Impact of protected areas on fuel choice : the case of Ivorian households

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Abstract

In Côte d'Ivoire, the vast majority of households use biomass as a cooking fuel. The objective of this study is to understand how the establishment of a protected area could modify the fuel choice of households. Using a mixed-effect model, the results show that the presence of a protected area influences household fuel choice. The presence of a protected area increases the risk of using biomass and more specifically purchased biomass compared to clean fuel. Furthermore, the influence of the protected area on fuel choice depends on the type of protected area and the area of residence. In addition, the choice of household fuel type depends on several factors such as the characteristics of the head of household and the socio-economic status of the household.

Keywords : *protected area, biomass, cooking fuels, Côte d'Ivoire*

1 Introduction

Côte d'Ivoire, a sub-Saharan African country once renowned for the extent and richness of its tropical forests, has seen its forest cover practically disappear in less than half a century for several reasons. This deforestation can be explained by the implementation of the "plantation economy" (Dao, 2004; Koné et al., 2014), the population density (Dao, 2004) and certain agricultural practices such as the intensification of agricultural clearings, bush fires (Koné et al., 2014). According to the results of the recent National Forest and Wildlife Inventory (IFFN), the country has a national forest area of 2.97 million hectares, of which 674,500 hectares are protected areas (TIMBER TRADE PORTAL, 2023).

In addition, as part of the implementation of the ECOWAS Renewable Energy Policy (PERC), Côte d'Ivoire put in place a National Renewable Energy Action Plan (PANER) in 2016 (WHO, 2022). The main objective of the PANER is to contribute to the achievement of the targets set by the PERC for 2030. To achieve this overall goal, Côte d'Ivoire has set itself some specific objectives. The first is to increase access to clean energy and to reduce the demand for polluting energy, more specifically to reduce the amount of wood energy used to meet household energy needs. To achieve this, awareness-raising activities on the use of improved stoves and butane gas have been undertaken (MPE, 2016). The second is the reduction of polluting emissions and the preservation of the forest cover. Indeed, in terms of cooking, biomass energy (firewood, charcoal, vegetable waste) represents a little more than 2/3 of the total final energy consumption of households (MPE, 2016). In view of the consumption of wood-energy, the vegetation cover of Côte d'Ivoire risks disappearing if nothing is done, as the Ivorian forest has gone from 9 million ha in 1965 to 2.8 million ha in 2021 (MPE, 2016; TIMBERTRADE, 2022). To achieve this, the PANER aims to increase the share of the population consuming modern alternative cooking fuels such as LPG to 90% by 2030 (MPE, 2016). Another important specific objective is to achieve gender equity in terms of cooking fuel use (MPE, 2016). Through PANER, Côte d'Ivoire is working to reduce the use of solid fuels (coal and biomass).

In sub-Saharan Africa, forests are a source of livelihood for poor households living in their vicinity. For example, they find food or firewood there. However, in the drive to combat deforestation and preserve biodiversity, protected areas have been set up. According to the IUCN (International Union for Conservation of Nature), a protected area is *"a clearly defined geographical space, recognised, dedicated and managed, by any effective legal or other means, to ensure the long-term conservation of nature and its associated ecosystem services and cultural values"*. Previous studies have looked at the impacts of the presence of protected areas and the authors find an effect on health (Romagosa et al., 2015; Puhakka et al., 2017; Jiricka-Pürrer et al., 2019; Buckley et al., 2019), household income (Nepal, 1997; de Sherbinin, 2008; Naidoo et al., 2019) and deforestation (Andam et al., 2008; Clark et al., 2008). Given that the establishment of a protected area helps to combat deforestation, the objective of the study is to find out how the presence of a protected area shapes the fuel choice of households living in the locality.

This study stands out in several ways. First, to my knowledge, this is the first to examine the impact of protected areas on the fuel choice of Ivorian households. Second, given the non-random distribution of protected areas, I take into account the characteristics of the sub-prefecture that may influence the location of protected areas. Thirdly, I use a multilevel mixed-effects logistic model that allows to take into account the structure of the data, which in reality are household and sub-prefecture level data. And random effects at the household level were added to the model to take into account certain factors that may affect the household fuel choice. Finally, to answer the research question, I use data from the 2015 Côte d'Ivoire Household Living Standards Survey and the World Database on Protected Areas (WDPA). This study is the first to use these data to investigate the relationship between the presence of protected areas and household fuel choice. I show that protected areas influence household fuel choice in Côte d'Ivoire.

The results show that the presence of a protected area influences household fuel choice because it increases the risk of using biomass and more specifically purchased biomass compared to clean fuel. Furthermore, the impact depends on the type of protected area and the area of residence. In addition, the choice of household fuel type depends on several factors such as the characteristics of the household head and the socio-economic status of the household.

The rest of the study is organised as follows : the next section presents the literature review. The materials are presented in the third section. The fourth and fifth sections describes respectively the stylized facts and the econometric analysis. Then, the sixth and seventh sections are devoted respectively to the presentation of the robustness checks and the heterogeneity tests. The last section discusses the conclusion and policy implications.

2 Background

2.1 Protected areas and their different impacts

Protected areas play several roles, including natural water purification in wetlands and carbon sequestration in forests. This helps to combat global warming. Several studies have looked at the different socio-economic impacts of protected areas. One group of authors finds that protected areas have an economic value because they improve the mental health and well-being of the population. Using the quality-adjusted life years (QALY), Buckley et al. (2019) show that this value amounts to 6,000 billion dollars per year in Australia. In the same vein, Koss et al. (2010) find a positive effect of protected areas on the mental health of volunteers who care for them. Visitors report that protected areas have a positive effect on their psychological, physical and social health (Puhakka et al., 2017; Romagosa et al., 2015; Jiricka-Pürrer et al., 2019).

In addition, another group of studies agree that protected areas affect the health of populations through improved nutrition. Aswani and Furusawa (2007) supports this idea by comparing two villages, one with a marine protected area and one without. The results show that the populations of the village with a marine protected area had a higher energy and protein intake than those of the other village without a protected area.

Also, some authors give protected areas the power to generate income for local populations, especially in developing countries. It is in this sense that Nepal (1997) proves that the benefits derived from wildlife or nature tourism in protected areas can meet the livelihood needs of local communities. de Sherbinin (2008) looks at the relationship between poverty and living near a park or protected area. By approximating poverty by the infant mortality rate, the results show an uncertain causal relationship between poverty and proximity to a protected area. In contrast, Naidoo et al. (2019) find a relationship between proximity to a protected area, poverty and general well-being. Indeed, households in the vicinity are richer and children do not show stunted growth compared to similar households that are far from the protected area. The authors explain this by tourism activities that generate income. This income could be used for medical consultations and the purchase of medicines. Also, wildlife conservation promotes the multiplication of animals that households can later sell. Also, the presence of a protected area favours the construction of infrastructure, especially roads, and this facilitates the transport of the sick.

Apart from its positive impact on human health, protected areas are considered an excellent tool for reducing deforestation. Several studies deal with the effect of protected areas on deforestation (Andam et al., 2008; Clark et al., 2008). These authors believe that protected areas help to combat deforestation. Indeed, the fact that certain parts of the forest are protected discourages the population from deforesting these parts on pain of paying a fine. It is in this sense that Andam et al. (2008) show that between 1960-1970, 10% of the protected forests would have been deforested if they were not protected in Costa Rica. Clark et al. (2008) add that the establishment of protected areas makes it possible to fight deforestation but it is not known to what extent this leads to a displacement of deforestation.

Furthermore, according to this literature, protected areas impact on the health of individuals through their positive psychological, physical and nutritional effects. They also constitute a source of income for some individuals and thus allow them to have the necessary resources to treat themselves. In addition, protected area are a tool to fight deforestation. In this study I will test the effect of the presence of protected areas on the household choice of cooking fuel. Given that the establishment of protected areas disincentivises the local population to deforest, I would expect this to change their choice of fuel.

