Laboratoire d'Economie Forestière

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Jonas NGOUHOUO POUFOUN
Philippe DELACOTE

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LEF – AgroParisTech/INRA – 14, rue Girardet – CS 4216 – F-54042 Nancy cedex
☎ 00 33 (0)3 83 39 68 66– 🖷 00 33 (0)3 83 37 06 45 – 💻 lef@nancy-engref.inra.fr
http://www.nancy.inra.fr/lef

What drives livelihoods' strategies in rural areas? Evidence from the Tridom Conservation Landscape using Spatial Probit Analysis

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Abstract

Very few scientific studies have focused on the determinants of households' livelihoods' strategies in the Congo Basin. The aim of this paper is to understand which factors drive the choice of portfolio activities in rural regions. More precisely, the role of human, financial, natural and location assets in the portfolio choice is investigated. A unique dataset is used from our recent survey with 1035 random and stratified households in 108 villages of the Tridom landscape to investigate household preferences between (1) specialization and diversification strategies, (2) land-conversion and non-land-conversion activities, and (3) between strategies relying on forest vs other strategies. Our results show significant similarities on the likelihood of households living in the same neighborhood to prefer a given livelihoods strategy. Beside socioeconomic characteristics, the existence of human-wildlife conflict, as well as the indigenousness, directly leads household's heads to make the choice of diversified strategies, or to choose activities related to land-conversion. These choices lead to some significant spillover effects on the likelihood of neighboring household's heads to adopt the same strategies.

Keywords: Forest-based livelihoods, Agriculture and cash crop, Diversification strategies, Deforestation, Spatial Spillover Effects, Spatial Autoregressive Probit.

JEL codes: C11; C 21; C25 ; D12; Q12 ; Q23

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[1] UMR INRA – AgroParisTech, Laboratoire d'Économie Forestière, 54042 Nancy Cedex, France. Corresponding author: email – jngouhouopo@inra.fr
[2] Center for International Forestry Research (CIFOR) - Central Africa Regional Office, PO Box: 2008, Yaounde, Cameroon
[3] BETA, University of Lorraine, 13 Place Carnot – CO n°70026. 54035 NANCY Cedex - France
[4] UMR INRA – AgroParisTech, Laboratoire d'Économie Forestière, 54042 Nancy Cedex, France

1. Introduction

Most rural households in the Congo Basin rely primarily on small-scale agricultural activities, harvesting and direct use of forest ecosystem goods and services for their livelihoods[1] including food security, fuelwood, water supply and primary healthcare (Megevand, 2013; Sonwa et al., 2009; Verchot, 2014). In the Tri-National Dja-Odzala Minkébé trinational conservation landscape (Tridom-TCL), approximately 78% of indigenous and local communities declare slash and burn small-scale farming (40.9%), cocoa and rubber or cash crop (19.6%), game hunting for bushmeat and NTFP gathering of or (14.8%) as well as traditional gold mining (3%) as predominant subsistence activities with a full time employment. A more detailed look of household heads' behavior in this landscape shows that an important share of household heads develop survival strategies based on activities portfolios, mixing two or three of above activities. Factors governing the decision to adopt a particular land-use or livelihood's strategy and the extent of their effects are complex and vary considerably from one place to another (Angelsen and Kaimowitz, 1999; Babigumira et al., 2014; VanWey et al., 2005). These individual decisions will have significant impact on the household's wellbeing, on the environment, and on the economic value of the landscape (Brown, 2004) and should therefore be taken into account by policy makers (Carrión-Flores et al., 2009). In these conditions, there is a crucial need to investigate the factors that drive households' livelihoods portfolio in rural areas. Therefore, this paper seeks to investigate how do local and indigenous households formulate their preferences among livelihoods strategies? We state that this decision depends on several strategical trade-offs: (1) specialization vs diversification, (2) land-converting activities vs non-land-converting activities, (3) forest-based activities vs non-forest-based activities. Our contribution is multiple: (1) As a pioneering study on the households' survival strategies in a transboundary conservation landscape, this paper tests the reliance on the ability to pursue livelihoods' strategies on natural, economic, human, physical and social assets in order to shed light on the validity of the traditional Sustainable Livelihoods Framework (SLF) in the Tridom-TCL. (2) Our research accounts for both types of location assets (environmental state and infrastructure) introduced by Jansen et al. (2006) and Soltani et al. (2012). Indeed, we consider the distance to the nearest protected area as an indicator of environmental state, and

[1] A livelihood comprises the capabilities and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stress and shocks, maintain or enhance households' capabilities and assets, and provide sustainable livelihood opportunities for the next generation (Chambers and Conway, 1992). However, in this paper, the term livelihood is restricted to subsistence goods and services from small-scale farming and from forest-based activities.

distance to the market as infrastructural asset. (3) Except for the Poverty and Environment Network (PEN)[2] and the Peruvian Amazon Rural Livelihoods and Poverty (PARLAP) initiatives, studies of forest peasant economies have been based on small and non representative samples of households due to practical, historical and financial reasons. As a result, very few generalizations can be made about spatial or social variations (Coomes et al., 2016). Our study uses a unique dataset collected in the field with 1035 geocoded households in 108 villages from the Tridom-TCL. The survey covered all the 26 administrative subdivisions of the Cameroonian and Gabonese segments of the landscape. Our study helps to address the lack of data at the landscape and the household levels. (4) Our survey with representative samples and subsamples in all the subdivisions allows us to account for shift effects as well as spatial spillover effects in a household neighborhood resulting from geographical proximity and related social interactions. To the best of our knowledge, no existing peer reviewed study has attempted to account for the effect of endogenous and exogenous interactions on households' livelihoods strategies, yet geographical determinants including household location were explicitly investigated by Jansen et al. (2006); Soltani et al. (2012) and Wunder et al. (2014).

We test following hypotheses.

- Household specific assets, including social capital (Community group membership, autochthonous, household's size and marital status), human capital (education, age and seniority[3]), access to natural capital (land-use conflict, human-wildlife conflict) and financial assets (loan and money transfers) drive household' heads preferences among livelihoods' strategies.

- Geographical assets including environmental state (distance to the nearest protected area) and infrastructure (distance to market) influence household's heads preferences among livelihoods' strategies. Indeed, beside household-specific assets, location is supposed to significantly influence households' livelihoods choices (Soltani et al., 2012). Further, distance to market can be considered as cost of market access (Losch et al., 1954; Von Thünen and Hall, 1966)

- Finally, we hypothesize that preferences among livelihoods' strategies of proximal households are correlated and changes in the level of household assets and characteristics will impact both

[2]The PEN is an initiative with more than 50 research partners that built a dataset containing detailed socio-economic data collected quarterly. It contains more than 8000 households at the village level in 40 study sites from 25 developing countries. (http://www1.cifor.org/pen)

[3]Seniority is the quality of households that has settled long ago in the village.

own preferences and neighbouring household preferences over strategies. Indeed, according to the strategic-interaction models, a farmer's decision is supposed to indirectly affect other farmers' decisions within the same neighbourhood (Anselin, 2002; Brueckner, 2003).

This paper is structured as follows. Section (2) presents the literature review. Section (3) describes the case study. Section (4) presents the theoretical framework, and section (5) specifies the Spatial Autoregressive Probit (SAR-Probit) econometric model. Results are presented in section (6). Finally, section (7) present discussion and conclusions.

2. Literature Review

Households' livelihoods strategies have been a subject of numerous papers, encompassing the framework for investigating sustainable rural livelihoods, global studies and case-specific analysis. Literature on the SLF asserts that the ability to pursue different livelihoods' strategies is dependent on the basic material and social, tangible and intangible assets that people have at their possession (Scoones, 1998). In different contexts, sustainable livelihoods can be achieved through access to natural, economic, human, physical and social capitals or resources. Jansen et al. (2006) have contributed to framing the livelihoods analysis by introducing geographical determinants as a sixth fundamental factor. Soltani et al. (2012) argued that, beside specific assets, location has a important effect on households' livelihoods' strategies. They propose dividing this location asset into infrastructures and environmental state. These assets are often combined to define different livelihoods' strategies including agricultural intensification, specialization or diversification (Angelsen, 2011; Coomes et al., 2004; DfID, 1999; Ellis, 2000a; Knutsson, 2006; Scoones, 1998).

Among the numerous case-specific studies on livelihoods' strategies, Soltani et al. (2012) examined poverty and forest degradation in rural areas of Zagros (Iran) accounting for location assets beside the traditional SLF approach in other to identify the most sustainable households' livelihoods strategies. They studied three continuous indices of poverty, over-grazing and over-harvesting on a stratified random sample of 79 households. They found that 64% of the households surveyed adopt mixed strategies, while, the livelihoods' strategies of poorest households (27%) are highly dependent on forest extraction and livestock grazing and that the remaining 9% combine cash crop with non farm work and earn higher income. They also found that locational capitals namely, development and marginality are important drivers of choice among livelihoods' strategies in addition to household traditional assets. They finally found some evidence of an Environmental Kuznets Curve. Indeed, over-harvesting and overgrazing indices are the highest for households in the mixed cluster and lowest for households in the non-farm/commercial one.

These diverse strategies have some key characteristics of interest. They can be decomposed in a set of diverse choices. In this paper, we focus on three types of strategic choices: choice of diversification, choice of land conversion and choice of relying on forest resources.

Diversification:. depending on available assets, households may prefer to diversify their activities as a survival strategy or safety net to cope with shocks in order to maintain or enhance their capabilities or for income motive, while, contextual effects can lead to specialization in a particular activity (Ellis, 2000b; Scoones, 1998). A range of global level studies have been focussing on the reliance on environmental income for gap-filling and as a safety net to cope with risk. Indeed, agriculture is subject to myriad risks including weather, price, pests, diseases and fire (Pattanayak and Sills, 2001), and diversification activities can be seen as a way to cope with risk, in a context of lacking insurance and credit markets. Angelsen et al. (2014); Delacote (2007, 2009); Vedeld et al. (2007) and Wunder et al. (2014) are among the main researchers who pointed out the importance of environmental amenities and income for seasonal gap-filling and as rural safety net to shocks. They found that households with poor human, natural and social capital were more likely to go to the forest after a shock; while forest extraction has limited importance for seasonal gap-filling (Wunder et al., 2014). They found that forest income contributes between 22.2% to 27% of total households' income with large and systematic variations among regions, and that, the poor rely more heavily on subsistence products such as wood fuels and wild foods, and on products harvested from natural areas other than forests (Angelsen et al., 2014; Nguyen et al., 2015; Vedeld et al., 2007). A similar result was found by Belcher et al. (2015) in a case study in Jharkhand (India). However, this category of households (poor households) are more likely to be trapped in common-property resources extraction activities, that provide only minimum requirement. This is especially true for households with a large need of insurance (Delacote, 2009).

