UNIVERSITY OF GHANA

COLLEGE OF BASIC AND APPLIED SCIENCE

ECOSYSTEM SERVICES DERIVED BY FARMERS FROM SAVANNAH WOODLANDS IN NORTHERN GHANA

BY

OPHELIA KABA-AYAMBA

INSTITUTE FOR ENVIRONMENT AND SANITATION STUDIES

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BY

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THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF DOCTOR OF PHILOSOPHY IN ENVIRONMENTAL SCIENCE DEGREE

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DECLARATION

I hereby declare that this thesis is the original work I did with the help of my supervisors. Except for references to other people's workwhich have been duly acknowledged, this work has neither been presented in whole nor in part for the award of any degree elsewhere.

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ABSTRACT

There are limited local level studies on all four categories of ecosystem services in Sub-Saharan Africa, which limits knowledge on the influence these services on the well-being of the population studied. The over-reliance on the woodland ecosystem as a result of climate change in Sub-Saharan Africa has led to increased risk of desertification. Improved understanding of the influence of climate change on ecosystem services and local level changes in land use land cover, as well as the value placed on woodlands by local farmers will influence climate change adaptation and poverty alleviation efforts in Sub-Saharan Africa. The study generally sought to assess the benefits smallholder farmers derive from the woodland. It identified the household factors influencing access to different types of woodlands in the Nandom District as well as off-farm adaptation practices that influenced the economic wellbeing of smallholder farming households. The study also examined the relationship between knowledge of climate change and management practices employed by farmers to conserve the woodland. Additionally, the study identified shifts in land use and land cover in the district and assessed willingness to pay for the conservation of the woodlands. Lastly, the study assessed the decomposition of leaves of four common woodland species and their nutrients remaining. Four different research methods were employed due to the multi-disciplinary design, these were the Geographical Information System (GIS) approach, cross-sectional survey, contingent valuation method and leaf litterbag experiment. Land use land cover changes for Nandom district, the study area, were estimated using satellite imageries for 1986, 2001 and 2017. The cross-sectional survey and contingent valuation method involved 303 farming households. Four dominant woodland species, *Parkia biglobosa*, *Vitelleria paradoxa*, *Cordia myxa and Lannea microcarpa* were used for leaf litterbag experiment conducted from May to October of 2017. The results showed a decrease in dense woodland cover by (30%) and area under cultivation (2%), and increase in built environment (9%) over the period 1986 to 2017. The introduction of community laws in

the Nandom District in 1985 contributed to the increase in dense woodland cover from 1986 to 2001 (20% increase). The modification of these laws and changes in local level dynamics led to the sharp decrease (42%) in dense woodland cover from 2001 to 2017. Household factors variably influence access to different categories of woodlands identified in the study area- reserve woodland, community woodland and family owned plantation. Sub-district ($\rho = 0.002$), settlement type ($\rho < 0.001$), ownership of agricultural land ($\rho = 0.020$) and bicycle ($\rho = 0.017$) were associated with access to community woodlands. Ninety-four percent, four percent and two percent of households prefer to contribute farm produce, cash and manpower respectively for woodland conservation in the district. Household minimum and maximum willingness-to-pay (WTP) median values, were 9.50 Ghana cedis ($2.15) and 20.00 Ghana cedis ($4.53) respectively. There was no difference in minimum WTP ($\rho = 0.733$) and maximum WTP ($\rho = 0.725$) in choice of conservation strategies- preservation, restoration or both. Results for the litter bag experiment showed *C. myxa* (0.803 g/g/day) as the fastest decomposing species followed by *P. biglobosa* (0.784 g/g/day), *L. microcarpa* (0.77g/g/day) and *V. paradoxa* (0.544 g/g/day). The same pattern applies to the initial nitrogen content of the species and could therefore be used by smallholder farmers as fertilizers trees or for composting. Households depended on multiple sources of woodland such as community or reserve woodland and family plantation for livelihood opportunities. Community laws play a significant role in preventing loss of woodland cover when well enforced by community chiefs, NGO and the District Assembly. Joint policies and programmes from NGO, Forestry commission, community leaders and the District Assembly to empower communities to use and manage resources are required to promote woodland conservation for sustainable use.

DEDICATION

TO THE ALMIGHTY GOD

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ABBREVIATIONS/ ACRONYMS

ALP	Adaptation Learning Programme
ASSAR	Adaptation at Scale in Semi-Arid Regions
AVHRR	Advanced Very High-Resolution Radiometer
BNF	Biological Nitrogen Fixation
CBA	Cost Benefit Analysis
CBD	Convention on Biological Diversity
CCA	Climate Change Adaptation
CSIR	Council for Scientific and Industrial Research - Ghana
CVM	Contingent Valuation Method
DFID	Department for International Development
DHS	Demographic Health Survey
ES	Ecosystem services
ETM+	Enhanced Thematic Mapper Plus
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
FSD	Forestry Services Division
GLSS	Ghana Living Standards Survey
GSS	Ghana Statistical Service

INDC	Intended national determined contribution
IPCC	Intergovernmental Panel on Climate Change
IRS	Indian Remote Sensing
KII	Key Informant Interview
LULCC	Land use land cover change
MA	Millennium Ecosystem Assessment
MESTI	Ministry of Environment, Science, Technology and Innovation- Ghana
MODIS	Moderate Resolution Imaging Spectroradiometer
MSS	Multispectral Scanner
MTS	Modified Taungya System
NFR	National Forest Reserve
NGO	Non-Governmental Organization
NOAA	National Oceanic and Atmospheric Administration
NPK	Nitrogen, Phosphorus and Potassium
NTFP	Non-timber forest products
OLI/TIRS	Operational Land Imager/Thermal Infrared Sensor
PHC	2010 Population and Housing Census, Ghana
PWD	Persons with Disability
REDD+	Reducing Emissions from Deforestation and Forest Degradation

RDS	Regional Diagnostic Study
SDG	Sustainable Development Goals
SES	Socioeconomic status
SOM	Soil Organic Matter
SPOT	Satellite Probatoire d'Observation de la Terre
SSA	Sub-Saharan Africa
TEEB	The Economics of Ecosystem and Biodiversity
TM	Thematic Mapper
TV	Television
UNCSD	United Nations Commission on Sustainable Development
UNFCCC	United Nations Framework Convention on Climate Change
UTM	Universal Transverse Mercator system
UWR	Upper West Region
WGS	World Geodetic System
WI	Wealth Index
WTP	Willingness-to-pay

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the study

Life on earth is supported and sustained by ecosystem services (ES). Ecosystem services are valuable services obtained from natural sources such as reserve woodland (forest reserve), community woodland, family or private plantation, etc. (Food and Agriculture Organization [FAO], 2016a; Boakye & Boafoe, n.d.). Ecosystem services have been categorized into: provisioning services e.g., food, clean water, fuelwood, and timber; cultural services (recreation and tourism, cultural identity and diversity, indigenous knowledge system); regulating services (pollination and seed dispersal, climate regulation); and supporting services e.g., nutrient cycling, soil formation, and primary production (Millennium Ecosystem Assessment [MA], 2005; The Economics of Ecosystem Biodiversity [TEEB], 2009).

The woodland ecosystem plays a significant role in regulating and stabilizing the climate, biogeochemical cycles, biological diversity, carbon sequestration, and soil conservation. (Shvidenko *et al.*, 2005). Woodlands serves as carbon sink which, when destroyed, releases greenhouse gas like carbon dioxide, which is the main constituent of anthropogenic emissions (FAO, 2016a). The conversion of woodland to other land uses (Forest Research, n.d.) accounts for 10% of net global carbon emission (Blanco *et al.*, 2014). Addressing deforestation is, therefore, vital in safeguarding ecosystem services and reversing the effects of climate change. In sustaining agricultural productivity, woodland-based ecosystems provide soil nutrients, fodder for livestock, and facilitate pollination while protecting the soil from erosion. The availability of tree-based fertilizers, weedicides, and pesticides are particularly beneficial to smallholder farmers that cannot afford other farm inputs (Oksanen, Pajari & Tuomasjukka, 2003).

Global calls for the conservation of ecosystem services for the wellbeing of humanity and the planet are evident in funded initiatives and projects such as; Reducing Emissions from Deforestation and Forest Degradation (REDD+), the Millennium Ecosystem Assessment, and The Economics of Ecosystem and Biodiversity study (Forestry Commission, 2016). The emphasis on the centrality of the woodland for humanity has been acknowledged by environmental agreements such as the United Nations Framework on Climate Change, the Convention on Biological Diversity, the United Nations Conventions to Combat Desertification and the United Nations Forum on Forest (Ministry of Environment, Science, Technology and Innovation (MESTI), 2016).

Nevertheless, efforts towards conservation to safeguard ecosystem services continue to be threatened by habitat loss as a result of deforestation and land degradation as well as climate change. Changes in climate and weather patterns are expected to influence the migration of species to locations which will impact the food supply chain and lead to the extinction of some species and affect the proper functioning of the ecosystem (Bellard *et al*., 2012; Settele *et al*., 2014). Climate change and variability will also impact agricultural productivity with consequences on food security in developing countries while deepening the vulnerabilities of smallholder farmers (Yangyuoru *et al*., 2014).

Rising population growth and further reliance on dwindling ecosystem services may result in the “tragedy of the commons’’ (Food and Agriculture Organization [FAO], 2016) which has direct consequences on Agenda 21, the Sustainable Development Goals (SDGs), and Aichi Biodiversity Conservation targets.

A manifestation of woodland ecosystem exploitation is the reduction in vegetative cover and exposure of bare land to erosion resulting in nutrient mining (Shvidenko *et al*., 2005). The adaptation mechanisms of smallholder farmers have always included the reliance on the woodland ecosystem, especially during the lean season. Therefore, ecosystem degradation and climate change would threaten the adaptation mechanism of the resource-poor smallholder farmer (Yangyuoru *et al*., 2014; Komba & Muchapondwa, 2015).

1.2 Problem Statement

An estimated 1.6 billion people globally continue to draw their livelihood from the woodland (and forest) ecosystem. Also, about 15 million people in Sub-Saharan Africa engage in forest based-micro enterprises such as fuelwood, charcoal, handicrafts, carpentry, small-scale logging, and commercial hunting. These resources are essential for the sustenance of all, especially the vulnerable groups, who are entirely dependent on such livelihoods in Sub-Sahara Africa. Additionally, ecosystem benefits derived from woodlands serve as safety nets in the lean season (Oksanen *et al*., 2003).

Despite the importance of ecosystem services at the global, regional, national, and local level, its rate of destruction is acute and accelerating regardless of efforts to protect it (TEEB, 2009). In Ghana, the savannah woodlands, covering the three northern regions, is being threatened by several factors including overexploitation. The Upper East Region, Upper West Region, and Northern Region are desertification prone areas as well as the most vulnerable regions in need of attention due to climate change (MESTI, 2016; Adaptation Learning Programme [ALP], 2014). These regions have higher poverty rates as compared to other areas of Ghana and are at risk of desertification (ALP, 2014). The emphasis is on Northern Ghana because climate change and ecosystem degradation threaten poverty reduction efforts. These areas are currently experiencing prolonged drought, erratic rainfall patterns, and rising temperatures, which are threatening food security in the regions (ALP, 2014; Ghana Statistical Service, 2015). This study was conducted in the Nandom District, a district in the Upper West Region of Northern Ghana with high poverty rates.

Limited local studies on all four ecosystem services in Sub-Saharan Africa: Benefits derived from woodland ecosystem services

Studies on ecosystem services access or benefits derived were limited to specific ecosystem services (Khanya-aicdd, 2008). Majority of these studies in Sub-Saharan Africa were on provisioning ecosystem services (Wangai, Burkhard & Müller, 2016) with few studies integrating more than two categories of ecosystem services (Hapsari, 2010). Savannah Woodlands in Sub-Saharan Africa provide varying ecosystem benefits- provisioning, cultural, regulating, and supporting services. Unfortunately, studies on all four ecosystem services of the Savannah Woodlands in Sub-Saharan Africa are limited. For example, Boafo, Saito, and Takeuchi (2014) limited their study in the Savannah Ecological Zone of Northern Ghana to provisioning services. As recommended by Khanya-aicdd (2008) and Shackleton *et al.* (2008), research on all four ecosystem services while relating these to human well-being in Africa is needed as “the more numerous single service studies preclude an assessment of trade-offs” by populations benefiting from these ecosystem services.

Additionally, there is the ongoing discussion on the interactions of poverty and well-being, vulnerability and social differentiation, access and use of ecosystem services and influence of climate change on households. These discussions have used global, regional level, and national level data to explain trends in ecosystem use and recommended ways to ensure sustainable ecosystem use, especially by the poor and vulnerable smallholder farmers. As highlighted by the United Nations Framework Convention on Climate Change (UNFCCC), local-level data, including socio-economic data, are required to understand the influences of climate change on households (UNFCCC, 2007).

This research examined the four categories of ecosystem services obtained from savannah woodlands in Northern Ghana.

Access to ecosystem services and research on household factors influencing access required (socially differentiated groups)

In their work, Fisher *et al.* (2014) present a conceptual framework on ecosystem services and poverty alleviation. Factors such as endowment, entitlement and livelihood assets (human, financial, physical, natural and social capital) were noted to influence household access and use of ecosystem services (Department for International Development [DFID], n.d.; Fisher *et al*., 2014). Understanding these factors at the local (geographic) and household level, with their interactions or interrelationships, is essential in the fight against poverty and deforestation in the Savannah Ecological zone of Ghana. Additionally, an understanding of the preferences of the people and their other means of livelihood is essential in the fight against poverty and deforestation.

Most studies on factors (determinants) influencing access to woodland (forest) products/ecosystem services concentrated on individual-level characteristics of the respondents (Coulibaly-Lingani *et al*., 2009; Tugume *et al*., 2015; Tassou, 2017). A study in Southern Ghana, in different ecological zones, also established relationships between respondent's characteristics with access and use of ecosystem services (Appiah, Osman & Boafo, 2014). In many traditional societies of Africa and especially in Northern Ghana, household characteristics may be more important than individual-level features. These areas practice the extended family system. There is, therefore, the need to investigate household characteristics that define or relate to the endowment, entitlement, capital, preference, and alternate household livelihood options. Knowledge of these factors will promote the fight on poverty alleviation as well as efforts to prevent deforestation.