2.2 Seeing the forest for the fuel

Tropical developing countries are home to many endangered and threatened species. As a result, many of the newer protected areas are located in poor areas of the world (Howlader and Ando, 2020). Many poor households live around protected areas. These households are highly dependent on natural resources, and more specifically forest resources, for income or subsistence. According to Velho et al. (2019) the increase in income of households living around protected areas in India, does not necessarily affect the use of collected wood as cooking fuel. It is in this same vein that Khanwilkar et al. (2021) finds that living near the forest slows down the adoption of LPG as a fuel by households in India. Also according to these authors, 90% of households using LPG continue to use firewood as fuel. The adoption of LPG does not necessarily encourage households to abandon the use of wood for cooking.

Howlader and Ando (2020) looK at the impact of protected areas on the welfare of households living in their vicinity in Nepal. The results show that the establishment of protected areas reduces timber collection by 20-40% compared to the period when there was no protected area. According to Pattanayak et al. (2004), the increased cost of accessing the forest could reduce people's dependence on collecting fuelwood from the forests. In addition, there are other factors that contribute to the decline in wood collection. These include wealth, use of alternative fuels, ownership of paraffin stoves, construction of primary schools and roads.

From previous studies it can be seen that the presence of a protected area could reduce (Pattanayak et al., 2004; Howlader and Ando, 2020) or not the use of collected fuelwood (Velho et al., 2019). In this study, we will examine the extent to which the presence of a protected area would change the fuel choice of households living in the relevant sub-prefectures in Côte d'Ivoire.

The following lines look at the data used to do the analysis.

3 Materials

This section describes the data sources and variables used.

3.1 Data

The data used in this study come from different sources. The unit of observation is the houshold, whose main characteristics are given by the 2015 household living standards survey. Main purpose of the Côte d'Ivoire household living standards survey is to provide the information needed to improve planning and evaluation of economic and social policies in Côte d'Ivoire. The survey provides information on household composition, education, employment and health, among other things. It was conducted by the National Institute of Statistics (INS) of Côte d'Ivoire. The sampling frame used to draw the sample is the 2014 General Census of Population and Housing. The sampling is based on a two-stage draw. The first stage consists of a proportional allocation of the Enumeration Areas (EAs). The second is a systematic drawing of 12 households per enumeration area. The total sample obtained consists of 12,900 African households residing in Côte d'Ivoire (INS, 2023). This study is based on a sample of 12899 households.

The information on protected areas comes from the World Database on Protected Areas (WDPA) which is a joint project of the United Nations Environment Programme (UNEP) and the International Union for Conservation of Nature (IUCN). The database includes all terrestrial and marine protected areas. For the purposes of this study, I am interested in terrestrial protected areas in Côte d'Ivoire. To obtain data on protected areas, I use the QGIS software, which has enabled us to obtain the surface area of protected areas present in the Ivorian sub-prefectures.

3.2 Outcomes variables

In the study, four indicator variables are used as dependent variables. These variables are constructed from the question *"O17: Main fuel sources"*. The possible answer modalities are: *"coal, purchased wood, collected wood, gas, electricity, oil, not applicable"*. The household was asked to choose the first three sources of fuel used. I am only interested in the first fuel source to construct the 4 dependent variables.

The first indicator takes the value of 1 when the household uses purchased or collected biomass (wood or charcoal) and the value is 0 if the household uses clean energy (gas, electricity or petroleum). This dependent variable allows us to see how the presence of a protected area influences the choice of fuel, regardless of the type of biomass supply used as fuel.

Then, the second indicator is equal to 1 when the household uses collected biomass (collected wood) and 0 when the household uses purchased biomass (coal or purchased wood). The objective of this indicator is to provide information on the extent to which the presence of a protected area could encourage the household to choose between collected and purchased biomass. The use of this outcome variable is justified by the fact that the protected area is sometimes considered a source of wood supply for some households, especially in rural areas.

The third indicator is 1 when the household uses collected biomass and 0 if it uses clean energy. The purpose of this variable is to show the extent to which the establishment of a protected area could force the household to choose between collected biomass and clean energy.

The fourth indicator equals 1 when the household uses purchased biomass and 0 if it uses clean energy. The objective is to see how the presence of a protected area might influence the household's transition from purchased biomass to clean energy.

3.3 Interest variable

After obtaining the protected area surface by sub-prefecture using QGIS software, some sub-prefectures end up with less than one square kilometre of protected area. To better target the sub-prefectures that actually have a protected area, I look at the protected areas on the map of the country, to see if the protected area actually belongs to the sub-prefecture. This allowed me to construct a "presence of protected area" indicator which is equal to 1 when the area of protected area present in the sub-prefecture is greater than 0.0128393 km^2 and the value of the indicator is 0 if the area is less than this value. I defined this threshold based on cartographic observation.

On the graph 1, it can be seen that there is a great difference between protected areas in terms of surface area. The very large protected areas are more concentrated in the North-East and South-West of the country. In the North-East, more precisely in the Savanes and Zanzan districts, is the Comoé National Park with a surface area of 1,149,150 hectares. In the south-western zone, there are large national parks such as the Mont Péko National Park, the Tai National Park, the Mont Sangbé

National Park and the Azagny National Park. These parks were created in the 1960s, 1970s and 1980s.

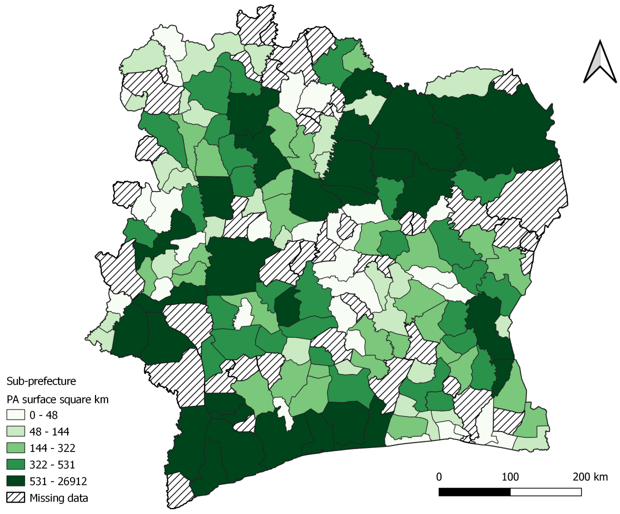

Figure 1: Size of protected areas by sub-prefecture

3.4 Covariates

Several factors influence household fuel choice in sub-Saharan Africa.

The first set of covariates used concerns the characteristics of the household head. I start by taking into account the age of the household head. The age of the head of the household is a very important characteristic that could affect the consumption choices of household members. Through an empirical study on the determinants of the transition to cleaner cooking energy in Ghana, Bofah et al. (2022) find that youth-headed households have a low probability of using dirty energy compared to elderly-headed households in Ghana. The authors explain this by the decrease in income of the elderly head of household. As a result, the household chooses cheaper fuels that unfortunately pollute a lot. To add, the author's result could be explain by the fact that these elderly-headed households do not have information about the harmful effects of using dirty energy. According to the descriptive statistics (Table A1), the household head age ranges from 15 to 120 years with an average age of 41 years.

The gender of the head of household is an important determinant in the choice of cooking fuel. Bofah et al. (2022) shows that female-headed households are about 1.3 times more likely to use dirty cooking energy (i.e. wood and charcoal). Indeed, female-headed households are likely to be poorer than male-headed households (Javed and Asif, 2011). This could be explained by the fact that these women do not have financial support from a spouse either because they are single, divorced or widowed.

