Factors Influencing Tropical Forest Conservation: Evidence from the W Reserve

by

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Abstract

We analyzed the factors that influence tropical forest resource conservation using the W Reserve in West Africa as the case study. Specifically, we first characterized the forms of pressure faced by the Reserve from the population in the villages within its periphery. Second, we characterized the villages in the Reserve periphery based on their socioeconomic and institutional characteristics using cluster analysis. Third, we identified based on the villages characteristics, the factors that could explain its degradation using Poisson regression model, Negative Binomial Regression model, linear and non-linear Seemingly Unrelated Regression (SUR) model.

Our result indicates that illegal cattle ranching is the most dominant form of pressure faced by the Reserve from the population in the villages within its periphery, and illegal logging the lowest form. Second, four types of villages were observed in the region with three discriminating factors, namely populations, number of non-governmental organizations promoting nature preservation, and average farm size. Third, three major factors that influence the Reserve' degradation have been identified as socioeconomic characteristics, institutional organization, and the location of the villages. Particularly, the variables distance and average farm size in the villages were identified as the factors that influence illegal farming activities in the Reserve. Illegal cattle ranching activities were influenced by the number of non-governmental organizations, the distance, and the existence of checkpoints between the Reserve and the villages. Population and distance were identified as the factors that influence poaching

activities while illegal logging was influenced only by the distance that separates the Reserve and the villages in its periphery.

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List of Abbreviations

CENAGREF	Centre National de Gestion des Reserves de Faune
FAO	Food and Agriculture Organization
GIS	Geographic Information System
IIE	Institute of International Education
IUCN	International Union for Conservation of Nature
SUR	Seemingly Unrelated Regression model

I. INTRODUCTION

1.1. Justification for the study

We analyzed the factors that influence tropical forest resource conservation using poaching, illegal logging, illegal farming, and illegal cattle ranching as a proxy of forest resource degradation. Natural resources are inputs in the production of goods and services. Although several combinations of inputs (such as labor, capital, etc.) are needed to increase production in the short run, production can be compromised in the long run if resources are not utilized efficiently. Such situations could result from the overuse of natural resources.

One of these resources whose exploitations is raising concerns is tropical forest resource. According to FAO (2016), although the degradation of forest resource has slowed down globally, tropical forest resource degradation is still ongoing in Africa. Indeed, the conservation of tropical forest resources is vital because they provide 25% of our medicines worldwide, and inhabit over 50% of the planet's biodiversity, even though they cover less than 10% of earth (Lasco, 2008). They sustain millions of people lives worldwide and contribute directly and indirectly to economies of many developing countries. Furthermore, cultural provisions include their use for recreation, education, and ceremonies. (Musyoki et al., 2013), while environmental services encompass biodiversity conservation, soil erosion control, water cycle regulation, carbon sequestration with effects on global warming reduction, etc. (FAO, 2016).

Although several studies have investigated the factors that influence forest resource degradation in general, and particularly tropical forest resource, tropical forest degradation persists, indicating incomplete understanding of the drivers of degradation. The rationale of this study comes particularly from the existence of several uncertainties in the literature on the identification of the factors that determine the degradation of forest resources because of their proxy for these resource degradations. Indeed, the studies on forest resource conservation measured the degradation of these resources using mostly deforestation and poaching individually as measurements, but no studies to our knowledge considered together poaching, illegal logging, illegal farming, and illegal cattle ranching as a proxy of these resources degradation. These forms of degradation of tropical forests are common and considering them together in the identification of the factors that influence the resource degradations could allow to account for the interaction effects that could exist between these different forms of pressures. Accordingly, this study appears as the first study to investigate forest resource degradation, and particularly tropical forest resource degradation considering together poaching, illegal logging, illegal farming, and illegal cattle ranching together in protected areas as a proxy of resource degradations.

In tropical areas, most forest resources are conserved as protected areas dedicated for the maintenance of biological diversity and managed through legal or other means (IUCN, 1998). Protected areas in general are created to meet three goals: (i) ecosystem preservation, (ii) local development, and (iii) environmental education (Barbero et al., 2011). Therefore, the persistence of the degradation in these areas implies the non-consideration, but not limited to, of the aforementioned factors. Such failure could come from the measurements that ignore a well-known phenomenon-illegal activity.

Apart from its proxy for the measurement of forest resource degradation, and particularly of tropical forest resource degradation, this study differs from the existing literature in its unit of observation. Indeed, the units of observation in the literature on the identification of factors explaining tropical forest resource degradation include country level (e.g. Culas, 2014;

Diarassouba and Boubacar, 2009) and households level (e.g. Daksa and Kotu, 2015; Babigumira et al., 2014), ignoring villages, which represent the first administrative units in rural areas around these resources in tropical regions. Although, countries' and households' characteristics provide significant information for understanding the drivers of the resource degradation; villages as observation unit would provide additional insights in understanding the phenomena for effective policies at the local level. This study bridges the gap by considering the villages as its observation unit.

1.2. Justification for the choice of the W Biosphere Reserve in West Africa

Within Africa, West Africa is one of the regions facing the most severe forest resource degradation (Bromhead, 2012). Pressures on forest resources in this region are rising, threatening reserves and protected areas which inhabit valuable trees and animal species. Particularly, the choice of the W Reserve in West Africa comes first from its place as one of the largest Reserves in the region, crossing three different countries (Benin, Burkina Faso, and Niger) with a wide range of villages. Second, in addition to its size, this Reserve is one of the richest in terms of biodiversity and represents an attraction for poaching, illegal logging, and fodder for the population in its periphery. Indeed, the Reserve is one of the rare place in Africa where endangered species (species on the red list of International Union of Conservation of Nature [IUCN] such as the cheetah, lycaon, African elephant) are living. It is a unique bird area (Birdlife International, 2013) and has four wetland sites under the Ramsar Convention. Other values of the Reserve include its economic and scientific importance in the region.

Several threats have been reported by the surveillance administrations of the Reserve. These pressures include:

- animal poaching (DPNW, 2015)

- illegal logging and tree harvesting on the Reserve (DPNW, 2015)
- increasing farms areas in the peripheries of the Reserve as well as illegal cases of farming within the Reserve (DPNW, 2015; Houessou et al. 2013);
- illegal grazing of cattle on the Reserve (DPNW, 2015)

These threats on the Reserve raise concerns about the biodiversity and the future of this unique place in the region. Although several authors have considered the Reserve as a study area (Houessou et al., 2013; Assogba, 2011; Hibert, 2007; Mahamane, 2005; Rabeil, 2003), they focused mainly on measuring the Reserve's biodiversity- namely plant biodiversity (e.g. Mahamane, 2005), animal biodiversity (e.g. Hibert, 2007; Rabeil, 2003), and land cover change (Houessou et al., 2013). This study differs from the previous studies in investigating the socioeconomic, institutional, and locational characteristics of the villages in the periphery of the Reserve that influence its degradation.

1.3. The objectives of this study

The general objective of this study is to identify the socio-economic, institutional, and locational characteristics of the villages in the periphery of the W Biosphere Reserve that may explain its degradation. Specifically, the study will:

- characterize the different types of pressure (incidents related to illegal poaching, illegal timber harvesting, illegal cattle ranching, and illegal logging) faced by the W Reserve from the population in the villages in its periphery;
- characterize socioeconomically the W Biosphere Reserve's adjacent villages using cluster analysis; and

- identify if, and to what extent, the socioeconomic, institutional, and locational characteristics of the villages in the periphery of the W Biosphere Reserve influence its levels of degradation.

1.4. Brief presentation of the W Biosphere Reserve and its periphery

The W Biosphere Reserve is in West Africa and crosses three countries: Benin, Burkina-Faso, and Niger. With respective populations of 10,870,000; 18,850,000; and 19,190,000, these three countries are French speaking countries and share several economic and cultural ties. Administratively, these three countries have similar administrative structures (divided in regions, districts, and villages). Within these countries, the Reserve crosses 12 districts (5 districts in Benin; 3 districts in Burkina Faso; and 4 in Niger) with about 210 villages (Benin: 83; Niger: 71; Burkina-Faso: 56) in its periphery.

The human population in the periphery of the Reserve is estimated at 405,000 people (ECOPAS, 2003) and belongs to different ethnic groups. The Bariba, Mokolle, and Dendi represent the main ethnic groups in Benin while the Gourmantche are the most dominant group in Burkina-Faso. In Niger, the Zarmas, Haoussa, Foulmaganis are the main ethnic groups while the Fulani are present in all three countries (Barbero et al., 2011). The source of livelihood of the populations in the periphery include farming, cattle ranching, hunting, fishing, wood and non-wood resources utilization (Barbero et al., 2011).

The Reserve comprises three zones:

- the core area of the Reserve (where no human activity is authorized) covers an area of 1,033,920 ha (56% in Benin, 23% in Niger, and 21% in Burkina- Faso);

- the buffer zone of 803,014 ha (29% in Benin, 68% in Niger, and 4% in Burkina Faso) where ecological and sustainable development activities from the communities are authorized and promoted;
- the last zone of an area of 25 km^2 around the buffer zone is called the transition zone with no protection status. However, in this area, sustainable development models are also promoted to reduce the pressure of the population in the periphery on the two previous zones.

Particularly, activities (poaching, farming, cattle ranching, and logging) of the population in the first zone (core area of the Reserve) are recorded by the Reserve administrations as illegal and were used for this study.

Although there are collaborations in the management principles of the Reserve, each country managed the areas of the Reserve on its territory based on its national legislation. The Centre National de Gestion des Reserves de Faune (CENAGREF) is the institution that manages the Benin part of the Reserve while the part in Burkina Faso is managed by the Forestry Decentralized Administration. The part of the Reserve in Niger is managed by the Parks and Reserves Administration.

The creation of the W Reserve started in the years 1920s because of the high presence of animal and plant species in the area. Its high concentration in biodiversity was explained by the low human population in the region due to the presence of human pathologies (such as onchocerciasis), and the Tse Tse fly (which prevents animal husbandry). Accordingly, the colonial administration took the decision to classify it as a park in 1927, and more formally in 1937 as protected area with the goal of protecting its biodiversity from any human threat.

However, although the human population density was low due to hostile life conditions for humans, small communities (Gourmantche, Fulani, Zarmas, Haoussa) were living in the area with its plants, and animals as their source of livelihood. Therefore, because of the threat that these local communities were representing for the preservation of this ecosystem they have been displaced by the colonial administration to the periphery of the protected area in 1940. From cattle ranching to farming, no human activity was authorized.

Starting with the independence of these three countries in 1960s, the countries reinforced the legal status of the complex for concerted management, and with international conventions (such as the Ramsar Convention on Wetlands in 1971, and the Convention on the Protection of World Cultural and Natural Heritage in 1972), the W Reserve became the W Biosphere Reserve. Since 2002, the Reserve became the first transboundary Reserve of Africa. Figure 1.1, and 1.2 present the study area.

