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Farmers' Perception on Land Degradation and Local strategies for Land Restoration and Livelihood Improvement in Mopti Region, Mali

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DEDICATION

I dedicate this master thesis to my parents, Mr. Ibrahim Binafou SANOGO and Mrs. Wandé DIABY for their advice, assistance, encouragement, and all the sacrifices made. May Almighty Allah (S.A.W) bless you.

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ABREVIATIONS AND ACRONYMS

CILSS/AGRYMET: Permanent **I**nterstate **C**ommittee for **D**rought **C**ontrol in the **S**ahel / **A**gro-**H**ydrometric **C**entre

ICD: International **C**ooperation and **D**evelopment

DRYDEV: Dry land **D**evelopment **P**rogramme

ETM +: Enhanced **T**hematic **M**apper **P**lus

FtF: Feed the **F**uture

FGD: Focus **G**roup **D**iscussion

GDP: Gross **D**omestic

GIS: Geographical **I**nformation **S**ystem

LULC: Land **U**se **C**over

MLC: Maximum **L**ikelihood **C**lassifier

RS: Remote **S**ensing

SHECC: Sida's **H**elpdesk for **E**nvironment and **C**limate **C**hange

SPSS: Statistical **P**ackage for the **S**ocial **S**ciences

SSA: Sub-**S**aharan **A**frica

USGS: United **S**tates **G**eological **S**urvey

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ABSTRACT

Land degradation by soil erosion is a socioeconomic and environmental problem facing many developing countries. In order to generate knowledge that supports sound and informed decision making for sustainable land restoration, this thesis examined farmers' Perception on Land Degradation and Local Strategies for Land Restoration and Livelihood Improvement in Mopti Region, Mali. Study was carried out in two districts Bandiagara and Bankass and used satellite images acquired over 29-year period, census and meteorological data to capture population dynamics and climate impacts on land cover change. Local households were interviewed to understand awareness and impacts of land-degradation, its perceived causes and preferred methods for restoration. Spatial analysis revealed rapid land use change characterized by a high conversion rate of vegetated areas to agricultural land, driven by increased population and changes in farming systems and rainfall. The perceived major causes of land degradation included: accelerated erosion, deforestation, non-adoption of adequate soil conservation measures.

This research conclude that policymakers could improve communities' knowledge such as contour bound line, terracing, cropping along contour, planting grasses in waterways and tree planting. Therefore, those local strategies have to be used in integrated approach for sustainable land management in order to improve livelihood of people. Sustainable land use requires a greater focus on resilient land management system such as agroforestry, soil and water conservation and rational grazing.

Key words: Land use dynamics, Human population density, Local knowledge, Sustainable use, Land degradation, Agricultural activities.

RESUME

La dégradation des sols due à l'érosion des sols est un problème socio-économique et environnemental auquel de nombreux pays en développement sont confrontés. Cette thèse a examiné la perception des agriculteurs sur la dégradation des terres et les stratégies locales pour la restauration des terres et l'amélioration des moyens de subsistance dans la région de Mopti au Mali. Les études ont été réalisées dans deux districts Bandiagara et Bankass et ont utilisé des images satellites acquises sur une période de 29 ans, des données de recensement et météorologiques pour saisir la dynamique des populations et les impacts climatiques sur le changement de couverture des terres. Les ménages locaux ont été interviewés pour comprendre la prise de conscience sur les impacts de la dégradation des terres, ses causes perçues et les méthodes de restauration préférées. L'analyse spatiale a révélé un changement rapide de l'utilisation des terres caractérisé par un taux élevé de conversion des zones végétalisées en terres agricoles, dû à une augmentation de la population et des changements dans les systèmes agricoles et les précipitations. Les causes principales de la dégradation des terres sont entre autres: l'érosion accélérée, la déforestation, la non-adoption de mesures adéquates de conservation des sols. Cette recherche conclut que les décideurs pourraient utiliser les connaissances des communautés telles que la ligne délimitée par le contour, les terrassements, les cultures le long des contours, la plantation d'herbes dans les zones à fortes érosions et la plantation d'arbres. Par conséquent, ces stratégies locales doivent être utilisées dans une approche intégrée pour la gestion durable des terres afin d'améliorer les moyens de subsistance des populations. L'utilisation durable des terres nécessite de mettre davantage l'accent sur un système de gestion des terres résilient tel que l'agroforesterie, la conservation des sols et de l'eau et le pâturage rationnel.

Mots clés: Dynamique de l'utilisation des terres, Densité de la population humaine, Connaissance locale, Utilisation durable, Dégradation des terres, Activités agricoles.

1. INTRODUCTION

Land degradation is an old phenomenon dating back to immemorial time. It is a global concern that is especially severe in the tropics and sub-tropics (Lal, 2015). It can be observed when “the potential productivity associated with a land-use system becomes non-sustainable, or when the land within an ecosystem is no longer able to perform its environmental regulatory function of accepting, storing, and recycling water, energy, and nutrients” (Vlek et al., 2..010). Land degradation directly affects the health, stability, and livelihoods of approximately 1.5 billion people. It is particularly acute in the world’s dry lands (i.e. arid, semi-arid, and dry sub-humid areas), which account for land on which one-third of the global population lives, up to 44% of all the world’s cultivated systems, and about 50% of the world’s livestock breeding and feeding grounds which is harmful to people livelihood (Monique Barbut, 2016). In addition to negatively impacting agronomic production, land degradation can also dampen economic growth, especially in countries where agriculture is the engine for economic development (Scherr, 2001).

While land degradation can occur as a result of natural processes, there is a widespread opinion that it mostly happens as a result of the impact of users’ activity on the land and is often a “social problem” which can be prevented if the underlying causes are addressed properly (Vlek et al., 2010). In the recent centuries, the impact of human activities on the land has grown enormously, altering landscapes and ultimately impacting the earth’s biodiversity, nutrient and hydrological cycles as well as climate (Garedew, 2010). The widespread prevalence of degraded soils in sub-Saharan Africa (SSA), a classic example of a downward spiral, is attributed to over exploitation, extractive farming, excessive grazing, low external inputs, and poor or improper management (Chabay et al., 2016). Land degradation is not caused directly by climatic variability, but may be worsened and initiated by it (Simonson, 2005), hence increasing the vulnerability of agro ecological systems to climate change and reduces the effectiveness of adaptation options (Webb et al., 2017).

During the second half of the 20th century, the Sahel region in Africa experienced one of the most striking shifts in climate known globally since instrumental record-keeping began. The region's climate has transitioned from anomalously abundant rains in the 1950's and 1960's to progressively drier conditions in the 1970's and 1980's (Hulme, 1996, Giannini et al., 2008).

Since then, a combination of recurrent droughts, a fast-growing human population and increasing pressure on the region's scarce natural resources have drastically reduced the productivity of the land (Sissoko et al., 2011). Environmental degradation continues to be a major ecological concern in the Sahel region and is exemplified by land use change, loss of biological diversity, and biological invasions (Garedew, 2010). Climate change and land use change will not only alter entire ecosystems and biodiversity patterns, but also the supply of ecosystem services. Severe consequences are expected for the Sahel region during the 21st century (Ipcc, 2007), in particular, the rural poor are considered as highly vulnerable (MA ,2005).

1.1. Problem statement

A large part of Mali falls in the Sudano-Sahelian region which has been increasingly plagued by land degradation, and this process has led to a southward extension of the Sahara desert in the last several decades (Heubes, 2012). In addition, the country as most countries in the Sahelian belt is still suffering from the repercussions of the drought-induced famines of 2005, 2008, 2010, and 2012 (CILSS/AGRYMET), and this further intensifies demand pressures on domestic land ecosystem properties, as population and economic growth needs have to be satisfied within the limited natural resources in the region. The on-going land degradation is threatening the sustenance of livelihood and human security. Land degradation is a major cause of the country's low and declining agricultural productivity, persistent food insecurity, and rural poverty. If land degradation is not adequately addressed, it is likely to jeopardize future food security for many farming households.

Containing land degradation entails an improved understanding of its causes, process, indicators and impacts. Various scientific methodologies have been employed to assess land degradation globally. However, the use of local community knowledge in elucidating the causes, process, indicators and effects of land degradation has seen little application by scientists and policy makers. Land degradation may be a physical process, but its underlying causes are firmly rooted in the socio-economic, political and cultural environment in which land users operate.

In Mali, major drivers for land degradation can be both climate-related extreme events like droughts and heavy precipitation or human-induced factors (Chabay et al., 2016). The increasing demand for food, feed, fuels (including biofuels), and fodder linked to an increase in human population and a conversion of land through deforestation contributes significantly to land cover change. Land degradation reduces both the agricultural productivity and soils' water holding capacity, which over time leads to decreasing agricultural production, while demand for it is increasing as population grows.

Analyzing the root causes and effects of land degradation from local community knowledge, perception and adaptation strategies and monitoring land use dynamics are essential to tune management strategies will provide essential information for designing and promoting sustainable land management practices. Any effort towards this direction should begin from research which aims at exploring location specific factors influencing the adoption of land management practices. Indeed, land degradation is a location specific meaning that any particular area has its specific causes, and impacts based on the rate of its vulnerability (Ofgeha, 2017). Hence, tailored solution should be designed for each specific location.

1.2. Objectives

The main objective of this study is to generate knowledge that supports sound and informed decision making for land restoration in Mopti region in Mali. The study explores various domains such as land use and land cover change at local level and assess local farmers' perceptions on management strategies for restoring land-based resources.

Specifically, the study intends to:

(i) Determine land use and land cover change over the last 29 years in the study area;

(ii) Evaluate the factors that drive land degradation in the study area;

(iii) Assess local knowledge on land degradation and its impacts on agricultural activities and livelihood as well as preferred methods for restoration;

1.3. Research questions

The questions therefore are: (a) what is the current trend in land use in the study area? (b) What are the drivers of land use and cover change? (c) What are the perceptions of farmers on the effects of these activities on agriculture? (d) What are the various strategies adopted by farmers to cushion the effect of land degradation in the area?

1.4. Hypothesis

(i) The observed trend in land use and land cover over the last 29 years is linked to population growth, land related resource use and climate change related impacts.

(ii) Local people have a wealth of knowledge on land degradation and adjustment strategies for their livelihoods.

2. LITTERATURE REVIEW

2.1. Land use and land cover change: Definition

Land use refers to the purposes for which humans exploit the land cover (Agarwal et al., 2002). Land cover is defined as the layer of soils and biomass, including natural vegetation, crops and human structures that cover the land surface. Land cover change is the complete replacement of one cover type by another, while land use dynamics also include the modification of land cover type, e.g., intensification of agricultural use, without changing its overall classification (Turner II et al., 1993). Land use is therefore the manner in which human beings employ the land and its resources such as agriculture, urban development, grazing, logging, mining, etc. In contrast, land cover describes the physical state of the land surface. Land cover categories include cropland, forests, wetlands, pasture, roads, and settlements. The term land cover originally referred to the kind and state of vegetation, such as forest or grass cover, but it has broadened in subsequent usage to include human structures such as buildings or pavement and other aspects of the natural environment, such as soil type, biodiversity, and surface and groundwater (Bottomley, 1998). Land use is determined by the interaction in space and time of biophysical factors such as soils, climate, topography, etc., and human factors like population, technology and economic conditions (Veldkamp and Fresco, 1996). Land use affects land cover and changes in land cover affect land use. Change in land use and land cover are worldwide issues, but the magnitude of change differs from one place to another.

2.2. Extend of land use and cover change in West Africa and Mali

In Africa, especially West Africa, most ecosystems have been affected by land degradation and other climate related-disasters. The conversion of grasslands, woodlands and forests into croplands and pastures has risen drastically during the last few decades (Mayaux et al., 2005). According to Salmon (2015), degraded lands are the center of much attention as global demand for food, feed and fuel continues to increase at unprecedented rates, while the agricultural land base needed for production is shrinking in many parts of the world.

The main socio-economic activity in these regions is basically traditional agriculture at small-scale. Currently, the area is affected by several hazards such as droughts and floods and other human-induced disasters mainly conflicts (Behrend, 2016).

For instance, insecurity and rapid migration contribute to further degradation of the natural asset base and increase competition for resources. Land degradation and water scarcity have been cited as drivers of conflicts between farmers and pastoralists, mostly in the Northern part, especially in Mopti Region, where livestock rearing is among the main agro-pastoral activities. Worsening soil degradation in recent decades has undermined Mali's capacity to produce food. In response, the Malian government has prioritized reforestation as a means to combat both the degradation of natural resources and poverty ICD (2016). Though the government is championing the course of sustainable land management and other major environmental issues, a bottom-up approach is highly recommended in rural areas.

2.3. Drivers of Land Use Change

The biophysical factors, socio-economic activities, and cultural contexts associated with land use change show high spatial and temporal variability (Geist & Lambin, 2002). Furthermore, identifying the causes of land use change requires an understanding of how people make land use decisions, and how various factors (at local, regional, and/or global scales) interact in specific contexts to influence those decisions. Hence, drivers of land use change can be classified into two main categories: proximate and underlying cause (Leeman's et al., 2003). Underlying causes are formed by complex relationships between social, political, economic, demographic, technological, cultural, and biophysical variables that constitute initial conditions in the human-environment relations. They originate from regional (districts, communal or country) or even global levels, with complex interactions between different levels of organization. Underlying causes are often exogenous to the local communities that manage land, and are thus uncontrollable by them, with only a few local-scale factors being endogenous to decision-makers.

The conceptual framework represents a simplified version of land use change and process drivers (Fig 2.1). Processes include the mechanisms (types) of soil degradation. Factors comprise agents of degradation related to natural or anthropogenic drivers such as climate, physiography, socio-economic or causes of land degradation which include specific activities that aggravate the adverse effects of processes and factors. Examples of specific causes include activities such as deforestation, land use conversion, extractive farming practices or over-exploitation like; excessive grazing and plowing (Lal, 2015).Thus, an analysis of the interaction between these components could help to propose mitigation measures to sustainably address land degradation issue. The effects of each major driver and process are reviewed below.