Land conversion:. the choice of land-conversion activities has been investigated, mainly through forest clearing and deforestation choices for example, using the PEN dataset. Considering the SLF presented above, Babigumira et al. (2014) introduced mediating and vulnerability indicators to examine the factors that influence rural household decisions to clear forestland in 24 developing countries and to identify robust global correlation between forest clearing and rural livelihoods. They found that shock patterns do not drive forest clearing, and that male-headed households with abundance of male labour living in recently settled places with high forest cover, as well as households with medium to high asset holdings and higher market orientation were more likely to clear forest than the poorest and vulnerable households.

Forest reliance:. Coomes et al. (2016) used a large scale census with 919 communities in four major river sub-basins in eastern Peru under the PARLAP initiative to analyse the drivers of the economic orientation of rain forest communities. The authors found that initial environmental endowments and market access of communities are important in shaping their economic orientation, however, they interact in different ways depending on the key natural resource upon which they rely. Further, they found a strong correlation between rich endowment of terrestrial activities components and participation in land-based extractive activities including hunting, non-timber-forest product (NTFP) and timber extraction. An important proportion of case-specific analysis of livelihoods' strategies has been carried out in Southern and Eastern Africa. Some results are similar to those from global studies stated above in terms of the importance of forest income for the poorest households (Kamanga et al., 2009; Mamo et al., 2007), the differential influence of livelihoods assets on the choice of households strategies (Babulo et al., 2008) in Ethiopia and Malawi.

One of the very few scientific publications in the Congo Basin on this issue was carried out by Nielsen et al. (2012). They used data collected in a typical CIFOR-PEN study in Democratic republic of Congo to point out the importance of including asset-based measures of wealth in studies of poverty–environment relations with poverty groups of households. Considering poverty as a transitory phenomenon resulting from an array of push and pull factors, and considering the importance of assets' wealth for seasonal gap-filling, four poverty groups were identified by dividing the sample into five annual income quintiles and into five equally sized productive asset quintiles. The authors found a strong reliance of the chronic poor on forest income and a strong reliance of richest households on business. They also found that the transient poor consume a higher share of harvested forest products, while the transient rich have higher agricultural productivity and absolute forest income.

3. Case study: The Tridom-TCL in the Congo Basin

The Tridom-TCL is a cross-border conservation landscape created in 2005 by an agreement between Cameroon, Gabon and Congo governments, as one of the twelve "priority landscapes" of the Congo Basin Forest Partnership (CBFP)[4]. The management of the Tridom-TCL is entrusted to a Regional Management Unit (RMU) with representative members in each of the three countries. Each representative member manages the corresponding segment of the landscape according to the national law. The RMU is prepared to act beyond national borders with the following missions: (1) sustainable management of transboundary biodiversity in the inter-zone, (2) maintaining the ecological, the economic and the social connectivity of the complex, (3) ensuring long term conservation of its protected area system and (4) fostering local development with reduced impact on environment. The Tridom-TCL consists of a network of 10 protected areas, namely, the Dja biosphere reserve, the Boumba-Bek NP, and the Nki-Mengamé gorilla sanctuary (Republic of Cameroon), the Odzala-Kokoua NP and the Lossi NP (Republic of Congo), the Minkébé NP, the Ivindo NP and the Mwagne NP (Gabonese Republic). These protected áreas, spread over $35,968$ square kilometers, are connected by a wide inter-zone of more than $111,000 km^2$ of which 36% (40,000 km^2) is inhabited. It represents 7.5% of the total area of the Congo Basin Tropical Forests in Central Africa. The inhabited inter-zone hosts indigenous and local people. These people depend on slash and burn agriculture, and forest-based activities such as hunting, NTFP gathering, fishing, traditional forest management and traditional mining for their survival. The human population density is between 1-7.9 inhabitants/km^2 and is currently growing due to resource exploitation (Ngoufo et al., 2012). The field work was carried out in the Cameroon and Gabon segments as shown in the figure (AppendixA.1) in appendix. Both segments are inhabited by more than 43 tribes, dominated by Bantu, with a minority group of the indigenous baka tribe.

[4] The Congo Basin Forest Partnership (CBFP) was launched as a multi-stakeholder partnership (with 70 partners, including African countries, donor agencies and governments, international organizations, NGOs, scientific institutions and the Tridom-TCL private sector) at the 2002 World Summit on Sustainable Development in Johannesburg, South Africa. It aims to enhance natural resource management and improve the standard of living in the Congo Basin (http://www.pfbc-cbfp.org/)

3.1. Data

The paper uses data from a representative face-to-face survey with a random and stratified sample of 1035[5] households. The total number of households is approximately 65140[6]. The survey lasted 8 months between December 2013 and July 2014 in 108 villages representing all the 26 administrative units of the Cameroonian and the Gabonese part of the landscape. The villages visited are spread over nearly 27,000 km^2, which is two third of the landscape livable inter-zone. The random sampling of households in the villages was based on the village inhabitants' registry held by the chief of the village.

The interviews lasted between 1 to 3 hours. In addition, there were evening visits in various households surveyed to quantify and measure daily, weekly and per annum livelihoods production. The survey was supervised by the first author. Ten Masters students selected after five training seminars participated as surveyors. Every village provided at least two local translators in the case the household's heads could not communicate in French. Every household was geo-localized with a GPS.

The per annum value of livelihoods were derived in two ways: Some well organized household's heads usualy record their daily, weekly and per annum livelihoods statistics. We trusted and collected these statistics. For the remaining households, we used contextual material to measure daily and weekly production. We extrapolated to have the per annum livelihoods production according to the recall data they stated and the seasonality of each species or product. For instance, among the forest-based livelihoods, (1) *Ricinodendron Heudelotti* is harvested every year for two-months period, it is measured with a 5 liters pail that weights 7.5kg, and a bag of 90kg is made of 12 pails. The total value for two months were considered as the per annum value. (2) Likewise, *Irvingia gabonensis* is harvested for three-months period a year. Some products are harvested during 12 months (*Gnetum africanum, Piper nigrum, Afromomum dalzeillii...*) and others are harvested during three to four months (*Fungi, Corylus avellana, Garcinia cola, Monodora myristica etc.*). The table AppendixB.1 in appendix shows the measurement indicators for the 20 NTFP, including fuel wood, that account for forest-based strategies. We also used a mechanical dynamometer to measure and to weight bushmeat, crop (banana, casava, potato, vegetables etc.) and cash crop (including rubber and cocoa) daily and weekly production. We used the average local sales price to estimate the value of such livelihoods resulting from each strategy.

[5]The sample size required at a confidence level of 95% (typical value of 1.96) is 384.

[6]The aggregate population size in both segments of the Tridom-TCL is 418,855 inhabitants (Bucrep, 2010; Gabon, 2010). Considering the mean household size of the sample (6.43), the number of households is around 65,140.

Indeed, price variation within rural areas is normally quite small (Angelsen and Kaimowitz, 1999).

3.2. Livelihoods portfolios

Based on an initial analysis we defined the households as member of one of six groups. Indeed, as illustrated in the figure AppendixA.2 in appendix, 35% of the Tridom-TCL households base their livelihoods' strategies on small-scale agriculture and forest products extraction (AF). Besides these two activities, cash crop is included as a third activity in a mixed strategy with three activities (ACF) by 17% of the households. 14 % mix small-scale agriculture and cash crop (AC) and the remaining households specialize in forest-based (F, 27%), cash crop (C, 4%) and small-scale agriculture (A, 3%).