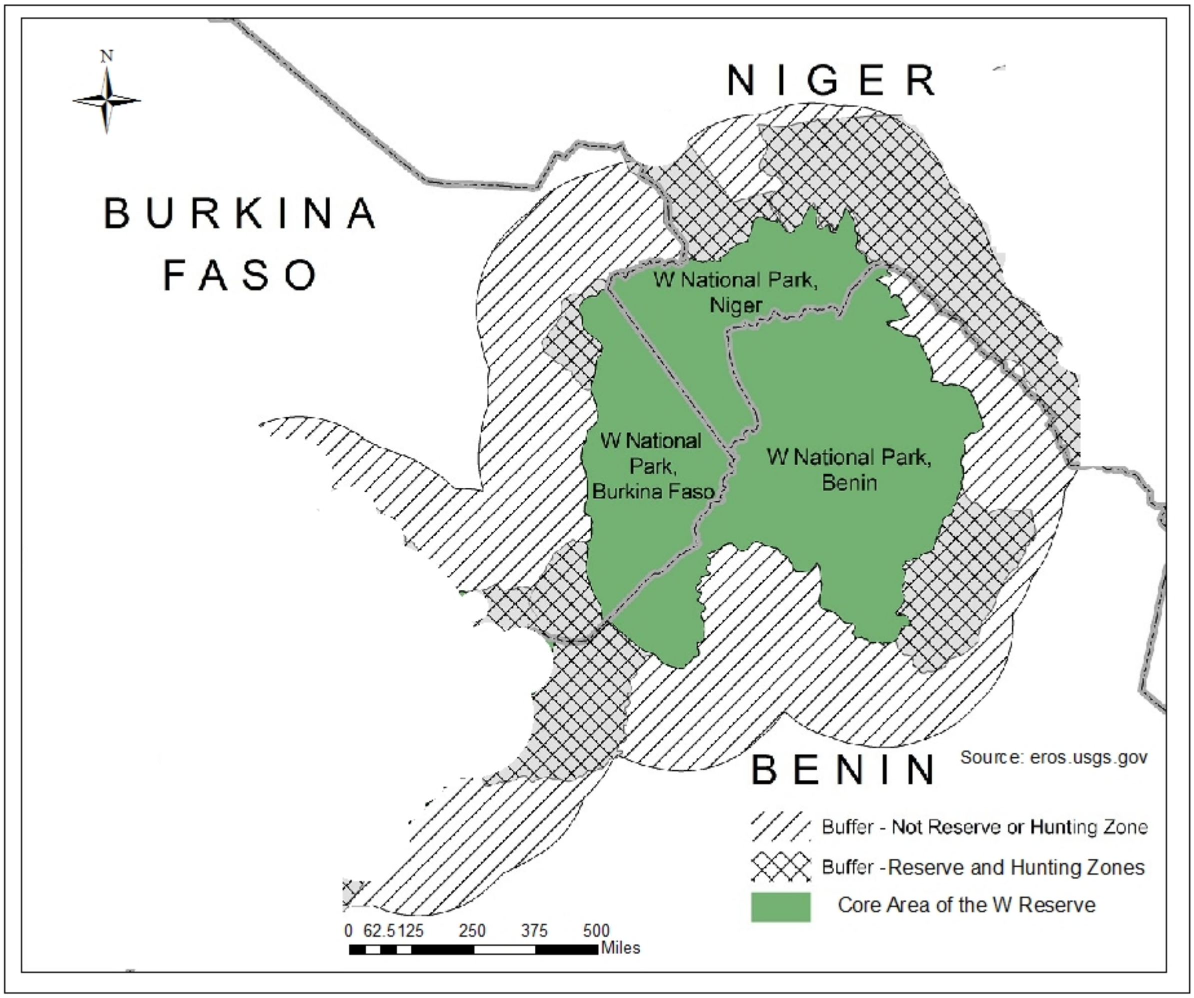

Figure 1. 1. Study area

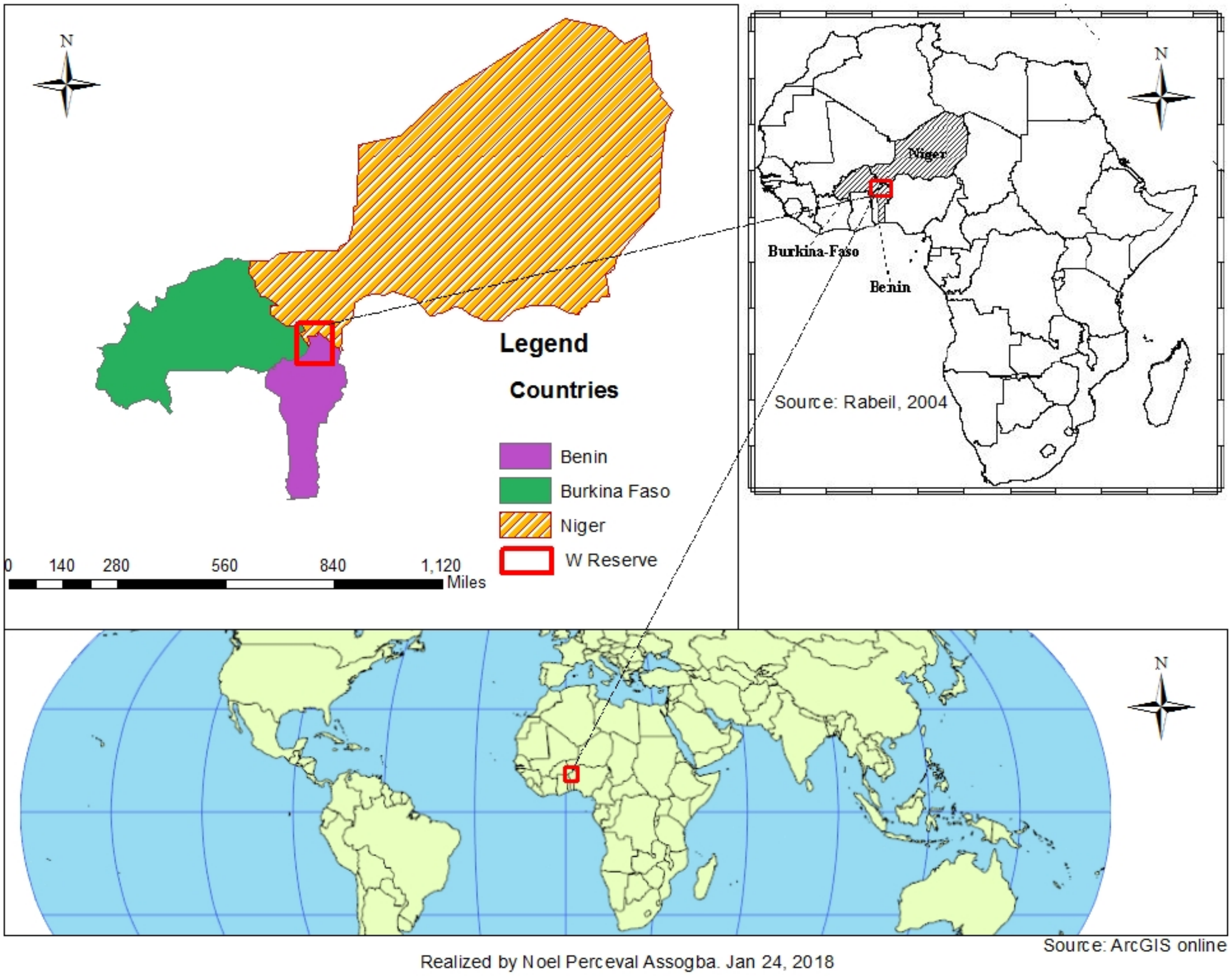

Figure 1. 2. W Reserve regions

2. LITERATURE REVIEW OF STUDIES ON FOREST RESOURCE CONSERVATION

Transforming the communities around protected areas into being part of the solution rather than part of the problem of their conservation could be an effective tool for ecosystem preservation in the world. Such a goal can be achieved through the implementation of sustainable models of biodiversity conservation that include both the interactions between biodiversity dynamic and the population in their periphery.

Biosphere reserves and protected areas are generally created to foster environmental education, ecosystem preservation, and local development. In the literature, threats to the conservation of these resources from the population in their periphery include deforestation, animal poaching, and extensive cattle ranching. Deforestation refers to the loss of forests areas resulting from the removal of tree species (FAO, 1978). According to FAO (2009), the tree cover loss should be below the threshold value that defines a forest in the specific area and the forest lands converted to a non-forest use. It can happen when forest lands with high opportunity costs are converted into alternative uses such as farming, roads, infrastructures, or when valuable tree species are removed without a replacement plan for domestic, commercial uses, etc.

Animal poaching, the second type of threat which refers to illegal hunting or fishing, happens when the animals are either protected, hunted, or fished during unauthorized periods or with prohibited tools (Barbero et al., 2011). According to Manel et al. (2002), poaching is one of the most significant threats to the survival of plant and animal species on our planet. The danger from this threat comes from the use of poisons and chemicals that can be responsible for major wildlife deaths in forests or reserves as well as the uncontrolled killing of wildlife. Additionally, extensive cattle ranching threatens protected areas' biodiversity through the risks of disease propagation, competition for fodders and the migration of wildlife to nonproductive areas.

2.1. Animal poaching as a proxy of forest degradation

Few authors have explored the potential factors influencing illegal hunting activities in protected areas in the literature with some results. One example of such studies includes the study of Knapp (2012) who analyzed the factors influencing poaching in Tanzania, with the Serengeti National Park as a case study. The author collected data through semi-structured interviews from 104 individuals (who voluntarily admitted being active or recently involved in illegal hunting activities) and analyzed them using a costs and benefits approach. He identified the provision of household protein and additional income as the benefits from the activity and personal injury, fines, and/or prison sentences as the associated costs. In the region, the study pointed out poaching as the highest income generating activity during a year with the revenue amount estimated at USD 425 against USD 61, USD 79, and USD118 respectively from livestock selling, crop selling, and trade or small business, respectively. The main drivers of this activity reported are poverty and income shortfall.

In Nepal, Poudyal (2005) investigated the potential factors explaining the rise of the poaching of the one-horned Rhinoceros with the Royal Chitwan National Park as a case study. With the data recorded from 1973 to 2003 by the surveillance unit of the park, the author using a reduced-form poaching model empirically estimated, through Poisson and Negative Binomial regression models, and observed a positive correlation between poaching and the population of rhinos at the start of a year. However, the results of this study indicated a negative correlation between poaching and the number of Anti-poaching units, as well as the real GDP per capita of Nepal.

In Zambia, Miller-Gulland and Leader-Williams (1992) analyzed the relationship between law enforcement, economic incentives, and poaching with the illegal hunting of rhinos and elephants in Luangwa Valley as a case study. The authors concluded from data recorded from 1979 to 1985 that high probabilities of being captured, with penalties (that vary with respect to the illegal hunters' outputs), are a more effective tool to reduce poaching than a fixed penalty. Moreover, the study pointed out that the reaction to law enforcement is specific to each type of poacher. Indeed, while reducing poaching activities from organized groups requires improved law enforcement operations, local investment schemes can be effective for local poachers.

In addition to the factors that may influence poaching activities, Dobson and Lynes (2005) analyzed how illegal animal hunting influences national parks' size. In this study, Dobson and Lynes (2005) pointed out that poaching has a negative effect on the effective size of national parks by reducing the protected areas' plants and animal' numbers. This effect varies depending on the original size of the park and whether the poachers hunt for subsistence or are members of organized networks. Finally, the authors concluded that increasing the probabilities of capturing the poachers as well as creating viable alternative livelihoods and benefits for the communities in the parks peripheries will be effective tools to tackle illegal hunting issue within these areas.

These studies pointed out, first, two major types of poachers: (i) local subsistence poachers, and (ii) professional hunters who are members of international networks. Second, poaching activities provides several benefits to the hunters such as protein and income with low costs (low probabilities of being captured, and penalties in comparison to the output). Third, the factors influencing poaching activities include poverty, income shortfall, and the absence of alternative sources of livelihood for the communities around the protected areas.

2.2. Deforestation as a proxy of forest resource degradation

In the literature, several authors have investigated the factors that influence forest resource degradation with deforestation as a proxy with different results. The differences in the results come from the differences observed in the observation units and the measurement of deforestation. Particularly, based on the observation units, two categories of studies are observed, namely country- level studies, and individual household- level studies. Similarly, based on the measurement of deforestation, the rate of deforestation, and the average annual agricultural land growth are the two major groups.

One example of a country- level study is the study of Culas (2014) who analyzed the causes of deforestation using data from 52 countries (9 countries from Asia; 22 countries from Africa; and 21 countries from Latin America) with forest cover change between 1991 and 2000 as the dependent variable. The data analyzed using a two-stage linear regression model indicated the annual round wood consumption and forests products exports as the factors explaining deforestation in Africa and Asia, respectively. In Latin America however, forest products exports, and the change in cropland are the factors explaining deforestation.

Another study on deforestation with countries as observation units is the study of Diarassouba and Boubacar (2009) who investigated the drivers of deforestation in Sub-Saharan Africa with the rate of deforestation from each country as a proxy to deforestation. The authors used data from 1990 to 2004 from 27 countries from the region and analyzed them using a linear regression model. They found a positive correlation between deforestation and the variables - population density and floating exchange rate regime.

Similarly, Southgate (1994) analyzed the causes of deforestation in Latin America using data from 24 countries with the average annual agricultural land growth over the period 1982-1987 as deforestation proxy and a linear regression model. The results of the study reported a positive correlation between forests clearance and the variables- population growth and agricultural export growth. Negative correlation was found between deforestation and growth in agricultural yields.

At individual country- level, Yiridoe and Nanang (2001) investigated the causes of tropical deforestation with Ghana as the study unit. The authors using a two-stage regression method with the average annual change in forests area and woodland as a proxy to deforestation identified four significant factors explaining deforestation in the country: fuelwood consumption, forest products exports, food crop production, and cocoa production. Indeed, while negative correlation was found between deforestation and cocoa production, a positive correlation was observed between deforestation and the three other variables (fuelwood consumption, forest products exports, and food crop production).

From these studies, the factors influencing deforestation at countries level can be summarized around five points: (i) domestic demand for woods products, (ii) international demand for wood products, (iii) domestic and international demand for farm products, (iv) demography, and (v) exchange rate between countries.

However, although country- level studies provided valuable information in identifying the factors influencing deforestation, additional factors have been reported by studies at the individual household- level. One example is the study by Babigumira et al. (2014) who analyzed forests clearing in rural areas with household- level data. The authors used data collected from 7,172 households from 24 developing countries and analyzed the dichotomous decision of converting forest areas into farms or not using random effects Logit, while the factors influencing the size of forest area cleared was analyzed using random effects Tobit model. The results from the Logistic regression model indicated a positive correlation between the decision to clear forests and the variables- availability of male labor within the households, household headship (with higher effect of male headed households), households with assets up to USD 100, size of land owned below 3ha, ownership of livestock (up to 5 Tropical Livestock Units), and the market orientation of the farming activities. Finally, as for the size of the forest areas, a positive correlation was found with the variables- land area owned by the farmers, distance from the forest, and quantity of tropical livestock units, while access to electricity has a negative correlation with forests areas clearing.

Similarly, in Ethiopia with individual households as observation unit Daksa and Kotu (2015) investigated the factors influencing deforestation with the Komto Forest as a case study. The results of their study using data collected from 150 household head respondents (with the volume of woody biomass consumed and sold in cubic meter as a proxy of deforestation) and analyzed using the Heckman maximum likelihood model indicated a negative correlation between large landholding size and deforestation. Other factors fostering trees removal from the forest are poverty and institutional failure related to the management of the forest.

In Tanzania with individual households as observation unit, Giliba et al. (2011) investigated the socio-economic factors explaining deforestation with the Bereku Forest Reserve as a case study. The authors using data collected from 120 respondents randomly selected in the area (with deforestation in the Reserve measured as a binary variable) and analyzed using the Logistic regression model identified as significant factors: livelihood activities, period of residence, and the distance from homestead to the forest. Indeed, deforestation in the region is positively correlated with the variables- livelihood activities and period of residency. The correlation between deforestation and the variable- distance from homestead to the forest is negative.

Likewise, in Haiti with individual households as observation unit, Dolisca (2005) analyzed the factors influencing deforestation with the Foret des Pins Reserve as a case study. The author used data collected from 243 households randomly selected in the study area (with the increase in the farm areas during a period of 6 years as a proxy of deforestation) and analyzed the data using Tobit regression model. The results indicated two groups of factors influencing forest clearance in the region. The first group encompasses factors fostering deforestation: household size and farm labor while the second group includes the factors having negative correlation with deforestation: level of education of the household head, land tenure regime, and the number of years of residency in the region.