Local knowledge and influence on woodland management and conservation

Information on the causes of climate change among households is limited (UNDP, 2016). The lack of information on climate change limits the capacity of smallholder farmers to adapt appropriately (Mutekwa, 2009). Notably, communities and households depend on woodland resources to supplement household needs/income (Shackleton *et al*., 2008; Oksanen *et al*., 2003; Tugume *et al*., 2015) and/or cope/adapt to the impacts of climate change (Eriksen, Brown & Kelly, 2005; Robledo, Clot, Hammill & Riché, 2012). According to Antwi-Agyei (2012), local knowledge and experience is a basis for communities' coping strategies to climate change. Mutekwa (2009) found that elderly farmers observed the changes happening in their locality based on their assessment of temperature and precipitation. In a study, the United Nations Development Programme [UNDP] (2016) found that minimal action was being taken by households to lessen or prevent the impact of climate change despite the belief that communities were affected by climate change. For the savannah woodlands, actions to mitigate or avoid the effects of climate change could include climate-smart agronomic practices; and woodland conservation practices such as bush fire control, minimizing overgrazing, control on tree feeling, and limits on charcoal burning (Environmental Protection Agency [EPA], 2002).

Despite the low level of knowledge on climate change and climate change adaptation (UNDP, 2016; Mutekwa, 2009), it is equally important to know the sources or custodians of knowledge on climate change and conservation of woodlands. These sources may influence conservation practices in the Savannah Woodlands of Northern Ghana. The Adaptation Learning Programme (2014) estimates that about half of the members of project communities in Northern Ghana obtain their knowledge on climate change and weather information from non-governmental organizations (NGO), relatives, friends or neighbours, radio and television (TV) programs and agricultural extension agents. The literature on the influence of these sources of knowledge and knowledge on woodland conservation practices in Northern Ghana is limited.

Woodlands as an adaptation measure and economic wellbeing of the household

Rural communities continue to devise means and ways of coping with the impact of climate change based on their experience and local knowledge (Antwi-Agyei, 2012). Their limitation to adaptation is as the result of several factors such as financial constraint, access to information, and institutional barriers (Yangyuoru *et al*., 2014). Resources extracted from forest increases the resilience of rural communities in responding to the uncertainties of climate change. For example, previous research suggests that households around the tropical forest margin rely on forest resources to cope with climate variability (Eriksen *et al*., 2005).

Research by Fisher, Chaudhury, and McCusker (2010) in Southern Malawi found that forest use among rural farming households was mainly for reactive adaptation, providing food in times of shortage, and a source of income for coping with weather-related crop failure. Their study also found out that farming households most reliant on forests for their coping strategy had low income per person, are located close to the woods, and are headed by older, more risk-averse, and less educated individuals (Fisher *et al*., 2010).

A study conducted in three African countries (Robledo *et al*., 2012) to determine their coping and adaptive strategies to climate change, in terms of the use of the forest ecosystem, found that:

- Smallholder farmers in Zambia engaged in activities such as charcoal burning, wild food, and *mongongo* seed harvesting and selling, as well as craft making, as coping strategies against extreme climatic events.
- In Mali, activities that farmers engage in to cope with climate change were the extraction and sale of shea butter and the nuts by women, sale of firewood, tree planting to prevent dryness of the soil, diversification of agricultural products and natural regeneration.

- In Tanzania, a community identified migration and increase in the charcoal making as their coping strategies.

A related study to determine the adaptive capacity and coping strategies of forest-based rural communities in Vhembe district, Southern Africa by Ofoegbu, Chirwa, Francis and Babalola (2016), found tree planting around houses and on farmland to be the most popular strategies (90-100%) in off-setting extreme temperature.

The Intergovernmental Panel on Climate Change (IPCC) defines adaptation as the "adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts" (IPCC, 2001). Adaptation thus involves an adjustment in natural or human systems in response to actual or expected climate stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC as cited by Levina & Tirpak, 2006). Furthermore, adaptation involves "taking practical actions to manage risks from climate impacts, protect communities" as well as households "and strengthen the resilience of the economy" including household income (Department of Environment and Energy, n.d.). The wealth index is a measure of material or economic wellbeing (Smits & Steendijk, 2013; Rutstein & Staveteig, 2014), as the composite variables evaluate household assets, wealth, and health security. Thus, adaptation to climate change may relate to economic wellbeing. It is therefore paramount to identify livelihood options from woodlands, which influence the economic wellbeing of smallholder farming households.

Research on local-level changes in land use and land cover required, issues in classification

Access and use of woodland for household or commercial purposes may influence changes seen on satellite imagery. Wardell, Reenberg, and Tøttrup (2003), concluded that many studies on tropical deforestation focused on the humid tropics with comparatively limited attention given to the semi-arid regions.

Generally, regional and national studies fail to identify specific causal factors that drive land use land cover changes. Duadze (2004) carried out a regional land use land cover change (LULCC) study of the Upper West Region of Ghana. The land use land cover classes used in this study were quite broad, making it difficult to decipher the extent of changes in farmland, fallow land, and the built environment. From the results of Duadze's study, farmland/bareland or constructed surface increased extensively for the period under review, but the contribution of each specific component to the total increase was not clear.

Studies on land use land cover changes specific to local geographic areas have concentrated in areas where environmental issues have been prominent such as areas of mining (Sonter, Moran, Barrett & Soares-Filho, 2014; Basommi, Guan, Cheng & Singh, 2016; Areendran, Rao, Raj, Mazumdar & Puri, 2013; Antwi, Boakye-Danquah, Asabere, Takeuchi & Wiegleb, 2014) or pollution (Superczynski & Christopher, 2011; Kozovits & Bustamante, 2013) and areas of over-logging (Mertens & Lambin, 2000; Boehm & Siegert, 2004; Addo-Fordjour & Ankomah, 2017; Kusimi, 2008; Alo & Pontius Jr., 2008). Amanor and Pabi (2007) conducted a more localized LULCC study in eight communities of Kintampo District using the multi-site approach technique. Their aggregated findings revealed a complex combination of local specific biophysical factors, land-use regimes, and past land-use/cover change dynamics (Amanor & Pabi, 2007). A LULCC study of the Nandom District was conducted to support findings in the cross-sectional survey.

Valuation of all four ecosystem services and household preferred conservation strategy

Despite the contribution of ecosystem services to the wellbeing of humanity, it remains undervalued and cannot compete with immediate gains derived from marketable products. The Economics of Ecosystem and Biodiversity (TEEB) have therefore advocated for the economic valuation of ecosystem services as a way of providing a basis for its protection and conservation. Global interest in the economic valuation of ecosystem services in recent times is rising which may be attributed to conservationists seeking to influence policies that will protect nature and biodiversity to safeguard ecosystems (The Economics of Ecosystem Biodiversity, 2009).

Methods on valuation are specific to use or non-use ecosystem services with no single valuation method best suited for evaluating all four ecosystem services in one study. Since households and individuals benefit from all four ecosystem services of the woodlands, it is vital to conduct valuation studies to include all four categories of ES. Boafo *et al.* (2014) who studied woodlands in Northern Ghana, recommended valuation of woodland ES. Their recommendation buttresses other recommendations by Nicholson *et al*. (2009) and Shackleton *et al*. (2008). Valuation of all four ES categories of woodlands will provide evidence for the protection and conservation of woods for sustainable use in Ghana.

There is the ongoing debate on willingness-to-pay (WTP) for ES based on type and scope of conservation strategy investigated- preservation, restoration, or both. That is, are people/households willing-to-pay more for preservation or restoration of ES? A meta-analysis to examine the sensitivity of conservation values to type and scope of conservation strategies found that WTP "values for preservation were greater than both forest and freshwater restoration and freshwater restoration was valued greater than forest restoration" (Hjerpe, Hussain & Phillips, 2015, p. 32). Studies and data used for this meta-analysis were from conservation studies in Europe, Canada, and the United States of America. Even though 44% of ES studies in Africa employed valuation methods (Wangai, Burkhard and Müller, 2016), the preservation versus restoration finding by Hjerpe *et al*. (2015) and it's applicability in the developing countries of Sub-Saharan Africa and more specifically, the Savannah woodlands of West Africa is limited.

Contribution of woodland species to soil fertility

Studies have shown a relationship between deforestation and low soil fertility (Kassa, Dondeyne, Poesen, Frankl & Nyssen, 2017; Anyanwu, Egbuche, Amaku, Duruora & Onwuagba, 2015; EPA, 2002). Organic matter from trees and shrubs contribute to soil fertility (Osman, 2013). Many of the studies that provided this evidence were studies conducted in dense forest areas (Owusu-Sekyere, Cobbina & Wakatsuki, 2006; Dawoe, Isaac & Quashie-Sam, 2010; Guendehou *et al.*, 2014; Kostel-Hughes, Young & Carreiro, 1998; González & Seastedt, 2001; Wang, You, Tang, Liu & Sun, 2015) with high humidity and rainfall as well as other factors that promote decomposition of organic matter.

The loss of woodland and reduction of soil organic matter owing to anthropogenic factors will severely affect soil fertility patterns (EPA, 2002). Soil fertility in the Northern parts of Ghana is poor, owing to deforestation and climate change (Duadze, 2004). However, studies on the influence of leaf litter from trees in the Savannah Woodlands and soil fertility are few. Published literature in the 1990s showed mixed results of the impact of woodland species on crop yield (Nair, Buresh, Mugendi & Latt, 1999). Nair and colleagues mentioned that the results of those experiments were specific to study sites (including woodland tree species investigated as well as woodland system employed). Research in Niger on four woodland species found that the distribution of soil parameters and nutrients were influenced differently by tree species investigated (Oumarou, 2016). Even though literature is available on soil fertility, LULCC, and crop production (Duadzi, 2004) the contribution of leaf litter to soil nutrients/richness in the Savannah Ecological Zone of Northern Ghana is limited.

Generally, reports on soil from the UWR have been documented to have a low content of organic matter, total nitrogen, and available phosphorus (Buah & Opoku, 2013; EPA, 2002; Duadze, 2004). To this effect, farmers in various communities are using strategies such as integrated soil fertility management practices and crop residue retention (Buah & Opoku, 2013) as a way to restore soil quality.

1.3 Study Rationale

The aim of the study was to add to knowledge on the benefits associated with access and use of the savannah woodland ecosystem by exploring the household factors influencing access. An understanding of these factors at the local level would help policy makers design appropriate participatory poverty alleviation interventions which adhere to the principles of environmental justice and ensure sustainable use of the woodlands.

The examination of land use land cover change in the light of access and use of the savannah woodland ecosystem services was to identify the changes taking place over time. It would provide evidence and serve as a useful tool for decision-makers, spatial planners, and local communities in formulating appropriate policies, strategies, and bye-laws toward protecting the savannah woodland.

Additionally, this study was to contribute to the on-going discussion on soil quality by adding to knowledge on the decomposition rate and mineralization of four dominant woodland species in Nandom District, and their likely roles in soil improvement. The essence of this was to provide evidence and serve as the basis for local actions towards the maintenance of trees on farmlands.

The study contributes to decision-support for policymakers and implementing bodies to develop woodland and farmland adaptation policies and strategies to improve communities' resilience to climate change and variability.

Finally, the study sought to determine the value of preserving the savannah woodland among smallholders' farmers. As such, communities, government agencies, and NGOs could use the information to set up a local conservation fund to support woodland conservation efforts. It is envisaged that this fund would provide a basis for partnership and co-management of woodlands by communities and NGOs, environmentalist or government agencies. This initiative, when implemented, will help Ghana move up the ladder in achieving the Aichi Biodiversity Conservation targets, Paris Agreement, Nationally Determined Contribution (NDC) as well as SDG 1, 2, 13, and 15.

1.4 Conceptual Framework and hypotheses

1.4.1 Conceptual Framework

The conceptual framework, Figure 1.1, shows the complex interactions of households and communities in accessing ecosystem services. The woodland ecosystem comprises living organisms interacting with the abiotic environment. Ecosystem functions produce ecosystem services which are valuable resources required by rural households for their subsistence. The benefits from ecosystem services hold different value for the different socially differentiated groups due to barriers and enablers in access, and from the economic angle can be valuated (MA, 2005).

To access ecosystem services, people must combine their capital (human, social, financial, and economic) which they possess to access the benefits. Different people/ households have various rights to access the ecosystem services which could be influenced by factors such as endowment, entitlement, and key institutions (e.g., Forestry Commission). The drivers of change, such as climate change and climate variability as well as human-induced factors, continue to threaten the woodland ecosystem functions and its services. The climatic and anthropogenic factors could result in the loss of vegetative cover, fodder, and forage; wild fruits, medicinal plants, and fuelwood, which may increase vulnerability among different social groups. The loss of vegetative cover could lead to conflict due to competition over limited resources. The loss of the ecosystem (and its services) may further worsen the plight of vulnerable groups, including women and children.

The diminishing woodland resources may, therefore, compel individuals and households to devise coping, adaptation, and mitigation strategies to overcome the situation. Some adaptation strategies may include livestock mobility in search of greener pastures, livelihood diversification, agriculture intensification, and migration. Some mitigation strategies may consist of tree planting exercise, natural regeneration, bush fire control, climate-smart agriculture, cultivation of fodder, and forage to reverse negative trends.