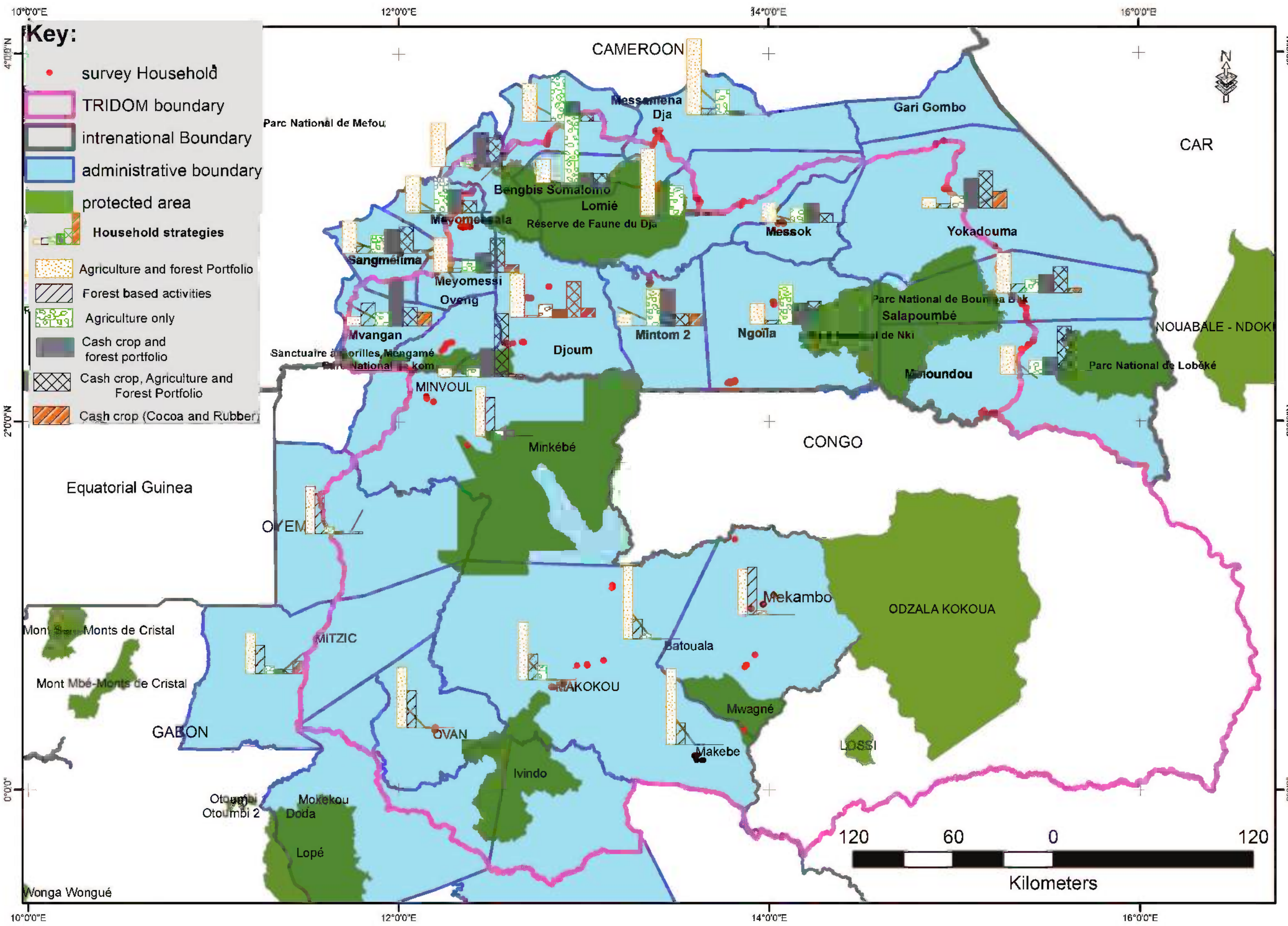


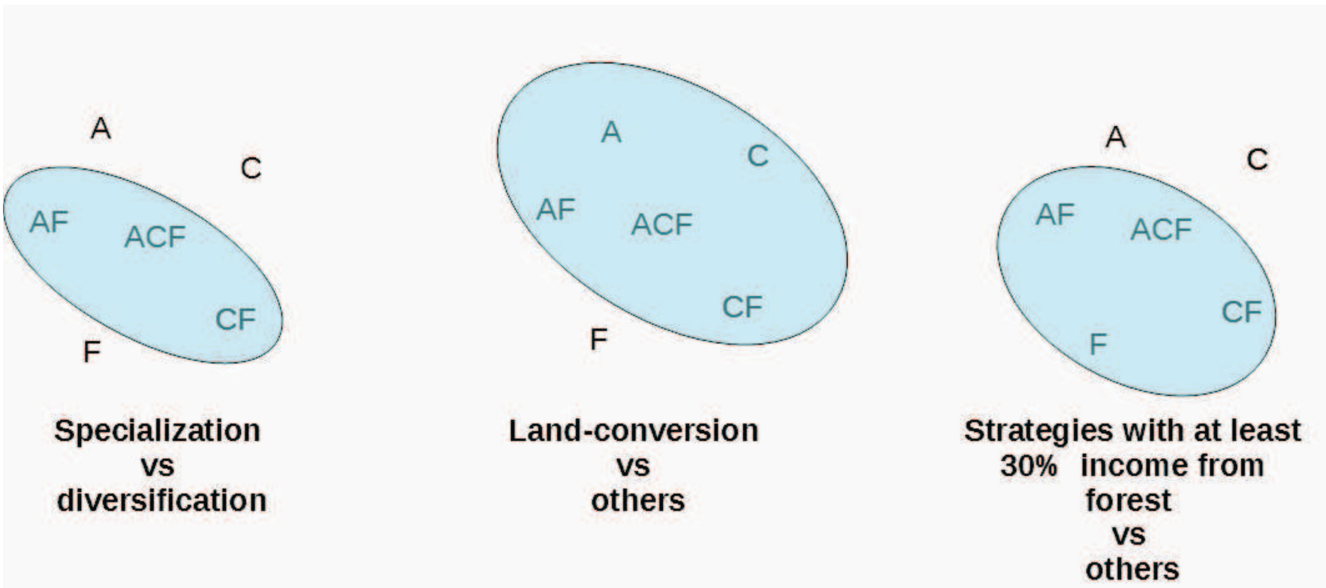
Figure 1: Livelihoods' strategies on the landscape

4. Theoretical framework

4.1. Strategic trade-offs in livelihood portfolio selection

Several interesting development and environment strategic trade-offs (s) can be investigated when considering the livelihoods portfolio selection (see figure 2). First, one can consider that those choices oppose specialization strategies and diversification strategies: $[A, C, F]$ vs $[CF, AF, ACF]$. The development literature generally considers that specialization strategies may be closer to profit-maximizing behaviors (the household's head selects the most profitable activity), while diversification strategies are likely to be the consequence of risk-minimization behaviors (the household's head diversifies his/her portfolio in order to mitigate risk). Investigating this trade-off allows us to analyze the factors that influence the household heads' behavior and especially how they balance profit-maximizing versus safety.

Figure 2: Trade-offs in livelihoods' strategies



Another matter of interest relates to land-use. Some portfolios encompass land-conversion activities, such as agriculture and cash crops, while others do not, such as forest-based activities including hunting bushmeat and gathering NTFP: $[A, C, CF, AF, ACF]$ vs $[F]$. This trade-off allows to understand which factors lead household's heads to make their choice of activities related to land-conversion. The relying results can bring evidence on the deep factors influencing deforestation behaviors.

Finally, one can distinguish portfolios relying on forests and the others: $[A, C]$ vs $[F, CF, AF, ACF]$. This distinction allows us to investigate which factors leads household heads to engage in forest-related activities. This is a matter of interests, as when household heads consider forests as assets, they may be more likely to consider them as valuable and thus be actors of forest protection.

4.2. A simple microeconomic model of livelihoods portfolios

Consider a household's head i that chooses among a set of livelihoods portfolios $L_i = [A, C, F, CF, AF, ACF]$ to maximize his/her utility U_i. X_i is a vector of the household's head i socio-economic variables, Z_{ip} stands for observed attributes of the activity portfolio p for the household's head i (Lancaster, 1966)[7]. Household i's utility function may encompass income derived from the livelihoods portfolios, but also other non-observable outcomes such as household's vulnerability. Thus, the household characteristics X_i may influence not only the economic return from the portfolios, but also other households matters of interest. Furthermore, we consider that household i's utility may be influenced by his/her neighborhood. L_j is the livelihoods portfolios selected by household i's neighbors, that are likely to influence his/her decision. The household maximisation problem is given by:

$$\max_{L_i} U_i(L_i, X_i, Z_{ip}, L_j) \tag{1}$$

The first-oder condition implicitly gives the optimal portfolio $L_i^*(X_i, Z_{ip}, L_j^*)$ for household i:

$$\frac{\partial U_i(L_i^*, X_i, Z_{ip}, L_j^*)}{\partial L_i^*} = 0 \tag{2}$$

As suggested by the trade-offs described in the above sub-section, households portfolio choice can be substituted by sets of binary strategies ($S = 1, 2$). Henceforth, S will be used for livelihoods' strategies instead of L. The model described in equation (1) leads to binary or discrete outcomes. Models of discrete choices have been known since Albert and Chib (1993); Bhat (1997); Horowitz (1991); McFadden (1974); Schnier and Felthoven (2011) and Thurstone (1927) and formulated as Random Utility Model (RUM). Basically, the theory of random utility assumes that the utility function is comprised by two components. The first is a systematic component representing the observed attributes of different strategies, the socioeconomic characteristics of an individual as well as the neighboring characteristics.

[7] According to Lancaster's theory, consumers derive their utility from the attributes that describe the product.

The second is a random component that captures the effects of unobserved attributes and characteristics that may influence individual choices. Therefore, the utility function U_i presented in equation (1) driven by household i's livelihoods strategy becomes:

$$\begin{cases} U_{is} & = V_{is} + \epsilon_{is} \\ V_{is} & = aZ_{is} + b_s X_i + c_{s'} f(S_j^*) \end{cases} \tag{3}$$

Where $i = 1, 2, 3...n$ and $s = s' = 1, 2$.

In equation (3), V_i denotes the systematic component of the RUM, Z_{is} is the vector of characteristics of the binary strategy S adopted by household 's i, X_i is the vector of household i socioeconomic characteristics. a, b and c denote parameters associated to the covariates and ϵ_{is} is the random variable that captures the random component of the utility function and / or the unobserved attributes of the strategy S.

5. Spatial Probit Model

5.1. The model

The household i's head will adopt the optimal livelihoods strategy S_i^* that provides him/her with the greatest utility. Since binary dependent variable observations can be treated as indicators that relate to underlying latent or unobservable level of utility (Albert and Chib, 1993; LeSage and Pace, 2009), the decision to choose or not to choose, or to choose among two strategies can therefore be guided by the difference in utilities brought about by both realizations. Therefore, assuming the couple $(0, 1)$ as the observed choice indicator of the strategy S by household i, the following holds:

$$\begin{aligned} S_i &= U_{1i} - U_{0i} = a\left(Z_{i1} - Z_{i0}\right) + \left(b_1 - b_0\right) X_i + \left(c_1 - c_0\right) f\left(S_j\right) + \left(\epsilon_{i1} - \epsilon_{i0}\right) \\ S_i &= a \bigtriangleup Z_s + \beta X_i + \rho f\left(S_j\right) + \mu_i \end{aligned} \tag{4}$$

In equation (4), S_i is not observed. It is considered as an unobserved latent dependent variable, representing the relative utility derived by the household i's head from his/her observed strategy S_i^*.

The microeconomic model of livelihoods' strategies developed above defines the household i's strategies and the resulting utility as function of neighboring households' matters of interest. Hence, the observed choice of a household may be similar or dissimilar to strategies of nearby households. Modeling such discrete variables generated by spatially interdependent processes requires defining a spatial weight matrix and an operator that help accounts for the intensity of spatial interaction among households as well as the resulting spatial spillover effects. In this paper, we are interested in the strength of spatial interdependence among households as well as its impacts on households' likelihood to choose a particular livelihoods strategy. Therefore, the spatial lag discrete dependent model is the most convenient among the spatially explicit econometrics models (Anselin, 2007). In the following, we removed the component $a \bigtriangleup Z_s$ from the model. Indeed, the main characteristics of households strategies are themselves the matter of the study.
Thus, equation (4) becomes:

$$\begin{aligned} &S = X\beta + \rho W S + \mu \\ &\mu \sim \left(0, \sigma_{\mu}^2 I_n\right) \end{aligned} \tag{5}$$

In equation (5), β is a kx1 vector of parameters to be estimated, ρ denotes the intensity of spatial interdependence, W is the spatial weight matrix and $WS(n\text{x}n)$ is the spatial operator that denotes the mean dependant variable of neighboring households. The term μ is a multivariate normal distribution corresponding to a Probit model. Under the hypothesis $\rho \neq 0$ and $(1 - \rho W) \neq I_n$, the matrix notation of the data generating process is given by equation (6) below:

$$S = (1 - \rho W)^{-1} X\beta + (1 - \rho W)^{-1} \mu \tag{6}$$

The observed value of the limited dependent variable S_i^* is defined as follows:

$$S_i^* = \begin{cases} 1 & \text{if } S > 0 \\ 0 & \text{if } S \leq 0 \end{cases} \tag{7}$$

Following LeSage and Pace (2009), the probability of choosing a particular strategy is given by:

$$\begin{aligned} &Pr\left(S^{*}=1 \mid X,W\right)=Pr\left(S>0\right)=Pr\left(\left(1-\rho W\right)^{-1}X\beta+\left(1-\rho W\right)^{-1}\mu>0\right) \\ &=Pr\left(\eta<\left(1-\rho W\right)^{-1}X\beta\right) \end{aligned} \tag{8}$$

In equation (8), $\eta = (1-\rho W)^{-1}\mu$. In the case where $\rho = 0$ and $(1-\rho W) = I_n$, the expression (8) follows a standard Probit model, and Maximum likelihood estimation (ML) techniques can be used. If $\rho \neq 0$ and $(1-\rho W) \neq I_n$, S and μ follow a Truncated Multivariate Normal Distribution, and the standard ML techniques are not suitable. Indeed, the inclusion of neighboring strategies WS as a determinant of the latent variable S involves n-dimensional integral in the likelihood function and generates some tractability and computational problems. Further, the reduced form of the latent process is nonlinear. This relates to the consistency of the model (Baltagi et al., 2014). In this case, estimation can be achieved using the Bayesian Markov Chain Monte Carlo (MCMC) simulation methods by Gibbs and Metropolis-Hastings sampling (Albert and Chib, 1993; Geweke, 1991; LeSage, 2004; LeSage and Pace, 2009; LeSage, 2000), using the Recursive Important Sampling (RIS) or the GHK (Geweke-Hajivassiliou-Keane) simulation methods (Geweke et al., 1994; Hajivassiliou, 2000) to name a few. In this paper, we use the Bayesian approach to estimate the SAR-Probit model with MCMC simulations and Gibbs sample with 1000 drawn, 20% of the draws used as burn-in, assuming a non-informative prior distribution for β. For a detailed presentation of the Bayesian approach to modelling limited dependent variable, see LeSage (2000); McMillen (1992); Wilhelm and de Matos (2013).