More recently, in the Congo basin using individual households' data, Ngouhouo-Poufoun (2016) investigated the relationship between the Tridom deforestation and the livelihood strategies and socioeconomics characteristics of rural households. Particularly, distinguishing two livelihoods strategies namely diversification (agriculture, cash crop, and or forest-based activities) and specialization, the author observed a significant and positive correlation between deforestation and the incomes from the livelihood strategies. Positive correlations were found between deforestation and the variables- age, household size, gender, membership to community group, while negative correlations were observed with the variables- human-wildlife conflict and auto consumption expenditures in the total income of the households.

These studies showed first, area specific factors which can be summarized under 5 major capitals: human capital (labor, household headship, etc.), physical capital, natural capital (size of land areas owned, land tenure regime, etc.), financial capital, and mediating capital (distance from the homestead to the forest, market orientation farming).

On the other hand, the results from the second source of differences in the literature on the factors influencing deforestation, namely the proxy for deforestation can be summarized around the following points. While the studies that considered the annual average agricultural land growth as the proxy for deforestation (e.g., Babigumira et al., 2014; Dolisca, 2005) identified the factors such as demand for agricultural products, availability of labor, land tenure regime, and number of years of residency in the region as influencing deforestation, the studies that used the rate of deforestation (e.g. Culas, 2014; Yiridoe and Nanang, 2001) reported demand for forests products, population, roads, exchange rate, etc.

However, although differences are observed in the literature on the factors that influence deforestation, Angelson and Kaimowitz (1999) observed that these factors can be grouped into three levels. The first level includes the agents of deforestation (e.g. small farmers, ranchers, plantation companies, etc.) who are the sources of deforestation. The second level comprises decision parameters (e.g. technology, markets, institutions, infrastructure, etc.) that provide incentive to the agents' decisions, while the third level includes macroeconomic level variables and policy instruments (e.g. exchange rate, property regime, etc.).

2.3. Cattle ranching as a proxy of forest resource degradation

The relationship between extensive cattle ranching and forest resource degradation have been investigated in the literature. One example of such studies is the study of Barona et al (2010) who analyzed the role of pasture and soybean in the Brazilian Amazon degradation. In this study, the authors used annual census data at municipality level and linear regression model for the data analysis. The results of their study indicated a strong correlation only between the amazon degradation and cattle ranching; allowing them to conclude that the expansion of pasture is the predominant cause of the Brazilian Amazon degradation.

Walker et al. (2000) focused on the relationship between forests degradation and extensive cattle ranching at household level in the same region (the Brazilian Amazon). The authors using both satellite imagery and data collected in 1993 from 134 individual herders observed that extensive cattle ranching contributes to the degradation of the Brazilian Amazon through the conversion of its forestlands into pasture areas. Indeed, dividing the study area in 4 sub regions (region 1: Santana do Araguaia; region 2: Ourilandia do Norte, region 3: Altamira; region 4: Uruara), the authors pointed out a non-uniform contribution of cattle ranching to the sub-regions deforestation. Hundred percent (100%) of the Amazon deforestation were attributable to cattle ranching in the region 1 against 12%, 8%, and 24% in the regions 2, 3, and 4 respectively. Finally, they found that the herd sizes, the market price of beef, and the availability of hired labor as the factors favoring the conversion of forestlands into grazeland by ranchers.

In Paraguay, Lovera (2014) analyzed the impact of livestock farming on the environment with forests degradation as the proxy of this effect on the environment. The result of this study indicated that about 50% of forest resource degradation is caused by extensive cattle ranching through their conversion into pasture lands. The activity is driven by the high demand of beef meat on the international market.

These studies show first, that cattle ranching contributes to forests degradation. Second, the conversion of forestlands into grazelands in Latin America are influenced by several factors including the market price of meats both locally and on international markets. Third, little is known so far on the relationship between cattle ranching and forests degradation in West Africa.

3. THEORETICAL APPROACH

3.1. Classification methods

In the literature, classification methods are recommended to summarize data based on their characteristics (Sharma, 1996). Indeed, they are effective tools to identify groups of data with common features and have the power of processing a wide variety of data (Phyu, 2009).

Classification methods consist of grouping data into classes based on their common attributes or resemblances (Kesavaraj and Sukumaran, 2013). The objective is to group within a same group, objects with similarities, and in different groups, objects that are different or unrelated. Hence, the greater the homogeneity within a cluster and the greater the dissimilarities between clusters, the better the classification. They provide an abstraction from individual data objects to the groups in which the data objects belong. They have been used in several areas such as medicines (Guerra et al., 2010), computer sciences (Phyu, 2009) and social sciences (Dolisca, 2005; Crossa et al., 2002), and they rely on algorithms that map the input data to a group (Guerra et al., 2010). Algorithms are principles underlying the definition of the groups or clusters in the methods. They are summarized in models which can be used to categorize data sets in classes in which the groups assignments are unknown.

Two main approaches can be observed. One is the supervised classification approach, and the other is the unsupervised approach. While the unsupervised approach does not define categories prior to the classification, the supervised approach (or cluster analysis method) based on the knowledge of the phenomenon, and/or the objectives of the researcher, defines the categories before the analysis. Cluster analysis methods include hierarchical clustering (which is a set of nested clusters structured like a tree, measuring the similarities among data using several techniques such as centroid method, single-linkage method, ward methods), and non-hierarchical clustering (that present non-nested structures) (Sharma, 1996).

Although these methods use different techniques to define the clusters, they yield similar results; justifying what several studies pointed out — that there is no single best method (Phyu, 2009). They can be used as complementary methods for the identification of the heterogeneity among groups of observations. Their effective use requires data with specific features and properties. These include multivariate data set with N observations (or objects such as the villages), and k variables representing the characteristics of the observations (or attributes which can be categorical, and/or continuous) (Dolisca, 2005; Crossa et al., 2002).

3.2. Forest conservation model

Failure in forest resource conservation in protected areas can result from several actions from the communities in their periphery (e.g., poaching, illegal logging, illegal cattle ranching, etc.) when their protection systems are ineffective. One source of the imperfection in the resources protection systems can come from the nature of these resources.

In the literature, several models have been proposed to analyze the factors that influence natural resource conservation. One such model is the livelihood framework (Babigumira et al., 2014; Allison and Horemans, 2006; Campbell et al., 2001). Within this framework, actions resulting in natural resource degradation come from the links that exist between these resources and the livelihoods of the households in their periphery. The livelihood framework considers essential the understanding of the livelihood strategies as well as the contextual realities in a specific place for the explanation of the interactions between the communities and the natural resources. It comprises 5 major factors, namely, external uncontrollable factors (e.g. employment opportunities), livelihood assets (e.g. human capital, natural capital), transforming structure (e.g.

enforcement system, education, market), livelihood strategies (e.g. cattle ranching, farming, hunting), and livelihood outcomes (e.g. income, food) (Babigumira et al., 2014; DFDI, 1999). This model takes a holistic approach, and because of its structure, it is considered as a more general model used for the derivation of specific models in understanding interactions between rural households and natural resources.

A specific model used in the literature is the open access model from Sutinen and Anderson (1985) and modified by Charles et al. (1999) to analyze the behavior of fishers in three regulatory contexts, namely, unregulated, imperfectly enforced input controls, and imperfectly enforced output controls. The open access model is a short-run profit-maximizing model consisting of a specification of production and cost functions, which of their forms depend on the type of resources being modeled. Particularly, for the analysis of illegal fishing activities by fishers in the context of inputs controls, Charles et al. (1999) assumed linear quadratic production and costs functions; and a bundle of variable inputs where one can serve as prohibited input. The open access model can be used to analyze the incentives of the degradation of natural resources on which the actors whose actions are responsible for the degradation have no control over the access to these resources (Bulte and van Kooten, 1999; Poudyal, 2005). For the conservation of the resources in protected areas, two major players can be observed: governments and the individuals who illegally use these resources. Governments assure the conservation of the resources through management and surveillance organizations of the protected areas, while the individuals in the periphery of the protected area who depend on the vulnerability context in their localities (DFDI, 1999) can illegally enter into the protected areas for poaching, farming, cattle ranching, etc.

Following the model by Milner-Gulland and Leader-Williams (1992); Charles et al. (1999); Bulte and van Kooten (1999), profit-maximizing individuals in the villages in the periphery of the W Reserve carry out illegal activities (such as poaching, illegal cattle ranching, etc.) to maximize short-run profit. Let's denote by *p* the unit price of output, *f* the quantity of output, *z* the quantity of input, and *d* the unit price of input. The optimization problem of the individuals can be expressed as follows:

$$Max_z \{pf - dz\} \quad (1)$$

Solving for the first order condition, equation (1) yields the following marginal condition:

$$pf_z = d \quad (2)$$

Equation (2) indicates that the individuals maximize their profit at the condition where marginal revenue and marginal cost are equal.

Illegal activities imply the existence of a law enforcement system or mechanism to prevent or reduce the activities. In the case of the W Reserve, the law enforcement system consists of the surveillance and checkpoints between the Reserve and some villages in its periphery. Hence, the implementation of these illegal activities is associated with some risks. These risks can be measured by the probabilities of being detected and/or being punished (e.g. prisons, fines, etc.). Considering the risks associated with the activities, and in the cases in which the individuals who carry out illegal activities in the Reserve are caught without the outputs they removed illegally from the Reserve (e.g. trees, or animals already sold or consumed, etc.), the optimization problem in equation (1) becomes:

$$Max_z = \{pf - dz - \Omega R\} \quad (3)$$

where Ω is the probability associated with being caught, *R* the level of fine, and ΩR the expected value of the fine. The output *f* is assumed to be a function of input level and of the biomass available for exploitation; Ω is a function of the enforcement and the output; and *R* a function of the output. Consequently, solving (3) the marginal condition for profit maximization is as follows:

$$\mathrm{p}f_z = d + f_z\, [\Omega_f R + R_f\, \Omega] \qquad (4)$$

Equation (4) indicates that profit is maximized when the marginal revenue equals the input cost per unit plus the marginal change in the expected fine with a change in output (Milner-Gulland and Leader-williams, 1992).

On the other hand, in the cases in which the individuals carrying out illegal activities in the Reserve are caught with the outputs (animals, trees, etc.) they removed illegally from the Reserve are confiscated, the optimization problem in equation (1) becomes:

$$Max_z = \{pf - dz - \Omega pf - \Omega R\} \qquad (5),$$

Consequently, solving (5) the decision rule of the individuals for profit maximization is as follows:

$$\mathrm{p}f_z = d + f_z\, [\Omega_f\, (pf + R) + \left(p + R_f\right) \Omega] \qquad (6)$$

Equation (6) indicates that profit is maximized when the marginal revenue equals the input cost per unit plus the sum of the marginal change in the expected fine and revenue with a change in output.

The optimum output is expressed as:

$$f^* = f(z^*, H) \qquad (7)$$

where *H* is the biomass of the goods (e.g. games, fodder, etc.) removed illegally by the individuals from the Reserve.

The explicit form of the profit-maximizing output can be obtained by defining the form of the production function. Following Poudyal (2005), Charles et al. (1999), and Milner-Gulland and Leader-williams, (1992), let's define the production function *f* as:

$$f = \mu zH \quad (8)$$

where μ is a catchability coefficient that is species specific. The probability of being caught is assumed to be proportional to the input:

$$\Omega = \alpha z \quad (9)$$

where $0 < \alpha < 1$.

The penalty or fine is assumed to be proportional to output:

$$R = \eta f + p \quad (10)$$

Substituting equations (8), (9), and (10) in equation (3), the optimization problem is:

$$Max_z = \{p(\mu zH) – dz - \alpha z (\eta \mu zH + p)\} \quad (9)$$

Equation (9) implies the following condition:

$$p\mu H – d - 2\alpha z\eta\mu H - \alpha p = 0 \quad (10)$$

Rearranging equation (9), we obtain:

$$z^{*} = \frac{(p\mu H - d - \alpha p)}{2\alpha \eta\mu H} \quad (11)$$

Substituting equation (11) in (6) the quantity of output harvested is:

$$f^{*} = \frac{(p\mu H - d - \alpha p)}{2\alpha \eta} \quad (12)$$

Equation (12) suggests that the quantity of output harvested through illegal activities are functions of the unit prices of the inputs and output, the stock of the biomass (or goods) in the Reserve, the penalties (or fines), and the probability of being caught.

Similarly, substituting equations (8), (9), and (10) in equation (5), the optimization problem is:

$$Max_z = \{p(\mu zH) - dz - (\alpha z)p(\mu zH) - \alpha z\,(\eta\,\mu zH + p)\} \qquad (13)$$

Equation (13) implies the following condition:

$$p\mu H - d - 2\alpha zp\mu H - 2\alpha z\eta\mu H - \alpha p = 0 \qquad (14)$$

Rearranging equation (14), we obtain:

$$z^* = \frac{(p\mu H - d - \alpha p)}{2\alpha\,\mu H\,(p + \eta)} \qquad (15)$$

Substituting equation (15) in (6) the quantity of output harvested is:

$$f^* = \frac{(p\mu H - d - \alpha p)}{2\alpha\,(p + \eta)} \qquad (16)$$

Similar to equation (12), equation (16) suggests that the quantity of output harvested through illegal activities are functions of the unit prices of the inputs and output, the stock of the biomass (or goods) in the Reserve, the penalties (or fines), and the probability of being caught.

Due to data limitation, we used the number of cases of illegal activities (e.g. poaching, illegal logging, illegal cattle ranching, and illegal farming) as measurements of resource degradation. On the markets of input and output, their unit prices are determined by demand factors (e.g. population, income level, substitutes etc.), supply factors (biomass, animal population, surveillance costs, etc.), and policies (promotion of financial institutions, participatory management policies, etc.) (Zhang and Pearse, 2012). We did not find data on the unit prices of the inputs and output from illegal activities in the Reserve. As alternative, we considered as measurements for their effects, the variables such as population, average level of incomes, and the existence of financial institutions. Finally, we considered the variables such as the existence of checkpoints for the measurement of the effects of the probability of being caught, the penalties, and the stock of biomass in the Reserve.

4. METHODOLOGY

This section presents the different phases followed during this study. These phases were three and comprise: (i) literature review; (ii) exploratory phase and data collection; and (iii) data analysis and thesis writing.