CONCEPTUAL FRAMEWORK

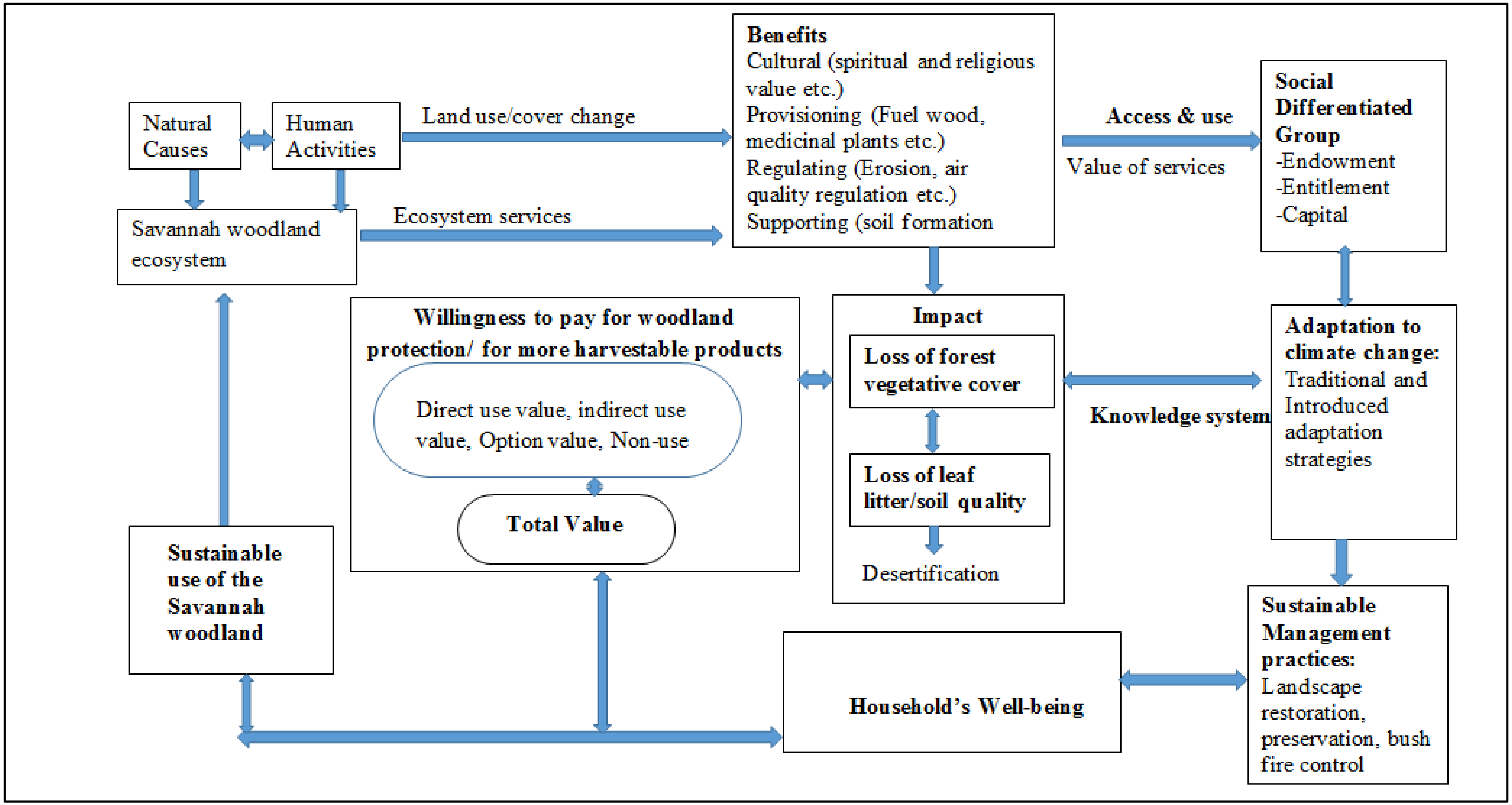


Figure 1.1 Conceptual framework of study

1.4.2 Hypotheses

Table 1.1 presents the research and null hypotheses of this study.

Table 1.1 Research and null hypotheses

Number	Null Hypothesis	Research/alternate Hypothesis
1	There is no association between household factors that define social differentiation categories/groups (endowment, entitlement or capital) and access to different types of woodlands in the Savannah Ecological zone	There is an association between household factors that define social differentiation categories and access to different types of woodlands in the Savannah Ecological zone
2	There is no relationship/association between knowledge on climate change (and its effects) and woodland conservation practices in the study area	There is a relationship/association between knowledge on climate change and woodland conservation practices
3	There is no association between woodland-related off-farm adaptation practices and economic wellbeing of households	There is an association between woodland-related off-farm adaptation practices and economic wellbeing of households
4	There is no significant difference in the value households are willing-to-pay for the conservation of the woodland ecosystem by their choice of conservation strategy (preservation, conservation or both)	There is a significant difference in the value households are willing-to-pay for the conservation of the woodland ecosystem by their choice of conservation strategy (preservation, restoration or both)

1.5 Research Objectives

General Objective

The overall objective was to assess the ecosystem benefits farmers and households derive from savannah woodlands in the Nandom District.

Specific Objectives

The specific objectives are to:

i. Assess household factors influencing access and use of savannah woodland ecosystem services in the study area.
ii. Assess the relationship between knowledge of climate change and woodland conservation (management) practices.
iii. Identify off-farm adaptation practices that influence the economic wellbeing of smallholder farming households.
iv. Assess changes in land cover of Nandom District from 1986 to 2017.
v. Compare household's willingness-to-pay for ecosystem services by preferred type of woodland conservation strategy.
vi. Assess leaf litter decomposition (and the quantity of nutrient remaining) in selected woodland species in the study area.

1.6 Research Questions

i. What household factors influence the access and use of woodlands in the Savannah Ecological zone?
ii. Does knowledge on climate change have an effect on woodland conservation practices by rural smallholder farming households?
iii. Which woodland-related off-farm adaptation practices influence the economic wellbeing of rural smallholder farming households?
iv. What changes have occurred in the savannah woodland ecosystem (land use/land cover types) from 1986 to 2017?

v. Is there any significant difference in the value that households are willing-to-pay for the preferred type of woodland conservation strategy?

vi. What are the quantities of nutrients remaining from decomposing leaf litter of selected woodland species?

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Benefits derived from the woodland ecosystem

2.1.1 Ecosystem services

An ecosystem refers to "*a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit"* (Convention on Biological Diversity [CBD], n.d.). Ecosystem services are benefits derived from nature (MA, 2005), and according to Daily (1997) and Roetter *et al*. (2007) the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life. Ecosystem services are also defined as the benefits human populations derive, directly or indirectly, from ecosystem functions (Costanza *et al*., 1997).

The definition of ecosystem services arises from an ecological and economic perspective. The ecological discourse (La Notte *et al*., 2017) is on benefits derived from the environment while the economic discussion (Farley, 2012; Gómez-Baggethun & Martín-López, 2015) depicts the value derived from the benefits obtained from the environment. The latter has its roots in economic valuation to increase awareness of accounting for environmental benefits in decision making (Fisher, Costanza, Turner & Morling, 2007; Fisher, Turner & Morling, 2009). The ecological and economic dimension to ecosystem services has been noted to have projected the field of ecosystem services high (de Groot *et al*., 2010; Polasky & Segerson, 2009). It is also raising the awareness of the declining nature of ecosystem services and the need for global research to address it, especially at the local scale (de Groot et al., 2010).

Ecosystem services are broadly categorized into four parts (Haines-Young & Potschin, 2010; MA, 2005). To date, the Millennium Ecosystem Assessment classification remains the most widely used, though criticized for not capturing all aspect of ecosystem services. These four parts or categories are provisioning services, cultural services, regulating services, and supporting services (MA, 2005). These categories are further discussed in section 2.1.2

2.1.2 Benefits derived from woodlands

There are several benefits associated with ecosystem services. These benefits are not limited to harvestable goods but include that of climate regulation, which is a global agenda against climate change (MA, 2005). At the centre of the ecosystem is the human element that benefits from ecosystem services as depicted in Fisher *et al*. (2014) conceptual framework. This dependency dates back to the old days where man had to transform nature to survive (Lambin, Geist & Lepers, 2003).

The social demand for ecosystem goods and services encompasses different key stakeholders with different roles, needs, and interest (Mensah *et al*., 2017). In the rural parts of the world today, farmers are recognized as the direct beneficiaries of ecosystem services (Oksanen *et al*., 2014). At the onset of the rains, farming becomes the main economic activity (GSS, 2014a). Livestock keeping becomes enjoyable due to the abundance of feed and water (Sansoucy, n.d.).

The direct over-exploitation of ecosystem services is noted for undermining the continuous supply of ecosystem services (MA, 2005). The results of the unsustainable exploitation of ecosystem services are changes in land use and land cover (MA, 2005). Also, ecosystem services are threatened by erratic rainfall pattern, prolong-drought, and floods, which are a manifestation of climate change (MA, 2005). Because of this, crop yield and livestock productivity have been reported to be on the decline in recent times (Yangyuoru *et al*., 2014). The threat of climate change on ecosystems is expected due to the continuous accumulation of greenhouse gases (MA, 2005). The wellbeing of humanity is at stake, and the tragedy of the commons is inevitable (Lambin *et al*., 2003).

Global initiatives such as the Inter-Governmental Platform on Biodiversity and Ecosystem Services, The Economics of Ecosystem and Biodiversity, and the Millennium Ecosystem Assessment have advocated for ecosystem conservation to guarantee a continuous supply of services (MA, 2005; TEEB, 2009). It is reported that conservation of the ecosystem in the tropics could have the potential to sequester and conserve 80% of carbon (Smith *et al*., 2014). Conservation practices such as slowing down deforestation, forestation and agroforestry practices, sustainable agricultural practices, sustainable land use practice, and resource conservation and management, could reduce the impact of climate change (EPA, 2002; MA, 2005). These practices would contribute to ensuring that natural ecosystems perform their critical roles as carbon sinks, means of livelihood, and towards the acceleration of development (MA, 2005).

2.1.2.1 Provisioning services

The livelihoods of many rural households depend largely on provisioning services, which serve as safety nets in a stressful situation such as poor harvest (Oksanen *et al*., 2003). It also provides means of employment, raw materials for construction, and fuel (Tugume *et al*., 2015). It has been estimated that 1.6 billion people globally derive their livelihood from forest-based products (Oksanen *et al*., 2003). Many researchers have identified provisioning services such as bushmeat, bamboo, fish, firewood, food crops, livestock, edible vegetables, fibre, timber, water for domestic purposes from their study (Boafo *et al*., 2014; Tugume *et al*., 2015; Chaudhary, McGregor, Houston, & Chettri, 2018). These services vary from one study area to the other and dependent on the source.

In Africa, the reliance on provisioning services is said to be more due to acute poverty, with 60% of rural Africans living below the poverty line (Oksanen *et al*., 2003). A study conducted in Northern Ghana showed that 80% of rural households rely heavily on provisioning services for sustenance (Boafo *et al*., 2014). Another study found that the livelihood of rural poor depended on the commercialization of provisioning services (Asamoah & Wiafe, 2016). Chaudhary *et al*. (2018) quantified the proportion of households' that accessed provisioning service to be: fuelwood- 94 %, fodder- 88 %, leaf litter- 53%, timber- 30%, water- 26% and bamboo- 19%.

2.1.2.2 Cultural services

The benefits of cultural services include aesthetic, spiritual, psychological, and other benefits that households draw from the ecosystems (MA, 2005). For many indigenous and otherwise traditional societies, forests play an essential role in cultural and spiritual traditions and, in some cases, are integral to the very definition and survival of distinct cultures and peoples (Shvidenko *et al*., 2005). Forests continue to play an important role in providing recreation and spiritual solace in more modernized, secular societies (Ansong & Røskaft, 2014; FAO, 2018). As such, forests and trees are symbolically and spiritually regarded valuable in most of the world's major religious traditions (FAO, 2018).

Forest and trees are noted for preserving the cultural and traditional values of indigenous and traditional societies and provide spiritual solace in urban and rural areas (Ansong & Røskaft, 2014; FAO, 2018). A study conducted in Nepal quantified benefits households derived from cultural services. A proportion of ninety-one percent (91%) households accessed spiritual and religious value, ninety-one percent (91%) enjoyed a sense of place, twenty-one percent benefitted from ecotourism, recreation, as well as traditional cultural practices and seven percent (7%), benefitted from research and education as well as the greenery (Chaudhary *et al*., 2018).

2.1.2.3 Regulating services

Regulating services are benefits obtained from ecosystem processes that regulate the earth, e.g., climate, floods, disease, and waste and water quality (MA, 2005; TEEB, 2009). Accelerating degradation of ecosystem services is directly affecting the regulating services worldwide (TEEB, 2009). Natural disasters such as floods, erratic rainfall pattern, drought, water crisis, pest, and disease affecting crop yield are directly linked to climate change (MA, 2005).

Ecosystem degradation and land-use change are the largest sources of greenhouse gas emissions in Africa (Sustainable Development in the 21st century, 2012). Soil and vegetation on the earth's surface store three times the carbon present in the earth's atmosphere (Osman, 2013). Land clearing and degradation turn this valuable carbon sink into a major source of greenhouse emissions (Sustainable Development in the 21st century, 2012).

Benefits derived from regulating services in Nepal were in the following: 31% benefitted from fresh air as well as water regulation, 27% benefitted from water purification and 21% from erosion control (Chaudhary et al., 2018).

2.1.2.4 Supporting services

Supporting services are necessary for the production of other ecosystem services such as provisioning services, cultural services, and regulating services (Jónsson & Davíðsdóttir, 2016). These services provide ecological functions such as nutrient cycling, primary production, water cycling, production of atmospheric oxygen, provision of habitat (Osman, 2013). These services support non-timber forest products (NTFP) production, agriculture productivity, and conservation of biodiversity, which supplies the livelihoods for rural households (Jónsson & Davíðsdóttir, 2016). It is reported that reducing trees in their natural environment affects soil productivity in terms of the accumulation of organic matter from litter fall (Osman, 2013). A study by Tanga, Erenso, and Lemma (2014), highlighted the benefits of trees such as nutrient addition, and soil microclimate when maintained on farmlands. This point buttresses the observation on the importance of agroforestry land use or agroforestry woodland use (Sileshi *et al*., 2014). This assertion may be as a result of the vital role soil play as a supporting service without which no primary production can take place (Jónsson & Davíðsdóttir, 2016). For example, Sabiitti and Cobbina (1992), and Kessler (1992) reported an increase and decrease in crop yield around some tree species.