As with the standard Probit model, estimates of the coefficients of the SAR-Probit do not have direct economic interpretation as the normal probability distribution is non linear. The sign of parameters is the only usable information, indicating the direction of the impact. The sensitivity of the probability to choose or not to choose a given strategy relative to one-unit change in the independent variables is measured by a single value standing for marginal effect in the standard Probit model. This does not hold for the SAR-Probit model. Indeed, the SAR-Probit model involves spatial lag of the dependent variable. This implies some spillover or indirect effect brough about by a one-unit change of the i_{th} household characteristics on the neighboring households' likelihood to adopt a strategy, in addition to the usual direct effect. Following LeSage and Pace (2009), the SAR-Probit yields three values of interest namely, the direct, the neighborhood and the total effect derived from expression (9).

$$\frac{\partial E\left(S^{*} \mid X_k\right)}{\partial X_k'} = \phi\left(\left[1-\rho W\right]^{-1} I_n \bar{X}_k \beta_k\right) \bigodot \left[1-\rho W\right]^{-1} I_n \beta_k \tag{9}$$

Where X_k denotes the k^{th} independent variable with $\bar{X}_k$ as mean value, ϕ is a standard normal distribution, and $\bigodot$ stands for element-wise multiplication.

The main diagonal elements of expression (9) represent the direct effect. That is the effect of a one-unit change in an independent variable of household i on the own likelihood to choose or not to choose a particular livelihoods strategy. The average value of each row results in the total impact brought about by one-unit change in the corresponding covariates. The neighborhood (indirect) effect is measured by the difference between the total effect and the direct effect. In the SAR-Probit, this number captures the effect of a one-unit change in an independent variable of the household i on the likelihood of the neighboring household to choose or not to choose a particular livelihoods strategy.

5.2. Spatial operator

The consideration of social interactions and / or spatial interdependence is made possible through the spatial operator WS that represents the neighboring livelihoods' strategies. The spatial weight matrix W that summarizes the spatial relations between observations depends on the neighboring structures. A large body of research has used the distance weight matrix, contiguity weight matrix or K-nearest-neighbours (KNN) matrix corresponding respectively to distance-based households structure, common boundary structure and nearest neighbors structure (Bivand et al., 2013). As pointed out by Fingleton and Arbia (2008); LeSage and Pace (2014), there is near universal agreement that estimates and inferences from spatial regression models are sensitive to particular specifications of the spatial weight structure.

To account for this "biggest myth in spatial econometrics" (LeSage and Pace, 2014), we consider three different structures of W, namely, the Gabriel graph weight matrix, the KNN weight matrix and the row-standardize distance-based weight matrix.

The Gabriel relative neighborhood graph is a geographic connectivity network between the sampling households. According to Matula and Sokal (1980) and Gabriel and Sokal (1969), two households i and j in the Tridom-TCL are considered to be contiguous if and only if all other households are outside the i - j circle. In this weight matrix, two households i and j are considered contiguous unless there exists another household l such that in the triangle ijl, the distance between i and j is less than the sum of the squares of the distances to any other locality l.

The KNN weight matrix bases its estimation on a fix number of k households closest to household i. The selection of the KNN households is made possible via the euclidean distance $dij\left(x_i, x_j\right) = \parallel x_i - x_j \parallel = \left(\left(x_i - x_j\right)' \left(x_i - x_j\right)\right)^{0.5}$. With $j = 1...k$. In this study, we consider 3NN, 5NN and 10NN spatial weight matrices. We choose 10 as maximum number because it is close to the minimum number of households in many villages surveyed.

In the row-standardize distance-based weight matrix, the i^{th} row contains the spatial weight of neighboring households influencing household i, such that each row sums up to unity. We consider the sparse matrices[8] in the three different structure of W we used.

6. What drives livelihoods' strategies in the Tridom-TCL?

This section first presents descriptive statistics (6.1). Then, it presents the specification used for the results, choosing among the standard Probit model and the best spatial model given various types of weight matrix to control the so called "biggest myth in spatial econometrics" (6.2). It ends with estimates and marginal effects for each of the three trade-offs (6.3).

6.1. Descriptive statistics

Among the 1035 households surveyed, this paper considers 987 households who were successfully geo-localised with GPS, representing 95.4% of of surveyed households. Regarding the first dependent variable that opposes specialization strategies and diversification strategies as presented in the first trade-off presented in table (AppendixB.2) in appendix, about 66% of household's heads diversify their strategy, mixing small-scale farming, cash crop and forest. As regards the second dependent variable related to land-use, 73% of the households adopt land-conversion activities and the remaining prefer forest-based activities. The final trade-off opposes 67% of the sample choosing strategies relying on single or mixed strategies with at least 30% income provided by forest-based activities to households who do not or who rarely value forest.

[8] Compared to the usual dense matrix, a sparce matrix stores only non-zero elements. It generates economy in terms of memory, it reduces the complexity of systems' resolutions and greatly speed up the calculations (Erhel, 2014).

the figure (AppendixA.3) in appendix shows that, among these trade-offs, households who diversify, those who choose land-conversion and those who rarely value forest would cause higher average deforestation ($5.26ha$, $5.57ha$ and $7.14ha$ respectively), with lower per annum return or yields (CFAF$0.40 * 10^6$, CFAF$0.40 * 10^6$ and CFAF$0.37 * 10^6$ respectively, that is \$84, \$84 and \$77.7)[9] while those who choose to specialize, to adopt forest-based activities or to rely on forest with a mixed of single strategies deforest twice less, with a two-time higher return.

Following these rough statistics, a tentative conclusion is that the forest resource would be socially beneficial, and could therefore constitute a safety net for rural households. Specialization, as well as strategies that value forests would be viewed as sustainable strategies. However, this result does not provide detailed information about those who specialize, those who adopt forest-based activities, or those who value forest regardless of diversification or not. Subsection (6.3) below will provide further insight about the factors that lead households to make the choice of a particular strategy.

Table 1 displays a description of variables included in the analysis to test the hypotheses. We basically distinguish social assets, human capital, natural capital, financial assets, the environmental context, and infrastructure assets. Regarding social assets, in 2014, 70% of the households in the overall sample were married. The average household size was 6.5 with a standard deviation of 4. Twenty-six percent of the households belong to a community group of interest, households employ on average 1.87 member of pygmy society. Regarding human capital, 56% of the households have reached at least secondary-school educational level. Regarding natural capital, we choose not to introduce land-holding as a determinant of livelihoods' strategies, as there is neither a market of lands nor a binding regime on access to land. Yet, we introduce human-elephant conflict which caused CFA620 mean damage cost per month. We also introduce the land conflict among households. Indeed, 18% of the households have faced conflicts with their neighbors. Both variables should also provide some information on the behavior of vulnerable households especially when facing a shock.

Financial assets are approximated by loans and money transfers with a mean value of $CFA8.66 * 10^3$ per month. Regarding the environmental context, households are located on average at $29.3km$ to the nearest protected area with a standard deviation of 22.58. As an indicator of transport cost and infrastructure assets, the average distance to the subdivision's market is $51.65km$ with a deviation of

[9]In 2014, year of the field work, CFAF1 = $\$0,0021$)

35.7. Female-headed households account for 23% of the sample, and the average age is 48.44 years. The table in appendix (AppendixB.2) provides a more detail description of these variables with respect to various strategies and trade-offs.

Table 1: Variables and descriptive statistics of overall sample

Variables	Description of variables	Mean	StDev
Social asset			
Marit_single	Matrimonial status. Dummy (1=Maried)	0.70	0.46
Hsize	Household size (continuous)	6.50	4.01
Pygmee_employmt	Pygmies employment (continuous)	1.86	2.95
CommunityGroup	Community Interest Companies . Dummy (1=yes)	0.28	0.45
Autochbaka	Indegenouesness . Dummy (1=pygmy. 0=Bantou)	0.05	0.22
Human Asset			
Age	Household's head age (continuous. in years)	48.44	14.61
Seniority	Seniority in the village (continuous. in years)	27.01	20.71
Schoolcycl	Education level . Dummy (1=secondary school)	0.56	0.50
Naturel asset (access to)			
Land holding	Deforestation per household (in ha)	4.55	5.31
Landconflict	Land use conflict . Dummy (1=yes)	0.18	0.38
Human_Wildlife	Damage cost of wildlife conflict (CFA/month)	0.62	1.45
Financial asset			
Finance_asset	Credit and money fransfert (CFAF/month)	8.66	33.54
Location asset			
Distance to PA	Distance to the nearest Protected Area (in Km)	29.30	22.58
Distmarket	Distance to market (in Km)	65.05	58.69
Other drivers			
Gender	Gender. Dummy (1=Male)	0.77	0.42
Country	Country. Dummy (1=Cameroon. 0=Gabon)	0.73	0.44

6.2. Spatial dependance and sensitivity

6.2.1. Data generation process and results' accuracy with the weight matrix type

The standard Probit model is contrasted to the SAR-probit model as suggested by LeSage and Pace (2009, 2014). Further, we check the sensitivity of the results to various specifications used for the spatial weight structure in the SAR-probit. It finally concludes on the nature of the spatial dependence in various trade-offs, considering the best model.

The table in appendix (AppendixB.3) displays the results of the standard Probit model that assumes non-spatial relationship among observations alongside with those of the spatial autoregressive model for the trade-off between specialization and diversification. This table shows some stark contrasts between the estimates and marginal effects of both standard Probit model and SAR-probit. It also suggests a significant effect of distance to market as well as distance to the nearest protected area. On the other hand, these effects are not significant for the SAR-Probit. In the latter model, the spatial autocorrelation coefficient, ρ, differs statistically from zero. It is thus clear that estimates and marginal effects of the standard Probit model are biased and inconsistent, allowing non pertinent causations as regards to both distances to the market and the nearest protected area. As result, the decision to choose among specialization and diversification is generated by spatially interdependent processes.