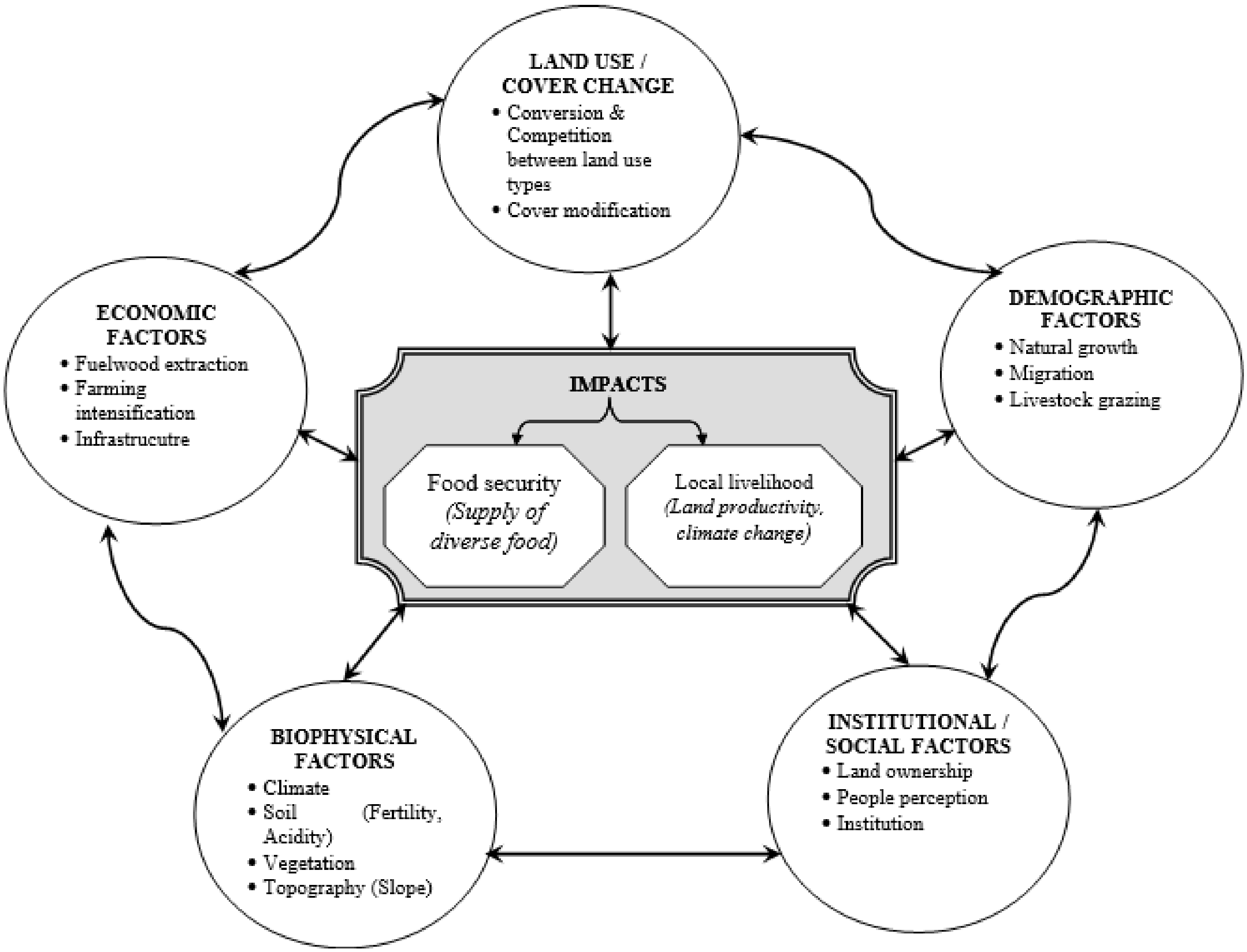


Figure 2.1: Conceptual framework for the study

Source: (Sanogo N., 2017)

2.3.1. Demographic drivers

The exact role of population growth as a major driver of environmental change is strongly debated (Veldkamp & Fresco, 1996; Ningal et al., 2008), with neo-Malthusian and Boserupian theories dominating the discussion (Perz et al., 2006). The growth of the population in the Sahel region has increased the pressure on arable land: population density linearly rose from 18 to 34 people km-2 between 1967 and 2003, which gives an annual average growth rate of 1.9% over the period (Ruelland et al., 2010). Indeed, population growth is considered as a major cause of increasing demands for food, fuel wood, fodder, and other ecosystem services. Progressive expansion of farm areas can then be mainly related to the increased demand for cereals like millet and sorghum production. Moreover, the production of those crops requires more land which is already affected by land degradation. Millet and sorghum are staple food crops in the rural areas of Mali. When the production of those cereal crops is affected by land degradation, it may lead to the reduction in crop yield, thus affecting the components of food security: availability, accessibility, stability and utilization which is a threat to people living in that area. Land degradation does not only affect food production; energy is equally under treat because woody vegetation and crops residue used as source of household energy are affected, too. Their scarcity has negative consequences on human security.

It was reported by Brien and Leichenko (2008) that human security refers not only to security from physical violence, but also to food security, livelihood security, environmental security, health security and energy security. Indeed, a study conducted by Kotir et al., *(*2017) on Volta River Basin in Ghana found that population underpins the major changes in the basin, including environmental degradation, changes in water quantity and seasonal flows, and increased competition and demands for land and water resources. In Mali, not all farmers have access to sufficient land (land which can support his/her food needs), quality production inputs, and subsidies from government at small-scale level. However, the rate of land degradation can be rapidly influenced by deforestation and other anthropogenic activities which expose land to several threats.

2.3.2. Institutional and Social Drivers

Next to population growth, socio-cultural, policy and institutional factors are driving land use changes (Ebanyat et al., 2016a). In attempting to understand the effects of culture as a driver of ecosystem change, it is useful to consider culture as the values, beliefs, and norms that a group of people share (Cotton, 1997). In this sense, culture conditions individuals' perceptions of the world, influences what they consider to be important, and suggests appropriate or inappropriate courses of action. Nevertheless, cultural differences have important impacts on direct drivers (Nelson *et* al., 2006). For example, cultural factors can influence consumption behavior (what, and how much, people consume) and may therefore be a particularly important driver of environmental change. Institutions include property-rights regimes, environmental policies, decision-making systems on the management strategies such as decentralization, democratization, roles of public, civil society, and of local communities in the decision-making process. Institutions also take into account information systems related to environmental indicators, social network representing specific interests related to resource management, conflict resolution systems concerning access to resources, and institutions that guide the distribution of resources and thus control economic differentiation (Lambin et al., 2003). Misleading or conflicting policies and institutions in landholding and management systems are sources of land and forest degradation in most developing countries.

Socio-political drivers are those forces that influence the decision-making process, and include the quantity of public participation, the make-up of participants in public decision-making, the mechanisms of dispute resolution, the role of the State relative to the private sector, and levels of education and knowledge. In addition, institutional factors, such as land tenure and legislation, can lead to land use/cover changes in tropical countries (Reid et al., 2000).

3.2.3. Economic Drivers

Economic activity is the consequence of human efforts to improve the quality of life, the outputs of which are determined by natural resources (Nelson et al., 2006). Although land use practices vary greatly across the world, the ultimate intention is generally the same; the acquisition of natural resources for immediate human needs, often at the expense of environmental conditions. In a particular communities when population grows, the need in terms of food increased over the period of time. Thereby, people will be forced to produce enough food in order to meet the demand. If that situation happened in an area where arable land is limited, (not able to afford required services) people will be forced to unsustainably use land through bad agricultural practices, deforestation and water bodies. In a review of 152 cases in tropical ecosystems of Asia, Africa, and South America, Geist and Lambin (2002) concluded that in 96% of the cases deforestation is associated with agricultural expansion, which in turn occurs as a consequence of economic, institutional, technological, sociopolitical, and demo-graphic factors (Zak et al., 2008). This situation may worsen human well-being in the nearest future. According to Nelson et al., (2006) "Human well-being is clearly affected by economic growth and its distribution. Income received by individuals and families determines their level and nature of consumption institutional and social drivers". Saguye (2017) found that direct human activities causing land degradation include: deforestation and clearing of vegetation, overgrazing, farming practices and continuous cropping. Many land use practices, such as fuel wood collection, livestock grazing and road expansion, can degrade forest ecosystems in terms of productivity, biomass, stand structures, and species composition, irrespective of whether such practices actually change the forested area (Foley et al., 2005). According to Ravi et al., (2010), human activities have profound influence on the hydrologic-eolian processes contributing to land degradation, and the increase in erosion processes as a result of anthropogenic disturbances since management practices have drastically increased over the past century. In this study socio-economic causes of land degradation and adopted strategies will be assessed from farmers' perception. Hansen & Brown (2009) reported that the various ways rural land use can alter ecological processes: natural disturbance, vegetation succession, carbon sequestration, and air pollution. Land use practices such as deforestation, grazing, and agriculture affect ecosystem structure and functioning and regional climate (Zak et al., 2008). Consideration of local farmers' knowledge could reduce the cost of restoration strategies.

2.3.4. Biophysical Drivers of Land Degradation

Brown (2009) stated that local impacts of land- use change are often determined by changes in land cover, which refers to the biophysical state of land. Frost et al (2006) also argued that Landscapes are also varied, with biophysical, social, and cultural elements shaping land-use patterns and land-management decisions. In the driest area land degradation has related to biophysical condition in several studies. For instance (Efrem Garedew et al., 2009; Appelgren 2009;) who found that, in dry-land areas, a major limitation for agricultural production is the constrained biophysical environment in terms of erratic rainfall. Sida's Helpdesk for Environment and Climate Change (2013) reported that degradation of soils, forests and water ecosystems are the key environmental constraints for reducing poverty in Mali, where climate change further aggravates existing stresses. Based on that, biophysical must be in the top of a framework analyzing sustainability strategies. The implication of Bandiagara and Bankass in this study could be necessary in such a way that it takes into account biophysical aspect in land degradation assessment.

The biophysical causes of land degradation differ from one geographical area to the other because each locality has different ecological and geographical conditions. They are location-specific and they depend both on natural processes and human activities. Degradation of soils may be caused by natural processes like, geographical position of the land, wind and water erosion Sida's Helpdesk for Environment and Climate Change (2013). The slope and the structure of land may increase the rate of exposure of land to the external hazards like heavy rainfall, increased siltation.

2.4. Effects of Land Use Changes

2.4.1. Effect of land use cover change on livelihood

"A livelihood comprises the capabilities assets (including both material and social resources) and activities required for a means of living". Soil, air and water are the natural capital and make up the capital that rural livelihoods can obtain there basic resources from. Hence, land degradation in terms of soil degradation is a major environmental issue posing threat to sustainable livelihood in the semi-arid region. Land degradation in most developing countries is becoming a major constraint to future growth and development of rural livelihoods (Chabay et al., 2016). In the Sahel region, like in the arid zone like Mali where livelihood depends mainly on natural resource exploitation, land degradation threatened human security at its seven domains (Food security, Economy security, environmental security, personal security, community security, political security, heath security). The degradation of natural resources poses a risk for farmers and pastoralists. Unsustainable management practices and policies lead to environmental degradation, increasing peoples' vulnerability by reducing productivity (Simonson, 2005). Hence, a good preparedness of this disaster risk reduction, socio-economic studies are needed. This study contributed to livelihood improvement in the specific context of Bandiagara and Mopti region of Mali.

2.4.2. Land Use Change and Climate

In the 21st century, global environmental changes are increasingly on top of the international scientific and political agenda. The most pressing issues in global change are land cover and climate changes, with anthropogenic land modification and conversion being the predominant contributing factors (Turner II et al., 1993). Land use and cover influence bio geophysical, biogeochemical and energy exchange processes (Houghton JT et al., 2001)and variations in these processes affect local, regional, and global climate patterns. Key processes include: uptake and release of greenhouse gases by the terrestrial biosphere through photosynthesis, respiration, and evapotranspiration, the release of aerosols and particle from surface land cover perturbations, variations in sensible heat exchange between the surface and the atmosphere due to land cover changes; variations in absorption and reflectance of radiation, as land cover changes affect surface reflectance and surface roughness effects on atmospheric momentum that are land cover-dependent. Human activity can and does alter many of these processes and attributes, but weather and climate, as well as geological and other natural processes, are also important.

Mali is one the Sahelian country where main energies, animal feed sources come from wild trees and shrubs. Due to demographic pressure, the rate of exploitation is getting higher and higher nowadays and most of the species (animal and plant) are ongoing of extinction. According to Orchard et al., (2017) there is a reduction of vegetation due to drought, topsoil losses, intense rainfall resulting in less grazing for cattle. Sidibé et al.,(2014) stated that communities located in the 15 villages within/around the Kelka forest in the Mopti region are particularly vulnerable to food insecurity due to the fragility and infertility of the land, and the impacts of an uncertain climate.

2.4.3. Farmers Perception and Response to Land use and Cover Change

Land degradation is considered as a threat to rural livelihood security. A sustainable management practice is required with full involvement of farmers. Sustainable land management will not be possible without the involvement of farmers (Dong et al., 2008 & Wei et al., (2009)). Farmers are the experts in their farming communities and they experienced several challenges which they coped with. According to Savadogo et al (2017), the experience of Farmer Managed Natural Regeneration (FMNR) is an example of a successful agroforestry system that made good impact in Niger. It is important to have a better understanding of farmers' decisions to adopt agroforestry technologies (Sanou et al., 2017). One of the foreseen challenge is: what approaches or strategies to use for "scaling up" of the successful experiences are going to be used taking into consideration farmer's perception? The farmers' knowledge could help in analyzing the complexity of the causes, driving factors and envisaged strategies for sustainable land management in drylands.

3. **MATERIAL AND METHOD**

3.1. Study Area

This study was carried out in four communes (Bara Sara, Soroly, Segue and Kani-Bonzon) located in Bandiagara and Bankass districts in Mopti region of Mali. The reasons why I selected Bandiagara and Bankass as study areas was that these sub-catchments cover a wide area with different physiographic characteristics. It is also extremely stressed in terms of the use of land and water resources by the people, demonstrating the anthropogenic factors involved in land degradation. Destruction of vegetation cover through fuel wood collection and bad climatic condition have further degraded the rangelands. The zone has two seasons (rainy and dry). The rainy season lasts from June to September in which the highest rainfall is recorded in August with 237 mm whereas the dry season is from October to May with an average temperature of 32.9 °C and January is the coldest with an average of 23.0 °C. The rainfall difference between the driest and the wettest month is 166 mm and a difference of 9.9 °C exist between the lowest and highest temperatures throughout the year. The soils is mainly sandy in the low elevation, rocky and mountainous area. The area is inter-mountainous with some caves where wilds and domestics animals drink through the years. A diversity of ethnic groups are present in the area, including the Bozo, the Songhai, the Dogon, the Fulani, the Malinke, and the Bambara but he most dominant are the Dogon. People live in a joint-family system. It is common that decision-making authority lies with the father or senior male member of the family (head). Herding, and agriculture (rice, millet and sorghum productions) are the main activities in the area. The farming system is characterized by a traditional subsistence farming. Almost all women in the area normally work in their homes and take part in outside agriculture or trade activities. Women have right to own land from their husband. They do insignificant trades, gardening and breeding in the dry season and groups farming in the rainy season to support their husband in family management. Vegetation cover is considerably under heavy degradation in both sites. In Bandiagara around 10% of the rocky and ferruginous plateaus are not suitable for agriculture, while most of the remaining portion is used for rainfed cropping by Dogon farmers and livestock herding by Fulani (pastoralists). In the past 30 years, droughts and human expansion have caused a considerable loss of natural woody vegetation, resulting in degraded land and an increase of cultivated areas. Prevailing woody species are *Balanites aegyptiaca, Combretum glutinosum, Guiera senegalensis,* and especially on farmlands *Faidherbia albida* (Brandt et al., 2014).