2.2 Access and use of ecosystem services

Access to ecosystem services (ES) refers to the ability of an individual to draw benefits from natural resources that exist in the environment (Ward, Stringer & Holmes, 2018). Use refers to the enjoyment of some kind of benefit (Hunt 1998 as cited in Ribot & Peluso, 2003). Access to ecosystem service implies benefit backed by law or custom (Ribot & Peluso, 2003). It does also include access through illegal means such as stealing or coercion. The land tenure system and direct buying are examples of legal ways of accessing ecosystem services (Ribot & Peluso, 2003; Antwi-Agyei, Dougill & Stringer, 2015). In Ghana, the land is owned and controlled by two institutions, the state, and traditional institutions (Kakraba-Ampeh, n.d). At the community level, land acquisition or access for farming by individuals and groups is by the customary system. As noted by Dittoh (2004), a community member cannot be denied access to uncultivated land for farming provided it is available. This social relationship at the community level enhances access to ecosystem services, as noted by Hicks and Cinner (2014).

As argued by Antwi-Agyei *et al.* (2015), owners of farmland are usually interested in long term conservation and adaptation practices such as agroforestry. According to Antwi-Agyei *et al.* (2015), agroforestry is a better way of securing the land than renting it for crop production.

Household and individual-level factors may influence an individual's ability to derive various products from a given forest/woodland. These include gender, household size, and education level, age of the household head, total household income, and other contextual factors (Tugume *et al*., 2015). These are discussed below.

2.2.1 Factors influencing access and use of Woodland Ecosystem Services

The concept of social differentiation

This section starts by focusing on the ways by which people are differentiated in terms of their access and use of ecosystem services according to factors such as capital, endowment, and entitlement.

Social capital in the context of Sustainable Livelihood Framework refers to the social relationship that enables individuals to draw ecosystem services from the environment (DFID, n.d.). Social capital includes the relationship among individuals with shared interest working together to expand their access to ecosystem services ("Social groups," n.d.). It also includes membership of more formalized groups which often entails adherence to mutually-agreed or commonly accepted rules, norms, and sanctions ("Social groups," n.d.). The importance of social capital comes in the form of providing social network at the local level that caters for the needs (support during funerals, hunger, and communal labour) of every member of the community (DFID, 1999). Drawing upon a study conducted in Madagascar, access to ecosystem services was far more for communities that had social identity and relationship with patrollers of the protected area than those that did not (Ward *et al*., 2018).

Research shows that institutions and social relations are the most important factors influencing access to ecosystem services (Hicks & Cinner, 2014). As pointed out by Agrawal and Gupta (2005), institutions play a vital role by linking individuals or households to local resources, serving as nexus between remote populations and national interventions. Ward *et al*. (2018) found that institutions and social identity are the main factors influencing access to ES.

A recent study examined the role of social factors in shaping access to ES in Nepal (Chaudhary *et al*., 2018). Using an environmental justice lens, Chaudhary and colleagues analysed access to ES from a community forest. Chaudhary *et al*. (2018) found that access to ES was associated with social characteristics such as caste, income, and gender as well as uneven resource distribution and participation.

Human capital comprises the skills, knowledge, ability to labour and good health that together allow people to draw benefits from the environment (DFID, 1999). The study conducted in Nepal revealed that the high-income group was the most educated and a more beneficiary of ecosystem services (Chaudhary *et al*., 2018).

Natural capital refers to ecosystems from which ecosystem services are generated (DFID, n.d.). These include common resources such as the soil ecosystem, aquatic ecosystem, agroforestry ecosystem, etc. Endowment refers to the proximity to the resources mentioned above, which comes with natural rights of use or legal, including statutory rights, to forest products (Fisher *et al*., 2014). Entitlement is what can be done with the resources (Fisher et al., 2014).

Physical capital comprises of the basic infrastructure that enables individuals to draw ecosystem services, which includes roads, transport, equipment, access to information, etc. (DFID, n.d.) required to access natural capitals.

Financial capital refers to the availability of resources that enhances one's capacity to derive livelihood benefits from ecosystem services (DFID, 1999). In Nepal, the high-income households were able to fence their farmland from destruction, while those from the low-income group could not (Chaudhary *et al*., 2018). Financial capital comprises of available stocks such as cash, bank deposit, or liquid assets such as livestock and jewellery or regular flows of money such as remittances (DFID, 1999). In a study conducted in Ghana, the access and use of ecosystem services were differentiated based on income (Asamoah & Wiafe, 2016). The results of the study revealed that individuals within the low-income brackets use more of the ecosystem services for commercial purpose and less for domestic use (Asamoah & Wiafe, 2016). Those within the high-income bracket used theirs more for domestic purpose than for commercial purposes (Asamoah & Wiafe, 2016). In Nepal, the community forest could not meet the provisioning needs of the entire community population; therefore, high-income households relied on the private forest for more service (Chaudhary *et al.*, 2018). The low-income households had to buy provisioning service such as fuelwood and fodder from their wealthy counterparts (Chaudhary *et al*., 2018).

There is also mounting evidence that, access to ES could be influenced by factors such as technology (tools), capital, markets, knowledge, institutional and social factors (ethical, ecological knowledge, demographic), spatial and environmental factors (Cuni-Sanchez *et al*., 2016; Hein, van Koppen, de Groot, & van Ierland, 2006; Martín-López *et al*., 2012). As argued by Kozak, Lant, Shaikh, and Wang (2011), the rate at which people visit, a recreational site, could be a function of distance to the site. All the factors influencing access to ES can be summarized into the five capitals of livelihood, which are financial, human, natural, physical, and social capital (Fisher *et al*., 2014). According to Fisher *et al.* (2014), these factors influence access to ES and despite their importance are the missing links in the Millennium Ecosystem Assessment conceptual framework.

2.2.1.1 Household and individual characteristics and access to woodland ecosystem services

Gender of household head and access to ecosystem services

Tugume et al. (2015) found that male-headed households were less dependent on the forest than women-headed households. Conversely, Campbell (1991) (as cited in Tassou, 2017) argues that men like taking the risk, hence more likely to assess the forest for provisioning service compared to women. Notably, women are often constrained in accessing and controlling land and forest resources due to the construction of gender identities within households (Agarwal, 1997; Goebel, 1998).

Coulibaly-Lingani *et al*. (2009), in Burkina Faso, found that men and women were equally involved in harvesting NTFPs. The women were more inclined to processing some NTFPs, such as fruits of *Vitellaria paradoxa* (shea nut) and *Parkia biglobosa* (locust bean) (Coulibaly-Lingani *et al*., 2009).

Age of head of household head and access to ecosystem services

The age of the household head may positively or negatively affect household access to provisioning service. Collection of NTFPs is labour intensive; hence, young people may be more dependent on forest products than older adults (Mamo *et al*., 2007). McElwee (2008) also analysed the socio-economic factors that affect the household decision to participate in collecting forest products. McElwee found that older adults are less likely to collect NTFP from the forest, hence rely more on their farm. Cavendish (2000) argues that older individuals have difficulty performing laborious agricultural tasks and may turn to resource collection activities that demand less physical labour. Coulibaly-Lingani *et al*. (2009) emphasized that age-forest access relationship depended on the type of forest products being gathered. The study by Coulibaly-Lingani and colleagues found a positive relationship between age class and NTFPs.

The study revealed that access to fuelwood and livestock grazing were significantly higher only for the active age group compared with the older groups (Coulibaly-Lingani *et al*., 2009). The age of the head of household may be positively related to forest resource utilization until a peak of physical strength is reached (Godoy *et al*., 1997).

Household size and access to ecosystem services

Household size affects significantly the decision to collect NTFP (Coulibaly-Lingani *et al*., 2009). The larger the household size, the more provisioning service required (Adikhari *et al*., 2004). Because of this, larger households have a higher demand for provisioning service and more likely to go in search of it (Adikhari *et al*., 2004). Zorondo-Rodríguez (2007) argues that the presence of an additional individual in the household may increase the household probability of collecting NTFPs. Large household size may be the motivation for dependency on forest products (Godoy *et al*., 1997). Again, larger households clear more forest because they have more workers and more mouths to feed (Godoy *et al*., 1997). On the contrary, a study found that in very large families, dependency on forest resources decreased (Mamo *et al*., 2007).

Household wealth status (socioeconomic status) and access to ecosystem services

Tugume *et al*., (2015) found that the higher the wealth quintile, the more likely the user depended on the forests. In another study, an increase in wealth index resulted in a decline in the dependence of NTFPs in Karnataka state, India (Ganeshaiah *et al*., 2003).

Household wealth exerts influence on the decision to collect NTFPs (Coulibaly-Lingani *et al*., 2009) as such higher-income households might not be interested in collecting or selling NTFPs as compared to lower-income families because they can afford to purchase NTFPs from the local markets (Coulibaly-Lingani *et al*., 2009). Therefore, poor households are likely to collect

NTFPs (Coulibaly-Lingani *et al*., 2009). Higher-income households may be attracted by the prices of forest products; hence, they may be interested in NTFP collection as evident in Uganda, where the outcome revealed that the higher the wealth quintile, the more likely the user depended on the forests (Tugume *et al*., 2015).

Owing to improved off-farm employment opportunities (Angelsen & Kaimowitz, 1999) and access to credit (Godoy *et al*., 1997), total household income (wealth) may be associated with reduced forest clearance as a supplementary income-generating activity.

<u>Ownership of household assets and access to ecosystem services</u>

Tugume *et al*. (2015) found that the relationship between land ownership and dependence on the forest was not significant. According to the authors, the more land an individual owns, the less the reliance on the woodland (Tugume *et al*., 2015). Higher incomes, within the relevant range of income in developing countries, are likely to increase the dependency on forests (Adhikari *et al*., 2004; Mamo *et a*l., 2007).

<u>Education and access to ecosystem services</u>

A higher level of formal schooling is associated with less forest cutting (Godoy & Contreras, 2001), due to higher opportunity costs of time (Adhikari, Di Falco, & Lovett, 2004), and increased social status and economic opportunities in this rural context (Adhikari *et al*., 2004; Agrawal & Gupta, 2005).

2.2.1.2 Enablers and Barriers to ecosystem services

The ability to benefit from ecosystem services is mediated by constraints or enablers identified by Ribot and Peluso (2003) to be technology, capital, markets, knowledge, authority, social identities, and social relations. Ward *et al*. (2018) categorize these factors into institutions, physical asset, social identity, or relationship, and knowledge. Fisher *et al*. (2014), focused on endowments and entitlements, preference, means other than ecosystem services and capital (natural, social, human, financial, and physical) in her conceptual framework as factors differentiating people's access to ecosystem services. When the availability of these factors at the community level is unevenly distributed then social differentiation is bound to take place. For example, in Nepal, the extraction of ecosystem services such as timber requires more capital investment and is, therefore, disproportionately available to wealthier people (Chaudhary *et al.*, 2018). In the coastal area of Kenya, Brown, Daw, Rosendo, Bunce, and Cherrett (2008) highlighted the role of technology such as a motorized boat in the extraction of provisioning services such as fish. In the hilly regions of Nepal, women have ownership right to agricultural land for farming (Chaudhary *et al*., 2018). By these few examples, the lack of capital, technology, and land may be regarded as a barrier preventing access to ecosystem services.

The role of institutions in linking local people to ecosystem services may be enablers or barriers. For example, the modified taungya system (MTS) by its adoption and implementation brought relief to "landless'' farmers in the Offinso district (Kalame *et al*., 2011). In contrast to MTS, the creation of the Kakum Conservation Area (KCA), a government conservation programme limited access to the Kakum National Park (Cobbinah, Erdiaw-Kwasie & Amoateng, 2015) by residents.

A study conducted in Burkina Faso by Coulibaly-Lingani *et al*. (2009) identified forest law, traditional rules, and regulations, gender, and residency status as the major constraints to accessing forest products. In Ghana, the customary law gives traditional authorities the power to allocate as well as control access and use of ES by enacting and enforcing by-laws (ALP, 2014). Cultural norms governing the land tenure system prevent women from land ownership (Dittoh, Snyder, & Lefore, 2015) this may reduce their capacity to assess ecosystem services legitimately (Ribot & Peluso, 2003). Therefore, women are disadvantaged concerning access to forest resources because land inheritance practices and procedures for formalizing land rights often discriminate against, them (Salifu, 2016; ALP, 2014).

Distances to forests and markets are common external forces that may often accelerate forest extraction (Angelsen & Kaimowitz, 1999; Mamo, Sjaastad & Vedeld, 2007). In contrast, forest policy and traditional rules governing forest use may impose excessive control over the use of forest resources in some developing countries. Table 2.1 presents a summary of factors influencing access to ES from Ward *et al*. (2018).

Table 2.1 Summary of factors influencing access to ecosystem services

Factor	**Definition**	**Relation to ES**
Institution/Governance	Laws, customs, and authorities. Access can be affected by both formal (e.g., laws) and informal (e.g., social custom) rules. Access may be affected by laws denoting property ownership, permits, and licenses	Ownership of land, paying for permits and local customs can all affect access to ES
Physical asset /Socioeconomic factors	Technology, capital, markets, and labour. Physical ability to access resources may require tools, infrastructure, financial capital, access to market and labour	Many provisioning services cannot be extracted without the use of tools. Financial capital may be required to buy a permit or legal right to access
Social identity and relationships	Identity, relationship, and power. Access is often affected by an individual's social identity (e.g., gender, age, etc.) status within society (e.g., community leaders, village chiefs) relationship with others. All mechanisms of access are social relations.	Relationship with protected area managers or committee members may allow easier access and more leniencies towards rule-breaking.
Knowledge	Direct knowledge relating to access (i.e., how, where, what) and also perceived knowledge status, e.g., expert status can give privileged access to resources or authority to control resource-use	Knowledge of where particular provisioning services may be found (e.g., medicinal plants). Within strictly protected area expert's or researchers may only be allowed access
Geographic factors	Distance to woodland Road condition, means of transportation, security during travel, transportation of harvested products	Proximity to ecosystem services may promote access

Source: Ward *et al*. (2018)

2.3 Knowledge of climate change and woodland conservation (management)

Information on climate change is needed to increase the knowledge of smallholder farmers to adapt to the uncertainties of climate change. Mutekwa (2009) noted that information on climate change is non-existent among many smallholder farmers limiting their capacity to adapt appropriately. Where it is available, farmers are unable to adapt due to the unpredictability of the prevailing climate. Lack of access to information on climate change has been highly rated as a barrier to adaptation. A section of smallholder farmers over the years have acquired knowledge on climate change through personal experience. The elderly farmer would have observed changes happening in their locality based on the assessment of temperature and precipitation (Mutekwa, 2009). For example, a study to assess farmers view and knowledge about climate change found that 47% of the farmers have noticed some changes in the climate with 58% mentioning the unpredictable nature of rainfall and prevalence of mid-season dry spells. A workshop for stakeholders on the impact of climate change on livelihoods in Northern Ghana revealed that, state institutions such as the Ghana Meteorological Agency and National Disaster Management Organization as their source of knowledge on extreme weather changes (ALP, 2014). In terms of temperature, farmers observed increasing trend (Mutekwa, 2009).