The table in appendix (AppendixB.4) contrasts the results of various SAR-Probits given the structure of neighbors to illustrate the impact of changing the type of the weight matrix. It shows that varying the type of the matrix does not lead to similar results. Indeed, the Gabriel-relative neighborhood graph (Gabgrahp) reports the absence of spatial patterns. The value of $\rho_{Gabgraph}$ is close to zero and non significant ($\rho_{Gabgraph} = 0.05$), while the KNN and the distance-based matrix report the influence of spatial effects on the households' likelihood to adopt a livelihoods strategy. Further, differing the number of neighbors yields different results. As the number of neighbors increases, the strength of spatial interaction increases. The spatial weight matrix based on 10 nearest neighbors (10NN) presents higher spatial dependence with $\rho = 0.36$ compared to 3NN ($\rho_{3NN} = 0.23$) and 5NN ($\rho_{5NN} = 0.29$). The distance-based matrix yields spatial effects that are closer to the 10NN.

This analysis validates the sensitivity of results to the weight matrix specification postulated by LeSage and Pace (2009, 2014). Therefore, a good analysis of households livelihoods' strategies should involve testing and accounting for spatial effects using spatially explicit econometric models, as well as checking the accuracy of the results with the form of the spatial weight matrix. In the following, we consider the distance-based weight matrix. Indeed, as the households were geo-localized during the field work, the distance-based weight matrix (that yields almost similar results with the 10NN matrix in our study) is better. This matrix allows for the magnitude of interaction among two individuals to be proportional to the inverse euclidian distance among them, while the KNN matrix tends to attribute the same weight to all the k individuals. The quantitative explanatory variables were checked for multi-collinearity, tables (AppendixB.5) and (AppendixB.6) in appendix suggest the independence among them.

6.2.2. Spatial dependence

Table 2 shows an evidence of spatial autocorrelation among the likelihood of proximal households to choose among livelihood strategies. Indeed, the value of ρ is positive and significant at 1%. This suggests that households tend to mimic the livelihood strategies of their neighbors.

The range of the ρ parameter suggests a difference among the strength of mimicry among the three trade-offs. Indeed, the dependence among closer households' likelihood appears to be stronger regarding strategies that value forest rather than choosing or not to choose between forest-based strategies and land-conversion based strategies, or between specialization and diversification.

Table 2: MCMC SAR-Probit estimates

	Specialization VS Diversification			Forest-based VS Land-Conversion			Valuing Forest VS Non Valuing Forest		
	Estimate	Std. Dev		Estimate	Std. Dev		Estimate	Std. Dev	
Social assets									
Marit_single(1=Maried)	0.0640	0.107		-0.0310	0.106		-0.191	0.106	*
Hsize(continious)	-0.0584	0.012	***	-0.058	0.012	***	-0.014	0.011	
Pygmee_employmt(cont)	0.0095	0.015		-0.018	0.017		-0.018	0.015	
CommunityGroup(1=yes)	-0.1531	0.098		-0.12	0.109		-0.086	0.102	
Autochbaka(1=pygmy)	0.4552	0.194	**	0.651	0.201	***	0.762	0.252	***
Human assets									
Age(continious)	0.0038	0.003		0.005	0.003	**	0.007	0.003	***
Seniority(years in the vlge)	-0.0056	0.002	**	-0.007	0.003	***	-0.004	0.003	
Schoolcycl(1=2ndschool)	-0.0857	0.087		-0.08	0.095		-0.057	0.095	
Natural assets (access to)									
Landconflict.(1=yes)	0.0631	0.112		0.129	0.119		0.024	0.123	
Human_Wildlife(Damage cost)	0.0497	0.03	*	0.06	0.03	**	0.091	0.033	***
Financian asset									
Finance_asset(CFAF)	0.0036	0.002	**	0.001	0.001		-0.001	0.001	
Location assets									
Distance(in Km)	0.0023	0.002		0.001	0.002		-0.001	0.002	
Distmarket (in Km)	0.001	0.001		0.001	0.001	*	0.001	0.001	
Other drivers									
Gender(1=Male)	0.0258	0.095		-0.011	0.102		0.15	0.104	
Country(1=Cameroon)	-0.2464	0.109	**	-0.165	0.114		0.01	0.098	
ρ	0.3616	0.122	***	0.484	0.094	***	0.732	0.049	***
L_{i}(0.1)		(654. 333)			(721. 266)			(321. 666)	
AIC		1199.268			1064.261			1224.836	
logLik.sarprobi		-583.63			-516.13			-596.41	
N draws		1000			1000			1000	
burn-in		200			200			200	

6.3. Coefficient Estimates and Marginal Effects

Table 2 presents the sign and the possible variables that drive household heads' decision in various trade-offs. Tables 3, 4 and 5 present the magnitude or the incremental change resulting from a one-unite change in the independent variables on both own and neighboring likelihood of choosing or not to choosing a strategy in various trade-offs. As a reminder, the independent variables include households' human, social, natural and financial assets; geographical assets of location and infrastructure; remaining households characteristics and spatial spillover effects.

6.3.1. Specialization vs diversification

Table 3 displays the results for the first trade-off where households choose between specialization (either on forest activities, or on cash-crop or small-scale farming) and diversification (mixing cash crop, forest and small-scale farming). One can argue that households specializing in one activity tend to be more income-maximizing oriented, while those tending toward diversification are more risk-coping oriented. Yet, other kinds of characteristics have to be taken into account: some households may have to specialize because there are some barriers to diversification, related to low levels of some assets.

- **Social asset**

  Among households' social assets, being part of a community group of interest, marital status and pygmies employment do not have any direct or indirect impact on the household's head likelihood to choose between diversification and specialization. The direct and indirect effect resulting from the household size is negative and significative. This suggests that larger households will be less likely to specialize than others. Moreover, they tend to have negative spillover on their neighborhood. Further, regarding the magnitude, a one-unit increase in household size will reduce both own probability and neighboring households' probability to specialize by 1.93% and 1.16% respectively. This leads to a total impact of 3.09%, (i.e. 1.93%+1.16%). Finally, autochthonous (wether indigenous pygmy or not) exerts a positive and significant direct and indirect influence on specialization strategy. Indeed, indigenous Baka pygmies are more likely to specialize in forest-based activities. Being a pygmy is associated with 15.08% more chances to specialize and tends to increase his/her neighboring households' likelihood to specialize by 9.16%, leading to a total impact of 24,23%.

- **Human asset**

  With respect to human capital, the direct and the indirect effect associated with secondary school education level as well as age is not significant. Yet, households who settled long ago in villages (seniority) are less likely to specialize in their livelihoods' strategies. An additional seniority year increases the likelihood to diversify by 0.18% with a positive spillover effect of 0.11% on the likelihood of neighboring households to diversify.

- **Natural asset**

  Human-wildlife conflict as well as land conflict with the neighboring households were considered as an indicator of access to natural capital. Table 3 also shows a non significant impact of land conflict within the household's neighborhood. It also shows that households who face human-wildlife conflict are more likely to specialize in a particular livelihood strategy. More precisely, a CFAf1000 ($2.1) additional elephants damage cost per month will lead to increasing own probability to specialize by 1.65% with a positive spillover effet of 0.98% on the probability of those living within their neighborhood to specialize, that is a total effect of 2.62%.

- **Financial asset**

  Household heads' financial capital endowment and more precisely, loan and money transfers increase both own and neighboring households' likelihood to specialize. A CFAf1000 ($2.1) increase of the household financial capital will increase own and neighboring likelihood to specialize by 0,12% and 0.07% respectively, that is a total effect of 0.19%. This result gives the insight that higher financial assets alleviate some barriers to specialization. Moreover, financial assets constitute a risk-management tool, which reduces the need for other risk-coping strategies such as diversification.

- **Geographical asset or location**

  Both location assets, including environmental state (distance to the nearest protected area) and infrastructure (distance to market), do not significantly influence households' choices between specialization and diversification.

- **Gender and Country effect**

  Gender seems to have no impact on the choice of specializing versus diversifying. Also, Cameroonian households are less likely to specialize in their livelihood strategies.

Table 3: Marginal effect Specialization VS Diversification

	Direct effects			Indirect effects			Total effects		
	Mean	z(1.96, 5%)		Mean	z(1.96, 5%)		Mean	z(1.96, 5%)	
Social asset									
Marit_single(1=Maried)	0.0212	0.7211		0.0133	0.764		0.0345	0.748	
Hsize(continious)	-0.0193	-6.2294	**	-0.0116	-2.0044	**	-0.0309	-3.9114	**
Pygmee_employement	0.0032	0.7392		0.002	0.7896		0.0051	0.7678	
CommunityGroup(1=yes)	-0.0507	-1.7847		-0.0306	-1.219		-0.0813	-1.7702	
Autochbaka(1=pygmy)	0.1508	2.7952	**	0.0915	2.2696	**	0.2423	2.6349	**
Human Asset									
Age(continious)	0.0013	1.7187		0.0008	1.7912		0.002	1.7292	
Seniority(years in the vlge)	-0.0018	-2.7086	**	-0.0011	-1.5184		-0.0029	-2.4753	**
Schoolcycl(1=2ndschool)	-0.0283	-1.1339		-0.0164	-0.8347		-0.0447	-1.1135	
Naturel asset (access to)									
Landconflict.(1=yes)	0.021	0.6682		0.0128	0.6911		0.0338	0.6751	
Human_Wildlife(Damage cost)	0.0165	1.9409	*	0.0098	1.9419	*	0.0263	1.9458	*
Financial asset									
Finance_asset(CFAF)	0.0012	2.6644	**	0.0007	2.3046	**	0.0019	2.6551	**
Location asset									
Distance(in Km)	0.0008	1.6009		0.0004	1.6234		0.0012	1.6066	
Distmarket	0.0003	1.8139		0.0002	1.8315		0.0005	1.8077	
Other drivers									
Gender(1=Male)	0.0085	0.3258		0.0046	0.2816		0.0132	0.3022	
Country(1=Cameroon)	-0.0813	-2.7045	**	-0.0465	-1.5516		-0.1278	-2.8956	**

6.3.2. Non-land-conversion activities vs land-conversion activities

Table 4 displays the marginal effects for the trade-off between non-land-conversion activities (which consists of forest-based specialization) vs land-conversion activities. This brings interesting insights, as it can help to understand which factors lead households to engage in activities related to land-use change and deforestation. As a matter of fact, households taking the non-land-conversion strategy were associated with average levels of deforestation of 1.78 ha, while those engaged in land-conversion activities had average deforestation levels of 5.57 ha.