Furthermore, the level of education and the type of occupation of the head of the household are also essential factors in the choice of cooking energy. Indeed, Bofah et al. (2022); Twumasi et al. (2021) show that the choice of fuel is influenced by the level of education of the head of household and non-agricultural employment. Having a high level of education would enable the household head to better understand the adverse effects of biomass use on the health of household members. The type of occupation of the household head informs about the economic conditions of the household.

In order to better take into account the level of household wealth, I construct a wealth index. Indeed, the construction of the wealth index is very important in a context where information on the level of income or expenditure of households is not reliable. It allows us to measure the economic status of households. It is created by aggregating information on housing, physical capital and assets held by the household. Thus, the value of the index provides information on the living conditions of households that affect the well-being of individuals. The index is created through multiple component analysis. The synthetic index obtained is then normalised and thus lies between 0 and 1 with an average of 0.18 (Table A1). The higher the level of wealth, the closer the index will be to 1. The variables used and their definitions are found in Table B1 in Annex B.

The size of the household influences the household's choice of fuel bofah2022transition,twumasi2021determinant Indeed, the larger the household, the more fuel expenses increase because a large quantity of food must be cooked. Under these conditions, a low-income household will have to choose a cheaper fuel, i.e. biomass. The average household size in the sample is about 4 members with a maximum size of 36 members (Table A1).

In addition to the information that allows us to understand the socio-economic status of households, which strongly influences household fuel choice, I need to take into account the characteristics of the sub-prefecture. To this end, I include rainfall, temperature and the number of mammals and birds in the analysis. This information could influence the establishment of a protected area in a zone.

The following section provides an understanding of the correlations between the presence of protected areas and household fuel choice.

4 stylized facts

Biomass is widely used in developing countries. This is the case in African countries, notably Côte d'Ivoire. Before the econometric analysis, it is important to look for a possible correlation between the use of biomass by households and the presence of protected areas. The graph 2 is in line with this idea. It shows that 52.58% of households in the sample that use biomass (firewood and charcoal) live in sub-prefectures where there is a protected area.

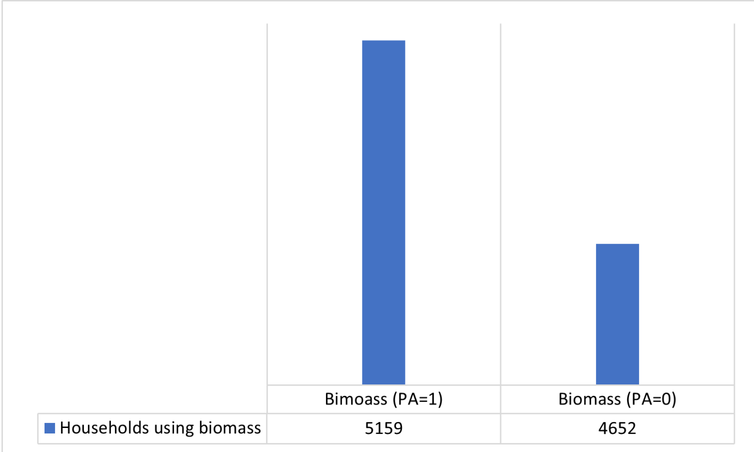

Figure 2: Households using biomass for fuel by presence of protected areas

Furthermore, the presence of a protected area could alter households' fuel choices in several ways. This is the logic behind 3. The graph on the left shows that 73.8% of households that use purchased biomass (fuelwood or charcoal) are located in sub-prefectures where there is a protected area. In view of these figures, it is tempting to say that the presence of a protected area would discourage households from using collected biomass, and more specifically collected wood. In other words, the presence of a protected area means that it is forbidden to collect wood there. This restricts the geographical possibilities for collecting wood. This situation would force some households to buy biomass instead of collecting it. In order to deepen the analysis, I focus on households that use purchased charcoal. According to the data, of households using purchased biomass and living in sub-prefectures with PAs, 79.52% (1456 households) use charcoal. In addition, among households using purchased biomass and living in sub-prefectures without PAs, 72.62% (472 households) use charcoal. Furthermore, the graph on the right (graphique 3) shows that 76% of charcoal-using households live in sub-prefectures with a PA. From this 3, one might imagine that there is a positive correlation between the presence of PAs and the use of purchased biomass, and more specifically charcoal.

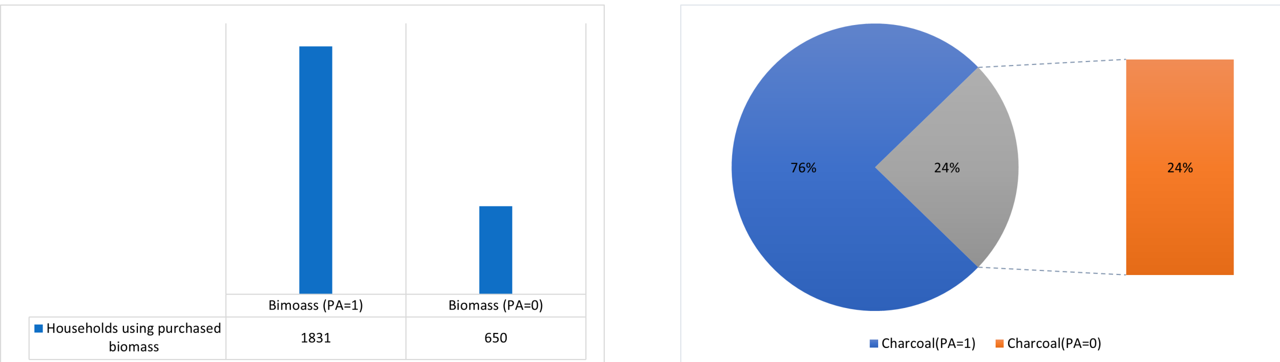

Figure 3: Households using purchased biomass (in the left) and households using charcoal

Figure 4 looks at households that use collected biomass (collected wood). The graph shows that 54.59% of these households live in sub-prefectures without a protected area. This finding could lead us to believe that there is a negative correlation between the presence of a protected area and the use of collected fuelwood.

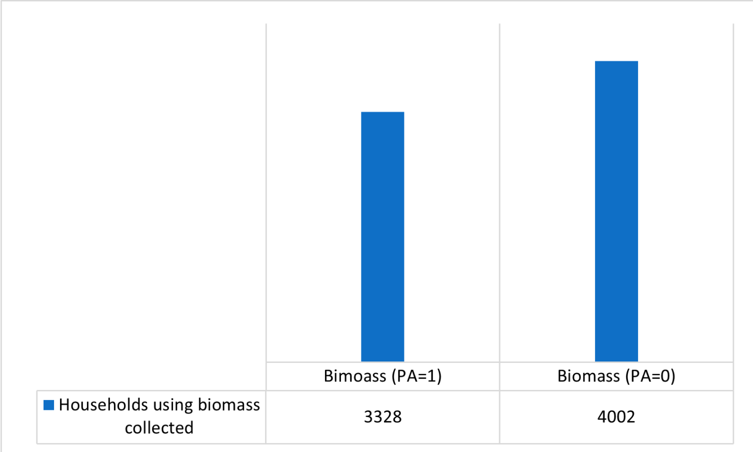

Figure 4: Households using collected biomass for fuel by presence of protected areas

Several types of fuel can be used. Some of these fuels are less harmful to the health of households. This is clean energy. Indeed, in the data I notice that some households use clean energy as cooking fuel. This type of fuel is less polluting but expensive for poor households. According to the data, 1638 Ivorian households use gas or electricity for cooking. A large majority of these households (82%) live in sub-prefectures with a protected area (graph 5). From these figures, one might imagine that there is a positive co-evolution between the presence of a protected area and the use of clean energy for cooking.