4.1. Literature review

This phase was transversal to all the steps followed during this study. two types of documents were used: the electronic documents (scientific papers, studies' reports, activities' reports) and hard documents (studies' reports, activities' reports) obtained in the libraries of the administrations in charge of W Reserve management (in Benin, Burkina-Faso, and Niger) and from the administrations of the districts in the periphery of the Reserve.

4.2. Exploratory phase and data collection

This phase comprises two steps: the exploratory step and the data collection step.

4.2.1 Exploratory step

The exploratory step was done in Benin. First, it consisted in meeting the national administration of the W Reserve in Benin for the presentation of the objectives of the study, the data expected, and the questionnaires elaborated. Second, this step allowed the understanding of the organization of the administrations in charge of the management of the Reserve in the three countries and the form of collaboration between these administrations.

From this step, the questionnaire was modified based on the statistics collected by the Reserve administrations. Third, the local administration in charge of the management of the W

Reserve in Kandi (Benin), and the conservators in the administrations of the W Reserve in the two other countries (Burkina-Faso, and Niger) were contacted by the Benin national administration of the Reserve for the introduction of the studies and their availability during the data collection.

4.2.2. Data collection

Three types of data were collected. The first type of data was data related to the types of pressures faced by the W Reserve from the population in the villages in its periphery, and the Reserve’ degradation statistics recorded by the administrations in charge of its management in the three countries (Benin, Burkina-Faso, and Niger). The second type of data comprises the characteristics of the villages namely, socio-economic variables (such as average level of income, population, etc.); institutional characteristics (such as existence of checkpoints, number of environmental organizations, number of credit institutions, participatory management of forest resource, etc.); geographic characteristics (such as distance from the Reserve and roads). The third type of data were Geographic Information System (GIS) data on the Reserve and its periphery. These data include shapefiles on the Reserve limits and the villages in its periphery, and the attribute table on the villages. Particularly, the attribute table included data on the population in each village, and their number of households in 2003.

The statistics on the Reserve degradation (first type of data) were obtained from the administrations in charge of the W Reserve management in each country and covered the period January 2016 to May 2017. The second type of data (data on the characteristics of the villages) was obtained from the administrations of the districts in the Reserve periphery in one hand, and from the national statistics on the demographic characteristics of the countries on the other hand. Finally, the GIS data were obtained from the administration in charge of the Reserve management in Niger. Particularly, for the population data no estimation for the villages was available for 2016. Hence, we estimated the 2016 population of each village using the 2003 GIS data on population and the average annual population growth rate of each country from 2003 to 2016. Also, to estimate the distance between the Reserve and the villages in its periphery, we used ArcMap 10.3 distance measurement with the GIS Data. Table 4.1, and Table 4.2 present the descriptive statistics of the continuous, and binary variables respectively of the data.

Table 4. 1. Descriptive statistics of continuous variables

Variables	Number of observations	Mean	Standard deviation	Min	Max
pop	93	1577.235	1679.487	55	10315
income	93	16715.050	6440.952	10000	30000
farm_size	93	2.1411	1.0880	1	4
credit	93	1.0430	0.8198	0	2
env_ngo	93	1.2043	0.7598	0	2
dist	93	15.3180	16.0764	0	66.3843

Table 4. 2. Descriptive statistics of binary variables

	Existence of checkpoints		Existence of road		Implementation of Participatory Management of forest resource	
Binary outcome	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
0	56	60.22	76	81.72	43	46.24
1	37	39.78	17	18.28	50	53.76

Additional data were collected through interviews with the representatives of the forests conservation associations, reference persons, and non-governmental organizations (NGO) promoting the preservation of the environment in the region.

4.2.3. Sample size

The total number of villages in the periphery of the Reserve in the three countries is estimated at 210. However, because the data on the socio economics characteristics were obtained for 93 villages, we used only these 93 villages for the study.

One issue that could be associated with our sample would be how representative is it of the villages in the periphery of the Reserve. To address this issue, we conducted the test of mean comparison between the villages in our sample with the villages not considered in the sample due to data limitation. Indeed, we obtained data on the variables population and distance on 190 villages (which includes the 93 villages used as for this study) that we used for the mean comparison. The p-values associated with the t test of mean comparison are not statistically significant for the variables population (p-value = 0.4089) and distance (p-value = 0.5828); indicating that the sample used for the study is representative of the villages in the periphery of the Reserve.

4.3. Data analysis

The data analysis methods are specific to each objective. Therefore, it is presented per specific objective.

4.3.1. Characterization of the degradation of the W Reserve (pressures faced by the Reserve from the population in its periphery)

Descriptive analysis method was used for the analysis of the data on the degradation of the Reserve (pressures faced from the populations in its periphery). This includes: percentage, maximum, minimum, graphs, and charts.

4.3.2. Socioeconomic characterization of the villages in the periphery of the W Biosphere Reserve using cluster analysis

The characterization of the villages based on their socio economics features was done using cluster analysis. Fours steps (namely, the standardization of the data, the identification of the similarities among the observations, the selection of the optimum number of clusters, and the clustering of the villages) were followed. The standardization aimed at reducing the bias that could result from the variables unit measures. As for the identification of the common features among the observations, the square Euclidian distance is used (Dolisca, 2005). Table 4.3 presents the description of the villages characteristics used for the analysis.

Table 4. 3. Description of variables used for the villages clustering

Variables types	Variables	Code
	Village population size	pop
Socioeconomics characteristics of the villages	Average annual income (in Franc CFA)	Income
	Average farm areas (in hectares)	farm_size
	Number of Credit (financial) Institutions	Credit
	Distance (in kilometer) between the border of the Reserve and the village in its periphery (measured using Geographic Information System: GIS)	dist
Institutions	Number of non-governmental organizations promoting nature preservation	env_ngo

4.3.3. Identification of the characteristics of the villages in the periphery of Reserve influencing its degradation.

The empirical identification of the factors that influence the W Reserve degradation from the villages in its periphery was done using univariate regression model, and multivariate regression model.

4.3.3.1. Univariate regression model

The identification of the factors influencing the Reserve degradation using univariate regression model was done for each form of degradation (e.g. illegal farming, poaching, illegal cattle ranching) with the following model:

$$y \equiv f(socioeconomics, institutional, location\ characteristics\ of\ the\ villages)$$

$$y = x'\beta \qquad (17);$$

where y represents the dependent variable (indicators of the level of degradation of the Reserve such as numbers of cases of illegal farming, number of cases of poaching cases, number of cases of illegal cattle ranching, and the number of cases of illegal logging); x is a K X 1 vector of the explanatory variables (characteristics of the villages in the periphery of the Reserve); x'= (*1*, population size, average level of income, average farm size, credit, number of non-governmental organizations, distance between the villages and the border of the Reserve, etc.); and, β a K X 1 vector of parameters.

The choice of the functional form, and the parameters estimation methods of the empirical models are determined by the characteristics of the dependent variables (Wooldridge, 2002). Consequently, the dependent variables (number of cases of illegal farming, number of cases of poaching, number of cases of illegal logging, and number of cases of illegal cattle ranching), indicators of the W Reserve degradation available being count data, several models, namely the Poisson regression model, the negative binomial model, the hurdles, and zero inflated model (Katchova, 2013; Cameron and Trivedi, 2010) can be used. The difference between the Poisson regression model, and the negative binomial regression model is determined by the assumption on the variance term. The Poisson regression model assumes that the data meet the equidipersion condition. The hurdle models differ from Poisson and negative Binomial model based on their assumption on the zeros (e.g. whether or not cases of poaching from a specific village is recorded), and the positive values in the dependent variables (e.g. number of cases of poaching from the villages where at least one case of poaching is recorded). They are estimated in two steps; the first step for a binary dependent variable regression, and the second step for a regression with the observation with positive dependent variables (Katchova, 2013). Futhermore, these models require samples with large number of observations for their estimation. Finally, the zero-inflated model is recommended for samples with excess zero.

For the data analysis and depending on the existence of Equidispersion or Overdispersion of the data, the Poisson or the negative binomial regression model was used for the parameters estimation (Camron and Trivedi, 2010; Poudyal, 2005).

The Poisson model is expressed as follow:

$$P(Y = y) = \frac{e^{-\mu}\mu^{y}}{y!}, \quad y = 0, 1, 2, 3\ldots.. \qquad (18)$$

with μ = exp $(x_i\beta)$, the only parameter of the model.

The equidispersion assumption of the Poisson model which fails to hold in general with real data, implies the equality of the conditional mean, and the variance: E$[y|x]$ = Var $[y|x]$.

4.3.3.2. Multivariate Regression (SUR) model

Non-linear SUR can be used to model system of equations when the dependent variables are count data (Cameron and Trivedi, 2010). Particularly, non-linear SUR is recommended when the error terms are correlated across equations for a given individual but are uncorrelated across individuals. Indeed, this model gains in efficiency over single equation model by considering cross-equation error terms correlation. In a village *i* in the periphery of the W Reserve while illegal activities (illegal farming, illegal cattle ranching, poaching, etc.) in the Reserve may be correlated, the correlation of these activities is less obvious across villages.

The non-linear SUR model used in this study is specified using the following system of equations:

$f_j = \varphi\ (X_j\beta_j\ \ )$, j = number of cases of illegal farming, number of cases of illegal cattle ranching, number of cases of poaching, number of cases of illegal logging (19)

where f_j is a T X 1 vector, X_j is a T X K_j matrix of explanatory variables, and T the totoal number of observations. The model can be rewritten in the following general form:

$$f = \varphi\ (X\beta) \tag{20}$$

where *f* is a 4T X 1 vector; X is a 4T X $(K_{ill\_farm} + K_{ill\_cat} + K_{poach} + K_{ill\_log})$ matrix, and β is a $(K_{ill\_farm} + K_{ill\_cat} + K_{poach} + K_{ill\_log})$ X 1 vector of parameters.

4.3.3.2. Ordinary Least Square (OLS) model

To identify the factors influencing the Reserve degradation using the Ordinary Least Square (OLS) method an indicator of illegal activities (dependent variable) is required. Because four types of illegal activities in the Reserve were observed, a data reduction method is recommended. To reduce multivariate data into fewer dimensions, several methods are widely used in the literature including Principal Component Analysis (PCA) and Factor Analysis (FA) methods. These methods aim at reorienting multivariate data into fewer components capturing the maximum variability in the original data. Although these two methods are similar, the FA method differs from PCA method based on the assumption its makes on the existence of few factors driving the variation in the data (Katchova, 2013). Indeed, PCA method makes no assumption on the factors driving variations in the data (Jollife, 2002) as opposed to FA method.

We used the PCA as data reduction method for the estimation of the index of illegal activities in the Reserve after having tested whether the four illegal activities have satisfactory common characteristics warranting the use of this data reduction method. The Least square model is specified as followed:

$$y \equiv f(socioeconomics, institutional, location\ characteristics\ of\ the\ villages)$$

$$y = x'\beta \qquad (21);$$

where y represents the dependent variable (score of the illegal activities in the Reserve on component 1 of the PCA); x is a K X 1 vector of the explanatory variables (characteristics of the villages in the periphery of the Reserve); x'= (*1*, population size, average level of income, average farm size, credit, number of non-governmental organizations, distance between the villages and the border of the Reserve, etc.); and, β a K X 1 vector of parameters.

The choice of the variables in the models was based upon previous empirical literature on the factors influencing forest resource degradation and the forest conservation theoretical model developed above. Particularly, the variables number of cases of illegal farming, illegal cattle ranching, poaching, and illegal logging are used as measurement of the quantity of output removed illegally from the Reserve. The population variable is included in the model to test whether human population size in the villages in the periphery of the Reserve influences its degradation. Indeed, while some authors observed that population has little influence on forest degradation (Ali, 2005; Westoby, 1989), the results of other studies (e.g. Laurance, 1999; Diarassouba and Boubacar, 2009) identified this variable as influencing significantly and positively forest degradation. The variable income is included in the model to account for the relationship that could exist between the Reserve degradation and the average level of income in the villages in the periphery of the Reserve. The variable credit is included in the model to test whether the number of financial institutions in the villages in the periphery of the Reserve influence its degradation. The existence of financial institutions and particularly access to credit could reduce the dependence of the individuals on nature-based resources, and consequently contribute to the decrease in the number of illegal activities in the Reserve. The variable farm size and the growing of cash crop in the model accounts for the relationship that might exist between them and the Reserve degradation. Indeed, in the literature farm exports product have been identified as variable influencing forest degradation (e.g. Southgate, 1994). To reduce the pressure on the Reserve several institutions are promoted in the villages in the periphery of the Reserve. Particularly, the env_ngo variable is included in the model to account for the relationship that could exist between the actions of the non-governmental organizations promoting nature preservation in the villages in the periphery of the Reserve and its degradation. The variable part_mana in the model tests whether participatory management policy influence the Reserve degradation. The variable check_p is included in the model as a measurement of the risks associated with illegal activities in the Reserve when checkpoints exist between the villages and the Reserve. Finally, the variable dist is included in the model to test whether the distance between the villages and the Reserve influence its degradation. Indeed, longer distance between the Reserve and the villages raises the private costs of the individual involved in the illegal activities, and consequently could decrease their incentives in carrying out these activities. Table 4.4 presents the description of the variables used in the models.