- **Social asset**

  The household size and the indigenous status of the households are both the social assets that influence households' likelihood to adopt either forest-based or land-conversion activities. Increasing household i_i's size by one unit will significantly decrease both own and neighboring households' likelihood to adopt forest-based activities as livelihoods strategy by 1.69% and 1.58% respectively. This result suggests that land-conversion activities are more labour intensive than others, and increased household size facilitates conversion. Belonging to the pygmy ethnicity is associated with a greather likelihood (18.8%) to adopt forest-based strategy, with a significant indirect spatial effect of 17.9% on the neighboring preferences for such strategy.

- **Human asset**

  This table suggests that education level does not influence households' decision between forest-based strategy and land-conversion strategy. However, the direct and the indirect, and thus the total impact of the household age and seniority on this trade-off, is significant, the first being positive and the second negative. In detail, when a household becomes one year older, their probability to practice non-conversion strategy increases by 0.15% with a positive spillover effect of 0.14% on their neighborhood. The resulting total effect is an increase in the likelihood to specialize by 0.29%. With regard to seniority, households who settled long ago in villages will be more likely to base their livelihoods' strategies on land-conversion activities. They are associated with an additional 0.21% probability to keep such strategies and with 0.2% positive spillover effect on their neighborhood.

- **Natural asset**

  Among the factors that influence access to natural assets, land conflict in a neighborhood does not have any effect. Moreover, human-wildlife conflict remains non neutral as in the preceding subsection. An increase of CFA1000 in crop damage by elephants increases the likelihood of the concerned household's head to prefer non-conversion strategies by 1.74% with a 1.62% positive knock-on effect on the neighboring household likelihood to adopt the same strategies.

- **Geographical asset or location**

  Distance to the nearest protected area remains non significant as previously. In contrast, households living far from local markets are more likely to rely on non-conversion strategies for their livelihoods, with a positive spillover effect within their neighborhood. This may reflect transport costs that are larger, which leads to lower profitability of agriculture and especially cash crops.

- **Other assets**

  Financial assets, gender and country do not exert any effect on the household decision in this trade-off.

Table 4: Marginal effect Non-land-conversion VS Land-conversion

	Direct Effect			Indirect Effect			Total Effect		
	Mean	z(1.96, 5%)		Mean	z(1.96, 5%)		Mean	z(1.96, 5%)	
Social asset									
Marit_single(1=Maried)	-0.009	-0.3605		-0.0084	-0.3319		-0.0174	-0.3451	
Hsize(continious)	-0.0169	-5.427	**	-0.0158	-2.813	**	-0.0327	-4.6673	**
Pygmee_employement	-0.0052	-1.2117		-0.0049	-1.0165		-0.01	-1.1997	
CommunityGroup(1=yes)	-0.0347	-1.319		-0.0328	-1.0939		-0.0675	-1.2449	
Autochbaka(1=pygmy)	0.1886	3.9571	**	0.179	3.0834	**	0.3676	3.6718	**
Human Asset									
Age(continious)	0.0015	2.2978	**	0.0014	2.222	**	0.0029	2.2329	**
Seniority(years in the vlge)	-0.0021	-3.3589	**	-0.002	-2.1831	**	-0.0041	-2.8667	**
Schoolcycl(1=2ndschool)	-0.0232	-1.0763		-0.0207	-0.9471		-0.0439	-1.0341	
Naturel asset (access to)									
Landconflict.(1=yes)	0.0374	1.2849		0.0352	1.3231		0.0726	1.303	
Human_Wildlife(Damage cost)	0.0174	2.341	**	0.0162	2.2367	**	0.0336	2.3308	**
Financial asset									
Finance_asset(CFAF10^3)	0.0004	1.1673		0.0003	1.2182		0.0007	1.1754	
Location asset									
Distance(in Km)	0.0002	0.5494		0.0002	0.5213		0.0005	0.5464	
Distmarket	0.0004	2.2866	**	0.0004	2.2933	**	0.0008	2.3702	**
Other drivers									
Gender(1=Male)	-0.0032	-0.1267		-0.0029	-0.1214		-0.0061	-0.1268	
Country(1=Cameroon)	-0.0472	-1.641		-0.0421	-1.5131		-0.0894	-1.7657	

6.3.3. Forest-based vs non forest-based

- **Social asset**

  Social capital, such as being part of a community group of interest, pygmies employment and the household size do not exert any influence on the households trade-off between forest-based activities and land-conversion strategies; while marital status and the indigenous status of the households do. Being married decreases the household head's likelihood to expect at least 30% of his/her income from forest-based activities by 6.4% without indirect spatial spillover effect within their neighborhood. In contrast, being a pygmy household head is associated with 25.6% more chances to exert livelihood strategies that value forest. This result is consistent with the main activity of pygmy communities being related to forests, specialization and non-land-converting-activities.

- **Human asset**

  Age is the only households' human asset that impacts the likelihood to choose or not to choose among both strategies in this trade-off.

- **Natural asset**

  Land-use conflict among households does not influence household heads' choice in this trade-off. But the marginal effect resulting from increasing the cost of crop damage caused by wildlife increases the likelihood of the household to choose strategies associated with at least 30% of income from forest.

- **Other assets**

  Financial asset, geographical asset, including distance to the nearest protected área, and distance to the nearest market, gender and country do not influence the preferences within the third trade-off.

Table 5: Marginal effect strategies valuing forest VS Non valuing forest

	Direct effect			Indirect effect			Total effect		
	Mean	z(1.96, 5%)		Mean	z(1.96, 5%)		Mean	z(1.96, 5%)	
Social asset									
Marit_single(1=Maried)	-0.0642	-2.0832	**	-0.1713	-1.8273		-0.2355	-1.9699	**
Hsize(continious)	-0.0046	-1.4943		-0.0121	-1.3673		-0.0167	-1.451	
Pygmee_employement	-0.0059	-1.3073		-0.0158	-1.2937		-0.0217	-1.3438	
CommunityGroup(1=yes)	-0.0287	-1.0346		-0.0776	-0.9803		-0.1063	-1.0561	
Autochbaka(1=pygmy)	0.2561	3.899	**	0.6889	3.4181	**	0.945	3.6702	**
Human Asset									
Age(continious)	0.0023	3.2291	**	0.0061	3.2878	**	0.0084	3.2939	**
Seniority(years in the vlge)	-0.0014	-1.9094		-0.0036	-1.757		-0.005	-1.822	
Schoolcycl(1=2ndschool)	-0.0194	-0.7046		-0.0521	-0.6465		-0.0715	-0.6632	
Naturel asset (access to)									
Landconflict.(1=yes)	0.008	0.2375		0.0225	0.2645		0.0305	0.2547	
Human_Wildlife(Damage cost)	0.0304	3.2818	**	0.0812	3.2239	**	0.1116	3.3479	**
Financial asset									
Finance_asset(CFAF10^3)	-0.0004	-1.1009		-0.001	-1.0613		-0.0013	-1.0746	
Location asset									
Distance(in Km)	-0.0004	-0.9262		-0.0012	-0.8947		-0.0016	-0.9092	
Distmarket	0.0002	1.0903		0.0006	1.0749		0.0008	1.0843	
Other drivers									
Gender(1=Male)	0.0502	1.7329		0.1351	1.7548		0.1854	1.7539	
Country(1=Cameroon)	0.0037	0.1363		0.0108	0.1428		0.0145	0.1399	

7. Discussion and conclusion

In rural areas of the developing world, livelihood strategies have key choices determining population wellbeing, sustainability and natural resource management. Yet, these choices are constrained by many types of variables, including assets at households' disposal. It is then of crucial importance to understand to what extent these assets influence the choice of livelihoods' strategies. In this paper, we argue that the choice of activities portfolios can be decomposed in diverse strategic choices. We focus on the choices of diversification versus specialization, land-conversion activities versus non-land-conversion activities, and forest-based activities versus non-forest-based activities. Moreover, we give a special emphasis to spatial spillovers, relying on the assumption that individual choices have external impacts within his/her neighborhood. For that purpose, we rely on a unique dataset of households survey, conducted in the Tridom-TCL.

Our paper brings interesting insights. First, belonging to the pygmy community has some key influence on livelihood choices: Pygmies tend to specialize in forest-based activities and to avoid land-converting activities. This result is not a surprise per se, but it underlines that autochthonous status has a strong influence on livelihood choices. Pygmies have historically been living in the forest and depending on forest products. Their traditional livelihood strategies are hunting bushmeat and gathering NTFP; this is why they are usally labelled as hunter- gatherers.

Second, we find evidence of a few drivers of specialization. Financial assets increase the likelihood to specialize. This can be explained by the fact that such assets can be seen as a safety net in case of shocks. Thus, higher financial assets decrease households' vulnerability, and increase the need to diversify to cope with risks. Seniority and household size increase the likelihood to diversify. These factors may have two kinds of explanation: (1) a larger household may increase the need to cope efficiently for all the risks the family faces; (2) these factors can also represent a higher capacity of larger households with deep roots in the community to diversify.

Third, the choice of land-converting activities is driven by household size, newer arrivants in the community, and smaller distance to markets. Indeed we can expect larger households to be able to engage in activities that are more land extensive, as it can represent a larger labour force. Smaller distance to markets represents smaller transportation costs, and thus higher profitability of land-converting activities.

Fourth, the role of wildlife conflict has to be pointed out. Larger crops losses implicitly increase forest valuation and the need to cope with the crops losses but also increase land conversion. Following this argument, it is interesting to analyze how human-wildlife conflicts influence the household preferences for wildlife conversation (this is done in Ngouhouo Poufoun et al. (2016)). Environmental state is also important when dealing with livelihood choices. Proximity to protected areas does not seem to impact these choices. This gives the insight that conservation policies do not influence much households in the neighborhood. Thus it appears that environmental protection is not carried out at the expense of setting more constraints on households' livelihood choices. Likewise, it appears that land conflicts do not influence the choice of livelihoods' strategies. This can indicate that access to land is not scarce in the study area. In this case, land access does not seem to impose a strong constraint on households in their livelihood choices.

Finally, it is crucial to note the existence of spatial spillovers. In all cases, the direct effects of the assets on livelihood choices are combined with indirect effects on the neighborhood. This result can be related to agglomeration effects: households of the same types tend to live in the same neighborhood. It can be also related to mimicking or other types of spatial dissemination.

The three strategic choices that we analyse in this paper have an impact in terms of well being, but also in terms of land use. A quick look at the figure (AppendixA.2) in appendix shows that households that specialize have better economic outcomes, both in terms of yields and income, than those diversifying their activities. This is consistent with the fact that households choosing specialization strategies tend to be income maximizers, while those choosing diversification tend to have others objectives, such as risk coping or they make a constrained choice. In terms of land use, specialized households tend to have smaller deforestation levels than others. Thus if economic development reduces households' vulnerability to shocks (e.g., through better access to markets), this can bring larger deforestation rates if those households decide to specialize [10].