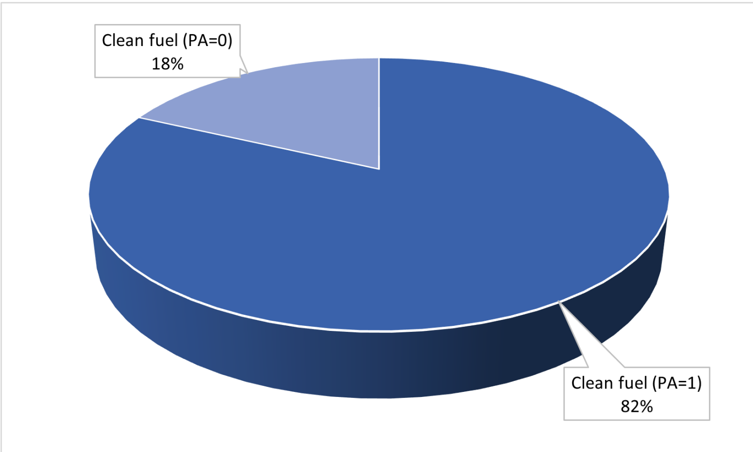

Figure 5: Households using clean fuel by presence of protected areas

In more detail, I looked at the level of wealth of the households in the sample through the wealth index. The index values show that households using clean energy (gas or electricity) are on average wealthier (0.4) than those using biomass (0.17). In addition, households living in sub-prefectures where there is a protected area are on average slightly richer (0.23) than households living in sub-prefectures without a protected area (0.16).

The remainder of the study will focus on econometric analysis to verify the stylized facts that have just been discovered.

5 Econometric analysis

5.1 Endogeneity problem

The distribution of protected areas is non-random (Sims, 2010; Amin et al., 2015). Their location is chosen according to certain characteristics of the area. These protected areas are generally located on land characterised by low soil fertility, the presence of slopes and poor accessibility: land that is not favourable for agriculture (Albers et al., 2006). Failure to take these characteristics into account could lead to an omitted variable bias that will subsequently lead to an endogeneity bias in the analysis. This endogeneity bias could lead to a bias in the estimation of the impact of the presence of protected areas.

To resolve the endogeneity bias I take into account certain characteristics of the sub-prefectures such as rainfall, temperature and biodiversity. These characteristics are crucial in the establishment of protected areas. Data on temperature and rainfall are taken from NASA databases. Biodiversity data is from the Schipper et al. (2020) database. All these data are satellite data that were extracted using QGIS software.

5.2 Econometric modelling

In this study I use a dichotomous model which is a model where the explained variable has two (02) modalities (0 and 1). I can choose between two types of dichotomous models: probit model and logit model. Difference between the two models lies in the mathematical law of the distribution function used. Logistic model uses the distribution function of the logistic distribution while probit model uses the distribution function of the reduced centred normal distribution. These two models provide fairly similar results because of the similarities between logistic and the reduced centred normal distribution. On the other hand, logit model has advantages in the interpretation of marginal effects. Furthermore, my data are at 2 levels: sub-prefecture and household. Indeed, beyond the characteristics of each household, several households live in common sub-prefectures. It is important to take into account the "context effects" in order to estimate the impact of the variables without bias. Therefore, for the econometric analysis, I use the multilevel mixed-effects logit model because it allows us to take into account the hierarchical nature of the data. I also add random effects at the household level as this allows for the influence of certain factors that affect household fuel choice. These could include the type of food cooked, cultural characteristics, etc.

The likelihood-ratio test is done to evaluate the goodness of fit of the chosen model. The test is done between a model with the control variables (unconstrained model) and another model without the control variables (constrained model.). The P-value of the test results are in the results tables.

5.3 Baseline results

An increase in the cost of access to the forest through the establishment of a protected area could have an impact on the fuel use patterns of households living near these protected areas. In Table 1 (column 1), I find that the presence of a protected area in a sub-prefecture has a marginal effect of 2.58%

on the probability of a household using biomass versus clean fuel. This is because the presence of a protected area could allow the household to access biomass by buying or collecting it. Furthermore, in column 4, the presence of a protected area has a positive marginal effect of 6.78% on the risk of using purchased biomass compared to clean fuel. These two results show that the presence of a protected area increases the probability of using biomass and more precisely biomass purchased as cooking fuel. In view of these results, one might think that the presence of a protected area has no effect on wood collection, but it does positively influence the use of purchased biomass (charcoal and wood) compared to clean fuel.

Furthermore, the characteristics of the household head affect the fuel choice of the household. Firstly, the results show that the household head age is a relevant factor in the the household's choice of fuel (Table 1). Indeed, an increase in the age of the head of household has a positive marginal effect (0.118% to 0.208%) on household fuel choice (column 1 to 4 Table 1). This can be explained by the drop in income of elderly heads of household, and this drop in income encourages them to use dirty fuels which are more accessible financially (Bofah et al., 2022). To add, this result could be explain by the fact that these elderly-headed households do not have information about the harmful effects of using dirty energy.

Also, the fact that the head of the household is a man increases the risk of using the biomass collected by 6.92% (Table 1 column 2). This could be explained by the fact that a male head of household could participate in the collection of wood.

The level of education of the household head is an important factor in the household's choice of cooking fuel. Having secondary and higher education has a marginal negative effect on the likelihood of the household using biomass for cooking (Columns 1, 2, 3 and 4 Table 1). A plausibe explanation is that having a high level of education helps to understand the negative health effects of using biomass as fuel.

Table 1: Baseline results

	Biomass/ no biomass	Biomass collected/purchased	Biomass collected/no biomass	Biomass purchased/no biomass
PA presence	0.0258**	-0.00193	-0.000960	0.0678***
	(2.05)	(-0.12)	(-0.08)	(2.61)
Head age	0.00142***	0.00169***	0.00118***	0.00208***
	(5.10)	(5.28)	(4.60)	(3.58)
Head gender (male)	0.00375	0.0692***	0.00646	-0.00729
	(0.46)	(6.45)	(0.81)	(-0.45)
No education (head)	ref.	ref.	ref.	ref.
Primary education (head)	-0.0132	0.00527	-0.000625	-0.0238
	(-1.30)	(0.40)	(-0.06)	(-1.15)
Secondary education (head)	-0.0218**	-0.0482***	-0.0113	-0.0259
	(-2.37)	(-3.58)	(-1.22)	(-1.43)
Higher education (head)	-0.106***	-0.0217	-0.115***	-0.174***
	(-5.42)	(-0.59)	(-4.50)	(-5.65)
Agriculture (head)	ref.	ref.	ref.	ref.
White collar (head)	-0.101***	-0.308***	-0.155***	0.0964**
	(-6.81)	(-9.95)	(-7.92)	(2.55)
Other occupation (head)	-0.0929***	-0.291***	-0.133***	0.111***
	(-8.72)	(-24.68)	(-12.43)	(3.22)
Wealth index	-0.676***	-1.558***	-0.821***	-0.901***
	(-26.72)	(-35.03)	(-28.98)	(-17.67)
Household size	0.0139***	0.00656***	0.0108***	0.0244***
	(8.01)	(3.47)	(6.61)	(7.27)
Rainfall	-0.155***	-0.131***	-0.141***	-0.238***
	(-12.15)	(-7.66)	(-11.35)	(-9.05)
Temperature	0.0316***	0.000728	0.0222***	0.0667***
	(11.62)	(0.23)	(9.24)	(11.12)
Mammals & birds	0.178***	0.105***	0.160***	0.284***
	(22.06)	(7.18)	(18.84)	(18.07)
Observations	7209	5751	5207	3460
LR test p value	0.0000	0.0000	0.0000	0.0000
Household RE	yes	yes	yes	yes

t statistics in parentheses,

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Robust standard errors

In addition, the type of occupation of the head of household influences the household's choice of fuel. The fact that the head of the household is a "white collar" worker or "other occupation" worker has a marginal negative effect (10.1% and 9.29% respectively) on the risk of using biomass compared to a farmer head of household (Column 1 Table 1). Going into more detail, it can be seen that the effect size is larger when it comes to the use of collected biomass compared to purchased biomass or to clean fuel (Columns 2, 3 Table 1). However, the effect changes sign when it comes to the risk of using purchased biomass (Column 4 Table 1). These results show that the fact that the household head is not a farmer reduces the risk of using collected biomass. This result seems to be consistent with the idea that a farmer may have access to wood when he goes to the field.