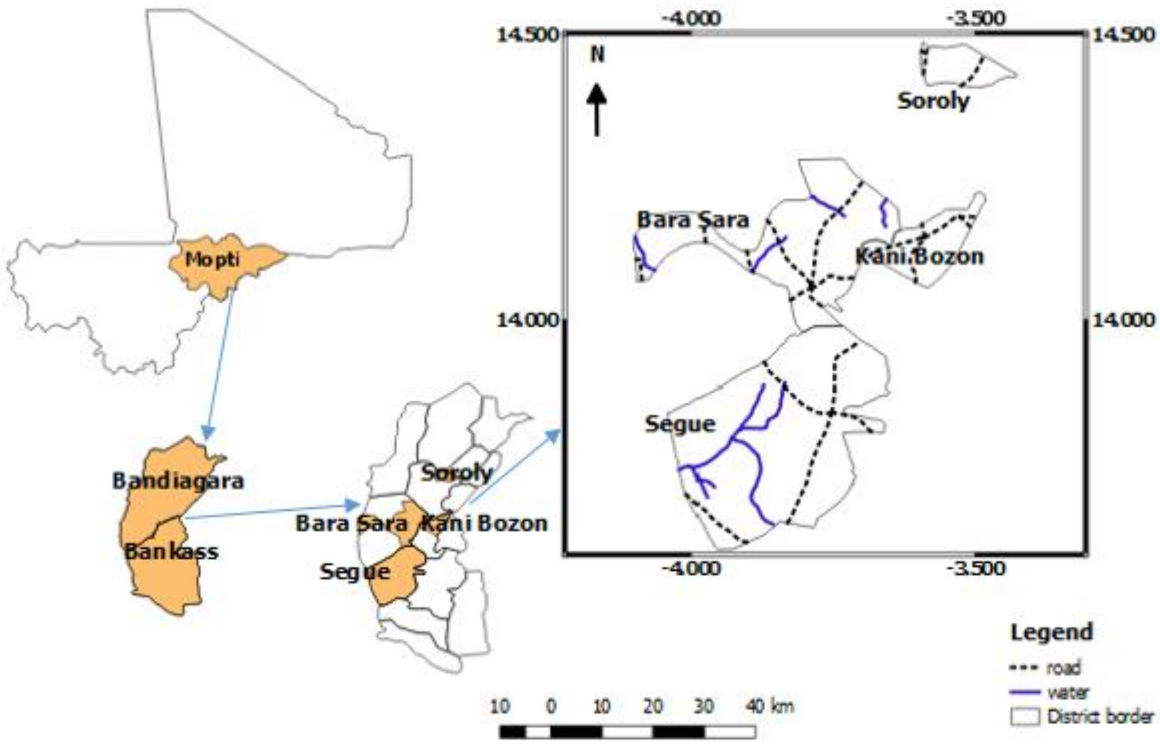


Figure 3.2: Location of the study area

Source: Diva; Map: (Sanogo N., 2017)

3.2. Research Method

The main objective of this study is to analyze the perceptions of farmers' on the impact of land degradation on agricultural land productivity decline, associated with soil erosion, fertility loss and land use cover changes effects on people's livelihood. The study used a multistage sampling procedure to select sample respondent households. Mixed-method research which combines collection and analysis of both qualitative and quantitative data in a single study was deployed (Teddlie and Tashakkori, 2009). For the assessment of the land use and land cover change, remote sensing data play a major role with their ability to provide quantitative information on the spatial dynamics of land cover from different time periods (Tottrup and Rasmussen, 2004; Deng et al., 2006; Mottet et al., 2006 in Paré et al., 2008). The combination of both approaches allowed us to critically analyse data in an integrated manner to achieve the set objectives.

3.2.1. Primary Data Collection

In this study, a combination of various conventional tools such as personal interviews, focus groups discussions (FGD), remote sensing (RS) and GIS (Geographical Information System) and field observations were used in an integrated approach to socially, economically and environmentally analyze the complexity of land degradation issues in the study area. To avoid missing respondents, an alert has been giving to each village chief through a phone call to mobilize communities in advance.

3.2.1.1. Sampling Method

A purposeful sampling of four communes (Bara Sara, Segue, Kani bozon, Soroly) were selected in Mopti region. Within the four communes, eight villages (Sadia Dogon, Mandali, Kogo, Soroly, Gani, Dounde, Kani bonzon) were chosen. The rationale behind the choice of these communities hovers around two development-oriented projects – DRYDEV, SmAT-Scaling. Apart from these reasons, the selected villages were also free from political instability which is common in major part of the country. Both projects aimed at transforming the degraded landscapes into productive lands. The dry lands Development Programme (DryDev) supports more than 56,235 smallholder farmers (of which 50% are women) in selected dry land areas of Mali. DryDev envisions a future where households in the targeted drylands areas have transitioned from subsistence farming and emergency aid to sustainable rural development. The SmAT-Scaling Project is funded by USAID operating under the guidance of the USAID/Mali’s Feed the Future (FtF) strategy and implemented by a consortium headed by the World Agroforestry Centre (ICRAF). It aims at strengthening the value chain of tree products, improving the nutritional status and food security of the targeted population, and building local capacity.

A total of 240 household heads, corresponding to 2.16% of the total population census of the four communes (INSTAT, 2009) was considered due to time and resource constraints. Sample were purposefully selected from the list of DryDev and SmAt-scaling projects beneficiaries. The respondents were selected based on some criteria: firstly, sample population in a given village should include 30% of women for the sake of gender balance, respondent age should range from 20 and beyond to ensure that they are old enough to provide their perception on the spatial and temporary changes in land use and land cover. Secondly was the availability of the respondents because the survey was conducted during the harvest period when people were busy in farm work. In the absence or unavailability of household heads, another adult in the house who is familiar with the household management was selected.

3.2.1.2. Focus Group Discussions

Prior to the household survey, focus group discussions and interviews with key informants were held. The focus group participants and key informants is composed by: three groups (Old men, women and youth) have been interviewed in FGDs at each selected village with a number of > = 6 persons per group of discussion. The discussion with youth and women were mostly done in the afternoon due to their time of availability because the study coincides with harvesting period in which the major part of the labor is done by women and youth. The goal of the FDG in this study is directed towards changes in perceptions, attitudes, and readiness to undertake actions. The primary aim of the discussions was to obtain a background understanding of the local roots causes, drivers and the effects of land use cover changes on rural livelihood security also how are they copping with and how their copping strategies can be sustainably improved. Information acquired during these discussions allowed us to identify the importance of the land use, the causes and drivers of their degradation to the livelihood security in the villages. The process of joint analysis and interpretation helps to define the changes that would bring about improvement of livelihood conditions in rural communities. The categories of land use cover considered in this study are croplands, water bodies’ shrub lands and savannahs because of their high contribution to livelihood security in the arid area like Bankass and Bandiagara.

Image 01: Group discussion with elders in Bara Sara (© Sanogo N., 2017)

Image 02: Group discussion with women Bara Sara (© Sanogo N., 2017)

Image 03: Group discussion with Youth in Kani Bozon (© Sanogo N., 2017)

3.2.1.3. Household Data Collection

A household survey was also done at two occasions. One from August 20nd to September 14th 2017 secondly from 08 to 17 October 2017 using semi-structured questionnaire (See Appendix). Prior to the interviews, each of the household head was asked whether he/she was willing to participate in the interview. The household heads are interviewed after giving their consent. All the household heads selected for the interviews agreed to be interviewed. Interviews are conducted at farmers' homes to avoid the influence of other farmers, and are carried out by a trained enumerator. A pretested semi-structured questionnaire is used for gathering information, and each interview lasted about 1 h 30 mn. Questions are organized in the way that they achieved the objectives. Demographic and socio-economic questions related to their household size, level of education, gender, age, residence and land tenure status and their forest-based income generating activities, household resource endowment. For the assessment of local knowledge and farmers' perception, the checklist of issues discussed during the interview dealt with: a) agricultural practices, b) soil erosion c) status of soil fertility and soil fertility enhancement practices, d) household source of energy and e) suggest management strategies. Close-ended questionnaires are used when relevant. Most of the factors tackled in the questionnaire represented a categorical type of data. For some questions, the interviewees are asked to rate them on a 4-point Likert-type scale (Clason and Dormody, 1994) as 1: not important, 2: moderately important, 3: important and 4: very important while for other binary response were considered.

3.2.1.4. Field Observation

A field observation has been conducted in the different land use categories (cropland, water bodies, tree savanna and shrub savanna) through transect walk with the local communities in order to identify the most affected areas and also to validate the information given by the respondents. Trees and shrubs species under extinction were recorded in scrublands and three savannah. Water bodies have been visited to have an overview on the available watershed in each selected villages.

Images 04: Cropland at Kani Bozon (© Sanogo N., 2017)

Images 05: Shrub savanna at Bara Sara (© Sanogo N., 2017)

Images 06: Tree savanna at Bara sara (© Sanogo N., 2017)

Images 07: Water body at Kani bozon (© Sanogo N., 2017)

3.2.2. Secondary Data Collection

3.2.2.1.Land Use Cover Data Acquisition Procedure

Remote sensing techniques are used to establish a land cover map to derive vegetation cover characteristics as input parameters for land cover type. Satellite images (Landsat TM, ETM+ (Thematic Mapper), ETM + (Enhanced Thematic Mapper Plus) are collected from the Global Visualization Viewer (GloVis). The Landsat image datasets were obtained from the United States Geological Survey (USGS) data archives (http://glovis.usgs.gov and https://earthexplorer.usgs.gov). Images are acquired from databases at the beginning of the dry season around October to November, so that the phenological stages of plants covers are not too different between dates. Moreover, this period, which follows the harvest, may be considered as the best time of year for distinguishing the various Sodano-Sahelian land-cover types, notably because the contrast between croplands and the natural environment (Ruelland et al., 2010). The images are then used for the classification of land use land cover types and change detection. Five classification schemes (Cropland, settlement, water bodies, shrub savannah, and tree savanna) are used to assign pixels to land use classes (Table 3.1). The Landsat Thematic Mapper (TM) imagery provides seven Multi Spectral channels (3 visible, 1 near-infrared, 2 mid-infrared, 1 thermal-infrared) at 30-meter resolution (120-meter resolution for the thermal-infrared band). Enhanced Thematic Mapper Plus (ETM+) adds an extra 15-meter resolution panchromatic band and improved resolution for the thermal-infrared band (60-meters). The rate of change was calculated using following formula:

$$r = 1 - \left(1 - \frac{A1 - A2}{A1}\right)^{\frac{1}{t}} \qquad \textbf{Eq. 1}$$

Where A1 is the area covered by a given land use/cover at time 1, A2 the area at time 2 and t is the number of years for the period of analysis (Dansoko, 2015).

Table 3.1: Description of LULC classes used in this study

Land use classes	Description
Settleme nt	A concrete area covered by scattered houses in bloc with interval around 5 m per houses
Cropland	Cultivated formations with or without scattered trees (canopy coverage 20%). These areas are characterized by annual crops (mainly millet and Sorghum), harvested in October–November, followed by a period of bare soil with crop residues (Dansoko, 2015).
Tree savannah	Mixed class. Land with herbaceous vegetation and a woody cover covering. Land with a dense cover of trees covering approximately >70% of the delineated polygon.
Shrubs savannah	Land covered by scattered small trees (5m in height), bushes, shrubs and mixed with grass vegetation (Efrem Garedew Æ Mats Sandewall Æ Ulf et al. 2009)
Water bodies	Permanent or temporary water bodies such as small dam, rivers or stream.

Source: *(Sanogo N., 2017)*

3.2.2.2. Population Data Collection

To estimate current data on the population, we used the 2009 national census (INSTAT, 2009). The projected population data from that census to 2015 were computed the population data of each of these time series based on cohorts of the recorded population living in the village at the census date. These data do not take into account people who passed away or migrated out of the village during these periods. The following equation was used:

$$P_{(n)} = P_{(0)} * \left(1 + \frac{P}{100}\right)^{N} \qquad \textbf{Eq. 2}$$

Where $P_{(n)}$ is the population projection for year x, $P_{(0)}$ is the population at the beginning (base), P is the growth rate, and N is the number of years. (Dansoko, 2015).

We could not unfortunately include the out-migration in the final estimation of the population because the national census did not report data related to internal population mobility.

3.2.2.3. Climate Data

Time series of 30 years from 1987 to 2016 weather data (rainfall) were collected from local station (Mopti meteorological station). Given the vagaries of the weather, especially in the Sahel, any desertification or (dynamic) degradation study must take into account the climatic aspect, in order to be able to verify the share of rainfall deficits. To this end, the World Meteorological Organization (WMO) adopted the Standardized Precipitation Index (SPI) in 2009 as a global instrument for measuring meteorological droughts, according to the "Lincoln Declaration on Drought Indices". To determine the wet or dry character of the season in the Sahel, the standardized rainfall index (SPI) is generally used.

Standard Precipitation Index analyses to compute rainfall anomalies from 1987 to 2016 using the following equation:

$$\boldsymbol{SPI = \frac{X_i - X_m}{S_i}} \quad \textbf{Eq. 3}$$

Where X_i is the cumulative rainfall for year i; $X_m$and S_i are respectively the mean and the standard deviation of annual rainfall observed in the series.

3.2.3. Data Analysis

3.2.3.1. Land Use Cover Data Analysis

3.2.3.1.1. Images Pre-processing

These are the operations performed on the images before any treatment in order to: gather images of a scene of the same date in a layer stacking extracting the study area, consisted in creating a frame or minimum bounding box in ArcGIS then export it to ENVI to extract the study area. Resize the pixel size in ENVI 5, to make the images of the three dates superimposable. It requires resizing to match the 1986. 2000 and 2015 OLI images that have 30 x 30 m pixels. Mosaic: these are three Landsat scenes that cover the study area. The already georeferenced images are connected to each other automatically, according to their exact position on the surface of the earth. The latter makes it possible not only to have an overview of the study area but also to obtain a database to carry out the study.

3.2.3.1.2. Image Processing

Supervised classification is a pattern recognition process. In remote sensing, it consists in making the correspondence between the elements of a scene of the image materialized generally by their radiometric values, and classes known a priori or not by a user. The correspondence is performed by discriminant functions in the form of a decision rule such as the “maximum likelihood” of probabilities, or geometric distances. The classification algorithm chosen is the “Maximum likelihood”. Indeed, this algorithm has the advantage of being a probabilistic method. It classifies unknown pixels by calculating for each class the probability that the pixel will fall into the class with the highest probability. If the probability does not reach the expected threshold, the pixel is classified unknown (Karambe, 2014).

- Extraction of plant formations from land use in 1986, 2000 and 2015

The plant formations are extracted from the land cover maps of each year. Thus the extraction of the formations (Hygrophilous Formation, savanna tree, and shrub savanna) was made with the analytical tools of ArcGIS (Analysis Tools - Extract - Select).

- Analysis of the evolution of the areas of the plant formations of the four communes between 1986, 1986-2000 and 2000-2015.

The results of the classification of the three dates made it possible to analyze the spatial dynamics of plant formations from 1986 to 2000; from 2000 to 2015 and from 1986 to 2015, thanks to the change detection approach in ENVI. Before proceeding with the "Change Detection" the "Masking" was done to extract the exact area of the study area.

3.2.3.2. Relationship between Land Use / Cover Change and Population

Pearson correlation analysis was done to make correlation between population data and different land use/cover types over the last 29 years. The Pearson's r coefficient (or r2), also known as the Pearson Product-Moment Correlation, is often used in modern software packages available for data display and curvetting. What is the meaning of this variable and how should it be used in fitting physical data?

It is defined as the ratio of the covariance of two variables representing a set of numerical data, normalized to the square root of their variances (Hall 2015).

3.2.3.3. Climate Data Analysis

A yearly rainfall anomaly of 29 years (1987-2016) was tested through Augmented Dikey-Fuller unit-root test in Stata 14. I based on confident interval of 95%. The test consisted to verify whether temporary series is stationary or not. Finally, the measurement of the climatic evolution was made by the calculation of the standardized index of the precipitations. This index, which is well adapted to monitoring changes in vegetation dynamics in relation to rainfall trends, is used to quantify precipitation variations at different time scales.

3.2.3.4. Focus Group Data Analysis

Focus groups began with open-ended "grand tour questions that seek to obtain participants' overall orientation towards a land use cover change. The main data are the perception of people on the changes of cropland, tree savannah, shrubs savannah, and settlement and water bodies over last 29 years. The perception of each group (male, female and youth) were analyzed separately using half-finished thoughts, parts of words, odd phrases, and other characteristics of the spoken word in a group discussion.