Table 4. 4. Description of variables used to identify factors influencing forest resource degradation

Variables	Description
ill_farm	Number of cases of illegal farming in the Reserve
ill_catt	Number of cases of illegal cattle grazing in the Reserve
poach	Number of cases of poaching in the Reserve
ill_log	Number of cases of illegal logging in the Reserve
pop	population
income	Average level of income in a village (FCFA)
credit	Number of financial institutions in a village
farm_size	Average farm area in a village in hectares
cash_cr	growing of cash crop in the village (yes/no)
env_ngo	number of non-governmental organizations promoting nature preservation in a village
part_mana	Implementation of participatory management of forests resources policy (yes/no)
check_p	Existence of checkpoints between the Reserve and the villages (yes/no)
dist	distance between the Reserve and the villages (kilometer)

5. RESULTS

5.1. Characterization of the different forms of pressure faced by the W Reserve from the population in its periphery

Four (4) types of pressures are faced by the Reserve from the population in its periphery, namely poaching, illegal farming, illegal logging, and illegal cattle ranching. Table 5.1 presents the number of cases of these infractions recorded by the surveillance administrations of the Reserve during the period January 2016 to May 2017. Illegal cattle ranching is the most important case of infraction recorded in the region followed by poaching. The predominance of illegal cattle ranching cases can be explained by the important role that cattle play in the economy of the local communities, and the extensive mode of animal husbandry in place in the region. Indeed, the natural fodders and water streams being the main source of food and water for the livestock, the W Reserve due its abundant resources of plants, and water resources (e.g. Niger river) represents an ideal place for ranching. Illegal logging is the less important infraction type recorded in the region. The number of these infraction cases varies from one village to another and depending on the type of infraction. The maximum number of cases recorded per village are respectively 9 for poaching, and illegal cattle ranching, and 4 for illegal cattle ranching, and farming. The minimum number of cases for each of the infractions is 0.

Table 5. 1. Descriptive statistics on number of cases of illegal activities

variables	Total number	Mean	Standard deviations	Min	Max
Poaching	148	1.5914	2.2469	0	9
Illegal farming	35	0.3763	0.8712	0	4
Illegal cattle ranching	161	1.7312	2.4143	0	9
Illegal logging	18	0.1935	0.6798	0	4

The distribution of the infractions recorded by the administrations in charge of the Reserve management is not uniform across the three countries. Poaching was mostly recorded in Benin representing 60% of the total number of cases faced by the Reserve while the lowest number of cases, 18% was recorded in Niger. The relative important number of poaching cases recorded in Benin could be explained by the hunting culture of the population in this country, and its proximity with Nigeria which represents an important market. Another reason that could explain this situation is the relatively important antipoaching units (surveillance) put in place in 2016 following the election of a new central government in the country who placed the preservation and conservation of natural resources as a key component of its policy. Figure 5.1 presents the repartition of the number of cases of poaching recorded in the region during the period January 2016 to May 2017.

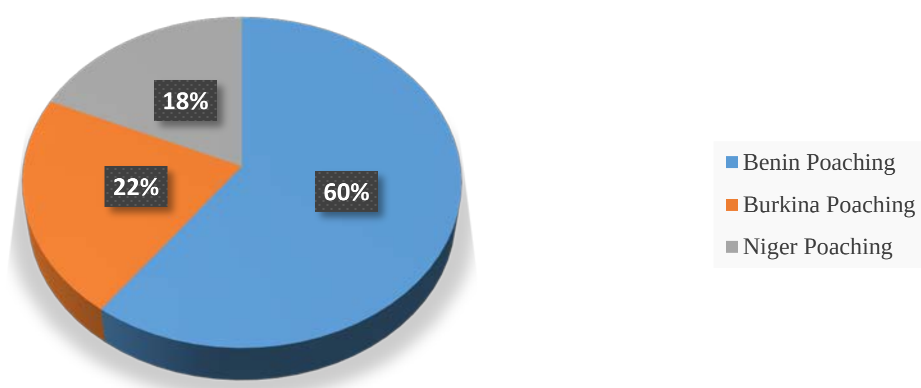

Figure 5. 1. Number of cases of poaching

Cattle is an important economic activity for rural households in the region. The activity is extensive with natural ranching the main source of food for the animals. The Reserve represents an important source of fodder in the region, and consequently is an attraction for the herders in its periphery and beyond. Figure 5.2 presents the distribution of the number of illegal cases recorded by the surveillance administration of the Reserve. The highest number of illegal cattle ranching cases was recorded in Benin, representing 55% of the total number of cases followed by Burkina Faso with 29% of the cases. The lowest number was recorded in Niger, 16%. The highest number of cases of illegal cattle ranching recorded in Benin could be explained by the increases in the investment of the surveillance administration of the Reserve following the installation of the new central government in 2016.

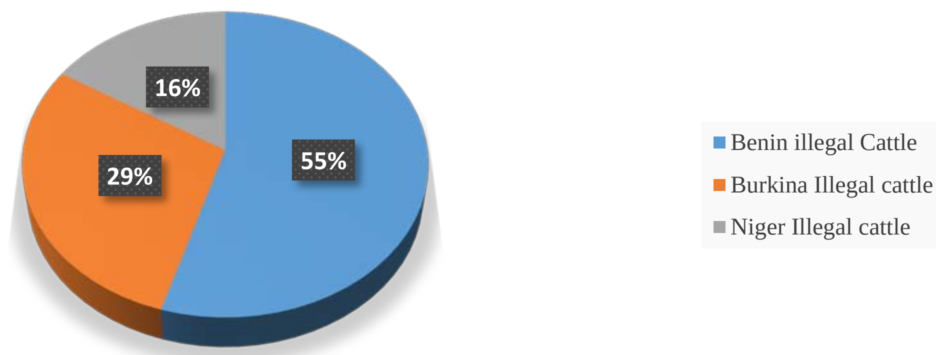

Figure 5. 2. Number of cases of illegal cattle ranching

Although illegal logging was the less represented infraction in the region, its number varies from one country to another. The highest number of this infraction was recorded in Niger, representing 61% of the cases in the region while the lowest number was observed in Burkina-Faso, representing 11% of the cases.

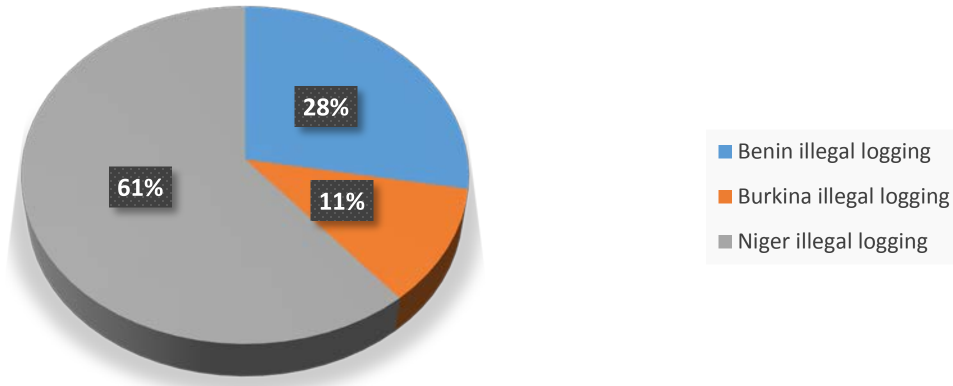

Figure 5. 3. Number of cases of illegal logging

Finally, as for illegal farming, no cases were recorded in Burkina Faso and Niger by the surveillance administrations in these countries during the period.

5.2. Characterization of the villages in the periphery of the W Reserve using cluster analysis

5.2.1. Selection of the optimal number of clusters

The relationship between human population and natural resources can be influenced by the socioeconomic and institutional characteristics of their localities (Angelson and Kaimowitz, 1999). Indeed, these characteristics provide incentive for different choices, and accordingly can be considered in the understanding of the interactions between humans and natural resources. To define the villages in the villages in the periphery of the Reserve into clusters based on their similarities, the optimal number of clusters was identified using the Akaike's Information Criterion (AIC). This method measures the similarities among the variables using the Log-likelihood, and considers as the optimal number of cluster, the number that minimizes the Auto-clustering AIC values.

Figure 5.4 presents the variation of the Auto-clustering AIC values with respect to the number of clusters based on the socioeconomic characteristics of 93 villages in the periphery of the Reserve.

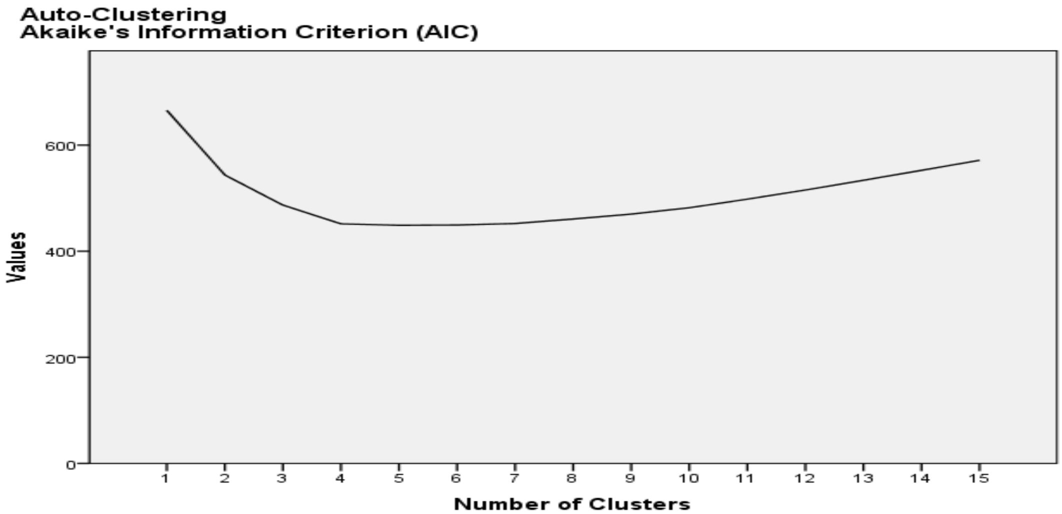

Figure 5. 4. Distribution of the Auto clustering AIC values with respect number of clusters

This figure shows that the Auto-Clustering AIC value decreased from cluster 1 to cluster 4, and increased from cluster 4 to cluster 15. Consequently, cluster 4 being the cluster with the lowest Auto-Clustering AIC value (420), it represents the optimal number of cluster to classify the villages in the periphery of the W Reserve. Table 5.2 presents the distribution of the villages within the clusters.

Table 5. 2. Distribution of villages within the clusters

Cluster	Number of Villages per cluster	Percentage
1	16	17.20
2	34	36.56
3	22	23.66
4	21	22.58

From this table, the cluster 2 represents the largest group with 34 villages while cluster 1 represents the smallest cluster with 16 villages.

5.2.2. Identification of the discriminant variables

Discriminant Function Analysis, Logit or Probit regression models can be used to identify the variables that determine observations membership to clusters (Green et al., 2008). Discriminant Function Analysis is particularly recommended for the identification of the best variables determining membership to clusters when the groups variances meet the homogeneity conditions (Green et al., 2008; Dolisca, 2005). The Box test of equality of variances among the clusters showed a p- value of 0.000, indicating the rejection of the null hypothesis of equality of variances among the clusters. Accordingly, the Logit or Probit regression model can be used for the identification of the discriminant variables with the data.

The difference between the Probit and Logit regression models relies on the assumptions on the error term. Indeed, while the Probit regression model assumes the independence normality on the error terms, the Logit model does not. Moreover, when the categorical dependent variable has more than 2 outcomes, the multinomial Logit or Probit regression models are recommended (Aldrich and Nelson, 1984). However, although both models yield similar results when having the same number of parameters, the best model is the one with the highest log likelihood (Cameron and Trivedi, 2010). The log likelihood value of the multinomial Logit model (Logit model log likelihood =-45.63) was higher than the log likelihood of the multinomial Probit model (Probit model log likelihood = -45.71); therefore, was used for the identification of the discriminant variables.

Table 5.3 presents the results of the multinomial Logit regression model on the socioeconomic characteristics of the villages in the periphery of the Reserve. Because cluster 2 was the cluster with the highest number of villages (34 villages), it was used as the base outcome.

Table 5. 3. Estimation results of the multinomial Logit regression model on the socioeconomic characteristics of villages

Variables	Cluster 1 (n=16)	Cluster 2 (n=34)	Cluster 3 (n=22)	Cluster 4 (n=21)
dist	0.6602		0.0207	0.0112
	[0.123]		[0.12]	[0.124]
pop	0.0004		0.0002	0.0003
	[0.0010]		[0.0010]	[0.0010]
Income	0.0008 *	(Base Outcome)	0.0010 **	0.0009 *
	[0.0010]		[0.0000]	[0.0000]
Credit	4.3431 *		4.4517 *	5.0046 **
	[2.2389]		[2.277]	[2.311]
env_ngo	5.6092 ***		7.0437 ***	6.8788 ***
	[2.123]		[2.204]	[2.226]
farm_size	1.8159		2.6488 *	-0.4273
	[1.379]		[1.433]	[1.512]
Road	0.2627		0.7892	-1.0116
	[2.52]		[2.591]	[2.596]
Constant	-25.4963 **		-32.0389 ***	-25.3544 **
	[10.4225]		[10.641]	[10.401]
Number of observations		93		
LR chi2 (21)		159.42		
Prob > chi2		0.0000		
Pseudo R2		0.6360		
Log likelihood		-45.6267		

*** 1% significance level ** 5% significance level * 10 % significance level; Standard errors reported in the brackets

This table shows three variables statistically significant in cluster 1, 3, and 4, namely the average level of income, the number of credit institutions, and number of non-governmental organizations promoting nature preservation in the discrimination of the villages. In cluster 1, the variables average income level, and credit (number of financial institutions) were statistically significant at 10% significance level. Finally, for this cluster, the third variable env_ngo (number of environmental non-governmental organizations) was statistically significant at 1% significance level. In cluster 3, four (4) variables were statistically significant. These variables were credit (number of financial institutions), and farm_size (the average farm areas) statistically significant at 10% significance level; income (average income level) statistically significant at 5% significance level, and the variable env_ngo (number of environmental non-governmental organizations) at 1% significance level. Finally, three significant variables were observed in cluster 4. These variables were income (average income level) statistically significant at 10% significance level; credit (number of financial institutions) statistically significant at 5% significance level; and env_ngo (number of environmental non-governmental organizations) statistically significant at 1% significance level.

However, since this individual statistical test will vary with respect to the base outcome (omitted cluster), the Wald test is recommended for the identification of the variables statistical significant in the discrimination of the villages (Cameron and Trivedi, 2010). Table 5.4 presents the results of the Wald test for the 6 variables.