When comparing households focusing on land-conversion activities, they unsurprisingly tend to have larger deforestation levels than others. In terms of economic outcomes, they have slightly lower levels of income, which may seem surprising. In such case, it is likely that higher income from households relying on cash crops are balanced by lower income for small scale farming households. In the same manner, one can see that households relying on forest resources have lower deforestation levels, while their income is comparable to others. Thus it appears that giving incentives to households so that they rely on forest resources would help to protect forests, while not hurting their livelihoods.

This work opens the field for further research using our database. First, the impact of the livelihood choices on deforestation requires a deeper analysis. Second, as mentioned, risk is an important matter in rural areas. Analyzing factors influencing households risk preferences, and the way those risk preferences

[10] However, this result may be driven by the presence of cash crops in the diversified portfolios. This would require further investigations in terms of land-use analysis.

influence livelihoods, deforestation and ecosystem services preferences is of crucial matter.

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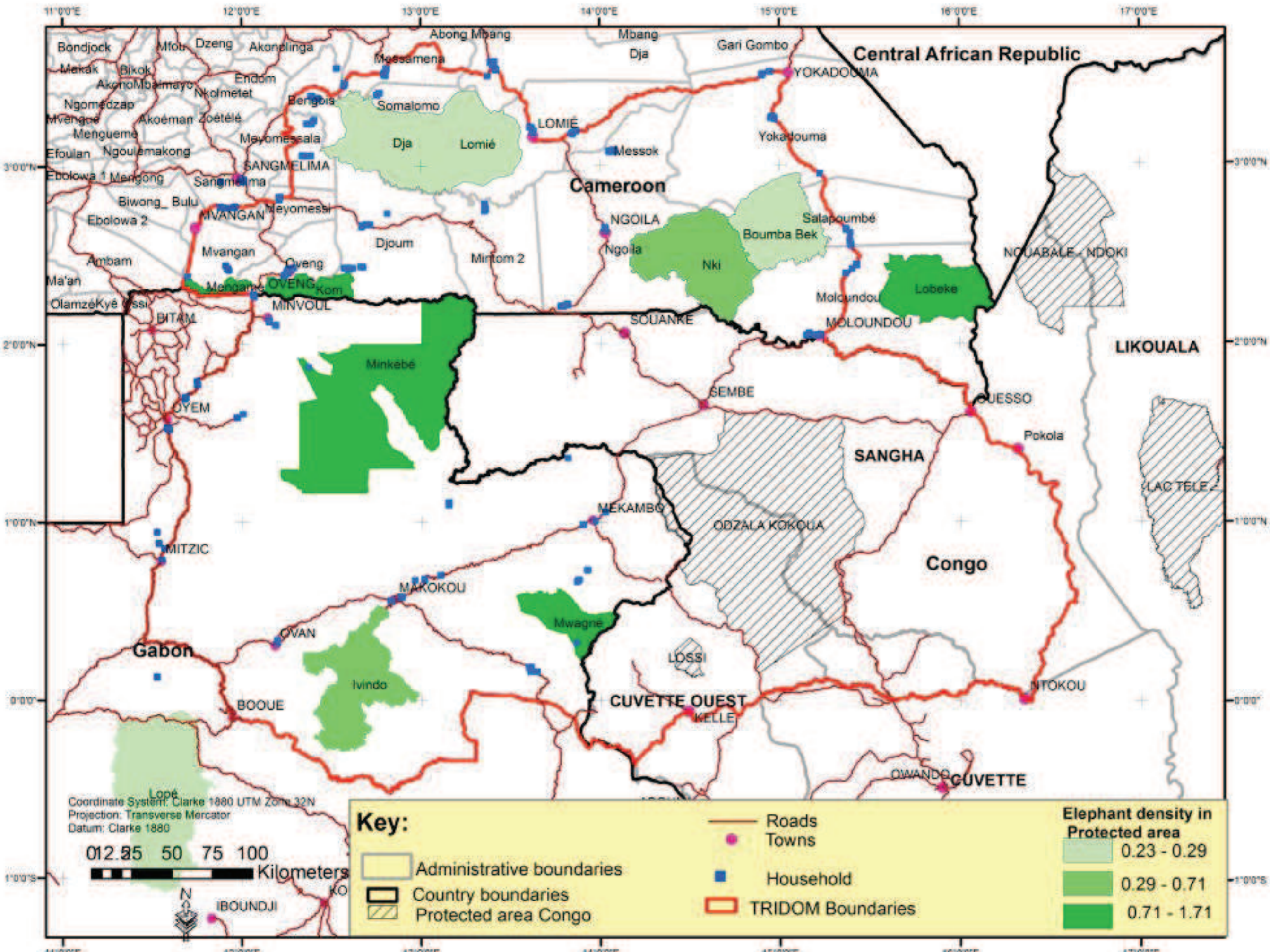
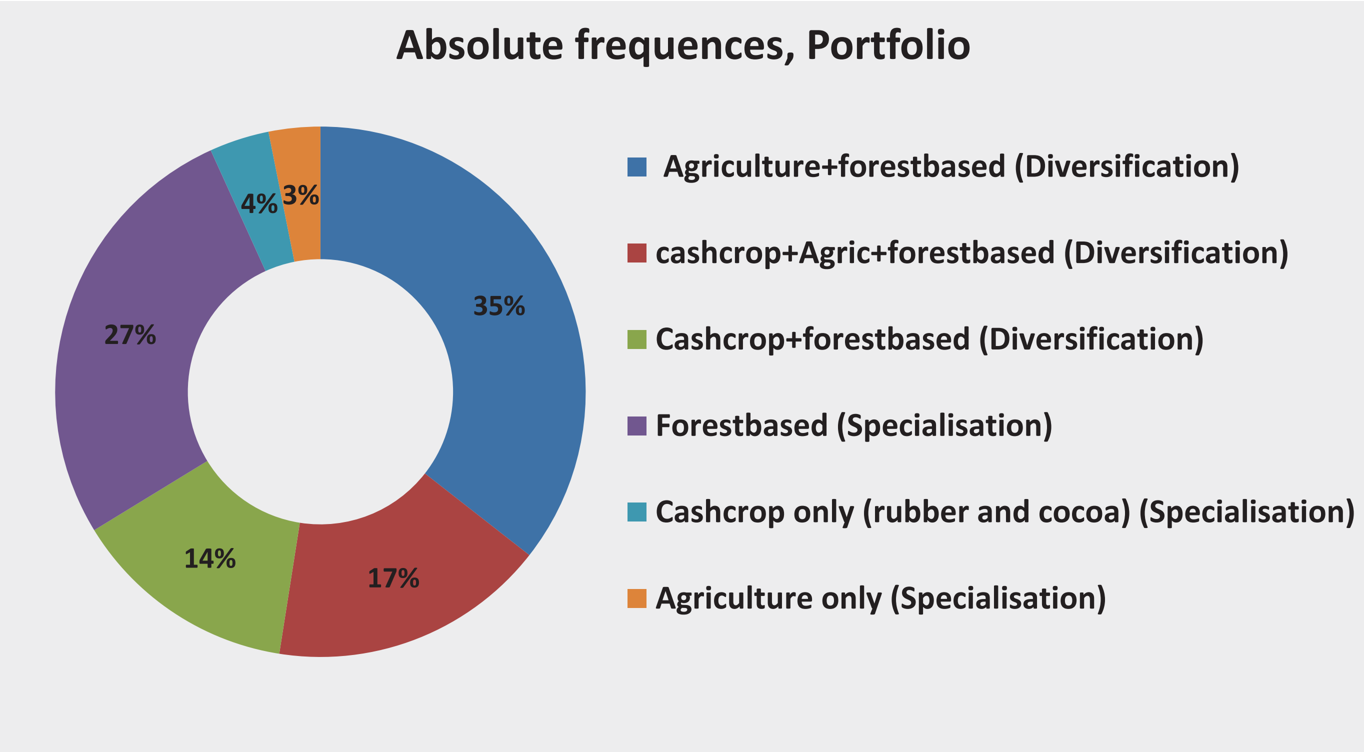
AppendixA. Figures

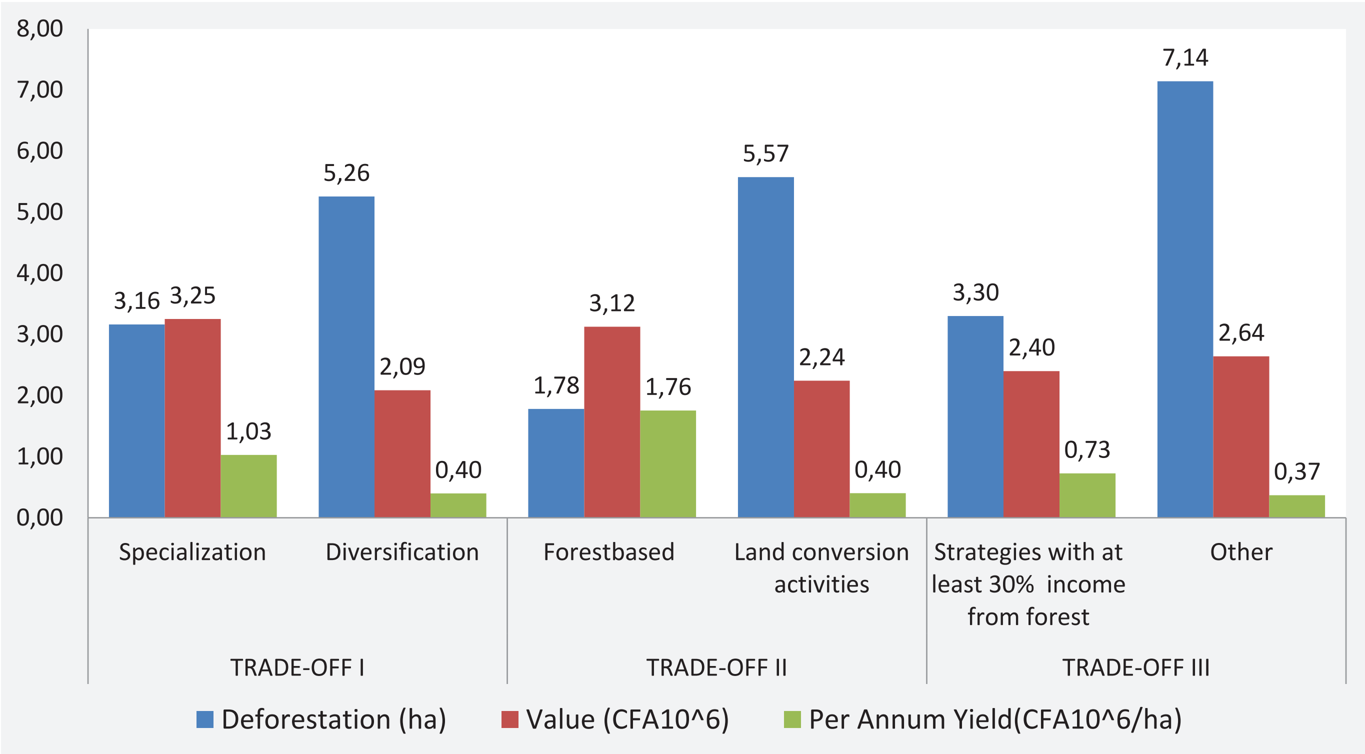
AppendixA.1. Study Area and Location of households surveyed