The level of wealth very significantly decreases the risk of using biomass as a cooking fuel (Table 1). This result shows that one of the essential determinants of fuel choice is the level of household income. Indeed, a poor household will be forced to use biomass because it is the cheapest fuel the household can afford. A rich household, on the other hand, has a wide range of fuels it can use. As a result, the rich household would tend to switch to cleaner fuels. This result is in line with previous studies that found that poverty is one of the main factors driving households to use biomass (Pattanayak et al., 2004; Velho et al., 2019).

The size of the household has a great influence on the choice of cooking fuel (Table 1). Indeed, a large household size would mean a large amount of food to cook and therefore a large amount of fuel to use for cooking. In this situation, a household would have an incentive to use biomass which is cheaper than clean fuels and therefore more affordable. Here again, I return to the household's socio-economic status factor. The results show that household size increases the risk of biomass use by 0.656% to 2.44%.

Furthermore, the characteristics of the sub-prefecture play an important role in the location of a protected area and could influence the fuel choice of households living there. In Table 1, we can see that the level of rainfall marginally decreases the risk of using biomass as fuel. This result is explained by the fact that biomass is not usable when it is wet. On the other hand, temperature has a marginally positive effect on the risk of using collected or purchased biomass compared to clean fuel (columns 1, 3 and 4 Table 1). Indeed, a rise in temperature as opposed to rain allows the biomass to dry better and it becomes even easier to use for fire. In addition, the mammal and bird stock in the sub-prefecture has a marginal positive effect (10.5% to 28.4%) on the risk of biomass use. This could be explained by the fact that more mammal and bird stock would mean more forest area, and when forest is accessible, it encourages the household to use biomass which becomes more accessible at lower cost.

The next section focuses on the robustness checks of the previous results.

6 Robustness checks

I test the robustness of the baseline results using generalized structural equation modeling (Table 2). The results obtained are in line with the baseline results and show that the presence of a protected area increases the risk of biomass use and more precisely of purchased biomass compared to clean fuel.

Table 2: Generalized structural equation modeling

	Biomass/ no biomass	Biomas collected/purchased	Biomass collected/no biomass	Biomass purchased/no biomass
PA presence	0.288**	-0.0152	-0.0147	0.399***
	(2.04)	(-0.12)	(-0.08)	(2.60)
Head age	0.0159***	0.0133***	0.0182***	0.0122***
	(5.08)	(5.21)	(4.61)	(3.56)
Head gender (male)	0.0417	0.544***	0.0991	-0.0429
	(0.46)	(6.32)	(0.81)	(-0.45)
No education (head)	ref.	ref.	ref.	ref.
Primary education (head)	-0.146	0.0413	-0.00932	-0.137
	(-1.31)	(0.40)	(-0.06)	(-1.15)
Secondary education (head)	-0.237**	-0.368***	-0.166	-0.149
	(-2.41)	(-3.65)	(-1.24)	(-1.44)
Higher education (head)	-1.025***	-0.168	-1.448***	-0.969***
	(-6.09)	(-0.60)	(-5.32)	(-5.75)
Agriculture (head)	ref.	ref.	ref.	ref.
White collar (head)	-1.202***	-2.280***	-2.159***	0.558**
	(-6.86)	(-12.01)	(-9.56)	(2.53)
Other occupation (head)	-1.122***	-2.183***	-1.921***	0.643***
	(-7.69)	(-20.56)	(-11.48)	(3.22)
Wealth index	-7.534***	-12.26***	-12.60***	-5.304***
	(-22.87)	(-24.13)	(-22.37)	(-15.32)
Household size	0.155***	0.0517***	0.166***	0.144***
	(7.87)	(3.46)	(6.49)	(7.10)
Rainfall	-1.729***	-1.033***	-2.165***	-1.401***
	(-11.32)	(-7.54)	(-10.27)	(-8.68)
Temperature	0.352***	0.00573	0.341***	0.392***
	(11.76)	(0.23)	(9.50)	(10.81)
Mammals & birds	1.982***	0.825***	2.451***	1.675***
	(18.72)	(7.07)	(15.75)	(15.65)
Observations	7209	5751	5207	3460
LR test P value	0.0000	0.0000	0.0000	0.0000
Household RE	yes	yes	yes	yes

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Robust standard errors

7 Heterogeneity and treshold effect

7.1 Heterogeneity

The influence of the presence of a protected area could vary depending on several factors. First, I look at how the influence of the presence of a protected area affects households' fuel choices according to the level of development of the sub-prefecture. In the Table 3, I use the level of nightlight to approximate the level of development of the area. The results show that living in a sub-prefecture with a nightlight level below the median level increases the risk of biomass use by 3.09% and of biomass collected by 2.28% (columns 4 and 6 Table 3). Then, still with a view to taking into account the level of development, in Table 4, I am interested in the heterogeneity of the effect depending on whether the sub-prefecture is urban or rural. Indeed, I assume that the more developed the area, the more households have access to clean energy compared to less developed areas. The results in Table 4 (column 2), show that the presence of a protected area in an urban area increases the probability of using purchased biomass by 8.01% compared to clean energy. However, the effect is insignificant when it is a protected area in a rural area. This could be due to the fact that in urban areas, protected areas are more guarded than in rural areas. As a result, households do not have the possibility to collect biomass and are therefore forced to use purchased biomass.

Table 3: Heterogeneity by sub-prefecture development level

	biomass/no biomass nightlight>median	collected/purchased nightlight>median	collected/no biomass nightlight>median	biomass/no biomass nightlight<median	collected/purchased nightlight<median	collected/no biomass nightlight<median
PA presence	0.0127	0.00966	-0.0255	0.0309***	0.0286	0.0228**
	(0.57)	(0.39)	(-1.30)	(2.85)	(1.46)	(2.10)
Head age	0.00258***	0.00236***	0.00202***	0.000476*	0.00156***	0.000664**
	(5.35)	(4.54)	(4.80)	(1.67)	(3.90)	(2.25)
Head gender (male)	-0.000605	0.0599***	-0.0119	0.000768	0.0597***	0.00391
	(-0.04)	(3.49)	(-0.92)	(0.10)	(4.61)	(0.47)
No education (head)	ref.	ref.	ref.	ref.	ref.	ref.
Primary education (head)	-0.0113	0.0181	0.00802	-0.00411	0.0104	-0.00279
	(-0.64)	(0.84)	(0.46)	(-0.40)	(0.65)	(-0.29)
Secondary education (head)	-0.0445***	-0.0343*	-0.00748	0.00254	-0.0483***	-0.000357
	(-2.83)	(-1.69)	(-0.48)	(0.28)	(-2.88)	(-0.04)
Higher education (head)	-0.160***	-0.0854	-0.160***	-0.0399*	0.00361	-0.0546*
	(-5.33)	(-1.23)	(-3.96)	(-1.86)	(0.09)	(-1.83)
Agriculture (head)	ref.	ref.	ref.	ref.	ref.	ref.
White collar (head)	-0.127***	-0.464***	-0.246***	-0.0576***	-0.154***	-0.0628***
	(-4.55)	(-10.50)	(-7.15)	(-3.49)	(-4.59)	(-3.11)
Other occupation (head)	-0.113***	-0.386***	-0.178***	-0.0365***	-0.193***	-0.0580***
	(-4.90)	(-16.63)	(-8.19)	(-4.50)	(-14.99)	(-6.67)
Wealth index	-0.904***	-1.486***	-0.928***	-0.303***	-1.300***	-0.465***
	(-21.25)	(-19.21)	(-18.02)	(-10.40)	(-22.93)	(-14.48)
Household size	0.0178***	-0.00335	0.00903***	0.00994***	0.0121***	0.0108***
	(6.19)	(-0.99)	(3.35)	(4.85)	(4.90)	(4.90)
Rainfall	-0.202***	-0.275***	-0.180***	0.0331**	-0.00355	0.0313*
	(-8.36)	(-9.67)	(-7.84)	(1.98)	(-0.13)	(1.84)
Temperature	0.0390***	-0.0159***	0.00831**	0.0134***	-0.000372	0.0134***
	(7.21)	(-2.80)	(2.12)	(5.21)	(-0.10)	(5.43)
Mammals & birds	0.247***	0.194***	0.208***	-0.0642***	-0.0498*	-0.0644***
	(18.84)	(9.22)	(15.04)	(-3.57)	(-1.75)	(-3.46)
Observations	3483	2254	2255	3726	3497	2952
LR test P value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Household RE	yes	yes	yes	yes	yes	yes