3.2.3.5. Household Data Analyses

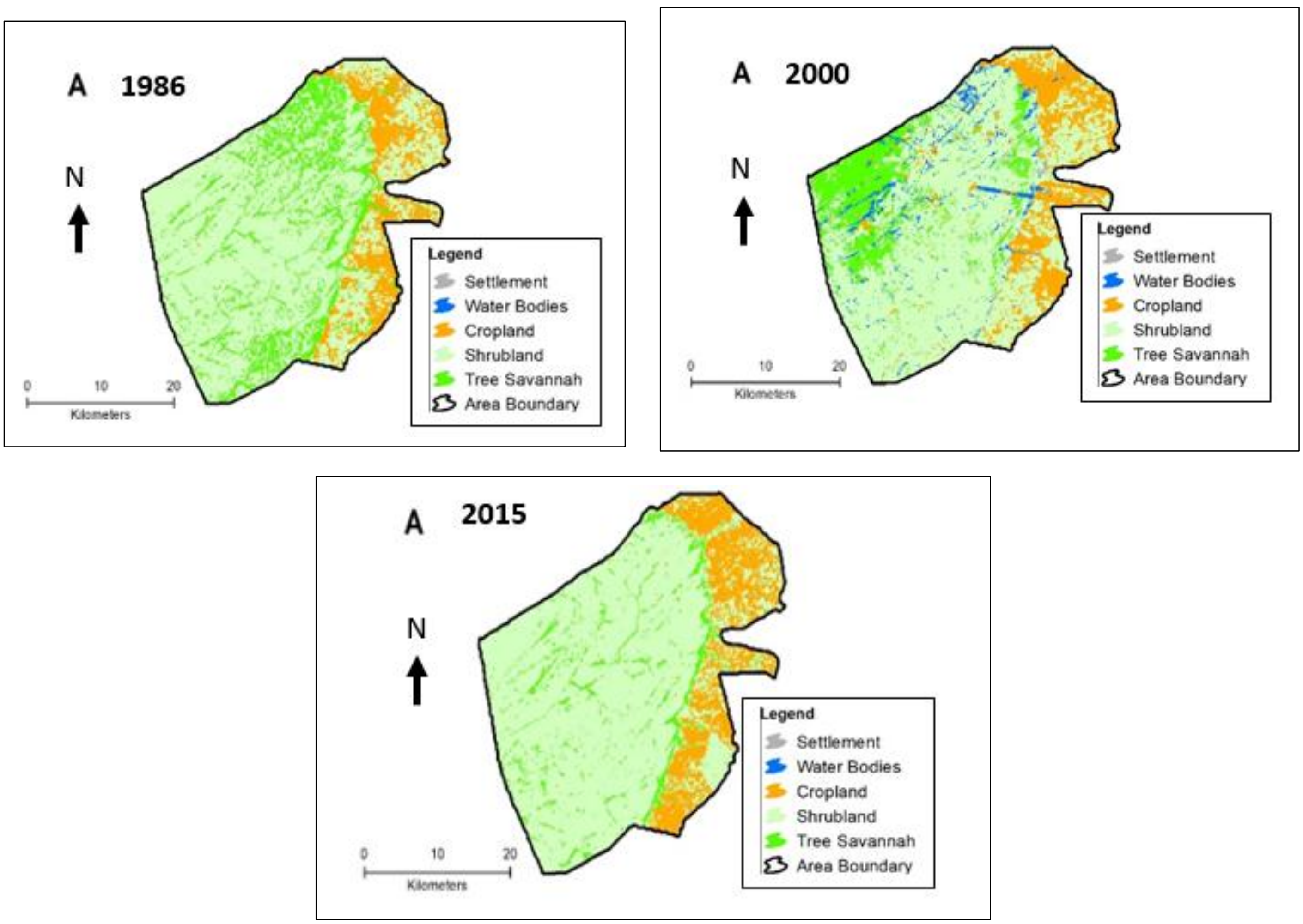
Household data were analyzed using the Statistical Package for the Social Sciences SPSS 20 software (SPSS for Windows, Release 2013 Chicago: SPSS Inc.). Likert scale questions were coded so positive responses corresponded with higher numerical codes. This process allowed the establishment of question related to agricultural practices, erosion processes. A composite scale (0–10) reflecting a respondent's perceived receipt of the causes and the effects of land degradation on the livelihood security and proposed land management practices for future planning were created by summing ranked responses from questions (Spiteri, 2008).

4. RESULTS

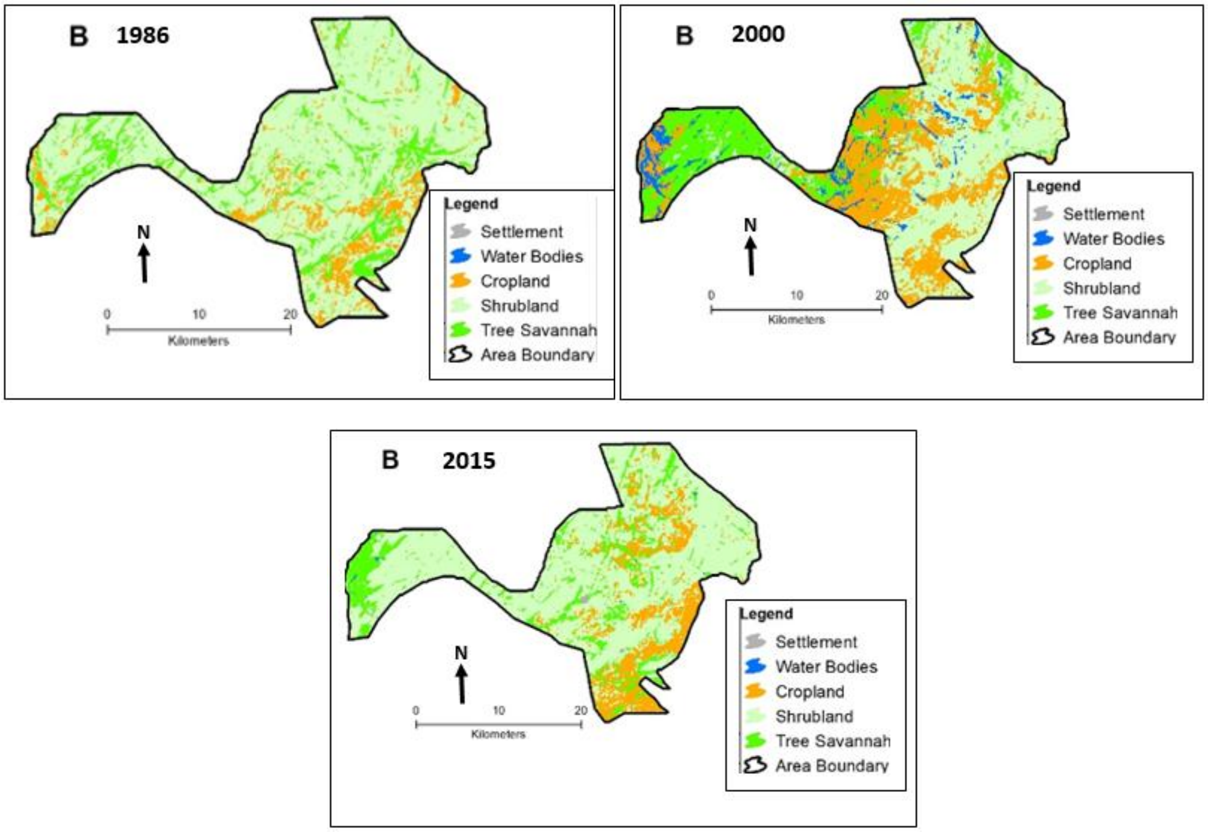
4.1. Land Use Change Maps

The rate of land use and land cover change emanating in the studied communes generally has been significant over the years as the results from the maps output indicate (**Figure 03**). They describe land use cover changes over 1986, 2000 and 2015. The supervised and unsupervised image classification produced categorized the area into five main land use/ cover classes as elaborated in the Table 01. The five categories are settlement, water bodies, cropland, and shrub land and tree savannah.

A. Segue



B. Bara Sara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Settlement
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Cropland
Shrubland
Tree Savannah
Area Boundary
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Cropland
Shrubland
Tree Savannah
Area Boundary
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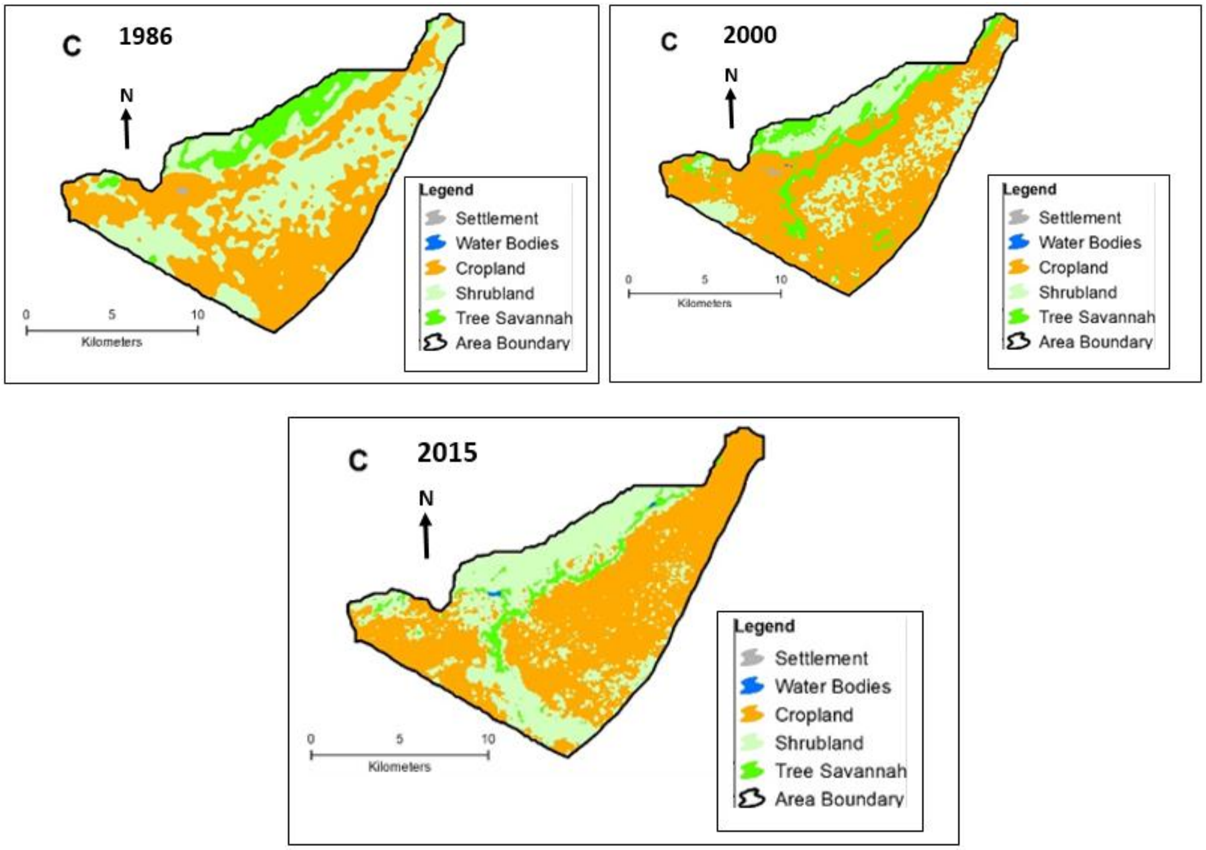
Cropland
Shrubland
Tree Savannah
Area Boundary

C. Kani Bozon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Cropland
Shrubland
Tree Savannah
Area Boundary

D. Soroly

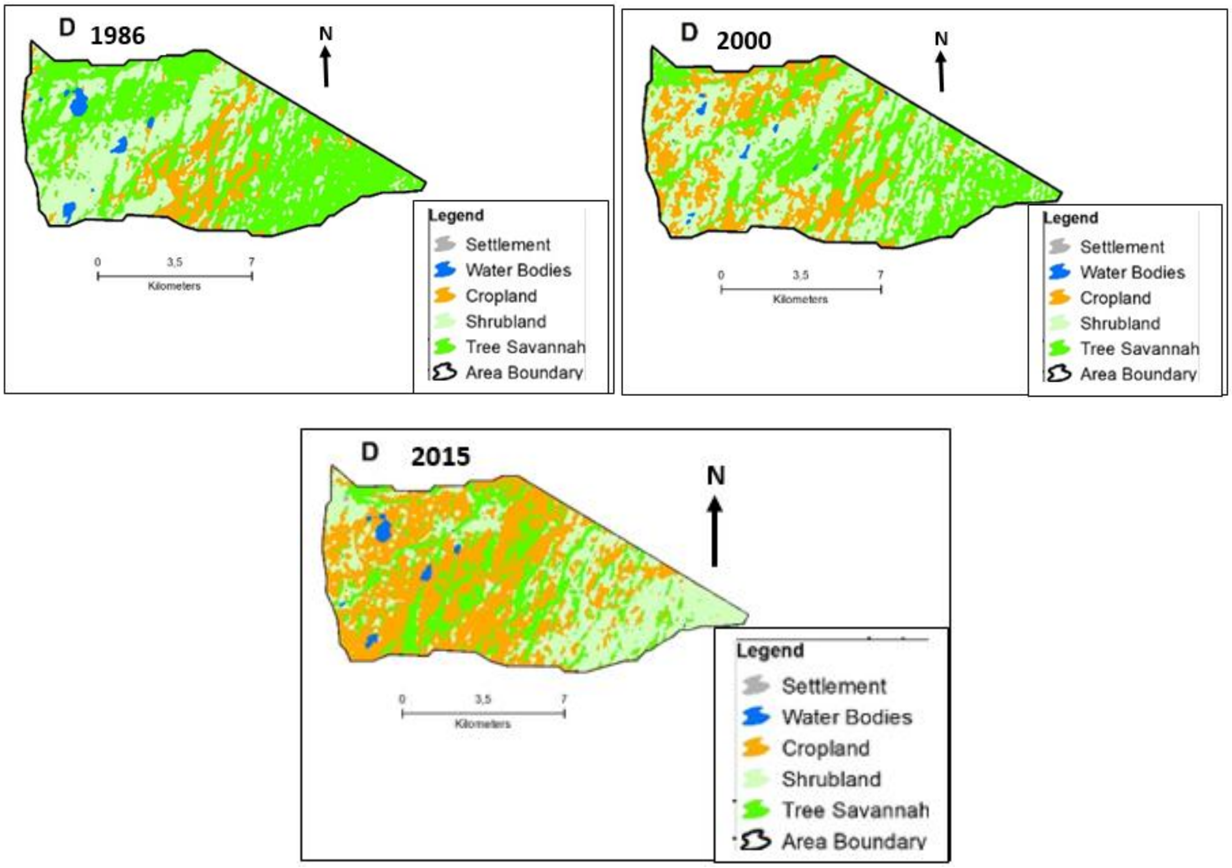

Figure 4.3: Pictorial representation of land use dynamics in four communes in Mopti region, Mali during the study period (A) Segue (B) Bara Sara, (C) Kani Bozon (D) Soroly.

Data Source: USGS database, Produced by: *(Sanogo N., 2017)*

4.2. Extent of Land Use and Land Cover from 1986 to 2015

The contingency graph obtained from the remote sensing based-classification shows the extent of each type of land use/ cover class at different study periods of the area. For instance, Figure 4 gives a summary of the total area of land under each class in the four communes between 1986 and 2015. For Kani Bozon the cropland area increases of 2515.54 ha in the interval 1986 to 2000 while it decreased of – 576.36 ha in the period of 2000 to 2015. An aggregate increase of 1939.18 ha were recorded between 1986 to 2015.The area covered by tree savanna decreased over the time period -1086.88 ha between 2000-2015 and -718.43 ha in the interval of 1986 to 2015. A remarkable increase of 1679.04 ha happened during 2000 to 2015 while an aggregate decreased in shrub savanna of -1423.81 ha occurred during 1986 to 2015. Further, water bodies increase of 3.67 ha, 20 ha and 23.67 ha respectively 1986 – 2000, 2000 – 2015, 1986 – 2015. Much increase of 1020.18 ha of settlement cover were recorded from 1986 to 2000 in Kani Bozon.