Table 5. 4. Wald test results on the variables determining village membership to clusters

Variables	**Chi 2 (3)**	**P-Value**
dist	4.16	0.2448
pop	0.79	0.8519
income	9.85	0.0199
credit	5.08	0.1661
env_ngo	13.79	0.0032
farm_size	16.36	0.0010

From the Wald test results presented in Table 5.4, the membership of the villages in the clusters is determined by three discriminating variables, namely the average income level (p-value = 0.0199), the number of environmental non-governmental organizations (p-value =

0.0032), and the average farm areas in the villages (p-value = 0.0010). Table 5.5 presents the characteristics of the clusters based on the socioeconomics of their villages.

Table 5. 5. Characteristics of clusters based on the socioeconomics characteristics of villages

Variables	Cluster 1 (n=16)	Cluster 2 (n=34)	Cluster 3 (n= 22)	Cluster 4 (n= 21)
pop	2010.9640	1602.4562	1796.8240	975.8947
	(1478.3140)	(1310.5840)	(1699.0600)	(2210.5450)
Income	16218.7500	12029.4120	20295.4550	20928.5720
	(3525.9460)	(2713.4380)	(7120.8260)	(6771.7900)
Credit	1.3125	0.2941	1.5454	1.5238
	(0.7041)	(0.4625)	(0.5958)	(0.6796)
env_ngo	1.3750	0.5294	1.5909	1.7619
	(0.7188)	(0.5066)	(0.5903)	(0.4364)
farm_size	2.4766	2.0220	2.8523	1.3333
	(0.8369)	(1.2019)	(0.9215)	(0.5381)
dist	20.4067	8.5170	17.1194	20.5648
	(12.1493)	(8.3261)	(20.3839)	(19.8918)

Standard deviations are reported in the parentheses

From Table 5.5, cluster 4 is the cluster with the lowest mean population (population = 975) while cluster 1 is the most populated cluster (population = 2010). The lowest average income level is observed in cluster 2 (average income level = Francs 12,029.412) while the cluster with the highest average income level is cluster 4. Cluster 2 has the lowest number of credit institutions while the highest number credit institution is observed in cluster 3. As for the number of environmental Non-Governmental Organizations, the highest number is observed in cluster 4 while the lowest is observed in cluster 2. Cluster 2 comprises the closest villages to the W Reserve. Indeed, the lowest mean distance was observed in cluster 2 while highest mean distance is observed in cluster 4. Finally, cluster 4 is the cluster with the lowest mean farm area (mean farm area = 1.33 ha) while the largest mean farm area is observed in cluster 3.

5.3. Identification of the socioeconomic and institutional characteristics of villages adjacent to the W Biosphere Reserve influencing its levels of degradation

5.3.1. Illegal farming

Poisson regression model or negative binomial regression model can be used when the dependent variables are count data (Cameron and Trivedi, 2010). Although these two models yield similar results, the negative binomial regression model is appropriate when the overdispersion assumption is met.

Table 5.6 presents the estimation results of the two regression models. The likelihood - ratio (LR) test for the joint significance of the regressors in the models with p-values of 0.0000 and 0.0001 respectively for the Poisson, and Negative binomial regression model indicate that the regressors are jointly statistically significant (at 1% significance level) in the models. Moreover, the test of overdispersion in Table 5.6 is statistically significant (with a p-value = 0.037). Therefore, the negative binomial regression model is the appropriate model. This model indicates two factors influencing illegal farming activities in the region, namely the variables average farm areas in the villages, and the distance between the villages and the Reserve. Indeed, both variables were statistically significant at 5% significance level. While a positive correlation was observed between the number of illegal farming cases and the average farm areas in the villages, this correlation was negative with the variable distance. The increase in the farm area of 1 hectare is associated with the increase in the number of illegal farming activities by 70.41% all other being constant. The positive correlation between the average farm area in the villages with the number of cases could be explained by the farming system in the region. Indeed, farming in the region is still traditional with low use of technology and inputs such as fertilizers. Hence, farmers to increase the production of their farm may tend to increase their farms areas to compensate for the low use of fertilizers; and consequently, find the W Reserve lands as attractive. However, the increase in the distance between the Reserve and the villages in its periphery by 1 kilometer is associated with the decrease in the number of cases of illegal farming by 3.1% all other being constant. This negative correlation between the variable distance and illegal farming activities could be explained by the positive correlation that exist between the variable distance, and production costs. Indeed, the increase in the distance is associated with the increase in the transportation costs that raise farmers private costs. Consequently, particularly in the cases that the marginal benefits generated by illegal farming activities are less than the marginal costs associated with them, illegal farming may appear as less attractive for profit maximizing farmers. Moreover, although negative correlation was found between illegal farming activities and the variables the existence of check points between the Reserve and the villages in its periphery, the number of financial institutions, and the number of environmental non-governmental organizations, these correlations were not statistically significant.

Table 5. 6. Estimation results of Poisson and Negative Binomial Regression models on factors influencing illegal farming

	Poisson Regression model		Negative Binomial Regression model	
	Coefficients	Marginal effects	Coefficients	Marginal effects
Socioeconomics characteristics				
pop	0.0001	0.0000	0.0002	0.0000
	(0.0001)		(0.0001)	
incom	0.0000	0.0000	0.0000	0.0000
	(0.0000)		(0.0000)	
farm_size	0.6286 ***	0.0939	0.7041 **	0.0856
	(0.2289)		(0.3048)	
cash_cr	0.3388	0.0506	0.2688	0.0327
	(0.4770)		(0.6293)	
Credit	-0.3034	-0.0453	-0.3177	-0.0386
	(0.3576)		(0.4401)	
Institutions				
Check_p	-1.0373	-0.1550	-1.0856	-0.1319
	(0.8840)		(1.0621)	
en_ngo	-0.4664	-0.0697	-0.6575	-0.0799
	(0.3306)		(0.4348)	
check_p *credit *part_mana	0.2443	0.0365	0.3133	0.0381
	(0.6897)		(0.8411)	
Location				
dist	-0.0303 **	-0.0045	-0.0310 **	-0.0038
	(0.0155)		(0.0203)	
Constant	-2.6407		-2.5395	
	(0.7999)		(0.9111)	
Number of observations	93		93	
LR chi2(9)	55.88		33.48	
Prob > chi2	0.0000		0.0001	
Pseudo R2	0.3338		0.2360	
Alpha			0.7975	
LR test of alpha=0: chibar2(01)			3.17	
Prob >= chibar2			0.037	
Log likelihood	-55.7701		-54.1843	

- Standard errors reported in parentheses

* 10% significance level 5% significance level *** 1% significance level

5.3.2. Illegal Cattle Ranching

Table 5.7 presents the results of the estimation of the parameters that influence illegal cattle ranching activities in the W Reserve. The likelihood -ratio (LR) test for the joint significance of the regressors in the models with p-values of 0.0000 and 0.0034 respectively for the Poisson, and Negative binomial regression model indicate that the regressors are jointly statistically significant (at 1% significance level) in the models. Moreover, the test of overdispersion in Table 5.7 is statistically significant (with a p-value = 0.000) indicating that the negative binomial regression model is the appropriate model. The results of this model showed three factors influencing illegal cattle ranching activities in the Reserve. These factors are the distance between the Reserve and villages in its periphery (statistically significant at 10% significance level), the number of environmental non-governmental organizations (statistically significant at 10% significance level), and the existence of check point in the villages (statistically significant at 5% significance level). While negative correlations were found between illegal cattle ranching activities, and the variables existence of check points between the Reserve and the villages in its periphery, and distance this correlation was positive with the variable number of non-governmental organizations. The existence of checkpoints between the Reserve and the villages in the villages in its periphery is associated with a decrease in the number of cases of illegal cattle ranching by 77.52% all other being constant. This negative correlation between the existence of checkpoints, and illegal cattle ranching cases in the Reserve could be explained by the risks it raises for the cattle to be caught by the Reserve surveillance units. Particularly, the penalties associated with illegal activities include fines, and jails time from 6 months to 5 years for the herders whose cattle are found in the Reserve. Consequently, ranching cattle in the Reserve may appear less profitable for herders in the villages where checkpoints exist; justifying the negative correlation observed between the variable and illegal cattle ranching activities in the Reserve. Similarly, the increase in the distance between the Reserve and the villages in its periphery by 1 kilometer is associated with a decrease in the number of cases of illegal cattle ranching by 2.14% all other factors being constant. This result may suggest that while the distance between the Reserve and the villages in its periphery increases, herders may resort to other places less far for ranching. However, a positive correlation was observed between the number of non-governmental organizations promoting nature preservation, and the number of illegal cattle ranching cases. The increase in the number of these non-governmental organizations is associated with 58.34% increase in the number of illegal cattle ranching cases all other factors being constant. Extensive cattle ranching is one of the most dominant economic activities in the W Region, and accordingly represents an important threat for the Reserve plants and animal species through the risks of diseases propagation. Therefore, aiming at reducing the pressure on the Reserve, the localities with high pressure might attract the non-governmental organizations promoting nature preservation indicated by the positive correlation between the number of illegal cattle ranching and number of non-governmental organizations promoting nature preservation. Negative but non-statistically significant correlation was found between illegal cattle ranching activities and the average level of income in the villages. Similarly, the model indicated positive but non-statistically significant correlations between illegal cattle ranching activities and the variables population, number of credit institutions, and the implementation of participatory management of forest resource.

Table 5. 7. Estimation results of Poisson and Negative Binomial Regression models on factors influencing illegal cattle ranching

	Poisson Regression model		Negative Binomial Regression model	
Variables	Coefficients	Marginal effects	Coefficients	Marginal effects
Socioeconomics characteristics				
pop	0.0000 (0.0000)	0.0001	0.0001 (0.0001)	0.0002
incom	-0.0000 (0.0000)	-0.0001	-0.0000 (0.0000)	-0.0001
credit	0.3739 (0.1522)	0.5147	0.3371 (0.2678)	0.4457
Institutions				
env_ngo	0.5448 *** (0.1802)	0.7501	0.5834 * (0.3470)	0.7713
part_mana	0.5740 * (0.3082)	0.7903	0.6278 (0.6111)	0.8300
env_ngo * part_mana*credit	-0.2783 (0.1193)	-0.3832	-0.3274 (0.2290)	-0.4328
check_p	-0.7076 (0.2055)	-0.9742	-0.7752 ** (0.3882)	-1.0249
Location				
dist	-0.0214 *** (0.0082)	-0.0295	-0.0228 * (0.0136)	-0.0301
Constant	0.4599 (0.4517)		0.5893 (0.8658)	
Number of observations	93		93	
LR chi2 (8)	63.10		22.99	
Prob > chi2	0.0000		0.0034	
Pseudo R2	0.1485		0.0699	
Alpha			1.0996	
LR test of alpha=0: chibar2(01)			55.81	
Prob >= chibar2			0.000	
Log likelihood	-180.9210		-153.0138	

- Standard errors reported in parentheses

* 10% significance level 5% significance level *** 1% significance level

5.3.3. Poaching

Table 5.8 presents the results of the estimation of the parameters that influence poaching activities in the W Reserve using the Poisson, and Negative Binomial Regression models. The likelihood -ratio (LR) test for the joint significance of the regressors in the models with p-values of 0.0000 and 0.0381 respectively for the Poisson, and Negative binomial regression model indicate that the regressors are jointly statistically significant (at 1% and 5% significance level) in the models. Moreover, the test of overdispersion in Table 5.8 is statistically significant (with a p-value = 0.000) indicating that the negative binomial regression model is the appropriate model. The results of this model identified two factors influencing poaching activities in the Reserve. These factors are the distance between the Reserve and the villages in its periphery (statistically significant at 5% significance level), and population (statistically significant at 1% significance level). 1 km increase of the distance between the Reserve and the villages in its periphery is associated with 2.6% decrease in the number of poaching cases, holding all other factors constant. On the other hand, a 1 unit increase of the population in the villages in the periphery of the Reserve is associated with a 0.35% increase in the number of poaching cases, holding all other factors constant. The negative correlation between the number of poaching cases and the distance of the villages from the Reserve can be explained by the fact that shorter distance from the Reserve reduces the private costs of poachers, and accordingly provides incentive for poaching activities. As for population, a positive correlation with poaching activities could be explained by the increase in the demand for protein that can result from population increases. No significant correlation was found between the average level of income, the number of non-governmental organizations promoting nature preservation, financial institutions, and the implementation of participatory management of forest resource in the region, and the existence road with poaching activities.

Table 5. 8. Estimation results of Poisson and Negative Binomial Regression models on factors influencing poaching activities

	Poisson Regression model		Negative Binomial Regression model	
Variables	Coefficients	Marginal effects	Coefficients	Marginal effects
Socioeconomics characteristics				
pop	0.0002 ***	0.0002	0.0003 ***	0.0004
	(0.0000)		(0.0001)	
incom	-0.0000	-0.0000	-0.0000	-0.0000
	(0.0000)		(0.0000)	
credit	0.1102	0.1506	0.0500	0.0649
	(0.1429)		(0.2621)	
access_r	-0.3878	-0.5300	-0.3335	-0.4327
	(0.2496)		(0.4251)	
Institutions				
part_mana	1.0451 **	1.4284	0.9361	1.2148
	(0.4547)		(0.7090)	
env_ngo	0.1742	0.2380	0.1711	0.2221
	(0.2502)		(0.3772)	
env_ngo*	-0.7466 **	-1.0204	-0.7882	-1.0228
part_mana	(0.2900)		(0.4910)	
check_p	0.2862	0.3911	0.3307	0.4292
	(0.2028)		(0.3676)	
Locations				
dist	-0.0228 ***	-3110	-0.0260 **	-0.0338
	(0.0075)		(0.0113)	
constant	-0.1164		-0.2866	
	(0.4743)		(0.7360)	
Number of observations	93		93	
LR chi2(9)	45.22		17.76	
Prob > chi2	0.0000		0.0381	
Pseudo R2	0.1129		0.0560	
Alpha			1.2271	
LR test of alpha=0 chibar2(01)			56.15	
Prob >= chibar2			0.0000	
Log likelihood	-177.67292		-149.599	

- Standard errors reported in parentheses

* 10% significance level 5% significance level *** 1% significance level

5.3.4. Illegal logging

Table 5.9 presents the estimation of the parameters that influence illegal logging activities. These parameters are estimated using robust standard errors recommended as appropriate by Cameron and Trivedi (2010) when non-robust standard errors do not fit Poisson or Negative binomial models. Indeed, the p-value associated with Likelihood-ratio test of the joint significance of the regressors in the Negative binomial regression model was not significant (p-value = 0.60), justifying the use of the non-robust standard errors. Moreover, higher log pseudolikelihood values (Poisson log pseudolikelihood = -32. 43; Negative Binomial log pseudolikelihood= -30.13) were observed for the models with the logarithmic transformation of the variables population, income, and distance, and consequently was adopted.