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Robust standard errors

Table 4: Heterogeneity by residence

	collected/purchased urban	purchased/no biomass urban	collected/purchased rural	purchased/no biomass rural
PA presence	-0.0100	0.0801***	-0.0144	-0.0354
	(-0.42)	(2.90)	(-0.97)	(-0.41)
Head age	0.00192***	0.00237***	0.000479	0.000760
	(3.66)	(4.04)	(1.63)	(0.42)
Head gender (male)	0.0770***	0.00512	0.000872	-0.0734
	(4.55)	(0.31)	(0.08)	(-1.13)
No education (head)	ref.	ref.	ref.	ref.
Primary education (head)	0.00902	-0.0280	-0.00418	-0.0261
	(0.42)	(-1.29)	(-0.33)	(-0.40)
Secondary education (head)	-0.0505**	-0.0387**	-0.00929	0.0557
	(-2.56)	(-2.10)	(-0.70)	(0.84)
Higher education (head)	-0.0803	-0.176***	-0.0150	-0.0165
	(-1.34)	(-5.48)	(-0.43)	(-0.12)
Agriculture (head)	ref.	ref.	ref.	ref.
White collar (head)	-0.400***	-0.00456	-0.0855***	-0.00866
	(-9.61)	(-0.09)	(-2.94)	(-0.09)
Other occupation (head)	-0.364***	0.000313	-0.0759***	0.0978*
	(-13.27)	(0.01)	(-7.81)	(1.65)
Wealth index	-1.390***	-1.001***	-0.474***	-0.193
	(-16.85)	(-19.47)	(-9.09)	(-0.80)
Household size	0.00729**	0.0249***	0.00698***	0.0141
	(2.26)	(7.26)	(3.21)	(1.16)
Rainfall	-0.154***	-0.257***	-0.0172	0.371***
	(-5.86)	(-9.27)	(-0.99)	(2.83)
Temperature	0.0113**	0.0628***	0.00856**	0.0590***
	(2.20)	(9.68)	(2.53)	(2.62)
Mammals & birds	0.106***	0.298***	0.0201	-0.324***
	(5.27)	(18.53)	(1.12)	(-2.66)
Observations	2621	3087	3130	373
LR test P value	0.0000	0.0000	0.0000	0.0000
Household RE	yes	yes	yes	yes

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Robust standard errors

The next part of the heterogeneity study looks at the effect of the presence of the protected area according to the type of protected area. In the database, I identify several types of protected area such as classified forest, national park, nature reserve and partial nature reserve. The results in Table 5 show that the fact that the protected area is a classified forest has no effect on households' choice of fuel.

Furthermore, the fact that the protected area is a park decreases the risk of using collected biomass compared to purchased biomass by 9.82%. The presence of this type of protected area also decreases the risk of using collected biomass compared to clean energy by 5.01% (columns 2 and 3 Table 6). This type of protected area decreases the risk of use of collected biomass because its presence would decrease the geographical possibilities of wood collection.

Table 5: Effect for classified forest

	Biomass/ no biomass	Biomass collected/purchased	Biomass collected/no biomass	Biomass purchased/no biomass
PA_forest	0.0112	-0.00159	-0.00699	0.0419
	(1.02)	(-0.10)	(-0.59)	(1.59)
Head age	0.00120***	0.00183***	0.00139***	0.00160**
	(4.02)	(5.13)	(4.42)	(2.20)
Head gender (male)	-0.00372	0.0667***	-0.00220	-0.0213
	(-0.44)	(5.82)	(-0.23)	(-1.08)
No education	ref.	ref.	ref.	ref.
Primary education (head)	-0.00719	0.00202	-0.00268	-0.00921
	(-0.68)	(0.14)	(-0.24)	(-0.36)
Secondary education (head)	-0.0105	-0.0476***	-0.00559	-0.00247
	(-1.09)	(-3.23)	(-0.52)	(-0.11)
Higher education (head)	-0.0929***	-0.0406	-0.115***	-0.183***
	(-4.07)	(-0.95)	(-3.59)	(-4.41)
Agriculture (head)	ref.	ref.	ref.	ref.
White collar (head)	-0.0728***	-0.261***	-0.113***	0.0832*
	(-4.90)	(-7.72)	(-5.56)	(1.92)
Other occupation (head)	-0.0645***	-0.266***	-0.110***	0.119***
	(-7.11)	(-21.56)	(-10.98)	(3.19)
Wealth index	-0.550***	-1.540***	-0.829***	-0.755***
	(-19.75)	(-32.87)	(-25.92)	(-11.24)
Household size	0.0163***	0.00644***	0.0123***	0.0341***
	(8.00)	(3.21)	(5.59)	(7.60)
Rainfall	0.0177	0.0409	0.0470**	0.0273
	(1.00)	(1.61)	(2.47)	(0.62)
Temperature	0.0279***	-0.00731**	0.0210***	0.0681***
	(10.10)	(-2.12)	(7.63)	(10.53)
Mammals & birds	-0.00473	-0.0935***	-0.0395**	0.0110
	(-0.29)	(-3.55)	(-2.23)	(0.28)
Observations	5638	4957	4031	2288
LR test P value	0.0000	0.0000	0.0000	0.0000
Household RE	yes	yes	yes	yes

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Robust standard errors

In the Table 7 (columns 1, 3 and 4), it can be seen that the fact that the protected area is a nature reserve increases the risk of using biomass (20.8%), collected biomass (18.7%) and purchased biomass (41.6%) compared to clean energy.