In Bara Sara, the results revealed that cropland has decreased of 12219.68 ha within 1986 to 2000 while it severely decreased of -8539.89 ha in the interval of 2000 to 2015 however it increases globally of 3679.79 ha during the period 1986 to 2015. The respondent related the decrease in cropland to the advancement of sand dune meaning that most of the cropland are covered by sand. The shrub savanna area increases of 40302.72 ha at the expense of the tree savanna that decreased of 959.16 ha during the period 1986 to 2015. A severe decrease of -3628.32 were recorded during the period 2000 to 2015 while an increase of 106.65 ha were noticed between 1986 to 2015. The change in water bodies was linked to the annual rainfall variability. Settlement cover increase of 88.15 ha from 1986 to 2015.

In the commune of Segue an increase in cropland area of 3491.33 ha was observed over 1986-2015. This was a significant change in land use over a short period of time that was mostly accelerated by human activities of the changing population in the commune. To meet the additional requirements of food of the growing population, intensive cultivation of land undertaken brought about clearing of shrub vegetation and destruction of wetlands in order to bring more land under agriculture. This is evidenced by the drastic decrease in cover of tree savanna of -11648.12 ha between 1986 to 2015. An increase of 7706.47 ha of shrub savanna area is observed for the same period. This is most likely explained by previous tree based land restoration activities promoted by some NGOs. Water bodies slightly increased up to 2.25 ha from 1986 to 2015 because of artificial pond creation. The high increase in settlement cover were noticed from 1986 to 2000 with 1020.18 ha.

For the commune of Soroly, cropland has increased with an additional land of 3486.13 ha between 1986 to 2015. However, the highest change of 2387.44 ha happened between the intervals from 2000 to 2015 where it increased by two folds. For the same period tree savannah decreased of - 3050 ha, shrub land of -391.6 ha and water bodies of -50.34 ha. Area covered by water bodies decreased during the period of 1986 to 2000. The reason of cropland expansion was linked to several factors such as increasing in population, land infertility and availability of agricultural inputs (Chemical fertilizers, pesticides and plows). The decreased in tree and shrub savannah may be explained through high firewood demand, low incomes level and cropland expansion. Bad climatic condition (bad rainfall distribution) has been also noted as driving a factor of vegetation cover decrease over the study. Soroly experienced a severe drought from 1986 to 2000 which really disturbed the ecosystem stability in the area. In Soroly, settlement covered with an additional land of 5.81 ha from 1986 to 2015.

Despite the variability of the causes LULC change in different location. In general, the causes of the changes are mostly related to overgrazing, deforestation, population growth and frequent rainfall anomalies.

Overgrazing because the amount of livestock doesn't merge with the available grazing land. Livestock are overconsuming tree and shrub fodders with any replacement strategy. People are deforesting for cropland expansion, firewood and wood needs. Those factors combined with frequent rainfall anomalies and demographic pressure are putting livelihood of investigated farmers of Bandiagara and Bankass under threat through reduction of the ecosystem services.

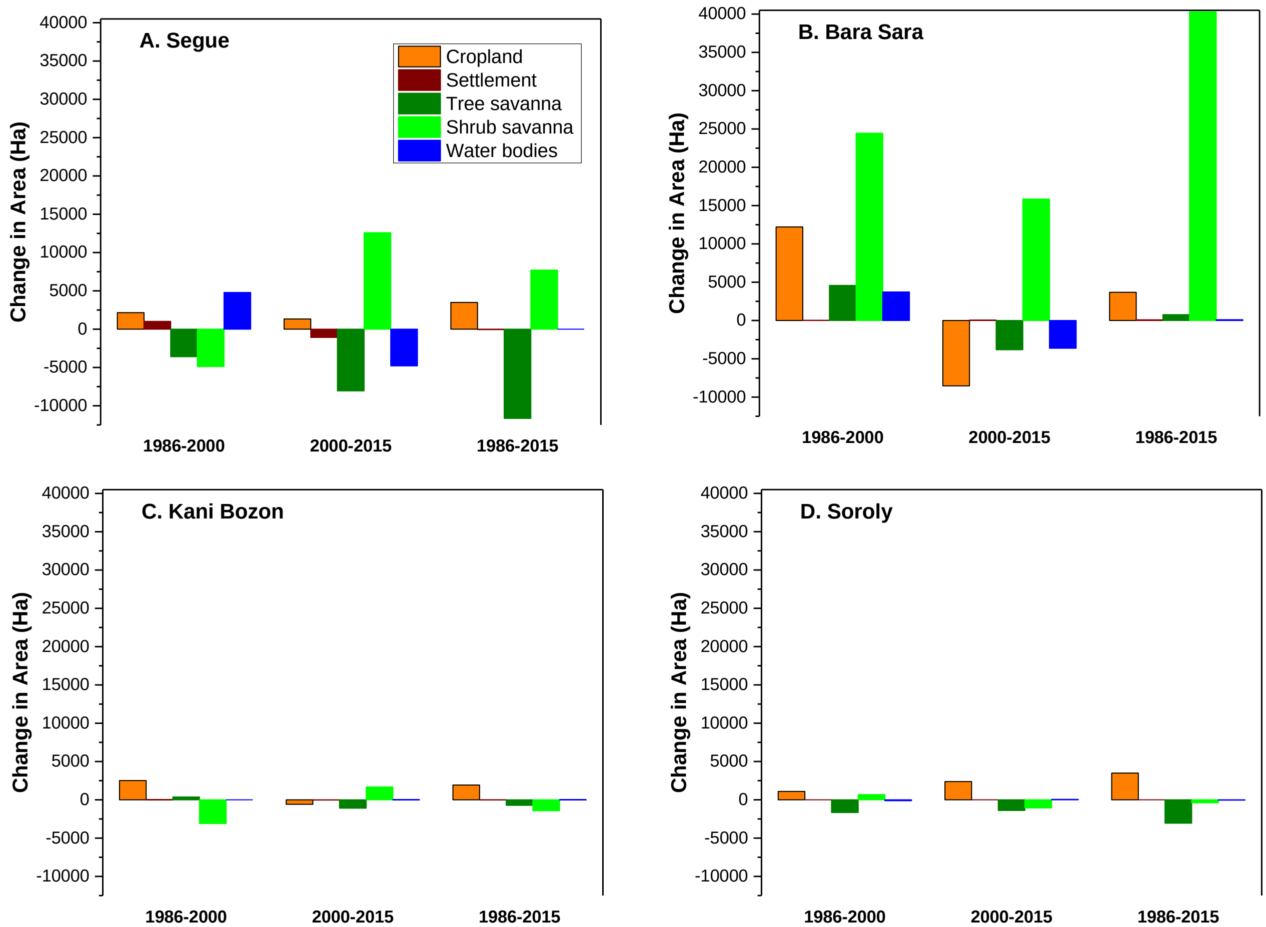

Figure 4.4: Change in land use types in size from 1986 to 2015 in the communes of Segue, Bara Sara, Kani Bozon, and Soroly in Mopti region, Mali.

Data source: USGS database,

4.3. Relationship between Land Use Change and Population

The total population of the four communes increased across the three-time periods (Figure 4.5). That result concur with the perception of farmers' because all the 100 % of the respondents are agreed of population growth in the area. It increased at a rate of 3 % per year from 1986 to 2015 resulting in a shift of population density in all communes (Figure 4.5). The growth was mentioned as natural without implication of any migration into the area. Pearson correlation analysis indicated that change in land cover could be linked to population growth (Table 4.2). In general, there is a strong correlation between land use types and population changes.

The change in size of cropland was strongly and positively correlated with population in all communes except in Bara Sara where it was relatively low. However, the correlation was not significant (p>0.05). Area covered by tree savanna was significantly strongly (p=0.012) and negatively correlated with population in Soroly. Tree savanna is also strongly and negatively correlated with population despite its insignificance (p>0.05). In contrast the relationship was weak in Bara Sara (r^2=0.185; p= 0.882). The area covered by settlement was positively and strongly correlated with population in Bara Sara and Soroly while it was negatively weakly correlated with population in Segue and Kani Bozon. There was a strong relationship between population and change in areas of shrub land in all communes except at Soroly but the relationship was not significant. Moreover, any correlation was found with water bodies' changes and population growth all the four.

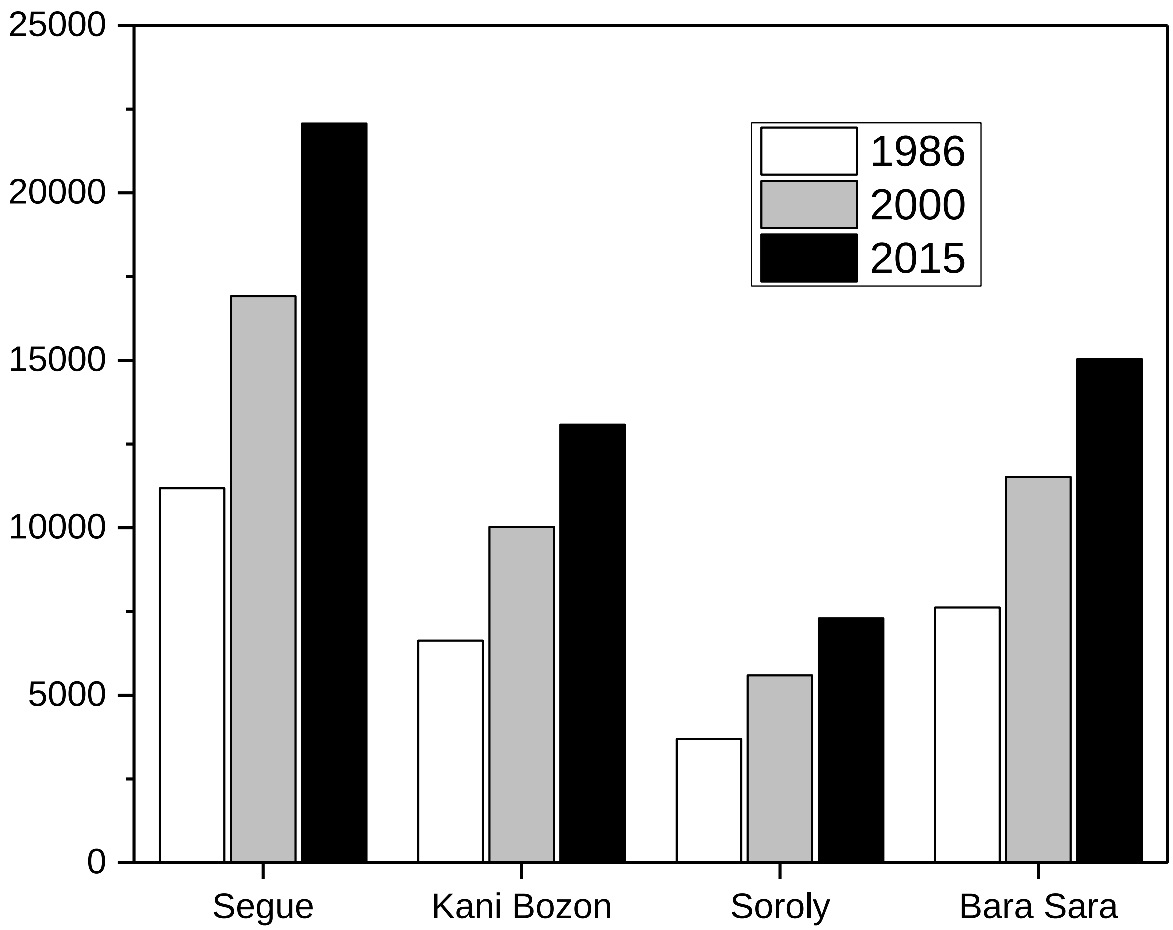

Figure 4.5: Total population size for each commune during the study period

Source: (Sanogo N., 2017)

Table 4.2: Coefficient of determination (r^2), together with p-values for Pearson correlation to examine relationship between areas of each cover type and population density

Land use types	Correlation	Communes			
		Segue	Bara Sara	Kani Bozon	Soroly
1. Cropland	Pearson correlation	0.995	0.323	0.756	0.971
	p-value	0.066	0.791	0.454	0.153
2. Tree Savanna	Pearson correlation	-0.969	0.185	-0.626	-1
	p-value	0.158	0.882	0.569	**0.012***
3. Shrub savanna	Pearson correlation	0.583	0.996	-0.485	-0.336
	p-value	0.604	0.058	0.677	0.782
4. Settlement	Pearson correlation	-0.012	0.961	-0.655	0.952
	p-value	0.992	0.179	0.545	0.198
5. Water bodies	Pearson correlation	0.031	0.056	-0.655	-0.467
	p-value	0.980	0.965	0.545	0.691

* Significant at 0.05 level (2-tailed)

Source: *(Sanogo N., 2017)*

4.4. Famers Perception on the Drivers of Land Use Cover Changes

4.4.1. Socio-demographic Characteristics of the respondents

The numbers of respondents with each set of household reference person's characteristics are summarized in table 4.2. The respondents were all from the Dogon ethnic group with 63.75 % of men and 36.25 % of women. Most of them (57.5 %) are in the age range from 31 to 50 years old while 96.25 % are married and the median household size was from 6 to 10 family members. The majority of the respondent are native meaning indigenous in the area. In term of education, most of the respondents (54.58%) were illiterate; only 16.25% of the respondents received basic alphabetical training and 15.41 % received some religious training (attending mainly Coranic School). The large majority of respondents own the land through inheritance 90.83% (from parents) and the rest borrow land for cultivation whereas women got the land from their husbands. The majority of the respondents were farmers 83.75 %), but few of them were involved in livestock husbandry and wood-cutting. The socio-economic factors are more labor forces in extensive agriculture practices which led to an increase of cropland over the time. 66.25 % of the respondents agreed that cropland is increasing and 23.75 % believed it remains unchanged. The cultivated cropland varies from 0.5 ha to 60 ha per household. The type of labor forces into farming is mainly family labor which is considered by the farmers as the cheapest one in the production system. About 97.5 % used such type of labor force. Land degradation in the area is attributed to the low education level, free land access from parents, family labor availability which are considered by farmers as free labor.

