. Unlike older households, younger households typically do not have fallows in their landholdings, and thus cannot choose to clear secondary forest fallows. Consequently, they are more likely to clear old-growth forests for establishing new plots, and, over time, build up their holdings of secondary forest fallows that they can use later in the household life cycle for cropping.

The experience of a major flood event is related to old-growth forests clearance. Households that experienced the major flood in 2011/2012 are more likely to have cleared old-growth forests. One potential explanation is that if households lost their lands or crops due to the flood and they do not have other fallows available, they need to establish new fields by clearing old-growth forests. Also, for households that live in the lowland, they may want to establish new plots on the upland for security in the event of future major flood.

6.3 Improvements

In this study, we developed two multivariate regression models to analyze the empirical relationship between farmers' forest clearing decisions and their background, demographic and socio-economic characteristics, as well as their surrounding environments. Although such farm-level regression models are the most appropriate modelling tool for analyzing these relationships (Angelsen and Kaimowitz, 1999), some improvements can be made to better understand the decision-making process of forest clearance, such as incorporating other variables, tracking household land portfolios overtime, and applying qualitative methods.

This study focuses on the community-level and household-level factors, whereas factors from other levels could be analyzed in future studies. According to our conceptual framework (Figure 1), other variables that could affect the decision on forest clearance include land tenure, market integration, protected area, and technology change. In addition, more biophysical factors could be added in the regression model, such as elevation and slope, as they may also be useful predictors of forest clearance.

Our study examines a one-time forest clearing decision made by households, i.e., the clearing of their most recent field. By employing a large sample we are able to infer relationship by studying the heterogeneity in conditions and outcomes. For future studies, we suggest tracking household land portfolios over time to better understand how households build up their land portfolios from old-growth forests and secondary forest fallows. Such research would be both expensive and time-consuming.

Lastly, a combination of both quantitative and qualitative analyses may provide deeper insight into the forest clearing process. In this study, we mainly used quantitative methods (i.e., statistical analyses) to analyze our survey data. Some qualitative methods, such as the in-depth interview with local people and oral history, could be used in future studies to provide useful insights that are not available from our quantitative approach.

6.4 Suggestions for Conservation Policies

Most factors that influence the choice of field location and forest type to be cleared are community characteristics that cannot be affected directly by policy instruments, such as environmental conditions and location with respect to the city, so there is limited scope for policy actions. Nonetheless, certain things can be done. First, the government and NGOs could promote the creation of community forests reserves by the community, and for the community, as this would reduce pressure on old-growth forests and increase the importance of older secondary forest fallows. Also, farmers could enhance soil fertility recovery in secondary forest fallows to enable their use over a shorter duration. To reach this goal, government can encourage farmers to plant leguminous trees and/or use biochar (List et al., 2019). Further, younger households just starting out could be assisted in accessing secondary forest fallows, rather than having to cut old-growth forests. For example, communities could agree to assign one secondary forest fallow to each young households. Lastly, government could provide support for lowland communities and household in upland communities with extensive lowland holdings when a major flood strikes. These households consider the upland old-growth forest as their safety net when floods occur; however, if subsidies or index-based food insurance are given to these households, their likelihood to clear upland old-growth forests will decrease (List et al., 2019).

Nonetheless, no matter what specific measures will be made to preserve old-growth forests, it is necessary for policymakers to consider the welfare of local people. The policy-making process is often a political endeavour, producing winners and losers, and unfortunately, this process often imposes adverse effects on local households' livelihoods and welfares. As Neumann (1992) argued, the establishment of national parks is, in essence, a process of reallocation which involves the introduction of new social structures for controlling and accessing natural resources, and this often disadvantages indigenous people. We hope that, by understanding the deforestation process better, conservation goals can be achieved without imposing negative impacts on local communities.

7. CHAPTER 7: CONCLUSION

Shifting cultivation system creates disturbances in tropical landscapes by converting parcels of forests, either old-growth forests or secondary forest fallows, into agricultural land for a temporary period of time. Forest clearing can induce adverse impacts on not only the ecosystem but also human livelihoods by decreasing biodiversity and aggravating climate change. Since preserving old-growth forests is given high conservation priority, we sought to identify the factors that drive farmers to clear old-growth forests over secondary forests fallows in shifting cultivation systems.

Guided by insights from a literature review, we constructed a conceptual framework that summarizes deforestation drivers and identifies the factors considered in plot selection by farmers under shifting cultivation. Then, we described our study area as a riverine landscape and introduced local people as well as their livelihood strategies in the Amazon-Napo basin. By using the survey data collected from the PARLAP project, we conducted exploratory and multivariate regression analyses to examine the factors that influence forest clearing decisions on plot location and forest type. Variables in multiple categories were examined, and community-level factors (e.g., community age, initial aquatic endowment, and land availability) as well as biophysical factors (e.g., percentage of Holocene soils nearby, old-growth forests availability) were found to be statistically significant predictors of clearing old-growth forests on the upland. Household-level variables, however, are found to be less influential than community-level and biophysical factors.

In the end, our study provides insights that may guide the design of policies on tropical forest preservation, including creation of community forests reserves, enhancement of soil fertility recovery in secondary forest fallows, and provision of index-based food insurance in the event of major floods.

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APPENDIX

Appendix A. Construction of independent variables.