Half of the members of a community in Ghana indicated that their knowledge on climate change and weather information was from NGO, relatives, friends or neighbours, radio and TV programs and agricultural extension agents (ALP, 2014).

2.4 Adaptation to climate change

2.4.1 Coping and adaptive strategies of smallholder farmers to climate change

Climate change and variability are expected to affect all ecosystems (MA, 2005). According to Africa Environment Outlook-3, a large part of Africa, representing 66% of the total land area is characterized by arid and desert conditions (United Nations Environment Programme [UNEP], 2013). Given this, the Intergovernmental Panel on Climate Change predicted that climate change would further worsen desertification in Africa (Boko *et al*., 2007), leading to drastic changes in ES supply and demand.

Smallholder farmers are already responding to the impact of climate change on their livelihood using various coping and adaptive strategies as evident in several studies (Antwi-Agyei, Dougill, Stringer, & Codjoe, 2018; Salifu, 2016; Menikea & Keeragala Arachchi, 2016; Alemayehu & Bewket, 2017).

The Intergovernmental Panel on Climate Change (IPCC) defines adaptation as the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects which moderates harm or exploits beneficial opportunities" (IPCC, 2007, p. 869). Importantly, adaptation differs from mitigation in the following: (1) it will in most cases provide local benefits, and (2) these benefits will be typically realized with shorter time lags (Stern, 2007). Further on, adaptation differs from a coping strategy in the following ways depicted in Table 2.2. Literature is not clear on the standard ways of assessing adaptation and coping strategies; hence, these two terms are often used interchangeably (Taylor, Harris & Ehrhart, 2010). Most often, researchers settle on a particular term and start working without recourse to the distinction underlying adaptation and coping strategies.

According to Mitchell and Tanner (2006), adaptation is a broad concept covering actions by individuals, communities, private companies, and public bodies such as governments. In the economic and agriculture literature, two types of adaptation with regard to the relevant actors are distinguished: (i) autonomous adaptation, motivated by the private, utility-maximizing paradigm of firms and individuals, and (ii) planned adaptation, based on collective action and mostly initiated by governmental entities (Dinar, Hassan, Mendelsohn, & Benhin, 2008; Mitchell & Tanner, 2006). Autonomous adaptation occurs as individuals naturally respond to the market and physical environment or other circumstances, they face (Osberghaus, Finkel & Pohl, 2010). Autonomous adaptation can also be described as a behavioural response to an environmental change that is mainly for one's benefit (Mendelsohn, 2000 as cited in Osberghaus, Finkel & Pohl, 2010). Planned adaptation, on the other hand, is the result of a strategic policy decision for the sustainable benefit of society (Dinar *et al*., 2008).

Table 2.2 Differences between Adaptation and coping strategies

Adaptation strategy	**Coping strategy**
Practices and results are sustained	Short-term and immediate
Oriented towards long term livelihood security	Oriented towards survival
A continuous process	Non-continuous
Involves planning: combining old and new strategies and knowledge	Motivated by crisis, reactive
Use resources efficiently and sustainably	Often degrades the resource base
Focused on finding alternatives	Prompted by a lack of alternatives

Source: Taylor, Harris & Ehrhart (2010)

Rural communities continue to devise means and ways of coping with the impact of climate change based on their experience and local knowledge (Antwi-Agyei, 2012). Their limitation to adaptation is as the result of several factors such as financial constraint, access to information, institutional barriers, etc. (Salifu, 2016).

Resources extracted from forest increases the resilience of rural communities in responding to the uncertainties of climate change. For example, previous research suggests that households around tropical forest margin rely on forest resources to cope with climate variability (Eriksen, Brown & Kelly, 2005). A study by Fisher, Chaudhury & McCusker (2010) in Southern Malawi found that forests use among rural farming households were mainly for reactive adaptation, providing food in times of food shortage, and a source of cash for coping with weather-related crop failure. Fisher *et al*. (2010) also found out that farming households most reliant on forests for their coping strategy had low income per person, are located close to forest, and are headed by individuals who are older, more risk-averse, and less educated than their cohorts.

A case study conducted in three African countries, by Robledo *et al*. (2012) to determine their coping and adaptive strategies to climate change in terms of the use of the forest ecosystem found activities such as charcoal burning, wild food, and *mongongo* seed harvesting and selling, and craft-making, as contributing to coping strategies against extreme climatic events Zambia. Shea butter extraction, sale of firewood, tree planting to prevent dryness of the soil, diversification of agricultural products and natural regeneration also served as coping strategies in Mali. A community, in Tanzania identified migration and increase in charcoal making as well as gathering, as their coping strategies.

A related study to determine the adaptive capacity and coping strategies of forest-based rural communities in Vhembe district, Southern Africa, found tree plantings around houses and on farmland to be the most popular strategies (90-100%) in off-setting extreme temperature (Ofoegbu, Chirwa, Francis & Babalola, 2016).

Table 2.3 Adaptation and coping strategies adopted by smallholder farmers

Adaptation strategy	**Coping strategy**
Tree planting (Komba & Muchapondwa, 2015) Agro-forestry (Antwi-Agyei, 2012) Reforestation (Mertz *et al.*, 2010)	Extraction of forest resource in Southern Malawi
	Charcoal burning, wild fruits, *mongongo* seed harvesting and sale, and crafts work- Case study Zambia
	Sale of shea nuts and the butter, sale of firewood and tree planting, natural regeneration – Case study Mali
	Tree planting – South Africa

2.4.2 On-farm and off-farm adaptation practices

Climate change adaptation depends greatly on the adaptive capacities of individuals and households (Osano *et al.*, 2013). Adaptive capacity is the ability of affected people to cope with the impacts and risks of climate change, which depends on the socioeconomic characteristics of the community (Osano *et al.*, 2013). Adaptation practices are nothing new to farmers (Antwi-Agyei, 2012). Common adaptation practices include on-farm adaptation strategies describe as agronomic practices aimed at taking advantage of the harsh climatic conditions to improve crop growth and yield (Antwi-Agyei, 2012). On the other hand, off-farm adaptation strategies are the complimentary activities embarked on outside the farm to reduce livelihood vulnerability to climatic and other related stresses (Antwi-Agyei, 2012).

The adoption of adaptation practices is associated with several factors, including socioeconomic factors. Socioeconomic factors such as age, gender, level of education, wealth, cultural norms and practices, household size, geographical location, and land tenure have been found to influence adaptation practices (Coirolo & Rahman, 2014).

Table 2.4 summarises the adaptation strategies used by smallholder farmers in Ghana and other African countries.

Table 2.4 On- and off-farm adaptation practices

On-farm adaptation strategies	**Source in literature**	**Off-farm adaptation strategies**	**Source in literature**
Shifting to new crops	Ali and Erenstein (2017)	Livelihood diversification	Bawakyillenuo, Yaro, and Teye (2014)
Adjustment in sowing time	Ali and Erenstein (2017)	Selling of livestock	Antwi-Agyei (2012)
Use of China groundnuts	Salifu (2016)	Changing dietary habits	Rademacher-Schulz *et al.* (2012)
Crop diversification	Ndamani and Watanabe (2015)	Temporary migration	Rademacher-Schulz *et al.* (2012)
Planting early maturity variety	Komba and Muchapondwa (2015)	Reforestation	Mertz *et al.* (2009)
Non-burning of farm residue to maintain fertility	Salifu (2016)	Avoid (by punishment) and extinguish bush fires	Mertz *et al.* (2009)
Use of irrigation	Salifu (2016)	Relying on family and friends	Antwi-Agyei (2012)
Change in tillage practices	Bawakyillenuo *et al.* (2014)	Support from government and NGOs	Yaro, Teye, and Bawakyillenuo (2014)
Application of fertilizer and other inputs	Etwire *et al.* (2013)	Reliance on indigenous knowledge and external climate information	Naab and Koranteng (2012)
Composting and manure	Salifu (2016)		

2.5 Land use land cover change

Land use land cover change (LULCC) has received global attention because of its influence on climate change, biodiversity, and ecosystem services. In recent times focus has been shifted to ecosystem goods and services, its sustainability as well as vulnerability with emphasis on the impact on human societies and ecosystems at the local scale (Lambin, 1997). Increasing research in LULCC may be ascribed to global concern for resource management, conservation, environmental planning, and human well-being (MA, 2005; TEEB, 2009). For example, the conversion of forest to other land use is reported to have contributed to the net loss of the forest (FAO, 2016b). Quantifying changes on the surface of the earth using land-use/changes is necessary for town and resource planning and conservation.

LULCC analysis has become a useful tool for gathering evidence for decision-makers, spatial planners, local communities, or actors who are operating within a given landscape (Hailemariam *et al*., 2016). It does contribute to formulating appropriate policies and strategies, to generate data for spatial planning, and develop detailed land use plans as well as understand agents of change (Hailemariam *et al*., 2016). The LULCC usefulness is to help decision-makers ensure sustainable development and understands the dynamics of the changing environment (Kuchay & Ramachandra, 2016).

2.5.1 Land use land cover change and Landsat imageries

The general observation in LULCC studies in recent times depicts a pattern showing an increase in cropland, settlement, and a decline in forest cover. Such studies have therefore concluded that cropland and settlement constitute drivers of LULCC and such studies have attributed the occurrence to increase in population. For example, Kuchay and Ramachandra (2016) used Landsat imageries to classify land use in the district of Utarra Kannada. The purpose of the study was to quantify the LULCC and assess LULCC changes for the period of

1979-2013. The emphasis of Kuchay and Ramachandra research was to determine the extent of forest area and non-forest area as well as the underlying cause of LULCC. The study area was classified into ten land use categories such as evergreen forest, moist deciduous forest, dry deciduous forest, scrub forest/Grassland, forest plantations, built-up, water, cropland, horticultural plantations, and open land. The results of their study showed a decrease in dense wood cover, a decrease in open cover, increase in built environment and farmlands, etc. Also, the land cover analysis of the study revealed an increase in the non-vegetation area from 2.76% (1979) to 16.66% (2013) with a substantial decrease in the vegetation from 97.24% to 83.34% (Kuchay & Ramachandra, 2016). The analysis of land use dynamics revealed the loss of evergreen forest from 1979 to 2013. The forest transition showed that evergreen forest cover has decreased from 57.15 % (1979) to 32.52% (2013) whereas agriculture land, as well as built-up area, increased (Kuchay & Ramachandra, 2016). The rate of change analysis of land use showed that the rate of evergreen forest loss had increased from 1.50% (1979-1999) to 1.88% (1999-2013). The rate of increase in the built-up and agriculture land decreased from 4.33% & 1.58% (1979-1999) to 2.17% & 0.19% (1999-2013) respectively (Kuchay & Ramachandra, 2016). The decline in forest cover was attributed to the increase in the built environment, which was extrapolated to the population increase in the district (Kuchay & Ramachandra, 2016).

In a study conducted by Pullanikkatil, Palamuleni and Ruhiiga (2016) in Malawi to assess LULCC in the Likangala river catchment and how the changes have impacted on ecosystem services, the authors used Landsat 5 and 8 images (1984, 1994, 2005 and 2013) to map land cover change. Post classification comparisons indicated that since 1984, there had been a decline in woodlands from 135.3km^2 in 1984 to 15.5km^2 in 2013 while urban areas increased from 9.8km^2 to 23.8km^2 in 2013. Pullanikkatil and colleagues pointed out that population growth, urbanization, and demands for agricultural land contributed to this change.

A regional study of the Upper West Region by Duadze (2004) sought to establish a causal relationship in the following parameters; the population, rainfall, soil fertility, and land use land cover change dynamics. The study utilized Landsat imageries for 1986, 1991 and 2001 to categorize six broad land use land cover classes comprising of farmland/bare land or constructed surface, close savannah woodland/riparian vegetation, open savannah woodlands with shrubs and grass, a mixture of grasses and shrubs with scattered trees, reserved woodland and water body. The analysis of Duadze's study showed that for the period of 1986 to 1991 open savannah woodland with shrubs and grass were the most extensive land cover followed by a mixture of grasses and shrubs with scattered trees, close savannah woodland/riparian vegetation, and farmland/bare land or constructed surface. In 2000, farmland/bare land or constructed surface, a mixture of grasses and shrubs with scattered trees, and water body increased spatially against a decrease in close and open savannah woodland (Duadze, 2004). Duadze (2004) concluded that there were changes in land use land cover in the Upper West Region over the fifteen years. This was attributed to an increase in farmland to feed an increasing population and the poor state of soil in the region (Duadze, 2004).

In a similar study in the northern forest - savannah transition zone of Ghana, Amanor and Pabi (2007) carried out a study to generate evidence-based information on LULCC dynamics that have prevailed in the study localities for the past ten years (1990-2001). The study by Amanor and Pabi, revealed a loss of 2.777.17 hectares (50.27%) of dense woodland; a marginal gain of 1,260.36 hectare (8.57%) of open woodland; a loss of 812.384 hectare (4.17%) in long fallow area; a loss of 1,343.12 (23.83%) in short fallow area; a marginal decline of 629.009 hectare (6.46%) of intensive cultivated area; and with less intensive cultivated area recording a gain of 7,307.285 hectare (62.35%).

2.5.2 Impact of land use land cover change on the environment

Common land-use practices such as crop cultivation, pastures, and grazing land, fuelwood harvesting, and bush fires have been noted for contributing to land degradation (FAO, 2016a; Mwingyine, 2008). Additionally, these practices contribute variably to loss of biodiversity or ecosystem services, loss of livelihoods, and climate change.

In Sub-Saharan Africa, land degradation is especially widespread, affecting 20-50% of land and livelihoods of some 200 million people. Land degradation is also felt in Asia and Latin America and other regions of the globe (United Nations Commission on Sustainable Development [UNCSD], 2000; UNCSD, 2002).