Table 4.3: Socio economic characteristic of the respondents

Variables	Indicators	Frequency	percentage
Gender	Female	87	36.25
	Male	153	63.75
Age	20 - 30	34	14.16
	31 -50	138	57.5
	51 - 70	68	28.33
Marital status	Never married	3	1.25
	Married	231	96.25
	Widow/widower	5	2.08
Residence status	Native	229	95.41
	Migrant	11	4.58
Ethnic group	Dogon	240	100
Level of education	No formal education	131	54.58
	alphabetized	39	16.25
	primary	24	10
	secondary	8	3.33
	higher education	1	0.41
	Coranic school	37	15.41
Agricultural practices	Full time	201	83.75
	Casual	39	16.25
Farm plot in one unity	No	204	85
	Yes	36	15

Cultivated land changing	Increased	159	66.25
	Declined	24	10
	Remained the same	57	23.75
How does the household own the land	In heritance	218	90.83
	Rent	1	0.41
	Gift	11	4.58
	Other	10	4.16
What type of labor is used on your farm	Family labor	234	97.5
	Hired labor	4	1.66
	Group labor	2	0.83
Total area of your cultivated land in ha/ household	Minimum	Maximum	Mean
	0.5	60	8.59

Source: Field survey, 2017

4.4.2. Factors of Soil and Vegetation Loss

The results demonstrate that 87% of the respondent practiced monoculture while 63.3 % used chemical fertilizers in their farms. 55.8 % mentioned used of Urea, 58.8 % DAP, 23.3 NPK at least once during the last three growing seasons. The use of fertilizer is attributed to the high soil infertility and the type of crops used in farming system. But it has been raised by some farmers' during FDG'S that use of chemical fertilizer is causing of the extinction of some microorganisms which contribute a lot to the soil fertilization eg: Earth worms, Cockroachs, Caterpillars, ants and Centipedes. In addition to that tillage practice also is contributing to the soil fragility. About 88.33 % of the farmer' used draught power. Such method combined both mechanic and animal traction. Elders group in Segue mentioned during FDGs that "most of machine drivers are youth and they drive without much on tillage methods, finally the soil get exposed to the external hazards (heavy rainfall, animals clogs)". During focus group discussion in Bara Sara commune, Souleymane Tesougue said that "during last rainy season, a tractors driver tilled his farmland without taking into account the steep slope and sandy type of the soil. When a heavy rain came it has removed the larger part of the soil to the downstream with more crops (millet)". Further, a majority of the respondents supported the same experience. However, animal traction is considered as a method with minor impacts compared to the tractors even though it also caused soil removal. Furthermore about 71.2 % of the respondents are facing severe erosion in their cropland and the explanatories factors are related to heavy rainfall, siltation, deforestation for agriculture purposes, overgrazing.

In addition to that high household energy (firewood) demand and wood extraction are the major factors causing a reduction in tree and shrub savanna cover in most of the communes except in Bara Sara where savannah is protected by local rules and regulation called “Allamodjou”. The causes of firewood extraction are linked to the high household energy demand. The combination of those factors (soil erosion and tree loss) are considered as some of the indicators of ongoing land degradation in the area.

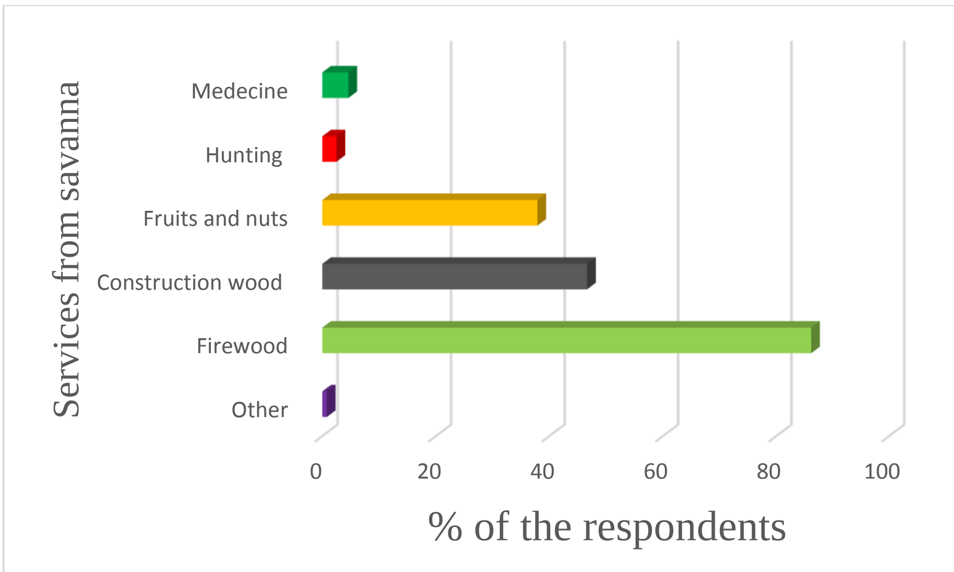

Figure 4 6: Farmers’ perception on the services from shrub and tree savanna

Source: Field survey, 2017

Table 4.4: Farmers' perception on the factors driving land degradation

Variables	Indicators	Frequency	Percentage
Tillage practice	Hand labor	28	11.66
	Draught power	212	88.33
Monoculture	No	30	12.5
	Yes	210	87.5
People used chemical fertilizers	No	76	31.7
	Yes	164	68.3
Urea	No	106	44.2
	Yes	**134**	**55.8**
DAP	No	99	41.2
	Yes	**141**	**58.8**
Perception on soil erosion	No	69	28.8
	Yes	**171**	**71.2**
Soil erosion	No		31.7
	Yes	**164**	**68.3**
Drought in general	No	94	39.2
	Yes	**146**	**60.8**
Overgrazing	No	75	31.2
	Yes	165	68.8

Source: *(Sanogo N., 2017)*

4.4.3. Biophysical Drivers of Land Degradation

4.4.3.1. Climatic Factors

From 1987 to 2016 there was drought except in 1994 and 1999 while the recovering period started from 2007 to 2015. The distribution of the rainfall over the rainy season still undented. This situation has negatively affected crop yields and shrubs and tree growth rate. An inter annual rainfall variability may threaten biomass production in a location specific. In the middle of dry season from March to May fodder trees and shrubs shed their leaves to prepare for the hottest period before the onset of the rainy season. The observed rainfall anomalies from climatic data analysis concur with the observation of the respondents. Nearly 60% of farmers see rainfall anomalies as one of the driving force of land degradation as it negatively impacts on vegetation.

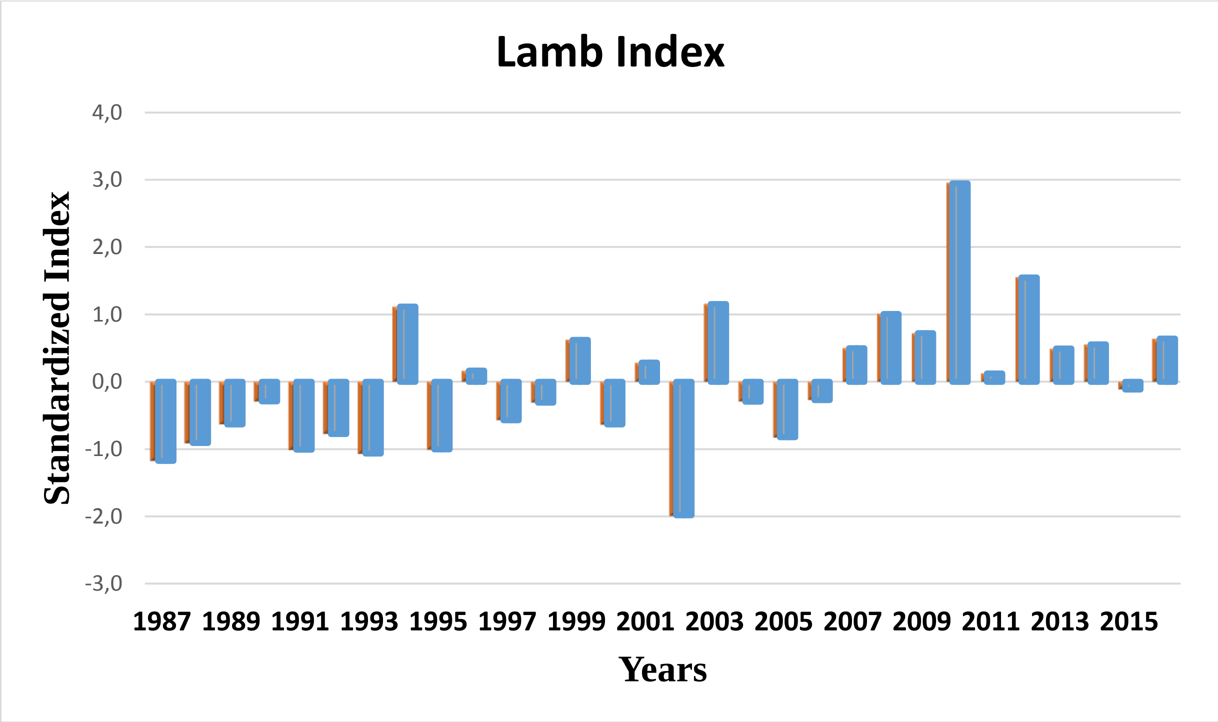

Figure 4.7: Rainfall anomalies in Mopti from 1987-2016: Data source: Mali Meteo

4.4.3.2. Analysis of Agricultural Productivity and slopes

Most of the farmers alluded that there are differences in the rate of soil losses, loss fertility and low crop yield in different slopes. A large proportion (89.58%) of the respondents expressed that they have noticed high soil losses while 63.75 % testified low soil fertility. In contrast, 65.41% of the respondents noticed of low crop yield in very steep slope. In addition to that about 82.91% noticed high soil losses, 58.75% remarked low soil fertility and 56.06% experienced low crop yield in steep slope. In other hand, 61.25% of the respondents noticed minor soil losses, 52.50% and 50.83% of the respondents expressed that they experience minor soil fertility and minor crop yield respectively in gentle slope. These results show that much of the soil losses, low fertility and low yield occurred in very steep slope. It has been raised by farmers that most of the eroded plots are in very steep slope where rain carried sediments to the downstream which is not accessible for agricultural purposes. An overwhelming (63.6 %) of the respondents mentioned that they face erosion severity along the productive farm areas. Moreover, farmers also noticed that most of their farm lands are getting acid. This is evident through appearance of a plant species called Striga commonly known as “witchweed”. It can be noticed that large area of crop of croplands are covered by this particular plant species. The plant (leguminous) grow as a parasite closer to the stem of the crops to compete for nutrient. As expressed by respondent during FDG, soil acidity is one of the major challenges that contribute to land degradation, thus affects farmers’ livelihood. There is a need of holistic approach to address soil acidity and slopes adjustment in order to enhance cropland production and productivity.

Table 4.5: Frequency and percentage of farmers perceiving level of soil fertility and crop yield according to slopes (n=240)

		Very Steep slope (31 - 60% gradient**)**		**Steep slope (**16 - 30 % gradient**)**		**Gentle slope(** 4 - 9 % gradient**)**	
		Frequency	%	Frequency	%	Frequency	%
Level of soil loss	High	215	**89.58**	199	**82.91**	59	24.58
	Middle	11	4.58	21	8.75	147	**61.25**
	Low	14	5.83	20	8.33	34	14.16
Level of soil fertility	High	43	17.91	45	18.75	60	25
	Middle	44	18.33	54	22.5	126	**52.5**
	Low	153	**63.75**	141	**58.75**	54	22.5
Levels of crops yield	High	43	17.91	45	18.82	64	26.66
	Middle	40	16.66	60	25.1	122	**50.83**
	Low	157	**65.41**	134	**56.06**	54	22.5

Source: *(Sanogo N., 2017)*

4.5. Effects of Land Use Cover Changes on Livelihood Sustainability

4.5.1. Local Livelihood (Land productivity, climate change)

Livelihoods of the respondents are mostly related to land exploitation and any threat that affects the land is going to affect the life cycle of the people in a community. The results showed that around 53.75% of the respondents cultivate the entire area of their available land. About 66.25% of the respondents testified that their cultivated cropland has increased over the last 30 years. It remained unchanged from the perception of 23.75% while for the remaining proportion of respondent it has declined. In addition to that, most of the fertile lands are under scarcity according to 77.5 % of respondents while 59.16 % considered available land as enough for their need even though crop yield is declining. In term of land ownership, respondent of the FDGs in the four communes did not consider land access as a factor causing or driving land degradation, because land ownership system is set in a way that indigenous and foreigners can afford without much complication for agriculture, plantation and habitats purposes. Indigenous can afford land without paying for it while foreigner rent for a period of time without monetary value.

In general view of the overall respondents, there is enough land but the fertile land for farming purpose (agriculture and livestock) are scarce. That fertile land scarcity is reducing agriculture productivity through yield declining as mentioned above and livestock are suffering from the adverse consequences like crop residues reduction. About 73.75 % of the respondents are affected by the soil degradation in the area. Its related impacts are affecting livelihood of people through yield reduction, less fertile land, flora and fauna extinction and worse climatic condition. In addition, the specific impacts of deforestation perceived is as follows:

73. 8 % of the respondents mentioned soil degradation as an impact. About 55.8 % point out poor rainfall. Poor rainfall in the area is linked to the reduction in vegetation cover from the perception of the respondents. 7.5 % mentioned loss of biodiversity, and 52.1 % noticed economical loss, 42.9 % raised loss of livelihood and the rest 0.8% cited other impacts like increases in wind speed (**Figure** 4.8*)*. `

Table 4.6: Local Livelihood (Land productivity, climate change) under land degradation

Variables	indicators	Frequency	Percentage
Farmers cultivating 100% of land (ha)	Yes	129	53.75
	No	111	46.25
	Increased	159	66.25
Cropland in last 29 years	Declined	24	10
	Remained the same	57	23.75
Level of fertile land scarcity	Scarce	186	77.5
	Abundant	54	22.5
Crops Yield	Increased	73	31.2
	Declined	161	68.8
Land holding	More than enough	23	9.6
	Just enough	142	59.16
	Too small	75	31.25

Soil degradation	No	63	26.25
	Yes	177	73.75
Poor rainfall	No	106	44.16
	Yes	134	55.83
Economical loss	No	115	47.91
	Yes	125	52.08
Reduced yields	No	32	13.3
	Yes	208	86.7
Less fertile lands	No	94	39.16
	Yes	146	60.83

Source: (Sanogo N., 2017)

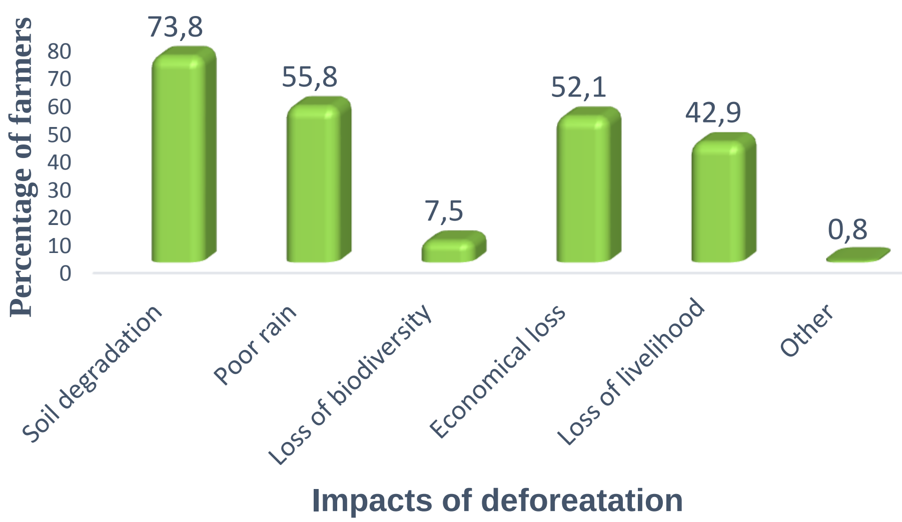

Figure 4.8: Impacts of deforestation in the study area

Source: (Sanogo N., 2017)

4.5.2. Flora and Fauna Extinction due to Land Cover Changes

Tree and shrub savanna are on degradation through extinction of tree and animal species. The most affected tree species are *Parkia bigloboza, Ziziphus mauritiana, Adansonia digitata and Vittelaria paradoxa* which contribute to household income and nutrition trough their fruits, nuts and leaves. In terms of animal species *Turtles, Crocodiles, Elephants* and *Lions* are the most affected. Most of them have even disappeared like *elephants* and *lions*. The extinction of those species has reduced food supply, reduced nutritional value of food and cultural value. According to women, *Adanosonia* leaves and *shea* butter contribute lot to household food nutritional value. Any threat that affects those species severely affects their food chain. From the perception of elders hunting is considered as cultural ceremonies and also source of livelihood in the community but the extinction of animal species led to the reduction of wild meat and traditional ceremonies.