1. **Community size.** The number of households present in the community.
2. **Community age.** The number of decades since the community was established in the current location, based on the year of establishment as reported by community authorities. We use decades because the year of establishment is missing in some communities.
3. **Migratory movement.** (1) Community has moved to another location since its founding; (0) Community has not moved to another location since its founding.
4. **Ethnicity.** Community authorities self-identified as a ribereños community (0); indigenous community (1). We excluded colonist communities from the analysis sample.
5. **Accessibility to main channel.** (1) Community has access to the main river channel; (0) Community does not have access to the main river channel.
6. **Distance to city.** River network distance calculated by using PARLAP data and the methodology described in Webster et al. (2016).
7. **Holocene soils.** The share of land (%) in a 5km buffer centred on the community that is underlain by Holocene parent material. Based on La Carta Geológica Nacional del Peru (1:100,000) published by INGEMMET (Instituto Geológico Minero y Metalúrgico, Lima); available online at https://www.ingemmet.gob.pe/carta-geologica-nacional.
8. **Intact forests on the upland.** The area (hectares) of intact forests available on the upland in a voronoi.
9. **Initial terrestrial endowment.** Measured by the availability of land, forest products, game, and other forest extractive opportunities around the community (Coomes et al., 2004).
10. **Initial aquatic endowment.** Measured by the availability of aquatic resources, access to fisheries, and fish stock around the community (Coomes et al., 2004).
11. **Initial land endowment.** Proxied by Euclidean distance (log) to the nearest neighbour settlement at the time of community establishment. With the settlement date for all communities, the sequencing of settlement was reconstructed and the nearest historical neighbour determined. Does not consider settlements that existed at the time of establishment but were abandoned.

12. **Household size.** Number of adults present in each household.
13. **Household age.** The number of years since the household was established.
14. **Number of generations lived here: household head.** The number of generations that have lived in current community, for household head.
15. **Number of generations lived here: spouse.** The number of generations that have lived in current community, for spouse.
16. **Household experience of major flood.** (1) Household experienced the major flood in either 2011/2012; (1) Household did not experience the major flood in either 2011/2012.
17. **Household initial land holdings.** The total area of land holding in hectare when the household was first established.
18. **Household initial assets.** Household assets comprise all the physical assets (i.e., land, equipment, and tools) as well as nonphysical assets (i.e., human, financial, and social capital) that provide the basis for participation in specific resource use activities (Coomes et al., 2004).
19. **Household fallow holding.** (1) Household has secondary forest fallows in their land portfolio before their most recent clearance; (2) Household does not have secondary forest fallows in their land portfolio before their most recent clearance.
20. **Basin control.** (1) Community located in the Napo Basin; (2) Community located in the Amazon Basin.

Appendix B. Results of OLS regression model in the forest analysis.

Variables	Simplest Model	Model I	Model II	Model III
Community size (number of households)	NA	NA	-0.0004 (0.0008)	NA
Community age (decades)	0.0057*** (0.0019)	0.0061*** (0.0020)	0.0079* (0.0047)	0.0154*** (0.0025)
Community relocation (1 = moved; 0 = not moved)	NA	0.0192 (0.0411)	NA	0.1785*** (0.0491)
Community ethnicity (1 = indigenous; 0 = ribereño)	NA	0.0351 (0.0479)	0.0345 (0.0458)	0.0141 (0.0627)
Accessibility to main river channel (1 = yes; 0 = no)	NA	-0.0465 (0.0321)	-0.0433 (0.0276)	-0.0791* (0.0427)
Distance to city (log_km)	NA	0.0089 (0.0449)	0.0010 (0.0431)	0.1261*** (0.0409)
Proportion of Holocene soils in 5km buffer (%)	0.5124*** (0.1195)	0.4317*** (0.1235)	0.4501*** (0.1329)	NA
Area of intact upland forest in voronoi (hectares)	0.0001*** (0.0000)	0.0001** (0.0000)	0.0001** (0.0000)	NA
Initial terrestrial endowment (z-score)	NA	-0.0017 (0.0288)	0.0033 (0.0308)	-0.0268 (0.0470)
Initial aquatic endowment (z-score)	-0.0526*** (0.0140)	-0.0520*** (0.0176)	-0.0547*** (0.0157)	-0.0346 (0.0335)
Initial distance to the nearest community (log_km)	-0.0487*** (0.0142)	-0.0389*** (0.0114)	-0.0431*** (0.0135)	NA
Household size (number of adults)	NA	-0.0031 (0.0088)	-0.0034 (0.0088)	-0.0072 (0.0135)
Household age (years)	NA	0.0004 (0.0013)	0.0004 (0.0013)	-0.0036** (0.0017)
Number of generations lived in community : Jefe	NA	0.0019 (0.0040)	0.0019 (0.0041)	NA
Number of generations lived here in community : Spouse	NA	-0.0054 (0.0047)	-0.0052 (0.0047)	NA
Household experience of major flood event (1 = yes; 0 = no)	NA	0.0024 (0.0253)	0.0040 (0.0248)	0.0562 (0.0383)
Household initial land holdings (z-score)	NA	0.0045 (0.0080)	0.0049 (0.0079)	-0.0028 (0.0087)
Household initial assets (z-score)	NA	0.0074 (0.0363)	0.0083 (0.0361)	0.0120 (0.0381)
Household fallow holding (1 = yes; 0 = no)	-0.8293*** (0.0265)	-0.8322*** (0.0246)	-0.8324*** (0.0245)	NA
Basin control: community location (1 = Napo; 0 = Amazon)	0.1360*** (0.0301)	0.1346*** (0.0412)	0.1434*** (0.0383)	0.1052 (0.0959)
Constant	0.6004*** (0.0667)	0.6215*** (0.1912)	0.6517*** (0.1836)	-0.4245** (0.1861)
F	269.98	152.54	166.91	9.23
P(F)	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Number of observations	468	455	455	456
Adjusted R-squared	0.5333	0.5357	0.5357	0.0963
AIC	261.9634	276.7721	276.7128	568.3394

Note: *p ≤ 0.10, **p ≤ 0.05, ***p ≤ 0.01
Standard errors clustered by community.