Also, land degradation threatens global food security and environmental quality. In Africa, inappropriate farming methods, deforestation, overgrazing and mismanagement of land resources have impacted 320 million hectares of land making it unproductive for agriculture purposes (Sant'Anna [2001] and Shher &Yadav [1996] as cited in Senayah, Kufogbe, & Dedzoe, 2005). Forest degradation and conversion to other land uses (MA, 2005) are the reasons for the change in the natural tropical forest ecosystem (FAO, 2015; FAO, 2016a, FAO, 2018). Land use land cover change affects ecosystem services and functions (FAO, 2016b). Studies have attempted to ascertain the direct and indirect drivers of tropical deforestation and the relationships among them (MA, 2005). The general conclusion is about the difficulty in isolating the cause of LULCC due to the complex socio-economic processes involved, and circumstances in which it occurs (Geist & Lambin, 2001).

Notwithstanding the complexity, it is clear that tropical deforestation is caused by a combination of direct and indirect drivers (Geist & Lambin, 2001; FAO, 2016b). Direct causes of deforestation have been identified to include agricultural expansion, urban growth, infrastructure development, and mining (FAO, 2016b). Indirect drivers of deforestation include demographic, economic, technological, social, cultural and political factors (Geist & Lambin, 2001; Millennium Ecosystem Assessment, 2005) that may operate at some distance from the forests they affect.

Deforestation in the tropics has the most significant impact on the carbon cycle of any land use and land cover change (MA, 2005). Globally, it is reported that land-use change (mostly deforestation) contribute 0.8-1.6 billion tons of carbon per year (Houghton, 1999 and 2003), although other estimates of net mean annual carbon fluxes from tropical deforestation and regrowth were 0.6 (0.3–0.8) and 0.9 (0.5–1.4) billion tons for the 1980s and 1990s (DeFries *et al*., 2002; MA, 2005). Land degradation and land-use change are the largest sources of greenhouse gas emissions in Africa (FAO, 2016a, and b). Soil and vegetation on the earth's surface store three times the carbon present in the Earth's atmosphere (FAO, 2016a and b). As land continues to degrade, livelihood options of at least 485 million Africans also dwindle (sited in Economic Commission for Africa, 2007, Africa review report on Drought and Desertification). As a result of land degradation in Ghana, the total land area at risk of desertification is approximately 83,489 km^2, i.e., 35% of the total land area of the country (EPA, 2002).

Average annual nutrient loss per hectare of arable land in Ghana in 1982, amounted to 30 kg N, 3 kg of Phosphorus (P) and 17 kilograms of Potassium (K) while the corresponding projected figures for 2000 were 35 kg N, 4 kg P and 20 kg K (Stoorvogel, Smaling & Janssen, 1993). Over 4.4 million tonnes N, 0.5 million tonnes of P and 3 million tonnes of K are lost every year from cultivated lands in Africa (FAO, 2015). Per capita food production has declined during the past three decades with the consequence of that food insecurity; malnutrition and poverty become a major problem (Vlaming *et al*., 2001).

2.6 Valuation of Ecosystem Services (ESV)

Globally, the use of valuation methods has increased due to the number of interest groups, corporations, governments, and researchers demanding economic values for non-marketed goods or services (TEEB, 2009). It is also attributable to international and national policies and environmental concerns (TEEB, 2009). Many in the environmental community are concerned about significant ecological losses (to species, water, and natural lands), and want to know the value lost if there were to be a substantial collapse in environmental quantity or quality (TEEB, 2009).

In recent times, ESV has gained prominence as a conservation strategy to reduce the degradation of ecosystems or erosion of ecosystem services (Morey, 2016; National Oceanic and Atmospheric Administration (NOAA), 1993; Hjerpe, Hussain & Philips, 2015). According to Hjerpe *et al*. (2015), valuation of the ecosystem is necessary for the restoration and preservation of ecosystem especially public goods. The Economics of Ecosystem and Biodiversity (2010) outlines six reasons for conducting the valuation. These are:

- Missing markets
- Imperfect markets and market failures
- For some biodiversity goods and services, it is essential to understand and appreciate its alternatives and alternative uses.
- Uncertainty involving demand and supply of natural resources, especially in the future.
- The government may like to use the valuation as against the restricted, administered or operating market prices for designing biodiversity/ecosystem conservation programs

- In order to arrive at natural resource accounting, for methods such as Net Present Value methods, valuation is a must.

Economic valuation has been applied in many studies across the globe in areas such as energy, health, ecosystems, and agriculture (Abdullah, Markandya & Nunes, 2011). Re-echoing the words of proponents of valuation:

> *"To say that we should not do valuation of ecosystems is to simply deny the reality that we already do, always have and cannot avoid doing so in the future"* (Costanza *et al.*, 1998 as cited in Salles, 2011).

> *"The world's ecosystems are capital assets if properly managed, they yield a flow of vital services, including the production of goods (such as seafood and timber), life support processes (such as pollination and water purification), and life-fulfilling conditions (such as beauty and serenity). Unfortunately, relative to other forms of capital, ecosystems are poorly understood, scarcely monitored, and (in many cases) undergoing rapid degradation and depletion. Often the importance of ecosystem services is widely appreciated only upon their loss"* (Daily, 2000).

Notwithstanding the emergence of valuation, a section of literature argues that the erosion in ecosystem services is due to the absence of valuation implying that whatever is not valued cannot be managed (MA, 2005).

Summary of valuation methods

Table 2.5 presents a summary of the valuation methods used to value ES. Details of these methods, their application, and use, as well as limitations, are widely available in the literature (Boyle et al., 1996; Hanley & Spash, 1993; Loomis,1990; Smith, 1989; Fletcher, Adamowicz & Graham-Tomasi, 1990; King & Mazzotta, 2000; Hanley, Mourato & Wright, 2001; Gürlük, 2006; Kumar et al., 2010; Morey, 2016; Wainger et al., 2017; Freeman, Herriges & Kling, 2014; Foster & Mourato, 2003; TEEB, 2010).

This study used the contingent valuation method to estimate the value of conservation in the Nandom District. A summary of findings from previous valuation studies using the contingent valuation method is presented below.

Table 2.5 Valuation method for ecosystem goods and services

	Revealed Preferences	**Stated Preferences**
Direct Methods	Monetary valuation at market prices, Avoided cost, productivity effects, Cost of restoration or Replacement	Contingent valuation
Indirect Methods	Prevention or protection expenditure, Travel cost, Hedonistic prices	Contingent ranking, Comparison by pairs, Joint analysis, Choice experiment, Choice modelling

Source: Salles (2011)

Brief findings on previous Contingent Valuation studies

In a study in Turky, Gürlük (2006), estimated the value of improving ES around the Misi Rural Development Project (MRDP) to be 2,306,474 USD/Year with respondents willing to pay 67.94 USD per head annually. Gürlük (2006) used the open-ended contingent valuation method.

Tao, Yan and Zhan (2012), estimated the economic value of forest ecosystem services in a typical deforestation-afforestation area in Jiangxi province, China. In their study, using a single-bound dichotomous choice method, Tao and colleagues found that, respondents were willing to pay at 238 Yuan per month yearly for both the restoration and preservation of the forest ES.

In Ghana, Bani and Damnyag (2017), applied an open-ended contingent valuation method to investigate farmers WTP for the provision of ES using food crops. Bani and Damnyag found that, 59% of farmers were willing to pay for the provision of ES and farmer's WTP were influenced by gender, age, educational status, farmers' perception to climate change, and access to land.

Alhassan (2012) conducted a CVM study in Northern Ghana on the Botanga Irrigation Scheme (BIS). Alhassan found that the mean value farmers were willing to pay for irrigation services was GHC 16.32 (US$8.5) per ha per year and median was GHC 14.00 (US$ 7.29) per ha per year. Alhassan used the payment card elicitation method.

In Tanzania, Lalika, Meire, Ngaga, and Sanga (2016) estimated farmers WTP for watershed services using the contingent valuation method. Lalika and colleagues found that positive factors influencing WTP for watershed conservation were education level, total land size, the yield from irrigated farm plot, marital status, household size, and distance from the water source. Other factors such as occupation, household size, income from irrigation and amount paid for irrigation were found to have a negative influence on WTP (Lalika *et al*., 2016)

Unlike the studies mentioned above, a study in Brazil found that respondents had low trust in public institutions, which negatively influenced WTP for the conservation of the forest (Bakaki & Bernauer, 2016).

2.7 Soil quality and contribution of nutrients from decomposing organic matter

Globally, agriculture productivity has been on the decline due to soil degradation with its effect on food security (Sustainable Development in the 21st century, 2012). According to Sileshi *et al*. (2014), soil degradation is the result of soil erosion and nutrient mining due to continuous farming. Soil erosion alone accounts for 83% of the global degraded area (Sileshi *et al*., 2014). It is estimated that in Africa, the annual average nutrient (Nitrogen-Phosphorus-Potassium) loss is 9-58 kg/ha/year in twenty-eight countries and 88 kg/ha/year in about thirty-three countries (Sileshi *et al*., 2014). The global analysis showed that Nitrogen (N) limitation was widespread in all ecosystems (Sileshi *et al*., 2014). It is therefore not surprising that N availability has been found low in Miombo woodland (Malmer, 2007) and the Guinea Savannah woodland in Ghana which has been subscribed to frequent fires (Buah & Opoku, 2013). Almost 80% of African countries experience N deficit resulting in food insecurity and malnutrition [Liu *et al*. (2010) as cited in van Alfen, 2014]. In terms of Phosphorus (P), a total of 29% of global cropland experiences P deficit. Average annual nutrient loss per hectare of arable land in Ghana in 1982, amounted to 30 kg N, 3 kg P and 17 kg of potassium (K) while the corresponding figures for 2000 were estimated as 35 kg N, 4 kg P and 20 kg K (Stoorvogel, Smaling & Janssen, 1993).

A model on the economic cost analysis of poverty implications on land degradation predicted that land degradation would reduce agriculture income in Ghana by a total of US$4.2 billion over the period 2006-2015 (Diao & Sarpong, 2007). The estimate was approximately five percent of total agriculture Gross Domestic Product (GDP) in these ten years (Diao & Sarpong, 2007).

Organic matter from litter decomposition may appear promising as an alternative source of nutrients application on farms. However, it constitutes nutrients are in inadequate quantities to meet the high application rates (10-40 Mg/ha/year) for the nutritional requirement of crops (Sileshi *et al*., 2014). Consequently, the use of inorganic fertilizer has been relied upon to increase crop productivity globally. The sole reliance on inorganic fertilizer comes with its setbacks due to the environmental consequence associated with its use and the cost of fertilizer. The emerging philosophy, therefore, is that adequate litter mineralization with moderately applied inorganic fertilizer can guarantee a win-win situation for the ordinary farmer (Sileshi *et al*., 2014). Mineralization of nitrogen from soil organic matter remains the principal source of nitrogen to plants in most forest ecosystems (Osman, 2013). Many farmers in arid and semi-arid tropics are yet to realize the full benefits of agroforestry practice.

Trees and crops compete for space, sunlight, and nutrients leading to the wrong 'compromise' which overrides the benefits of soil enrichment and microclimate improvements. Various authors (e.g., Sileshi *et al*., 2014; Whitmore, 1990) have reviewed the role of trees in soil productivity and conservation and hence have concluded that trees improve soils by:

1) Improvement in soil physical properties such as bulk density, aggregate stability water-holding capacity, and soil biological properties,

2) Increase nutrient addition to the soil through the build-up of organic matter, nitrogen and phosphorus fixation, and

3) Improvement in soil nutrient cycling and crop productivity, soil rehabilitation services, and carbon sequestration.

Nutrient losses such as NPK which is usually associated with soil degradation, contributes to soil nutrient deficiency. The incorporation of fertilizer trees on the agricultural landscape has been reported to lead to an increase in crop yield as evident by some studies (Isaac, Timmer & Quashie-Sam, 2007; Mweta, Akinnifesi, Saka, Makumba & Chokotho, 2007; Kho *et al*., 2001). Fertilizer trees capitalise on biological nitrogen fixation (BNF) in supplying N and organic matter to annual and perennial crops (Sileshi *et al*., 2014). This is accomplished by specialized bacteria living on nodules of plant roots that absorb atmospheric nitrogen gas and convert it into ammonium. The N-fixing tree is a tripartite symbiotic system involving an association between the plant, N-fixing bacteria, and mycorrhizae-forming fungi (Nygren, Fernandez, Harmand & Leblanc, 2012). Atmospheric N-fixation by symbiotic, single-celled bacteria (Rhizobia or Brady-rhizobia) in root nodules is common in 340 species of the family Leguminosae. N-fixation also occurs in over 200 non-leguminous plants species in 25 genera of eight families associated with *Frankia*, which are filamentous bacteria (Franche, Lindström, & Elmerich, 2009).

Agroforestry practices such as alley cropping, improved fallows, cereal-legume intercropping, biomass transfer, etc. capitalise on biological nitrogen fixation (BNF). In Latin America, coffee and cacao agroforestry, pruning residues and litterfall from shade trees have been found to contribute 60-340 kg N /ha/year (Beer, Muschler, Kass & Somarriba, 1998). According to a study on cacao agroforestry in Ghana, the ammonium sulphate fertilizer equivalence of *Albizia* leaves is 21-72 kg N/ha; the leaves could substitute 29-63% of fertilizer when applied to the soil at 2.5Mg/ha (Anim-Kwapong, 2006). Also, several empirical studies have reported a higher N and P soil concentration and uptake by crops in the presence of fertilizer trees (Isaac *et al*., 2007; Mweta *et al*., 2007; Kho *et al*., 2001). Palm, Myers, and Nandwa (1997), however, cautions that fertilizer tree innovation may not eliminate the need for P inputs in P deficient soil. He went further on to stress that plant material even when added in large quantities may provide less P than what is being required by the crop. This problem has been attributed to the low P concentration in plant residue. Fertilizer tree, have been noted to contribute an increase in soil organic manure (SOM). A compilation of studies in woodlands of West Africa (Boffa, 1999) report 11-100% increase in SOM under *Faidherbia* trees than in open areas.