Table 6: Effect for parc

	Biomass/ no biomass	Biomas collected/purchased	Biomass collected/no biomass	Biomass purchased/no biomass
PA_parc	-0.00130	-0.0982***	-0.0501***	0.0771
	(-0.04)	(-4.11)	(-3.00)	(1.39)
Head age	0.00203***	0.000600	0.000846**	0.00274***
	(3.69)	(0.94)	(2.23)	(3.30)
Head gender (male)	0.0179	0.0613***	0.0183	0.0124
	(1.08)	(2.90)	(1.53)	(0.51)
No education (head)	ref.	ref.	ref.	ref.
Primary education (head)	-0.0313	0.000787	-0.00641	-0.0468
	(-1.49)	(0.03)	(-0.41)	(-1.47)
Secondary education (head)	-0.0412**	-0.104***	-0.00590	-0.0470*
	(-2.29)	(-3.68)	(-0.43)	(-1.75)
Higher education (head)	-0.103***	0.00368	-0.0588*	-0.135***
	(-3.16)	(0.06)	(-1.68)	(-3.31)
Agriculture (head)	ref.	ref.	ref.	ref.
White collar (head)	-0.225***	-0.272***	-0.199***	-0.103
	(-5.62)	(-5.21)	(-4.99)	(-1.07)
Other occupation (head)	-0.219***	-0.279***	-0.186***	-0.0993
	(-6.18)	(-10.71)	(-5.79)	(-1.05)
Wealth index	-0.896***	-1.451***	-0.685***	-1.056***
	(-19.24)	(-15.33)	(-15.07)	(-14.60)
Household size	0.0141***	0.00493	0.00847***	0.0189***
	(4.35)	(1.18)	(4.00)	(4.01)
Rainfall	-0.201***	-0.108***	-0.105***	-0.312***
	(-5.48)	(-3.73)	(-5.21)	(-5.10)
Temperature	0.0460***	-0.0171***	0.0137***	0.0925***
	(4.75)	(-2.83)	(2.83)	(4.26)
Mammals & birds	0.216***	0.127***	0.119***	0.311***
	(8.63)	(5.83)	(8.32)	(7.16)
Observations	2363	1443	1751	1532
LR test P value	0.0000	0.0000	0.0000	0.0000
Household RE	yes	yes	yes	yes

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Robust standard errors

Table 7: Effect for nature reserve

	Biomass/ no biomass	Biomas collected/purchased	Biomass collected/no biomass	Biomass purchased/no biomass
PA_ReserveNatur	0.208***	0.0137	0.187**	0.416***
	(3.10)	(0.33)	(2.32)	(3.74)
Head age	0.00182***	0.000931	0.00190***	0.00235
	(2.64)	(0.97)	(2.59)	(1.52)
Head gender (male)	0.00462	0.0469	0.0158	-0.00646
	(0.22)	(1.60)	(0.73)	(-0.15)
No education (head)	ref.	ref.	ref.	ref.
Primary education (head)	-0.00871	-0.00190	-0.0149	0.000401
	(-0.33)	(-0.06)	(-0.58)	(0.01)
Secondary education (head)	-0.00663	-0.106***	0.000989	0.0197
	(-0.28)	(-2.63)	(0.04)	(0.40)
Higher education (head)	-0.0434	-0.120	-0.0943	-0.0617
	(-0.99)	(-1.09)	(-1.22)	(-0.75)
Agriculture (head)	ref.	ref.	ref.	ref.
White collar (head)	-0.135***	-0.209***	-0.159***	-0.140
	(-4.22)	(-2.76)	(-3.66)	(-1.02)
Other occupation (head)	-0.151***	-0.283***	-0.184***	-0.155
	(-6.46)	(-9.60)	(-6.36)	(-1.14)
Wealth index	-0.705***	-1.382***	-0.874***	-1.070***
	(-10.35)	(-8.92)	(-10.51)	(-7.39)
Household size	0.0203***	0.00752	0.0119***	0.0399***
	(4.13)	(1.33)	(2.60)	(4.28)
Rainfall	-0.0554	0.136**	0.0309	-0.206**
	(-1.19)	(2.29)	(0.72)	(-2.13)
Temperature	0.0346***	-0.0295***	0.0151**	0.0909***
	(4.32)	(-3.49)	(2.12)	(4.50)
Mammals & birds	0.0646*	-0.179***	-0.0233	0.213***
	(1.70)	(-3.00)	(-0.65)	(2.74)
N	1038	866	742	468
LR test P value	0.0000	0.0000	0.0000	0.0000
Household RE	yes	yes	yes	yes

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Robust standard errors

The Table 8 looks at the heterogeneity of effect depending on whether the protected area is a national or international protected area. The terms ”National” and ”International” refer to the type of convention under which the protected area was established. Thus, the ”National” protected area is derived from a national convention, whereas the ”International” protected area is derived from an international convention. For example, a UNESCO World Heritage site would be an ”International” protected area.

The results in Table 8 show that the presence of a ”National” protected area increases the risk of using biomass (2.68%) and purchased biomass (6.76%) compared to clean energy (columns 1 and 4). In contrast, the fact that the protected area is of the ”International” type has a marginally low significant effect on the risk of using purchased biomass compared to clean energy (column 8). These nil or low significant results could be explained by the fact that the ”International” type protected areas are very few compared to the ”International” type.

Table 8: Effect by PA type (national or international)

	Biomass/ no biomass	Biomas collected/purchased	Biomass collected/no biomass	Biomass purchased/no biomass	Biomass/ no biomass	Biomas collected/purchased	Biomass collected/no biomass	Biomass purchased/no biomass
PA_National	0.0268**	0.000794	-0.0000855	0.0676***				
	(2.10)	(0.05)	(-0.01)	(2.60)				
PA_International					0.105	-0.0242	0.0126	0.360*
					(1.42)	(-0.42)	(0.25)	(1.80)
Head age	0.00146***	0.00169***	0.00118***	0.00213***	0.00164**	0.000794	0.00165**	0.00224
	(5.15)	(5.17)	(4.52)	(3.67)	(2.46)	(0.88)	(2.38)	(1.40)
Head gender (male)	0.00404	0.0699***	0.00634	-0.00670	0.000670	0.0564*	0.0112	-0.0144
	(0.49)	(6.44)	(0.78)	(-0.42)	(0.03)	(1.95)	(0.55)	(-0.33)
No education (head)	ref.	ref.	ref.	ref.	ref.	ref.	ref.	ref.
Primary education (head)	-0.0124	0.00436	-0.000753	-0.0219	-0.00599	0.00472	-0.00681	0.000734
	(-1.20)	(0.33)	(-0.08)	(-1.05)	(-0.24)	(0.15)	(-0.29)	(0.01)
Secondary education (head)	-0.0228**	-0.0475***	-0.0116	-0.0277	-0.00425	-0.139***	0.00101	0.0277
	(-2.45)	(-3.49)	(-1.23)	(-1.53)	(-0.18)	(-3.33)	(0.04)	(0.52)
Higher education (head)	-0.107***	-0.0246	-0.116***	-0.175***	-0.0402	-0.0485	-0.0800	-0.0684
	(-5.44)	(-0.65)	(-4.50)	(-5.68)	(-0.92)	(-0.56)	(-1.13)	(-0.78)
Agriculture (head)	ref.	ref.	ref.	ref.	ref.	ref.	ref.	ref.
White collar (head)	-0.103***	-0.313***	-0.159***	0.0919**	-0.130***	-0.180***	-0.140***	-0.154
	(-6.85)	(-10.02)	(-7.96)	(2.42)	(-4.19)	(-2.70)	(-3.65)	(-1.14)
Other occupation (head)	-0.0954***	-0.295***	-0.136***	0.105***	-0.148***	-0.253***	-0.173***	-0.168
	(-8.80)	(-24.54)	(-12.43)	(3.05)	(-6.73)	(-9.04)	(-6.76)	(-1.26)
Wealth index	-0.677***	-1.568***	-0.828***	-0.886***	-0.695***	-1.486***	-0.869***	-1.081***
	(-26.43)	(-34.96)	(-28.83)	(-17.38)	(-10.38)	(-11.03)	(-11.58)	(-7.28)
Household size	0.0138***	0.00676***	0.0108***	0.0238***	0.0208***	0.00255	0.0119***	0.0433***
	(7.84)	(3.53)	(6.50)	(7.10)	(4.25)	(0.48)	(2.73)	(4.42)
Rainfall	-0.160***	-0.137***	-0.146***	-0.239***	-0.0474	0.0350	0.0244	-0.182*
	(-12.25)	(-7.78)	(-11.38)	(-9.03)	(-1.05)	(0.64)	(0.60)	(-1.77)
Temperature	0.0340***	0.000606	0.0234***	0.0708***	0.0302***	-0.0240***	0.0132**	0.0829***
	(12.04)	(0.18)	(9.48)	(11.58)	(3.73)	(-3.36)	(2.00)	(3.87)
Mammals & birds	0.183***	0.103***	0.163***	0.289***	0.0510	-0.0343	-0.0205	0.177**
	(22.47)	(6.90)	(18.95)	(18.41)	(1.37)	(-0.71)	(-0.60)	(2.09)
Observations	7076	5621	5092	3439	1070	898	791	451
LR test P value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Household RE	yes	yes	yes	yes	yes	yes	yes	yes

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Robust standard errors

In the following, it is important to investigate whether the effect of the protected area on fuel choice depends on the size of the protected area present in the sub-prefecture. This is the objective of the next section.