Table 4.7: Species (flora and fauna) ongoing extinction in the study area

Tree species ongoing extinction	Animal species ongoing extinction
Parkia biglobosa	Elephants, Crocodiles
Adansonia digitata	Lions, Turtles
Detarium microcarpum	Rabbits, Bees, Butterflies
Vitellaria paradoxa	Deers, Snails
	Monkey
Tamarindus indica	Wild Guinea fowls Earth worms

Source: *(Sanogo N., 2017)*

4.5.3 Food and Water Shortages

It has been mentioned by the communities that the changes in the land and land cover is causing several challenges to their daily life of farmers. Among them we have food shortages, health issues related to water shortages, low income level due yield decreases, undernourishment of children, hunger, drought and loss of cultural values. The critical issues are food and water shortages. The causes of such issues are attributed to the bad climatic, deforestation, reduction of tree food base and extinction wild animals and plants species which contributed a lot to the food and water supply. About 73.8 % of farmers mentioned that they faced food shortages during the month of August and 37.5 % mentioned water shortages in May.

This period coincides with middle of the raining season when they have already used the available food and the new harvest is not yet done. They even raised that it is during that period that youth migrated a lot to the neighboring cities or countries. The outcome consequences of that migration combined with poor climatic condition are yield declining at the rainy season. From the view of farmers, the migration has an implication to the food shortages. From the views of elder's groups and women groups migration of youth has an influenced on the labor force (capital of production) and at end yield becomes low. The critical period when the community stressed out both food and water shortages are: the period of 1983 to 1985 and 2016. Those periods have been the critical period when most of the youth migrated to the big cities in order to support families through food and financial supports. Elders point out that financial support from children allowed villagers to put their hand together to dig wells in order to do gardening, drinking water supply for livestock during driest and hunger period. But the available water sources are no longer able to meet the threshold of water need of the community. The cultivated gardens cannot supply the basic food demand of the communities during the driest period. People are forced to put pressure on natural resources or ask help from friend from other areas in order to support their livelihood. The consequences of that is the lack of resources from shrub and tree savanna, bad climatic conditions and low-income level in Bandiagara and Bankass.

4.5.4. Pasture Shortage

Pastoralist faced several challenges all over the period of the years due to climatic and feed or pasture shortages. In Bandiagara and Bankass about 32.9% faced feed shortage through the years. The challengeable period pasture shortages from pastoralist perception merge with the period of water shortages. The combination of both conditions has a drastic consequence on livestock well-being (production and productivity). Also, it is at that period that most the pastoralist moves away from their home for look of pasture in wet areas. Such movement of pastoralist caused lot of problems between Bandiagara - Bankass pastoralists and gardeners of Sahinde wet land area of Mopti Region. The related causes of the pastoralist migration have been attributed to the lack of crop residues, lack of shrubs and tree fodders, early dry up of water bodies.

In order to cope with situation or to avoid the conflict, pastoralist started to cope with the situation. About 12.08 % bought supplement feed during the dry season but around 71.25% don't do anything until now. If such situation continues the pastoralist will start to go to the same Sahinde wetland and that situation may trigger conflict between pastoralists of Bandiagara - Bankass and Sahinde farmers. The recurrent feed shortage is causing loss of animal weight, low milk production and mal physiological functioning of animals in the area. It has been agreed that livestock development sector in Mali is characterized by low herd productivity due to recurrent seasonal feed shortages, poor forage quality and high disease burden (USAID, 2017). If pasture shortages continue in the area livelihood of most the pastoralist could be insecure in the area.

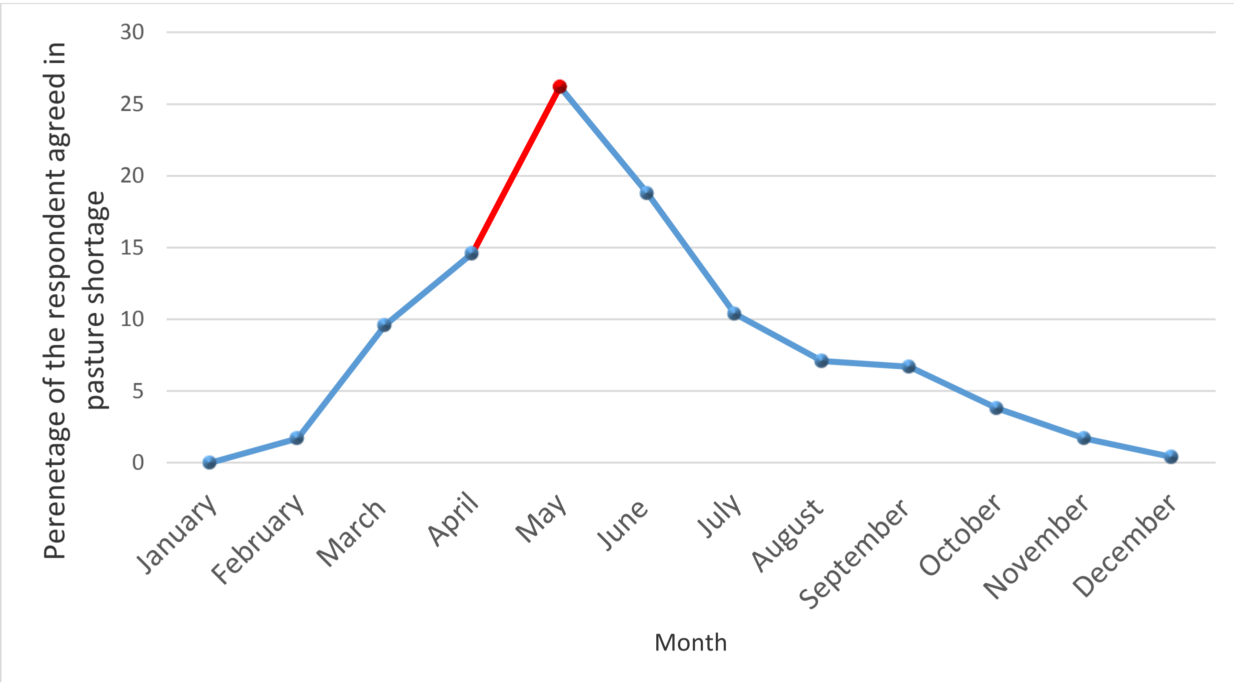

Figure 4.9: Respondents perception of periods associated with pasture shortage

Source: *(Sanogo N., 2017)*

4.6. Local Strategies against Land degradation

4.6.1. Local Strategies against Erosion and Soil Infertility

Farmers are adopting various coping strategies to increase their resilience. About 60.4% of the respondents believe that soil erosion can be controlled and 62.1% of the respondent used local methods to prevent soil erosion. To prevent erosion, farmers used several measures in order to conserve soil fertility and avoid its losses. The common and mostly used practices is contour bunding. Such method consist to bund the surrounding of the plots of farm by the mass of soil to reduce the speed of water flows and conserve fertilizers within the plots.

It is used by around 35 % of the farmers in the area. In addition, 30% of the respondents also checked dams as erosion prevention measure. 15% of the farmers put grasses on water ways to reduce the speed of water flows. The types of grass used is *Andropogon gayanus*. This type of grass as a particularity to produce a huge quantity of ramified roots and branches which also reduce the speed of water flows. Around 15% of the respondents' conserved trees in their farms through Farmer Managed Natural Regeneration (FMNR) approach for soil fertility improvement. Several trees are used by farmers but most abundant are shrubs with few trees cover. Shrubs are mainly used as fodder for livestock, trees for firewood, fruits and nuts. This approach (FMNR) is appreciated but adopters but applied by less of the farmers due to lack of information on its advantages for farmers' livelihood improvement.

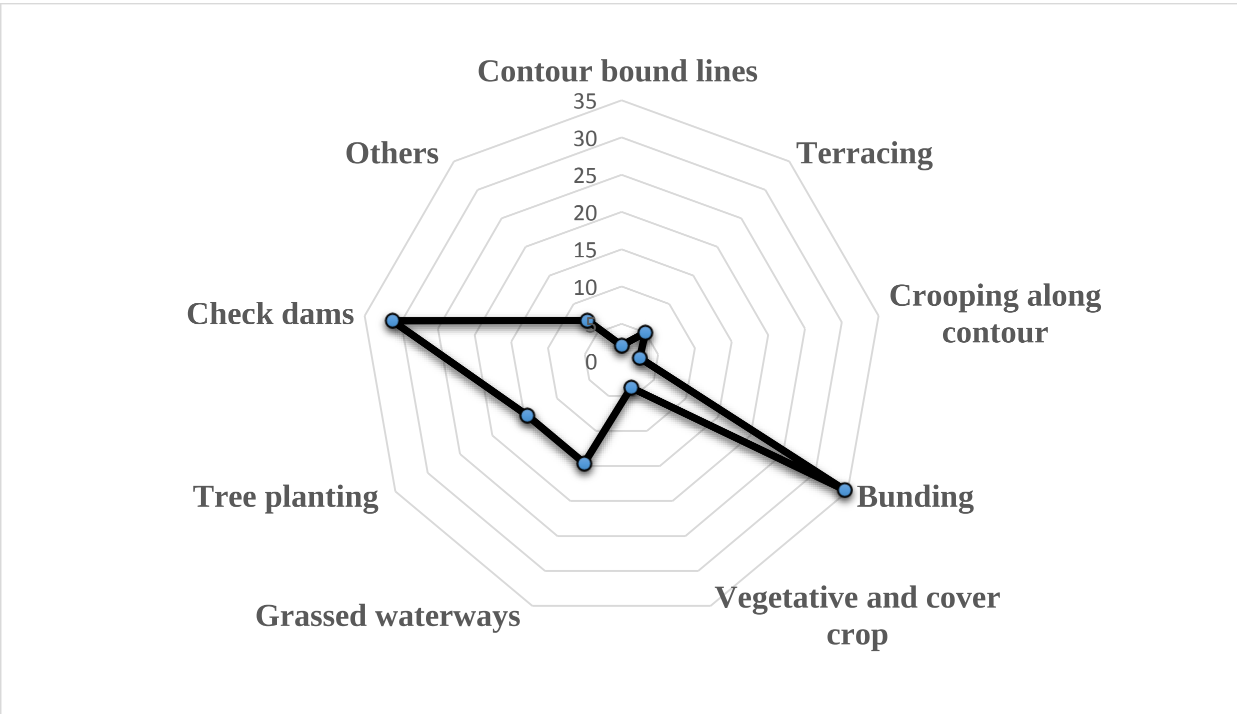

Figure 4.10: Radar diagram of respondents copping measures to soil erosion

Source: *(Sanogo N., 2017)*

4.6.2. Farmers Copping Strategies during Drought and Hunger Period

In general, most of the respondents (34 %) exploit forest resources as an alternative of agriculture in order to meet the family needs during the period of drought and hunger. In Bara Sara commune, during FDG women point out that in 1987 they used bush plants like the seeds and leaves of *acacia pennata called "*Toufing*" as* the food. Also about 22 % of the respondent migrate to the cities or to the wetland areas during difficult periods and 19 % get help from relatives. Pastoralist move way to look for fodders (shrubs, tree and grasses) in order to feed their livestock in the wet areas. In other hand youth raised high migration at that period. Migration is considered as coping strategies to the hunger or drought by youth (ladies and gentlemen). They perceived that, the money they get outside contribute lot to livelihood support of their respective families. Some buy food for the family, feed for animals and construct their houses or get married. Farmers' use others copping strategies like used of saved money, sale of lands, taken loans, sale of livestock and practices of casual jobs. From the beliefs of farmer those strategies are not sustainable but lack of alternatives pushed them to use them as the copping strategies.

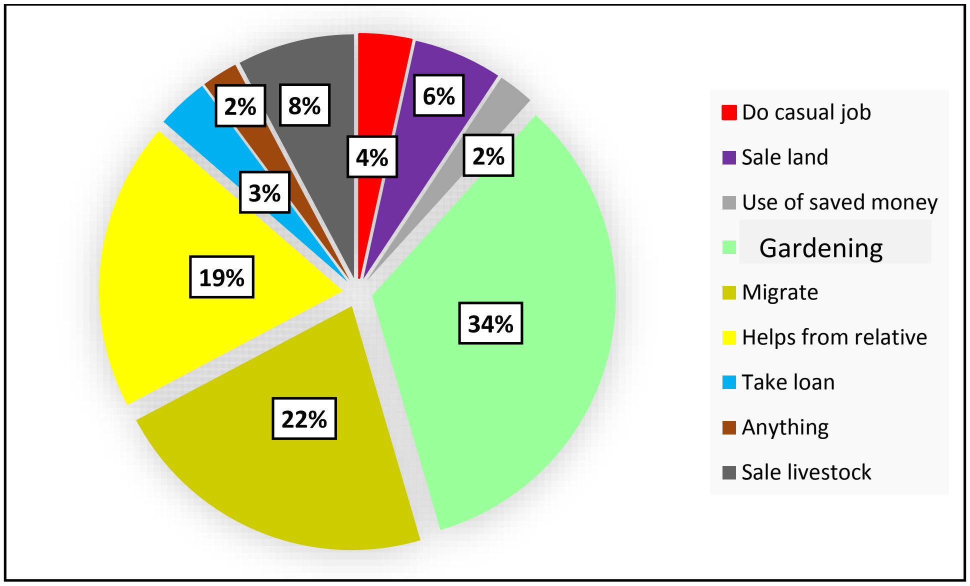

Figure 4.11: Farmers copping strategies during drought and hunger period

Source: *(Sanogo N., 2017)*

4.8. Contribution to Resilience Building from Different Land Restoration Projects in the Study Area.

There are some projects working on land restoration activities in order to reduce the vulnerability of affected people through awareness creation on the effects of deforestation on livelihood sustainability. Two of them belong to World Agroforestry Centre. They contribute in enhancing the capacity of farmers to enable them train (in their respective villages) their peer farmers on rainwater harvesting techniques, the dissemination of improved and grafted local fruit trees, agroforestry, restoration and improvement of soil fertility. New champion farmers will be identified and trained. Rural resources centers are established and served as training and experimentation sites for farmers. Some participatory learning activities on land restoration are conducted to promote options that are most suitable to each farmer context. Moreover, effort is being made on improving access to financial services and agricultural extension for value chain actors on the promotion of agricultural businesses. Also, a project called Mussow is on the ground giving supplement food to the undernourished children, taking care of pregnant women over the period of pregnancy but less area is covered by the project.

Image 08: SmAT-scaling project (© Sanogo N., 2017)

Image 09: DryDev project (© Sanogo N., 2017)

4.9. Factors reducing the performance of the local strategies

The respondents stated that there are various constraints to sustainability of their copping strategies. The major constraints from elders are: Lack of rules and regulations (Policy) for biodiversity (flora and fauna) protection, bad climatic conditions while women pointed out lack of cereal Bank and financial support from the NGOs and Government during difficult period. Coming to youth group, they raised lack of financial support and critical infrastructures (hospital, schools, food production and processing factories.

4.10. Discussion

The result obtained reveal an important spatial and temporally change in LULC types over the 29 years (1986 to 2015). In general, a conversion and competition were noticed between land use cover types (Cropland, tree savanna, shrub savanna, water bodies and settlement) but the differences change is different from commune to the others. The highest-level soil losses, fertility losses, yield declining were recorded in very steep slope. Rainfall, variability during a long period of time caused by anthropogenic activities like tree and shrub savanna deforestation may be qualified as climate change indicators. Such change in climatic condition were mentioned as driving factors of land degradation. Overexploitation, overgrazing, bad agriculture practices, heavy erosion and high firewood demand were also mentioned by most of the respondent as contributing factors which severely cause land degradation in addition to population growth as indicated by data sources.