However, although both models yield similar results, the test of overdispersion of the data was not statistically significant (p-value = 0.680) indicating Poisson regression model as the appropriate model. The results of this model indicated one factor influencing illegal logging in the Reserve, namely the distance between the Reserve and the villages in its periphery. Indeed, the distance is statistically significant at 1% significance level with negative correlation with illegal logging activities. A 1 km increase of the distance between the Reserve and the villages in its periphery is associated with the decrease in the number of illegal logging activities by 0.57 holding all other factors constant. This negative correlation between distance and the illegal logging activities could be explained by the fact that short distance decreases the private costs (e.g. transportation of the logs) of illegal loggers, and therefore provides incentives for the activities. Finally, no significant correlations were found between illegal logging activities, and the population, average level of income, number of financial institutions, number of environmental non-governmental organizations, existence of check points, and the implementation of participatory management of forest resource policy.

Finally, in addition to the analysis of the factors influencing illegal logging activities in the Reserve using Poisson and Negative binomial regression models (due to the relative low number of cases recorded by the W Reserve administrations), the binary logistic and probit models were used. However, the estimation results of these binary models were not globally statistically significant and consequently not presented in the thesis.

Table 5. 9. Estimation results of Poisson and Negative Binomial Regression models on factors influencing illegal logging in the W Reserve

	Poisson Regression model		Negative Binomial Regression model	
Variables	Coefficients	Marginal effects	Coefficients	Marginal effects
Socioeconomics characteristics				
Ln_Pop	-0.1561	-0.0129	-0.1327	-0.0116
	(0.8649)		(0.4158)	
Ln_Inc	-0.0176	-0.0015	0.8537	0.0748
	(1.4485)		(1.3416)	
credit	0.0343	0.0028	0.2277	0.0200
	(0.4024)		(0.4293)	
Institutions				
env_ngo	-0.4673	-0.0385	-0.7425	-0.0651
	(0.4340)		(0.5258)	
part_mana	0.1389	0.0114	0.5356	0.0469
	(0.7096)		(1.0784)	
check_p	0.8531	0.0703	0.5108	0.0448
	(0.8178)		(0.9181)	
access_r	-0.9927	-0.0818	-0.3471	-0.0304
	(1.5810)		(1.9908)	
Location				
Ln_dist	-0.5726 ***	-0.0472	-0.6296 ***	-0.0552
	(0.1867)		(0.2296)	
constant	0.2776		-8.2082	
	(18.3143)		(13.9702)	
Number of observations	82		82	
Wald chi2 (8)	15.84		16.20	
Prob > chi2	0.0448		0.0396	
Pseudo R2	0.2262		0.0965	
Alpha =			0.5285	
Prob > |t|			0.680	
Log pseudolikelihood	-32.4313		-30.1284	

- Standard errors reported in parentheses

* 10% significance level, ** 5% significance level, *** 1% significance level

In addition to analyzing the factors influencing illegal activities in the Reserve (illegal farming, illegal cattle ranching, poaching, and illegal logging) using univariate regression model, the identification of the factors has been done considering the illegal activities together. The dependent variables being count data, non-linear Seemingly Unrelated Regression (SUR) can be used in the case of two or more dependent variables (Cameron and Trivedi, 2010). However, the model was estimated using illegal farming, illegal cattle ranching, and poaching. Indeed, due to poor explanatory power of the model with illegal logging ((R-square value = 0.0749), this variable was removed from the model.

5.3.5. Non-linear SUR estimation results of the factors influencing illegal farming, illegal cattle ranching, and poaching in the Reserve

The results of the estimation of the factors influencing illegal farming, illegal cattle ranching, and poaching using non-linear SUR are presented in Table 5.10. The results indicated that the villages in the periphery of the Reserve socioeconomics characteristics namely, population, average income level, average farm size, number of financial institutions; institutional characteristics namely existence of check points, and non-governmental organizations promoting nature preservation; and location namely distance influence its degradation.

Particularly, illegal farming activities were statistically significant (at 5% significance level), and positively correlated with the average farm size in the villages in the region. Indeed, the increase in the average farm size by 1 hectare is associated with an increase in the number of cases of illegal farming by 21.12% holding all the other factors constant. However, negative correlation and statistically significant (at 10% significance level) was found between illegal farming activities in the Reserve and the number of financial institutions, and number of non-governmental organizations promoting nature preservation. Indeed, the increase in the number of financial institutions in the villages in the periphery of the Reserve is associated with the decrease in the number of illegal farming activities by 21.78%, holding all the other factors constant. The negative correlation between the number of financial institutions in the region and illegal farming activities may be explained by the fact that the increase in the number of financial institutions may increase credit access to farmers. Consequently, rather than increasing farms size, farmers with credit access improve their farm performances using improved technology, and production inputs such as fertilizers. Another explanation could be that access to credit through financial institutions provides the means to farmers to undertake non-farming income generating activities that reduce their dependence on the Reserve and natural resources in general. Similarly, the increase in the number of non-governmental organizations promoting nature preservation in the villages is associated with the decrease in the number of illegal farming cases by 20.57%, holding all the other factors constant.

Illegal cattle ranching activities in the Reserve were statistically, and negatively correlated with the average income level (at 5% significance level), the existence of checkpoints (at 5% significance level), and distance (at 10% significance level) between the Reserve and the villages in its periphery. The existence of checkpoints is associated with a decrease in the number of illegal cattle ranching in the Reserve by 94.83% holding all the other factors constant. This negative correlation between the existence of checkpoints, and illegal cattle ranching cases in the Reserve could be explained by the risks it raises for the cattle to be caught by the Reserve surveillance units. Particularly, the penalties associated with illegal activities include fines, and or jails times for the herders whose cattle are found in the Reserve. Similarly, the increase in the distance between the Reserve and the villages in its periphery by 1 kilometer is associated with a decrease in the number of cases of illegal cattle ranching by 2.07%, holding all the other factors constant.

Finally, poaching activities in the Reserve was only statistically significant (at 1% significance level), and positively correlated with population. Indeed, an increase of the population by 1 unit is associated with the increase in the number of cases of poaching by 0.04% holding all other factors constant.

Table 5. 10. Estimation results of non-linear SUR model on factors influencing the Reserve degradation

Variables	ill_farm	ill_catt	poach
Socioeconomics characteristics			
pop	0.0000	0.0002	0.0004 ***
	(0.0000)	(0.0001)	(0.0001)
incom	0.0000	-0.0001 **	0.0000
	(0.0000)	(0.0000)	(0.0001)
credit	-0.2178 *	0.3761	0.0296
	(0.1135)	(0.3445)	(0.3451)
farm_size	0.2112 **	-	-
	(0.1058)		
cash_cr	0.0291	-	-
	(0.1517)		
Institutions			
env_ngo	-0.2083 *	0.5238	-0.4970
	(0.1137)	(0.3505)	(0.3128)
part_mana	0.2892	-0.1506	-0.0994
	(0.1769)	(0.4269)	(0.4695)
check_p	-0.0485	-0.9483 **	0.7209
	(0.1619)	(0.4152)	(0.6761)
Location			
dist	-0.0106	-0.0207 *	-0.0254
	(0.0076)	(0.0125)	(0.0215)
Constant	-0.2667	2.4667 ***	1.6974 **
	(0.3603)	(0.7261)	(0.8381)
Observations	93	93	93
R-squared	0.3510	0.1678	0.1351

Standard Errors in parentheses

* 10% significance level 5% significance level *** 1% significance level

5.3.6. Ordinary Least Square (OLS) estimation results of the factors influencing illegal activities in the Reserve

To estimate the OLS results on the factors influencing illegal activities, an index of illegal activities (as dependent variable) was estimated using the Principal Component Analysis (PCA) (Jollife, 2002). However, before using the Principal Component Analysis as the data reduction method, the Kaiser-Meyer-Oklin (KMO) test for sampling adequacy measurement was performed to test whether the four illegal activities have satisfactory common characteristics that justify the use of the PCA method. Table 5.11 presents the KMO measure of sampling adequacy of the variables.

Table 5. 11. Kaiser-Meyer-Oklin (KMO) statistics for the four variables

Variables	KMO
Illegal cattle ranching	0.5905
Illegal logging	0.5472
Poaching	0.5145
Illegal farming	0.4616
Overall	0.5203

Table 5.11 indicates that the overall KMO statistic (0.5203) of the four illegal activities is above 0.5, the minimum value recommended for the use of PCA method (Katchova, 2013). Consequently, the index of the four illegal activities was estimated using the Principal Component Analysis (PCA) method.

Table 5.12 presents the principal components, eigenvalues, and proportion of variances explained by the components.

Table 5. 12. Principal Components, eigenvalues, and proportion of variances explained by the components

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	1.4563	0.3808	0.3641	0.3641
Comp2	1.0755	0.2380	0.2689	0.6330
Comp3	0.8375	0.2068	0.2094	0.8423
Comp4	0.6307		0.1577	1.0000
Observations			93	
Components			4	
Trace			4	
Rho			1	

Table 5.12 indicates that the first component accounts for the highest variability (36.41%) among the four illegal activities. Hence, the score of illegal activities on this component is used as index of illegal activities in the W Reserve.

Table 5.13 presents the estimation results using Ordinary Least Square (OLS) of the factors influencing illegal activities in the W Reserve. Particularly, two regression models are presented in Table 5.13 namely Regression 1 and Regression 2. Indeed, while both regression models tested the relationship between socioeconomic, institutions and location characteristics of the villages in the periphery of the W Reserve and its degradation, they differ on two points. First, while no country control variables are included in Regression 1, country control variables are included in model 2 (to account for the variabilities that could exist between the countries). Second, while Regression 1 tested the relationship between the variable part_mana (participatory management policy) and the Reserve degradation, this variable was not included in Regression 2 due to collinearity issue of this variable (participatory management) with country control variables.

Table 5. 13. OLS estimation results of the factors influencing illegal activities in the W Reserve

Variables	Regression 1	Regression 2
Socioeconomic characteristics		
Pop	0.0001 *	0.0001
	(0.0001)	(0.0001)
income	-0.0000	-0.0000
	(0.0000)	(0.0000)
credit	-0.0827	-0.0687
	(0.1619)	(0.1541)
farm_size	0.5170 ***	0.5356 ***
	(0.1515)	(0.1529)
cash_cr	-0.2868	-0.1703
	(0.2569)	(0.2331)
Institutions		
env_ngo	-0.1507	-0.1112
	(0.1551)	(0.1684)
part_mana	-0.4414	-
	(0.2881)	
check_p	0.4127	0.3819
	(0.3243)	(0.3208)
Location		
dist	-0.0201 *	-0.0273 **
	(0.0102)	(0.0129)
Countries		
Benin	-	-0.0617
		(0.3361)
Niger	-	0.7808
		(0.5239)
Constant	-0.1908	-0.6361
	(0.4847)	(0.4960)
Observations	93	93
Prob > F	0.0000	0.0000
R-squared	0.2285	0.2656

Standard Error in parentheses

* 10% significance level 5% significance level *** 1% significance level

The results in Table 5.13 indicated that both regression models are globally statistically significant (p-value =0.0000) with relatively low explanatory power (R^2 = 0.2285, and 0.2656 respectively for regression 1, and regression 2). Particularly, not controlling for the variabilities among the countries, the regression model 1 identified socioeconomic characteristics, namely population and average farm size in the villages in the periphery of the W Reserve as influencing its degradation. Indeed, while a 1-unit increase in the population in the villages in the periphery of the Reserve is associated with 0.0001 increase in the number of illegal activity in the Reserve, a 1 hectare increase in the average farm size in the villages is associated with 0.5170 number of illegal activity in the Reserve holding the other factors constant. The second major factor influencing the degradation in the Reserve when the variabilities among the countries are not considered is location attribute (distance) between the villages and the Reserve. Indeed, a 1 kilometer increase of the distance between the villages and the Reserve is associated with 0.0201 decrease in the number of illegal activity in the Reserve holding the other factors constant.

On the other hand, while accounting for the variabilities among the countries (regression 2), only two factors have been identified as influencing the Reserve degradation, namely population and the distance between the villages and the Reserve. Particularly, a 1 hectare increase in the average farm size in the villages is associated with 0.5356 increase in the number of cases of illegal activity in the Reserve holding the other factors constant. Finally, similar to the result in the regression, a 1 kilometer increase of the distance between the villages and the Reserve is associated with 0.0273 decrease in the number of illegal activity in the Reserve holding the other factors constant. No significant correlation was found between the Reserve degradation and the institutional characteristics of the villages in its periphery.

CONCLUSIONS

In response to the persistence of tropical forest resource degradation, we analyzed the factors that influence their conservation with the W Reserve in West Africa as the study area. Specifically, we first characterized the forms of pressure (poaching, illegal logging, illegal farming, and illegal cattle ranching activities) faced by the Reserve from the population in the villages in its periphery. Second, we characterized the villages in the Reserve periphery based on their socioeconomics and institutional characteristics. Third, using Poisson model, Negative Binomial model, linear, and non-linear SUR model, we identified based on the villages socioeconomic, institutional, and locational characteristics, the factors that could explain its degradation.