Notwithstanding the many benefits associated with fertilizer trees, many authors have advocated for the combined use of organic and inorganic nutrients for sustainable agriculture (Sileshi *et al*., 2014). Within this goal, there is an excellent potential for more BNF and a reduction on the reliance in inorganic fertilizer use (Sileshi *et al*., 2014).

The current debate on sustainable intensification of agriculture will require both organic and inorganic fertilizer to improve crop and land management. This practice will also reduce the adverse effect of synthetic fertilizer on the natural environment (Mafongoya, Bationo, Kiharam & Waswa, 2006).

2.7.1 Decomposition of leaf litter

Litter decomposition is the process where the organic substance is physically broken down and converted into simple chemical substances, resulting in the release of water, carbon dioxide and energy (Chapman, 1986 as cited in Fernando & Bandeira, 2009). Decomposition rate can be described as the time taken by an organic substance to lose its mass to half of its initial value (Hogarth, 1986 as cited in Fernando & Bandeira, 2009). During the decomposition process, structural compounds accumulate while soluble minerals are initially leached and subsequently mineralized or immobilized depending on the demands of micro-organism (Osman, 2013). Generally, leaf litter decomposition follows an exponential decay function in which the remaining mass declines asymptotically towards zero (Cotrufo, Del Galdo & Piermatteo, 2010). The single exponential equation given by Olson (1963), therefore remains the simplest way of determining the rate of litter decomposition within different ecosystems.

$$\frac{X}{X_0} = e^{-kt}$$

Where X is the weight remaining at time t, X_0 the initial weight, e (exponent) is the base of the natural logarithm, k is the decay rate coefficient, and t is the time of placement.

Leaf litter decomposition is mainly a function of climate (temperature, rainfall), leaf litter quality and biological diversity and activities of decomposer community, etc. (Osman, 2013; Cotrufo *et al.*, 2010). By climate, faster decomposition rates are measured under wet and warm conditions, which explain the higher decomposition of litter in the tropics than temperate regions (Bayala *et al*., 2005).

2.7.2 Litter quality

Leaf litter quality is associated with a very fast decay rate, high N and P concentration as well as a high proportion of biodegradable carbon-based compound (Semwal, Maikhuri, Rao, Sen, & Saxena, 2003). Some researchers have adopted climatic and leaf litter quality indexes in qualifying decomposition, due to the absence of a universal index (Senwal *et al.*, 2003). Available literatures suggest that plant materials with attributes such as N > 1.7%, lignin < 15%, polyphenol < 3% and C/N ratio < 20 could be a good predictor of decomposition (Senwa.*et al.*, 2003; Cotrufo *et al.*, 2010). Therefore, species within this given range of attributes would experience mineralization, while those outside the range immobilization (Constantinides & Fownes, 1993; Bayala *et al*., 2005). Semwal *et al*. (2003), however, argues that this generalization may not apply to all tree species. As evident in their work, species such as *A. nepalensis, A. lebbek, D. sissoo,* and *F. glomerata* with polyphenol > 3% and *B. rugulosa* with C/N ratio >20 did not immobilize N (Semwal *et al*., 2003). Additionally, *F. roxburghii* with < 15% lignin concentration showed prolonged immobilization (Semwal *et al*., 2003). The C/N ratio has since remained the most widely used predictor of decomposition rate even though it does not consider the availability of nutrients for microbial growth.

2.7.3 Litter decomposition rate

Under the influence of the prevailing climatic environment, different litter species have their specific rate of decomposition, which governs the rate at which nutrients are released from the litter (Das & Chaturvedi, 2005). Hossain, Siddique, Rahman, Hossain, and Hasan (2011) reported the highest rate of decomposition for *M. azadirachta* (3.6 % per day) followed by *A. indica* (2.9 % per day) and *D. sissoo* (2.4% per day) for a study conducted in Bangladesh.

Bayala *et al*. (2005), from Burkina Faso, compared decomposition of confined leaf litter in a litter tube study of *P. biglobosa* and *V. paradoxa* found a higher rate of decomposition for *P. biglobosa* compared to *V. paradoxa*. At the end of the study, less than 32% of *P. biglobosa* leaf material remained while 43 % of the leaf material of *V. paradoxa* remained undecomposed (Bayala *et al*., 2005).

Hasanuzzaman and Hossain (2014), observed high rates of decomposition for the following four species; *Magnifera indica*, *Litchi chinensis*, *Artocarpus heterophyllus*, and *Zizyphus jujube* for the first thirty days. It was followed by a gradual mass loss for the subsequent 150 days, depicting the initial and advanced stage of decomposition (Hasanuzzaman & Hossain, 2014). The study also found the decay constant within the range of 2.34-0.94 in the wet season (Hasanuzzaman & Hossain, 2014).

Hossain *et al*. (2011) reported a decay constant within the range of 3.46 -2.35. The initial rate of decomposition (10 days) was the highest (2.35% per day) for *Z. jujube* and the lowest (0.79 % per day) for *L. chinensis* while the final rate of decomposition (180 days) was the highest (0.32% per day) for *A. herophyllus* and the lowest (0.14% per day) for *L. chinensis* in the wet season (Hossain *et al*., 2011).

Semwal *et al*. (2003) conducted a litterbag experiment to examine the decomposition of six litter types, namely *Alnus nepalensis, Albizzia lebbek, Boehmeria rugulosa, Dalbergia sissoo, Ficus glomerata*, and *F. roxburghii*. The study was carried out in a mixed plantation established on an abandoned agricultural land site in a village at 1200 meters altitude in Central Himalaya, India (Semwal *et al*., 2003). The decomposition was measured over one year. Mass losses after a year were between 30 and 50% (Semwal *et al*., 2003). *A. nepalensis, A. lebbek, D. sissoo,* and *F. glomerata* showed three phases in mass loss, N, and P release (Semwal *et al*., 2003). There was a slow loss in the initial period of incubation, rapid loss during the intermediate phase, and again, a low loss during the end of the year (Semwal *et al*., 2003). *B. rugulosa* and *F. roxburghii* showed two phases in mass loss and P release (Semwal *et al*., 2003). Semwal *et al*. (2003) observed a faster decomposition for *A. lebbek, A. nepalensis, D. sissoo,* and *F. glomerata* compared to *B. rugulosa* and *F. roxburghii*. The authors concluded that the fast decomposing species could be used in restoring degraded land (Semwal *et al*., 2003). Similar conclusions were drawn in the works of Hasanuzzaman and Hossain (2014), for the fast decomposing species.

Litter decomposition rates were studied in exotic nitrogen (N)-fixing black locust (*Robinia pseudoacacia*) plantation and an indigenous non-N-fixing oak (*Quercus liaotungensis*) forest near Yan'an, on the Loess Plateau, China (Tateno *et al*., 2007). Tateno *et al*. (2007) observed a higher decomposition rate of black locust leaves than that of oak leaves, most likely because of the higher N content of black locust leaves. These results suggested that N cycling was greater and faster in the black locust plantation than in the oak forest (Tateno *et al*., 2007).

Tree species can affect the decomposition process through the quality of their leaf fall and the species-specific conditions that they generate in their environment (Aponte, Garcia & Marañón, 2012). In a sub-tropical evergreen forest of Okinawa Island, Japan, litterbags containing leaf litter of indigenous species such as *Castanopsis sieboldin, Schima wallichii, Elaeocarpus japonicus* and *Daphniphyllum teijsmannii* were monitored over twelve months (Alhamd, Arakaki & Hagihara, 2004). Alhamd *et al*. (2004) observed the last species to have the highest initial N concentration and the fastest rate of decomposition compared to the others.

2.7.4 Litter nutrient lost/remaining

Nutrient release pattern from decomposing leaves in the tropical forest follows three patterns. An initial phase characterized by leaching and nutrient release, a net immobilization phase where nutrients increase due to the presence of microbes, and a net release phase where nutrient mass decrease. However, not all these stages are present in a practical experiment. For example, the immobilization phase may be absent in litter with high N concentration (Seta, Demissew, Woldu & Lemenih, 2016).

Mechanical leaching occurs especially during the initial stages of decomposition often causing loss in major nutrients such as potassium (K), calcium (Ca), magnesium (Mg) and sodium (Na) (Bayala *et al*., 2005; Hasanuzzaman & Hossain, 2014; Slovic, 1997 as cited in Seta *et al*., 2016). Many authors have noted the decomposition dynamics of K, Ca, and Mg during litter decomposition (Seta *et al*., 2016). Potassium (K) is rapidly leached from the onset of decomposition, Ca decreases with carbon loss, and Mg often show an intermediate release pattern.

Some elements are found to be released only at an advanced stage of decomposition. Nitrogen (N) in most cases is released after more than 50% mass loss has occurred (Bayala *et al*., 2005; Semwal *et al*., 2003) while sometimes nitrogen and phosphorus (Gosz, Likens & Bormann, 1973) are even accumulated in decomposing litter due to microbial immobilization. Short immobilization of nitrogen occurred in *V. paradoxa* litter for the first two months, followed by low net mineralization with subsequent release of phosphorous, calcium, and magnesium (Bayala *et al*., 2005). In a litterbag study with litters of *Picea mariana*, *Cladina stellaris*, *Betula glandulosa,* and *Ledum groenlandicum*, Moore (1984) observed that Ca, Mg, and K were rapidly lost from the decomposing tissues, except for *C. stellaris*. All the tissues, except *B. glandulosa*, showed an accumulation of N, associated with high C/N ratios.

CHAPTER THREE

3.0 MATERIALS AND METHODS

The study was conducted within the Wa-Bobo-Dioulasso-Bamako transect, a semi-arid region where the Adaptation at Scale in Semi-Arid Regions (ASSAR) Project (2014-2018) was implemented. This study applied four different methods to collect data. These were Cross-sectional survey, Contingent Valuation, Mapping, and Leaf litter experiment. These methods are described in this chapter.

3.1 The study area: Nandom District

3.1.1 Geographic and physical features

3.1.1.1 Geographic location and size

The Nandom District is located at the North-Western corner of the Upper West Region between longitudes 2°25"W and 2°45"W and latitudes 10°20"N and 11°00"S (Nandom District Assembly, 2014). The district is bounded by the Lambussie-Karni District to the East, the Lawra District to the South and the Republic of Burkina Faso to the North and West. The total area of the District is 567.6 square kilometres (sq. km), which constitutes nearly 3.1% of the Region's total land area (Ghana Statistical Service [GSS], 2014a). The District has 85.0% of its inhabitants living in rural areas (GSS, 2014a).

The Nandom District is politically divided into four Area Councils: the Nandom Town Council, Baseble Area Council, Puffien Area Council and Ko Area Council. Figure 3.1 shows a map of the study area.

Figure 3.1 Map of Nandom District (Source: Centre for Remote Sensing and Geographic Information Services, University of Ghana, Accra)

According to the GSS (2014a) and Nandom District Assembly (2014), the district's closeness to Burkina Faso offers it a strategic location for international interactions and exchanges. It, however, poses a challenge related to the influx of Fulani herdsmen into the district from the Sahel.

3.1.1.2 Geology

The District is within a geological region characterized by Birimian and granitic rocks, with a gently undulating topography (GSS, 2014a). As a result, the main soil types in the District are sandstone, gravel, mudstone, alluvium, granite, and shale that have weathered into different soil grades (GSS, 2014a; Nandom District Assembly, 2014). Due to seasonal erosion, soil types emanating from this phenomenon are sand, clay, and laterite ochrosols (GSS, 2014a; Nandom District Assembly, 2014). The availability of these soil types has contributed to housing development, which has resorted to the use of local building materials such as sand, gravel, and clay (GSS, 2014a; Nandom District Assembly, 2014).

3.1.1.3 Geomorphology

The more significant part of the UWR is underlain by granites, Birimian formations, and basic intrusives (Bates, 1962). Due to continuous erosion, the topography of the region is generally flat to gently undulating with most slopes having a gradient of 4% (Dickson & Benneh, 1988). The general terrain consists of a series of dissected plateaux, which average between 180 and 300 meters above sea level with higher sporadic hills or inselbergs of Birimian rocks or granites at few locations (Duadze, 2004; GSS, 2014a).

3.1.1.4 Soils

The soils of the District are closely related to the underlying geology, which is made up mainly of granite and in isolated places, Biriman rocks and sandstone (GSS, 2014a). The granites are known to produce loamy-sand or sandy-loam on weathering. The Birimian rocks are phyllites, greywackes, and quartz sericite schist, which weather to produce sandy-clay to clay soils with common to many quartz gravel and stones occurring on the topsoil layer (Bates, 1962). Areas with sandstone also produce sandy soil. In many places, they are shallow and underlain by iron pans and can also be concretionary (Duadze, 2004).

Most of the soils vary in depth ranging from < 30 to > 80cm, and in most cases, the soil types that dominate in UWR are laterite, sandy, and sandy loam (savannah ochrosols) (Buah & Opoku, 2013). Their organic matter content, buffering capacity, and cation exchange capacity are low (EPA, 2002). The soils are consequently of low inherent fertility with nitrogen and phosphorus as the most deficient nutrients (EPA, 2002). The area consists of the iron pan and shallow concretionary and rocky soils which have low water-holding capacities and limited suitability for agriculture.

3.1.1.5 Drainage

The Black Volta River forms a boundary to the west with the Republic of Burkina Faso (GSS, 2014a). It is a major river considered as a potential for aquaculture (GSS, 2014a). Also, dams and dugouts are serving as source of water for irrigation, domestic chores, construction, and animals on graze (GSS, 2014a). The interconnected water bodies in the district facilitate stormwater drainage, thus making the district less floodable, except in few low-lying areas (GSS, 2014a). These minor rivers and streams are reduced to seasonal pools while others completely dry up in the dry season (GSS, 2014a).

3.1.1.6 Climate

The District falls within the tropical continental climatic zone (GSS, 2014a). According to Owusu and Waylen (2009), mean annual rainfall amounts in the Guinea and Sudan Savannahs have declined by 10%. The average annual temperature is said to have increased by 1℃ in the last thirty years (Yangyuoru *et al*., 2014).