Population change is a crucial factor that influences land use and land cover changes and eventually land degradation. An attempt was made to examine how population transitions have occurred in the study area. Population is an important source of development and; yet a major factor of environmental degradation when it exceeds the threshold level of support system or the carrying capacity of the ecosystem.

Ouedrago et al (2009; 2010) explained that population growth and density is one of the most important factors behind the declining use of fallows and increased land fragmentation in Burkina Faso. Mopti region entirely falls in the rural area where land is majorly put under cultivation and settlements. For instance, direct impacts of agricultural development to sustain the rising population arise from farming activities which contribute to soil erosion, a change in the soil salinity, and to some degree, loss of the soil fertility. The study area has experienced significant change in human population density throughout the study period, and it is therefore obvious that a reduced land cover and land use change witnessed in the area is related to increased human activities throughout the entire period of study. A higher population density leads to subdivisions of land into uneconomical units, thus more pressure on natural resources available in the area.

High population density also subjects much pressure to the available environmental resources leading to unsustainable use of natural resources at many times and possible depletion and degradation of environmental resources.

High population growth and density in rural areas increases pressure on the available arable land resulting to fragmentation and encroachment into marginal lands, reduced fallow periods, and methods of cultivation that lead to land degradation. The growing in population pushed people to expand their cropland in order to meet livelihood need of the community, but the conversion of tree and shrub land into cropland seems not to take into account the sustainability of natural resources, because destroyed trees and shrubs are not replaced. World Bank (2015) found in Bamako/ Mali that the population growth rate accelerated from about 1.6-1.7 percent between 1976 and 1987, to 3.1-3.6 percent between 1998 and 2009. Such a rapid rate of population growth has consequences for jobs, unemployment and the demand for social services. It increases pressure on cultivable (irrigated) land and access to water and has the potential to become a driver of social change and possibly even conflict in the future. Also Simonson (2005) argued that higher population densities, such as those in urban areas, increase pressure on the environment and, if not managed, may lead to severe problems including soil, water and air pollution. Linar et al., (2010) observed, population growth leads to expanding human settlements and increasing demand for food, fuel, and building materials. The unsustainable expansion of human needs leads to habitat destruction and loss of biodiversity. The loss of vegetation cover resulting from human impacts in the studied communed therefore has significant effects on habitat destruction and loss of biodiversity thus causing environmental degradation. An increased human population density has also led to significant rising demand of energy for domestic consumption. The rising demand for energy consumption in the area has resulted to significant changes and reduction in both tree and shrub savanna land cover thus leading to land degradation. Bationo et al.,(2006) reported that 24% of total land degradation in the rural areas of Nigeria is as a result of unsustainable agricultural activities. Other major causes of land degradation according to them included overgrazing (49%), deforestation (14%), and overexploitation of vegetative cover (13%) that constitute the primary causes of land degradation in most rural areas of Africa. Soil fertility depletion and nutrient mining in most of the smallholder farms is a fundamental biophysical root cause of the declining per capita food production in the area. This has largely contributed to poverty and food insecurity in the district.

In addition to population growth overgrazing is considered by 68.8 % of the respondents as contributing factor to the land use cover change by over consumption of grasses, shrub and tree fodder and grinding of the top soil by animal's clogs. It has been noticed by (Toure, 2010) that population pressure on resources could rise in the coming years and threaten the survival of plant and animal areas and beyond the well-being of people in Mali and the poor especially in the current context of climate change. The main livestock kept are: cattle, goats, sheep, and poultry. Grazing of this huge number of livestock far beyond the carrying capacity in forest lands exerts tremendous pressure on forestland with resultant degradation. Farmers are keeping more livestock than the carrying capacity of the land that they possess. This therefore predisposes the animals not only to forage on grass but also on the vegetation as well leaving the ground bare and susceptible to the agents of soil erosion thus leading to land degradation. The bare ground also exposes the soil particles to hot sun during the dry period that dries the soil hence causing the soil to suffer from wind erosion that takes away the fertile top soil. Livestock densities are high, overgrazing readily occurs. Removal of protective vegetation and trampling of exposed soils by livestock hooves lead to decline in biological productivity of the land, reduced water infiltration and storage, and soil compaction and erosion (Savadogo et al., 2007).

Fortunately, some copping strategies are adopted by people to reinforce farmer's adaptive capacities through technologies development that could be a way of solving land degradation challenge in the area if they are considered in land management planning. In Mali, the conservation in the face of ongoing poverty and deprivation is unrealistic; development that destroys the natural resource base and environmental service functions is unsound (Frost et al., 2006). An adoption of sustainable land management measures is a challenge for livelihood improvement in Bandiagara and Bankass but copping strategies adopted by farmers can be improved through participatory integrated approach with farmers. The implementation of any type of improvement must include the farmer participation and other stakeholders with regard to land issue. An integrated approach of different stakeholders related to land management could improve sustainably livelihood of the communities and benefit future generation.

5. CONCLUSION

This study documented farmers' perception on land degradation and local strategies for the restoration and livelihood improvement.

The result from this study could be a guide for decision making in a particular condition of -- Bandiagara and Bankass communes in Mopti Region.

Several factors (socio-demographic, Environment, Biophysical, Institutional and socio economical) have triggered land degradation in the area. The area faced the changes in LULC dynamic over the 29 years (1986 - to 2015). The driving factors vary from communes to communes due to biophysical and socio-economic situation of each particular area. A correlation has been noticed between population growth and the changes in land use and land cover categories (cropland, shrub and tree savanna and water bodies) in most of the communes. In addition to that, slope, climatic condition, overgrazing, tillage practices, monoculture, use of chemical fertilizers and low education level are also contributing to the land degradation in the area. Moreover such complex situation is negatively affecting livelihood of the community through food and water shortages over the period of time.

Household in Bandiagara and Bankass are coping with land degradation through some strategies but needs is required to improve them sustainably. In order to address livelihood sustainability in the area, an integrated approach of stakeholders (farmers, researchers, government, NGOs) is require for decision making. This thesis can be used as a contributing guide for decision making for degraded land restoration in Bandiagara and Bankass of Mopti region/Mali.

6. RECOMMENDATIONS

The following measures need to be undertaken by the Government in collaboration with the development partners, interested parties, and the local population, for proper management, conservation, and sustainable land use practices in the area.

Recommendations from farmers' perception to:

Community level:

❖ Communities should be ready at any particular time to provide labor forces for opportunities of planting trees.

❖ Farmers could monitor and record erosion processes, fertility declining and yield amount in their respective production system in order to inform policy makers with reliable information.

❖ Afforestation, reforestation, and social forestry programs should be implemented at the local level in the area so as to protect land cover and to preserve the existing forests and vegetation in the area.

NGOs

❖ Should improve local adaptation measures through in integrated approach including local people, policy makers, government and other related stakeholders.

❖ Early warning system should be put in place with local leaders for alert on the land degradation processes in order to be prepare for successful response.

❖ Fodder trees and shrubs should be promoted through agroforestry technology to support livelihood of Agro-Pastoralist.

❖ Soil and Water Conservation (SWC) methods should be promoted by NGOs to reduce water shortages and soil fertility declining.

Government

- Efforts should be made by the government to educate the residents and their local leaders about the adverse effects of population growth on the environment through specifically designed information, education and communication activities.
- Foster the dissemination of clear and accurate weather information system at the local level.
- Trained, sensitized farmers on new approach of sustainable land v use/cover planning.
    - There is need to investigate alternative sources of fuel (energy) needs for sustainable vegetation cover management.

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APPENDIX

Questionnaire

Land degradation processes in the region of Mopti: local people's perceptions and Local Strategies for land management.

Date of interview: Year_____, Month____, Day_____

The investigator's name:

I. Identification of the respondent and socioeconomic characteristics of the household

1. Household number:

2. Name of the household head:

3. Name of the respondent: Gender_____, Age_____

4. What is your residence status? Native I___I Migrant I___I

5. Respondent's educational level:

a) No education I___I b) Primary school I___I c) Secondary school I___I

d) Adult education I___I e) Agricultural training I___I

6. Household composition and demographic data

Gender	Age			Education				
	0-15	15-60	60<	a	b	c	d	e
M								
F								
Total								

a=No education, b=Primary school, c=Secondary school, d=Adult education, e=Agricultural Training

7. How does the household own the land (tenure status)?

a) Inheritance I___I b) Rent I___I c) Gift I___I d) buy I___I

8. What is the total area of your cultivated land? Ha

9. Are you cultivating all your land? Yes___, No____

10. If no, what are the reasons?

____

____

11. Are all your fields in one unit? Yes__, No_

12. What is the distance from your home to the most fertile plot? Km

13. What is the distance from your home to a less fertile plot? ___

14. Has the size of your cultivated land changed?

Increased____, Declined____, Remained the same____

	Reasons of increase	Reasons of decline	Reasons unchanged

15. How do you address this problem? (Strategies)

16. Do you have any off-farm employment? Yes___, No___

17. If Yes above, what type of work do you do?

18. Overall, do you think land is becoming scarce or it is abundant in the community? Scarce____, Abundant______________

19. If you feel that land is becoming scarce, why?

a) ________ b) ______________ c) _____ d) ______________ e) ____________ f) __________________ ____________

20. Compared to the land needs of your household now, how do you rate your present land holdings? More than enough____, Just enough____, Too small_____

21. What type of labor is used on your farm?

Family labor [ ], Hired labor [ ], Group labor [ ]

II. Agricultural Practices

1. What are the major crops grown on your farm in order of importance?

a) ________ c) ______ e) ______ b) _____ d) _____ f) _______

2. Do you grow each of these crops alone or do you mix them with other crops? Alone , with other crops , (name the most common combinations)

a) __________________ b) _________________

c) ___________________ d) __________________

3. Do you plant the same crop every year or change to other crops or practice fallowing?

Plant the same crop each year , Change to other crops _, Practice fallow , Change to other crops and then practice fallow

4. Tillage practice used by farmer

(i). Hand labor [ ], family labor [ ], hired labor [ ], group labor

(ii). Drought power [ ], owned [ ], hired [ ],

5. What do you do with your crop residue?

Bum them [ ], Use them as feed [ ], Use them for cooking [ ], others (specify) _______

6. Do you use improved seed? Yes [ ], No [ ]

If yes, for which crops?

7. Your livelihood mainly depends on:

Cropping only [ ], both cropping and livestock [ ], Livestock only [ ], others (specify) ____

8. Do you observe change in the level of crop yield on your cultivated land?

Yes [ ], No [ ]

If yes, has it been increasing or declining?

Increased [ ] Declined [ ]

What are the major reasons of increase?

a) _______________ b) _______________

c) _______________ d) ______________

9. If you feel that the general trend is declining, what do you think are the reasons? Probe by mentioning the following:

Failure of rains [ ], Land degradation/ soil erosion [ ], Small farm plot due to fragmentation [ ], Drought in general [ ], Lack of agricultural inputs [ ], Overgrazing/too many animals [ ], Less labor available in the household [ ], Over cultivation [ ], other (specify) ______

10. How often have you experienced drought and famine in this area?

____

____

11. What measures do you take in times of drought and famine?

____

____

12. Which months of the year are often associated with food shortage?

____

____

13. Which months of the year are often associated with water shortage?

____

____

14. Do you grow trees on your farm? Yes [ ], No [ ]

15. If yes, for what purposes?

(i). Fuel wood [ ], tree type ________________________

(ii). Building materials [ ] tree type _________________

(iii). Fodder [ ], tree type _____________

(iv). Soil fertility maintenance [ ], tree type __________

(v). Fruits or nuts [ ], tree type _______________

(vi). Shades [ ], tree type _________

(vii).Others (specify) [ ], tree type_________

16. If you have livestock, indicate type and number?

Type	No	Use

17. Do you have shortage of pasture or feed for livestock? Yes [ ], No [ ]

18. If yes, which are the critical months?

____

19. How do you deal with this problem?

____

20. Are there sufficient water sources available during summer period for livestock? Yes [ ], No [ ]

21. Do you think that livestock contribute to land degradation? Yes [ ], No [ ]

If yes, which are the critical months? _______________

III. Soil Erosion

1. Do you perceive the problem of soil erosion on your land? Yes [ ], No [ ]
If yes, what are the causes?
a) ____
b) ____
2. How severe is the problem of erosion? Severe [ ], Moderate [ ], Minor [ ]

3. What indicators do you associate with soil erosion?
a) ____
b) ____

4. Do you observe appearances of plant species that signify the severity of erosion? Yes [ ], No [ ]
5. How you identified levels of soil loss, soil fertility and crop yields along different slope positions.

	soil loss	soil fertility	crop
	high/mid/	high/mid/low	high/mid/
i. very steep slope [ ]			
ii. Steep slope [ ]			
iii. Gentle slope [ ]			

6. Are there any local methods used to prevent soil erosion? Yes [ ], No [ ]
7. If yes, which of the following measures do you practice?
Cultivation along the contour [ ], Terracing [ ], Strip-cropping along the contour [ ],
Bundings [ ], Vegetative and crop cover [ ], Grassed waterways [ ], Tree planting [ ], Check dams [ ], other (specify)? [ ] _______________
8. Have you taken any of the following measures because of erosion? (i).Abandoned your cultivated land?
Yes [ ], No [ ]
(ii).Expanded to marginal land? Yes [ ], No [ ]
(iii).Have taken off-farm employment? Yes [ ], No [ ]
(iv). other (specify) _____________________
9. Do you believe that erosion can be controlled? Yes [ ], No [ ]

Iv. Soil Fertility

1. Do you perceive the problem of soil fertility decline on your cultivated land? Yes [ ], No [ ]
2. If yes, has it been: Increasing [ ], Decreasing [ ], Unchanged [ ]
61. What are the causes Soil Fertility decline?
a) _____________________________
b) _____________________________
c) _____________________________
d) ______________________________

4. Do you observe appearances of plant species that signify decline in soil fertility? Yes [ ], No [ ]
5. If yes, what are the names of these species? Local Name Scientific Name

a) ________________________ b) _________________________

c) ________________________ d) __________________________

6. Do you use some kinds of practices to maintain or enrich soil fertility of your cultivated land? Yes [ ], No [ ]

7. If yes, which of the following practices do you use?

Use of fertilizer [ ], Use of manure [ ], Intercropping [ ], Mulch or compost [ ], Agroforestry [ ] Others (specify) _____________________

8. If you use fertilizer, what kinds of fertilizers do you use and how many kilograms?

____

9. Has your fertilizer use increased, decreased, or remained the same? Increased [ ], Declined [ ], Remained the same [ ]

10. What are the reasons for this change?

a) ______________________ b) _______________________

c) ______________________ d) _______________________

11. Is fertilizer readily available in your village? Yes [ ], No [ ]

V. Availability of Household Energy

1. What is the primary source of your fuel?

Fuelwood [ ], Crop residue [ ], Dung [ ], Kerosene [ ], other (specify) _____________

2. Indicate the time and distance you travel to collect the primary source of fuel?

(i).Time __________, (ii). Distance ___________ .

3. If you face fuelwood shortage, what are the reasons?

a) _________________________

c) _________________________

4. What measures are you taking to deal with this problem?

Agroforestry [ ], Private tree planting [ ], Communal tree planting [ ],

Natural regeneration [ ], Use of energy saving devices [ ], other (specify) _________

5. What are the effects of SWC measures?

i. increased crop yield Yes [ ], No [ ],

ii. Prevent soil erosion Yes [ ], No [ ],

iii. Improved soil-water retention Yes [ ], No [ ]

iv. Assuring long term productivity of land Yes [ ], No [ ]

VI. Suggestion

1. ____________________________________

2.____________________________________