AppendixA.2. Absolute Frequencies of Households Strategies



AppendixA.3. Trade-offs in livelihoods, Deforestation and Per Annum Yiels/ha



AppendixB. Tables

AppendixB.1. Measurement of NTFP in the forest-based strategy

Scientific name	Vernacular name	Measure unit	Measure Conversion	Season (Months per year)	Conversion 12 pails
Ricinodendron Heudelotti	Ndjassang	5-liter pail	1 pail=7,5kg	2	1 bag=90kg
Gnetum africanum	Okok	packs	1 pack=2,5kg	12	
Irvingia Gabonensis	Peke/Ndo'o	5-liter pail	1 pail =4kg	2 - 3	1 bag=48kg
Elaeis guinensis	palm nuts	5-liter pail	1 =7,5kg	12	1 bag=90kg
Fungi	Edible mushroom	5-liter pail	1 pail=2,5kg	5	
Coula edulis	Noisettes	5-liter pail	1 pail = 6kg	2 - 3	1 bag=72kg
Garcinia kola	Bita Kola	5-liter pail	1 pail =7,5kg	3	1 bag=90kg
Cola acuminata	Cola spp	5-liter pail	1 pail = 10kg	3	1 bag= 120kg
Monodora myristica	Pepe/ndind	5-liter pail	1 pail = 5kg	3	1 bag=60kg
Pausinystalia johimbe, garcinia klaineana,	Bark	5kg	5kg	12	
Dacryodes edulis	Safout	5-liter pail	1 pail = 7,5kg	3	1 bag=90kg
Calameae	Rattan	bundle	KG		
Piper nigrum	sap	5-liter pail	1 pail = 6kg	12	1 bag=72kg
Raphia farinifera	Raphia	bundle			
Diospyros nigra	black fruits	5-liter pail	1 pail = 7,5kg	12	bag=90kg
Fagus	Fuelwood	bundle	1 bundle=25kg	12	
	Matango	liter		12	
Baillonella Toxisperme	Adjap moabi	liter			
Morinda	Ndong-Tondo	5-liter pail	1pail = 6kg	12	1 bag=72kg
Afrostyrax lepidophyllus.	Nguimba sihé	5-liter pail	1 pail = 5kg	3	1 bag=60kg

AppendixB.2. Descriptive statistique among various trade-off

PART I	Specification (n=333)				Diversification (n=654)			
	Mean	St Dv	Min	Max	Mean	St Dv	Min	Max
Country(1=Cameroon)	0.62	0.48	0	1	0.78	0.41	0	1
Age(continious)	47.81	15.42	16	90	48.77	14.18	17	90
Gender(1=Male)	0.75	0.43	0	1	0.78	0.42	0	1
Marit_single(1=Maried)	0.66	0.47	0	1	0.73	0.45	0	1
Hsize(continious)	5.27	3.65	0	20	7.12	4.04	0	19
CommunityGroup(1=yes)	0.22	0.42	0	1	0.31	0.46	0	1
Seniority(years in the vlge)	24.08	21.22	0	86	28.5	20.3	0	90
Autochbaka(1=pygmy)	0.08	0.26	0	1	0.04	0.19	0	1
Schoolcycl(1=2ndschool)	0.52	0.5	0	1	0.58	0.49	0	1
Landconflict.(1=yes)	0.17	0.37	0	1	0.18	0.38	0	1
Human_Wildlife(Damage cost)	0.76	1.56	0	8.33	0.55	1.39	0	8.33
Distance(in *km*)	30.67	23	0	94.54	28.6	22.34	0	94.55
Distance to Market (in *km*)	64.84	58.23	0	224.12	65.47	59.65	0	224.01
Finance_asset(CFAF/month)	11.67	52.34	0	750	7.12	17.28	0	170.83

PART II	Forest-based act. (n=266)				Land-Conversion (n=721)			
	Mean	St Dv	Min	Max	Mean	St Dv	Min	Max
Country(1=Cameroon)	0.6	0.49	0	1	0.78	0.42	0	1
Age(continious)	46.61	15.57	16	90	49.12	14.19	17	90
Gender(1=Male)	0.74	0.44	0	1	0.78	0.42	0	1
Marit_single(1=Maried)	0.62	0.49	0	1	0.74	0.44	0	1
Hsize(continious)	4.94	3.26	0	18	7.07	4.11	0	20
CommunityGroup(1=yes)	0.21	0.41	0	1	0.3	0.46	0	1
Seniority(years in the vlge)	22.76	20.71	0	86	28.58	20.5	0	90
Autochbaka(1=pygmy)	0.09	0.29	0	1	0.03	0.18	0	1
Schoolcycl(1=2ndschool)	0.49	0.5	0	1	0.58	0.49	0	1
Landconflict.(1=yes)	0.17	0.38	0	1	0.18	0.38	0	1
Human_Wildlife(Damage cost)	0.83	1.63	0	8.33	0.54	1.37	0	8.33
Distance(in *km*)	28.89	22.02	0	94.4	29.45	22.79	0	94.55
Distance to Market (in *km*)	63.55	57.73	0	224.12	69.13	61.14	0	224.01
Finance_asset(CFAF/month)	9.4	49.91	0	750	8.39	24.97	0	425

PART III	Strategies + Forest (n=666)				Other strategies (n=321)			
	Mean	St Dv	Min	Max	Mean	St Dv	Min	Max
Country(1=Cameroon)	0.69	0.46	0	1	0.81	0.39	0	1
Age(continious)	48.01	14.86	16	90	49.34	14.07	17	81
Gender(1=Male)	0.76	0.43	0	1	0.78	0.41	0	1
Marit_single(1=Maried)	0.66	0.47	0	1	0.79	0.4	0	1
Hsize(continious)	6.13	3.85	0	19	7.25	4.23	0	20
CommunityGroup(1=yes)	0.26	0.44	0	1	0.33	0.47	0	1
Seniority(years in the vlge)	26.2	20.75	0	90	28.7	20.57	0	80
Autochbaka(1=pygmy)	0.06	0.25	0	1	0.02	0.15	0	1
Schoolcycl(1=2ndschool)	0.53	0.5	0	1	0.63	0.48	0	1
Landconflict.(1=yes)	0.17	0.37	0	1	0.19	0.39	0	1
Human_Wildlife(Damage cost)	0.71	1.55	0	8.33	0.43	1.19	0	6.67
Distance(in *km*)	27.85	21.45	0	94.49	32.3	24.52	1.52	94.55
Distance to Market (in *km*)	58.65	56.81	0	224	68.14	59.36	0	224.12
Finance_asset(CFAF/month)	7.4	34.07	0	750	11.27	32.3	0	425

AppendixB.3. Standard Probit VS SAR-Probit

	Standard Probit Model			***SAR-Probit Model***				
	Estimates		Marginal effect	***Estimates***		***Direct effects***	***Indirect effects***	***Total effects***
Country	-0.4210	***	-0.1418	***-0.2464***	**	***-0.0813***	***-0.0465***	***-0.1278***
Age	0.0025		0.0008	***0.0038***		***0.0013***	***0.0008***	***0.002***
Gender	0.0180		0.0061	***0.0258***		***0.0085***	***0.0046***	***0.0132***
Marit_single	0.0604		0.0203	***0.0640***		***0.0212***	***0.0133***	***0.0345***
Hsize	-0.0596	***	-0.0201	***-0.0584***	***	***-0.0193***	***-0.0116***	***-0.0309***
Pygmee_employt	0.0098		0.0033	***0.0095***		***0.0032***	***0.002***	***0.0051***
CommunityGroup	-0.1440		-0.0485	***-0.1531***		***-0.0507***	***-0.0306***	***-0.0813***
Seniority	-0.0058	**	-0.0019	***-0.0056***	**	***-0.0018***	***-0.0011***	***-0.0029***
Autochbaka	0.4056	**	0.1366	***0.4552***	**	***0.1508***	***0.0915***	***0.2423***
Schoolcycl	-0.1045		-0.0352	***-0.0857***		***-0.0283***	***-0.0164***	***-0.0447***
Landconflict.	0.0733		0.0247	***0.0631***		***0.021***	***0.0128***	***0.0338***
Human_Wildlife	0.0476		0.0160	***0.0497***	*	***0.0165***	***0.0098***	***0.0263***
Distance	0.0032	*	0.0011	***0.0023***		***0.0008***	***0.0004***	***0.0012***
Distmarket	0.0016	**	0.0005	***0.0010***		***0.0003***	***0.0002***	***0.0005***
Finance_asset	0.0030	*	0.0010	***0.0036***	**	***0.0012***	***0.0007***	***0.0019***
ρ	-			***0.3620***	**			

AppendixB.4. results' accuracy with the weight matrix type

	Specialisation vs Diversification				
	Gabgrah	3NN	5NN	10NN	Distance
ρ	0.0501	0.2322***	0.2974***	0.3682***	0.3616**
AIC Criterion	1200.15	1194.85	1194.12	1190.58	1199.26
logLik.sarprobit	-584.07	-581.42	-581.06	-579.29	-583.63

AppendixB.5. Variance Inflation Factor

Variable	VIF	1/VIF
Age	1.56	0.64
Country	1.51	0.66
Seniority	1.40	0.71
Marit_single	1.30	0.77
Distmarket	1.26	0.79
Schoolcycl	1.22	0.82
Pygmee_employment	1.13	0.88
Autochbaka	1.13	0.89
Distance to nearest Protected Area	1.12	0.89
Hsize	1.09	0.92
Gender	1.09	0.92
CommunityGroup	1.08	0.93
Landconflict	1.05	0.95
Financial Asset	1.05	0.96
Human_Wildlife ConflictDamage cost	1.04	0.96
Mean VIF	1.20	

AppendixB.6. Correlation matrix among quantitative variables

		v2	v7	v8	v11	v12	v13	v14	v15
Age	v2	1,00							
Hsize	v7	0,03	1,00						
Pygmee_employment	v8	-0,12	0,18	1,00					
Human-Wildlife ConflictDamage cost	v11	-0,03	-0,07	-0,03	1,00				
Seniority	v12	0,47	0,10	-0,01	-0,02	1,00			
Distance to nearest Protected Area	v13	0,10	-0,02	-0,03	0,00	-0,03	1,00		
Distmarket	v14	-0,13	-0,04	0,09	0,01	-0,02	-0,29	1,00	
Financial Asset	v15	0,03	0,03	0,00	-0,02	-0,10	0,06	-0,09	1,00