Our result indicates first, that illegal cattle ranching is the most dominant form of pressure faced by the Reserve from the population in the villages in its periphery (with the highest number of cases recorded: 161) and illegal logging the lowest form of pressure (number of cases recorded: 18). Second, four types of villages are observed in the region with three discriminating factors (populations, number of non-governmental organizations promoting nature preservation, and the average farm areas). Third, as for the factors that influence the Reserve degradation three major factors have been identified namely socioeconomics characteristics, institutional characteristics, and the location of the villages. Particularly, the variables distance and average farm size in the villages were identified as the factors that influence illegal farming activities in the Reserve. Illegal cattle ranching activities were influenced by the number of non-governmental organizations, the distance, and the existence of checkpoints between the Reserve and the villages. Population and the distance were identified as the factors that influence poaching activities while illegal logging was influenced only by the distance that separates the Reserve and the villages in its periphery.

This study has implication for policies for better preservation and conservation of tropical forest resource in general, and particularly the W Reserve in West Africa. To control for the pressure from the population in the villages in the periphery of the Reserve, significant importance should be put on the villages closer to the Reserve as well as the farming system. The installation of checkpoints and the promotion of policy aiming at improving farm performances in the area could be suggested as effective policies to reduce the pressure faced by the Reserve when the marginal costs associated with the investments are less than the marginal benefits associated with the Reserve conservation. Moreover, the promotion of financial institutions, and access to credit could facilitate the development of other income generating activities less dependent on the use of the Reserve resources for the population. Finally, although no significant correlation was found between the Reserve degradation and the implementation of participatory management policies of forest resource management, the promotion of such policies could raise the awareness of the population on the benefits (economic and ecological) that could be derived from the preservation of the Reserve.

However, the results of this study have to be interpreted with caution because of several reasons. First, the data used in this study covered a short period of time (January 2016 to May 2017). Furthermore, additional characteristics of the villages in the periphery of the Reserve could be included if available. Finally, and perhaps most importantly, we used reported data for illegal activities as our dependent variables, and in case illegal activities are not caught, there would not be reported (under-reporting of the true number of illegal activities).

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APPENDIX

1. Questionnaire/ Guide

Research topic

Factors influencing Tropical Forest Conservation : Evidence from the W Reserve (West Africa)

Identification of the questionnaire

Date of focus group:	_____/ ______ / 2017
Name of the interviewer:	
Questionnaire number:	
Size of the group :	1_☐Male (_______________) 2_☐Female (_______________)

1.1 Geographic localization

Code	Question	Response
101	Country	1_☐Benin 3_☐Niger 2_☐Burkina Faso
102	Department	1_☐Alibori 2_☐Other (precise) _______________
103	Agro ecological zone	1_☐Zone 1 2_☐Zone 2 2_☐Other (precise) _______________
104	District (Commune)	1_☐Karimama 3_☐Kandi 2_☐Malanville 4_☐Banikoara 5_☐Other (precise) _______________
105	Arrondissement	
106	Village	

1.2. Indicator/ Measures of the degradation of the Reserve

Code	Question		Response
107	What is the current distance between the village (from its center) and the W reserve		_______________km
108	Have you noticed any increase in this distance (distance between the village and the reserve) if yes, always precise the distance in Km)	During this year (from January 2017 to now)	0_☐No 1_☐yes (_______) km
109		From January 2016 to December 2016	0_☐No 1_☐yes (_______) km
110		From January 2015 to December 2015	0_☐No 1_☐yes (_______) km
111	Have you heard incidents related to animal poaching in your village	During this year (from January 2017 to now)	0_☐No 1_☐yes, precise number of cases (___)

Code	Question		Response
112			If yes, what are the animal species poached? (precise quantity/number poached, location on the map) 1_______________________, number of cases[1]_____ Average quantity[2] per case _____ 2_______________________, number of cases[1]_____ Average quantity[2] per case _____ 3_______________________, number of cases[1]_____ Average quantity[2] per case _____
113			Are the animal poached used for: 0_☐Domestic consumption 1_☐Sold in the market 2_☐Both
114			Are the illegal poachers from : 0_☐this village 1_☐neighboring village 2_☐Others (list them) (___)
115		From January 2016 to December 2016	0_☐No 1_☐yes (___) precise number of cases (___)
116			If yes, what are the animal species? (precise quantity/number poached, location on the map) 1_______________________, number of cases[1]_____ Average quantity[2] per case _____ 2_______________________, number of cases[1]_____ Average quantity[2] per case _____ 3_______________________, number of cases[1]_____ Average quantity[2] per case _____

[1] number of illegal cases of poaching for the species

[2] number of animals poached per case for each animal species

Code	Question		Response
			4_______________________, number of cases[1]_____ Average quantity[2] per case _____
117			Are the animals poached used for : 0_☐Domestic consumption 1_☐Sold in the market 2_☐Both
118			Are the illegal poachers from : 0_☐this village 1_☐neighboring village 2_☐Others (list them) (___)
119		From January 2015 to December 2015	0_☐No 1_☐yes (___) precise number of cases (___)
120			If yes, what are the animal species ? (precise quantity/number poached, location on the map) 1_______________________, number of cases[1]_____ Average quantity[2] per case _____ 2_______________________, number of cases[1]_____ Average quantity[2] per case _____ 3_______________________, number of cases[1]_____ Average quantity[2] per case _____
121			Are the animals poached used for : 0_☐Domestic consumption 1_☐Sold in the market 2_☐Both
122	Have you heard incidents related to illegal timber harvesting in this village ?	During this year? (from January 2017 to now)	0_☐No 1_☐yes (___) precise number of cases (___)
123			If yes, what are the trees species (precise per species quantity harvested in cubic meter, number of illegal cases, and location on the map)?

Code	Question		Response
			1________________________, number of cases[3]_____ Average quantity[4] per case _____ 2________________________, number of cases[3]_____ Average quantity per case[4]_____ 3________________________, number of cases[3]_____ Average quantity[4] per case _____
124			Are the trees species harvested used for : 0_☐Domestic consumption 1_☐Sold in the market 2_☐Both
125			Are the illegal harvesters from : 0_☐this village 1_☐neighboring village 2_☐Others (list them) (___)
126		From January 2016 to December 2016	0_☐No 1_☐yes (___) precise number of cases (___)
127			If yes, what are the trees species ? (precise per species quantity harvested in cubic meter, number of illegal cases, and location on the map) 1________________________, number of cases[3]_____ Average quantity[4] per case _____ 2________________________, number of cases[3]_____ Average quantity per case[4]_____ 3________________________, number of cases[3]_____ Average quantity[4] per case _____
128			Are the trees species harvested used for :

[3] number of cases of illegal timber harvesting for the tree species
[4] average quantity (in **m^3** for example) of tree specied harvested per case for the tree species

Code	Question		Response
			0_☐Domestic consumption 1_☐Sold in the market 2_☐Both
129			Are the illegal harvesters from : 0_☐this village 1_☐neighboring village 2_☐Others (list them) (___)
130		From January 2015 to December 2015	0_☐No 1_☐yes (___) precise number of cases (___)
131			If yes, what are the trees species ? (precise per species quantity harvested in cubic meter, number of illegal cases, and location on the map) 1_______________________, number of cases[3]_____ Average quantity[4] per case _____ 2_______________________, number of cases[3]_____ Average quantity per case[4]_____ 3_______________________, number of cases[3]_____ Average quantity[4] per case _____
132			Are the trees species harvested used for : 0_☐Domestic consumption 1_☐Sold in the market 2_☐Both
133			Are the illegal harvesters from : 0_☐this village 1_☐neighboring village 2_☐Others (list them) (___)
134	Have you heard incidents related to cattle illegal	During this year (from January 2017 to now)?	0_☐No 1_☐yes, precise number of cases (_______),

Code	Question		Response
	grazing (transhumance) in this village ?		and average size of the cattle per case (_______)
135			If yes, Where are the cattle coming from (precise location on the map) ? 0_☐this village 1_☐neighboring village 2_☐ Others (list them) (_________)
136		From January 2016 to December 2016	0_☐No 1_☐yes, precise number of cases (_______) and average size of the cattle per case (_______)
137			If yes, Where are the cattle coming from (precise location on the map) ? 0_☐this village 1_☐neighboring village 2_☐ Others (list them) (_________)
138		From January 2015 to December 2015	0_☐No 1_☐yes, precise number of cases (_______) and average size of the cattle per case (_______)
139			If yes, Where are the cattle coming from (precise location on the map) ? 0_☐this village 1_☐neighboring village 2_☐ Others (list them) (_________)
140	Have you heard incidents related to illegal farming in the reserve from this village ?	During this year (from January 2017 to now)?	0_☐No 1_☐yes
141			If yes (show location on the map), - precise number of cases per type of crop (___________) - Estimated total crop area grown in the reserve per type of crop (______________) hectares
142		From January 2016 to December 2016 ?	0_☐No 1_☐yes

Code	Question		Response
143			If yes (show location on the map), - precise number of cases per type of crop (___________) - Estimated total crop area grown in the reserve per type of crop (______________) hectares
144		From January 2015 to December 2015?	0_☐No 1_☐yes
145			If yes (show location on the map), - precise number of cases per type of crop (___________) - Estimated total crop area grown in the reserve per type of crop (______________) hectares

1.3 Villages Characteristics

Code	Question	Response
146	What is the distance between the village (from the center of the village) and the W Reserve (border of the Reserve) ?	____________km
147	What is the main source of income in the village ?	1_☐ Agriculture (*precise* average farm areas owned by a farmer ___ha) 2_☐ Animal husbandry/cattle ranching (*precise* average number of cattle owned by a herder ___TLU[5]) 3_☐Hunting/Fishing 4_☐Trade 5_☐Other (________________)
148	Do you have Forest Conservation Associations in the village ?	0_☐No 1_☐yes, precise number (_______) and years of creation of each association
149	Do your village have contact with NGOs or projects promoting environment (or biodiversity conservation) ?	0_☐No 1_☐yes,
150		If yes, precise NGO/ projects name and years of contact or implementations 1___________________________ 2____________________________ 3____________________________
151	What is the size of the village population (precise source of the statistics, if any) ?	

[5] Tropical Livestock Units

Code	Question	Response
152	What is the average level of income of a resident of your village in the year 2016 (all sources of income considered) in CFA ?	0_☐< 240,000 1_☐240,000 ≤ R < 480,000 2_☐480,000 < R < 720,000 3_☐> 720,000
153	What is the average level of schooling of residents (age 18 and older) in your village ?	
154	What is the maximum number of years of schooling offered by the schools in the village ?	
155	Do you have the reserve check points (or guards from the reserve) in the village ?	0_☐No 1_☐yes, precise number (_______)
156	Do you have credit institutions (or Bank, NGO, farmers' cooperative, etc.) providing credit for small business) in your village ?	0_☐No 1_☐yes, precise number (_______)
157	What is the average land area owned by a farmer in the village ?	0_☐No 1_☐yes,
158	How many roads leading to the W Reserve from the village do you have ?	0_☐ bicycle roads; if yes, precise number (_______) 1_☐cars/truck roads; if yes, precise number (_______) ,
161	Are you aware of the punishment (sanctions) of those who illegally enter in the reserve?	0_☐No 1_☐yes
162		If yes, list and describe them (per type of infraction):
163	General questions : - What are their perceptions on the reserve ? - Have they noticed any decrease in the level of biodiversity of the reserve (Eg : Was it common to see some animal species in the village that they no more see now ?) - What are the causes of the degradation of the reserve if any ? - What measures do they think should be taken to decrease the reserve degradation if any ? Do they have any questions to ask us ?	

QUESTIONNAIRE (GUIDE) TO INTERVIEW THE CENAGREF[i] ADMINISTRATIONS (AND OTHER ADMINISTRATIONS)

Research topic

Factors influencing Tropical Forest Conservation : Evidence from the W Reserve (West Africa)

1- Literatures	- Documents presenting the W Reserve; - Studies done on the W Reserve; - Do you have aerial/spatial maps (pictures) on the W Reserve at different times;
2- Projects	- How many projects have been implemented for the conservation of the W-reserve from year 0 to 2017 o Names of each project, o years covered by each project o village covered by each projects
3- W Reserve and the villages	- Original distance (or distance at time 0) between the reserve and each village? - What is the current distance between the reserve and each village? • in the cases that the distances increased (meaning that the reserve has lost its cover) what are the causes of this situation (specify reasons for each)? • in the case of the villages where the degradation of the reserve has been low, list what are the potential reasons? - Check Points o Do you have check/points in each village? (since when are the check/points installed in the village?) o How many guards do you have in each village where you had check points? - What are the sanctions that individuals entering illegally in the Reserve face? (Please list, and describe them)

	- What are the different incidents you have experienced from the neighboring villages? (map each type of incidents on the Reserve map, number of cases, and quantity removed for each type) o incidents related to animals poaching (provide records if possible); o incidents related to illegal timber harvesting (provide records if possible); o incidents related to cattle grazing (provide records if possible) o incidents related to illegal farming (provide records if possible) Regarding illegal farming precise the crops illegally grown and the areas) - How do you assess the level of biodiversity of the reserve (or indicators of the level of biodiversity)? - Did the level of biodiversity of the reserve decreased between now, and 5 years ago, - What are the animal species under threats currently in the reserve? - What are the trees species under threats currently in the reserve? - Other species under threats? - What benefits do the neighboring communities get from the Reserve? - What are the neighboring communities allowed to do in the reserve, and what are they not allowed to?
4- General questions	- Statistics on the size of the population of each village - What are the pressures facing the reserve from the neighboring communities? - What are their causes? - What are the potential solutions? - What are the projection of the level of pressure faced from the neighboring communities? (will these pressures decrease or increase in the future)?

	- Do they have any questions to ask us?

[i] CeNAGREF is the administration in charge of managing the W Reserve and all the public forests of Benin