7.2 Treshold effect

In the study, I am interested in the existence of a threshold effect with respect to the influence of the protected area on the choice of cooking fuel of Ivorian households. To do so, I use the surface area of protected areas expressed in km^2. The idea is that when the protected area reaches a certain size the effect might change. On the one hand, a large protected area could mean a lack of monitoring of some parts of the protected area, perhaps due to a lack of suitable manpower. On the other hand, a large protected area could mean that the authorities give more importance to the protected area.

Furthermore, to calculate the threshold I pose the following equation:

Let $Y = aX + bX^2$

We find a threshold $X = -a/2b$.

Table 9: Threshold effect study

	Biomass/ no biomass	Biomass collected/purchased	Biomass collected/no biomass	Biomass purchased/no biomass
PA surface (km^2)	-0.0000276***	0.0000227**	-0.0000118	-0.0000773***
	(-2.93)	(2.13)	(-1.36)	(-3.99)
PA surface squared	1.06e-09***	-7.73e-10**	5.29e-10*	2.68e-09***
	(3.15)	(-1.98)	(1.75)	(3.96)
Head age	0.00140***	0.00171***	0.00118***	0.00198***
	(5.02)	(5.36)	(4.56)	(3.43)
Head gender (male)	0.00367	0.0681***	0.00644	-0.00655
	(0.45)	(6.35)	(0.81)	(-0.41)
No education (head)	ref.	ref.	ref.	ref.
Primary education (head)	-0.0129	0.00553	-0.000560	-0.0238
	(-1.27)	(0.42)	(-0.06)	(-1.15)
Secondary education (head)	-0.0221**	-0.0466***	-0.0118	-0.0287
	(-2.40)	(-3.47)	(-1.27)	(-1.59)
Higher education (head)	-0.106***	-0.0222	-0.116***	-0.177***
	(-5.43)	(-0.61)	(-4.48)	(-5.74)
Agriculture (head)	ref.	ref.	ref.	ref.
White collar (head)	-0.102***	-0.308***	-0.154***	0.0871**
	(-6.83)	(-9.96)	(-7.88)	(2.36)
Other occupation (head)	-0.0941***	-0.291***	-0.132***	0.0990***
	(-8.83)	(-24.52)	(-12.28)	(2.97)
Wealth index	-0.683***	-1.549***	-0.823***	-0.913***
	(-27.03)	(-33.00)	(-29.29)	(-18.01)
Household size	0.0140***	0.00670***	0.0108***	0.0246***
	(8.01)	(3.55)	(6.60)	(7.28)
Rainfall	-0.131***	-0.142***	-0.137***	-0.170***
	(-11.46)	(-8.72)	(-12.02)	(-6.93)
Temperature	0.0297***	0.00158	0.0214***	0.0621***
	(10.90)	(0.48)	(8.63)	(10.38)
Mammals & birds	0.173***	0.102***	0.161***	0.269***
	(23.99)	(7.15)	(20.41)	(20.19)
Observations	7209	5751	5207	3460
LR test P value	0.0000	0.0000	0.0000	0.0000
Household RE	yes	yes	yes	yes

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Robust standard errors

The results of the threshold effect study can be found in Table 9 and show the existence of a threshold effect. In the first column it can be seen that the size of the protected area influences the choice of using biomass as cooking fuel compared to clean energy. Indeed, when the protected area reaches a certain size it has a positive marginal effect on the choice of biomass. The threshold area is 23.31 m^2. On the other hand, it can be seen that when the area reaches 8645.5136 km^2, this reduces the risk of using collected biomass compared to purchased biomass (column 2). Also, when the protected area reaches an area of 275652.95 m^2 it increases the probability of using purchased biomass over clean energy. The threshold effect analysis shows that when the size of the protected area increases and reaches a certain level it increases the risk of using biomass and more precisely purchased biomass. This could be explained by the fact that the larger the protected area, the more likely it is that there will be individuals involved in selling wood or charcoal from the protected area. Households could therefore obtain it quite easily.

8 Conclusion

This study investigates the influence of the presence of a protected area on the fuel choice of households living in the locality.

The results show that the presence of a protected area influences households' choice of cooking fuel. It is found that the presence of these areas increases the risk of using biomass and more specifically purchased biomass compared to clean energy. The protected area does not encourage them to stop using biomass. This is because the choice of fuel depends on several other characteristics such as the level of wealth, the characteristics of the household head, the size of the household and the characteristics of the sub-prefecture. Also, the effect varies according to the area of residence of households and the type of protected area. In addition, there is a threshold effect with regard to the influence of the protected area on the choice of fuel for Ivorian households.

In terms of economic policies, Ivorian public decision-makers must put in place policies to strengthen the management policy of protected areas. These include policies to monitor protected areas so that their presence can help achieve the set objectives. The country could also put in place policies to facilitate access to clean energy. In addition, the population should be made aware of the adverse health effects of the use of plant biomass. This would help to reduce the use of biomass.

This study has limitations. The main limitation is the availability of data. I do not have information on the precise location of households. This type of information would allow me to better target households living near protected areas based on a certain distance. This analysis would have been a bit more interesting. I hope that future surveys will provide this type of information.

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A Descriptive statistics

Table A1: Descriptive statistics

Variable	**Obs**	**Mean**	**Std. dev.**	**Min**	**Max**
Fuel biomass / no biomass	11,476	.8549146	.3522023	0	1
Fuel collected / purchased	9,811	.7471206	.4346846	0	1
Fuel collected / no biomass	8,995	.8148972	.3884026	0	1
Fuel purchased / no biomass	4,146	.5984081	.4902793	0	1
Protected area presence	12,899	.5657803	.4956733	0	1
Head age	12,549	41.21444	14.72488	15	120
Head gender	12,899	.8036282	.3972684	0	1
Head education	12,797	.687583	.9317503	0	3
Head occupation	12,899	1.162648	.9420635	0	2
Wealth index	12,899	.1790776	.1400787	0	.9911834
Household size	12,899	3.692922	2.597198	1	36
Rainfall	8,421	3.67931	.6761816	1.224417	5.798827
Temperature	8,421	28.77085	1.460775	26.22738	33.06827
Mammals & birds	8,421	8.666437	.8084434	5.851593	11.02025

B Wealth index

Table B1: Variables used for the wealth index construction

Variable classification	Variable definition
Housing	Housing tenure status Wall material Floor material Roof material Soil type Material fo the roof Number of rooms
Physical capital	Type of water supply Light source Latrine inside Having mobile phone Having TV Having a post radio Having refrigerator Having freezer Having ventilator Having air conditioner Having computer Having gas stove Having satellite dish Having car Having truck Having iron Having tablet computer Having sewing machine Having dining room Having living room Having chair Having table Having bed Having mattress
Assets	Pocess dwelling Owner of cropland