Rainfall

The rainfall pattern in Nandom district is uni-modal (single season) lasting 5-6 months starting from between April and May, reaching a peak in August and ending in October (GSS, 2014a). The average rainfall is 885 mm, with average annual effective rainfall estimated at 685 mm (Yangyuoru *et al*., 2014). Due to the rainfall dependency of crop production, the start and duration of the cropping seasons are mostly determined by the start and length of the rainfall season. While the offset or end periods of the rainfall are generally stable, the onset or starting periods vary markedly (Yangyuoru *et al*., 2014).

Temperature

Throughout the year, temperatures are high with a minimum of 23℃ at night and a maximum of 42℃ during the day (GSS, 2014a; Nandom District Assembly, 2014). The mean monthly temperature ranges between 21℃ and 32℃ (GSS, 2014a; Nandom District Assembly, 2014). The highest monthly maximum temperature rises to 40℃ before the rainy season usually in May with the lowest minimum temperature falling to about 12℃ in December when the Harmattan winds from the Sahara dry up the vegetation (GSS, 2014a; Nandom District Assembly, 2014). The range in temperature favours plant growth.

3.1.1.7 Vegetation

The District falls within the Guinea Savannah vegetation zone, which covers almost the northern two-thirds of the country with an area of 147,900 km^2 (GSS, 2014a; Nandom District Assembly, 2014). The vegetation is characterized by drought-resistant trees such as the *Acacia spp*., *Adansonia digitata*, *Vitellaria paradoxa*, *Parkia biglobosa*, *Mangifera indica*, *Ceiba pentandra* and *Azachdiracta indica*, interspersed with grasses such as *Andropogon gayanus* and *Heteropogon contortus* (Blench & Dendo, 2004; GSS, 2014a). The vegetation contributes to livestock production, which contributes significantly to household incomes in the district (GSS, 2014a). It also provides ecosystem services serving as an alternative source of livelihood in the dry season, more especially the provisioning services (Boafo *et al*., 2014).

The most considerable influence on the vegetation is the prolonged dry season and human activities (Nandom District Assembly, 2014). Human activities such as bush burning, indiscriminate tree felling for fuelwood, charcoal production, and poor animal husbandry practices have continuously decreased the vegetation cover (EPA, 2002; GSS, 2014a; Nandom District Assembly, 2014). Consequently, increasing soil erosion and depletion of soil fertility are common occurrences (EPA, 2002; GSS, 2014a). Moreover, inappropriate farming practices such as shifting cultivation, road construction, sand, and gravel winning increase land degradation (GSS, 2014a; Nandom District Assembly, 2014).

3.1.1.8 Fauna

In Nandom District, species of diversity and conservation include *Hippotragus equinus* (Roan Antelopes), *Neotragus pygmaeus* (Royal Antelopes), *Erythrocebus patas* (Pastas Monkey), *Cricetomys gambianus* (Rat), Eimaceus spp (Ground squirrels), *Animalurus spp* (flying squirrels), *Ptilopachus petrosus* (Stone Partridges), *Python sebae* (African Python), rabbits and grasscutters (Bangwon Bawo Forest Reserve Plan, n.d.). Also, domesticated animals ranging from poultry to livestock are reared on subsistence and commercial basis. The engagement in these domesticated animals serves as major source of employment, income, food, as well as socio-cultural values (Naazie & Canaacoo, 2007).

3.1.1.9 Land Use

The general pattern of land use includes agricultural or non-agricultural. The agricultural land use includes cultivated annual and tree crops, bush fallow, and unimproved pasture. The major annual crops are classified as cereals, root crops, pulses and nuts, and vegetables with the cereals being cereals are maize, millet, and sorghum. The non-agricultural land use includes forest reserves, wildlife reserves, unreserved closed forest, unreserved savannah lands, mining, settlements, and institutional uses (EPA, 2002).

A land use land cover study conducted by Duadze (2004) of the entire UWR saw an increase in farmland/bare land/constructed surface (a mixture of grasses and shrubs with scattered trees), and a decrease in close savannah woodland/riparian vegetation, and open savannah woodland with shrubs and grasses. In Duadze's study, conducted over a period of 1986 to 2000, the results were attributed to the rise in population growth.

3.1.2 Demographic and Socio-economic characteristics of Nandom District

3.1.2.1 Demographic and socio-economic characteristics

According to the Ghana Statistical Service (2014a), Nandom had a population of 46,040 in 2010 with 48.2% being male and 51.6% being female. The average annual growth rate of the Upper West Region was 1.9% (GSS, 2012). The projected population of the Nandom District for 2017 and 2018 were 52,589 and 53,598 respectively. The sex ratio was 93.89 males per 100 females in the District (GSS, 2014a). The average household size in the Nandom District was 6.0 persons per household (rural, 6.2; and urban, 5.3 persons per household) (GSS, 2014a). Table 3.1 presents a summary of population distribution and socio-economic characteristics of the Nandom District.

The predominant tribe in the District is the Dagaaba. Other tribes present in the district include Sissala, Mossi, Hausa, and Asante (GSS, 2014a). The extended family system is widely practiced in all communities in the Nandom District. Each community is led by a leader (chief or sub-chief) and recognized as one social entity (GSS, 2014a). The extended family system and community engagement system and governance provide support to households in varying forms (GSS, 2014a).

There are no available statistics on the number of people migrating from or to the Nandom District. However, studies have shown a seasonal variation in migration patterns (Geest, 2011). During the dry season, migrants from the Nandom and neighbouring districts migrate to work on farmlands in the Southern part of Ghana (Geest, 2011).

Table 3.1 Population distribution and socio-economic characteristics of Nandom District

Characteristic	Percentage	Remark
Population distribution by age		
0 – 14 years	37.3%	Age dependency ratio: 82.8 dependents to 100 people in working age 15-64 years
15 – 64 years	54.7%	(Rural- 87.4 per 100; Urban- 60.4 per 100)
65 years and more	8.0%	
People living with Disability (PWD)	3.3%	48.5% of PWD are male and 51.5% female. 91.8% of PWD live in rural areas
Household distribution by sex of household head		
Male-headed	78.1%	
Female-headed	21.9%	
Population Distribution by religious affiliation		
Catholic	84.8%	
Non-Catholic Christian	0.8%	
Moslem	6.6%	
Traditional	5.7%	
No religious affiliation	2.0%	
The population who are economically active	67.5%	48.5% being male and 51.5% were female 97.3% of the economically active population was employed. 78.2% of the employed population are into agriculture
Households in agriculture	85.3%	98% in crop farming; 0.3% in tree planting; 55.7% in livestock rearing; 0.1% in fish farming

Source: Ghana Statistical Service (2014a)

3.1.2.2 Poverty in Nandom District

The Upper West Region has been noted as the poorest region in Ghana with seven out of every ten persons considered poor (GSS, 2014b). According to the Ghana Statistical Service (2015), the poverty incidence, the proportion of the population that is poor, in the region is 70.7%. The Nandom District recorded poverty rate above 70% with a wide poverty gap (GSS, 2014b). The incidence of poverty in the Nandom District is estimated between 70.0% and 79.9% (GSS, 2015). The poverty depth, is estimated between 40.0% and 44.9% (GSS, 2015) which is an indicator of living below the poverty line. Generally, across Ghana, the incidence of poverty was high among smallholder farmers, female-headed households, and uneducated household heads (GSS, 2014b).

3.1.2.3 Governance and development priorities

The Nandom District Assembly is the highest political and administrative decision-making body in the district. The District Assembly is made of 38 assembly persons (25 elected and 11 appointed by government assembly persons, the Chief Executive Officer and the Member of Parliament). The Nandom District has one paramount Chief and supported by 17 Divisional Chiefs. The traditional governance system compliments the decentralized political and administrative system. For political-administrative purposes, the district is divided into one Town Council and three Area Councils (Nandom District Assembly, 2014). There are twenty-two Unit Committees in the district (Nandom District Assembly, 2014; GSS, 2014a).

Agriculture modernization and sustainable natural resource management is a major development priority area of the District (Nandom District Assembly, 2014). Hindrances to sustainable natural resource management in the District includes: the lack of preservation of economic trees, inadequate tree growing, and wildlife conservation practices, and increased bush fires (Nandom District Assembly, 2014). This also includes the absence of monitoring and regulation on charcoal producers, high level of land degradation, and lack of monitoring herdsmen (Nandom District Assembly, 2014). Activities stipulated in the Medium-Term Development Plan (2014-2017) of the Nandom District Assembly (2014) included training of farmers on compost preparation, establishing community woodlots, introducing and enforcing by-laws to preserve economic trees, promoting afforestation and establishing rangeland.

3.2 Cross-Sectional Survey

3.2.1 Cross-sectional study design

The cross-sectional survey fieldwork, was conducted from November 2017 to May 2018. Since the data to answer research questions were collected at one time, historical data on uses of woodlands were explored during the cross-sectional survey to explain changes in land cover found by mapping. The cross-sectional survey was conducted in the Nandom District to assess the benefits farming households derive from woodland ecosystem services. As a result, there were challenges in describing some specific benefits related to cultural, regulating, and supporting services. Therefore, proxy definitions, which could be easily understood by respondents and translated in the local language, were used. It is therefore not surprising to see empirical studies being limited only to provisioning service without the other three dimensions.

To achieve the second objective of this study on relationship between knowledge on climate change and woodland management practices. The level of knowledge of climate change was assessed using 23 questions. These questions explored respondents' reasons for the changes in rainfall and temperature patterns (i.e., the proxy definition of climate change in the local context). Additionally, local actions taken to prevent climate change were explored. The level of knowledge of climate change was assessed using 23 questions. Addressing objective three were based on the premise that adaptation leads to long term benefits while coping responds to short term reliefs to the impact of climate change (Taylor *et al.*, 2010). Therefore, adaptation would lead to wealth creation which relates to the economic wellbeing of households which can be used using the wealth index.

In addition to the household survey, key informant interviews and focus group discussions were conducted. These provided additional qualitative data on access and use of woodlands.

In section 3.3, the Contingent Valuation Method (CVM)is described. However, data collection tools (Appendix II) were integrated into the cross-sectional study design. Therefore, the sample size estimation, and sampling techniques for CVM, pretesting of CVM tool (Appendix II), data handling and data analysis are included in this section. Additionally, the study population for CVM was the same as that for the cross-sectional study.

3.2.2 Data collection tools and techniques

A researcher-administered questionnaire was used to collect quantitative data from households. Qualitative data through focus group discussions (FGD), and key informant interviews (KII) were collected using a focus group discussion guide and a key informant interview guide, respectively. All participants in the FGDs and KIIs, except one key informant, did not consent to the recording of interview sessions.

3.2.3 Study population

The study population consisted of farming households in the Nandom District of the Upper West Region. A household was defined as “a person or group of related and unrelated persons who usually live together in the same dwelling unit(s) or in connected premises, who acknowledge one adult member as the head of the household, and who have common cooking and eating arrangements” (GSS, GHS & ICF International, 2015). Households, instead of individuals' characteristics, were helpful to explain the collective roles individuals in farming households play in accessing woodland ecosystem services as well as the collective interaction between the different households. Of primary interest were crop farming households whose activities may influence the woodland ecosystem.

3.2.4 Study Variables

From the conceptual framework of this study, variables were broadly categorized into predictor variables (household factors and respondent characteristics), dependent variables, and confounding variables. For analysis, dependent variables were classified into two categories- intermediate variables and outcome variables. The intermediate variables may be influenced by predictor variables and by themselves cause variation in the outcome variables. For example, the wealth index (WI) of households (HH), which indicates their socio-economic status (SES), is an aggregate of individual household assets. Thus, WI/SES is both a predictor variable and an outcome variable.

Table 3.2 (a and b) present the independent/predictor variables of the study, and Table 3.3 shows the dependent (intermediate) variables for this study. The following definitions, adapted from the United Kingdom's Department for International Development (DFID) Sustainable Livelihoods Framework (DFID, n.d.), are applicable to describe the types of capital.

- Human Capital: Skills, knowledge, the ability to work, capacity to adapt and good health
- Social Capital: The social resources that people draw on to make a living, such as a relationship with either more powerful people (vertical connections) or with others like themselves (horizontal connections or membership with groups or organizations
- Natural Capital: The natural resource stocks that people can draw on for their livelihoods, including land, forests, water, air, and so on.

- Physical Capital: The basic infrastructure that people need to make a living, as well as the tools and equipment that they use — for example, transport and communication systems, shelter, water and sanitation systems, and energy.
- Financial Capital: Savings, in whichever form, access to financial services, and regular inflows of money

Social Differentiated Groups

Social differentiation is defined as "the distinction made between social groups and persons on the basis of biological, physiological, and sociocultural factors, as sex, age, or ethnicity, resulting in the assignment of roles and status within a society" ("Social differentiation," n.d.). A social category is a collection of people who do not interact but who share similar characteristics ("Social Groups," n.d.). A social category is different from a social group, which is a "collection of people who interact with each other and share similar characteristics and a sense of unity" ("Social Groups," n.d.). This study used a cross-sectional methodology, and adopts social differentiated categories since the degree of interactions among individuals within each category are unknown or uncertain. Thus, socially differentiated groups and categories are used interchangeably. The following socially differentiated categories were identified in the study:

- Sub-District and settlement
- Sex of household head
- Dependents in households, i.e., children less than 15 years and adults 65years or more
- People living with disability in households
- Household size
- Household socio-economic status
- Household ownership of agricultural land

- Availability of household assets (bicycles, motorcycles, and animal-drawn carts)
- Household possession of farm animals

3.2.4.1 Predictor Variables

Table 3.2a Predictor variables - Household factors

Household factor/ characteristic	**Type of variable**	**Type of capital**
Sub-district	Categorical (nominal)	Social Capital
Settlement (rural or urban)	Categorical (nominal)	
Sex/ gender of household (HH) head	Categorical (dichotomous)	
Household socio-economic status	Categorical (ordinal)	
Household size	Numerical (discrete)	
Household members that work	Numerical (discrete)	Human Capital
Children less than 15 years in HH	Numerical (discrete)	
Adults 65 years and more in HH	Numerical (discrete)	
People living with some form of disability in HH	Numerical (discrete)	
The proportion of household members on health insurance	Measurement variable	
Ownership of agricultural land	Categorical (dichotomous)	Natural Capital
Size of agricultural land	Numerical (continuous)	
Trees on farmland	Categorical (dichotomous)	
Ownership of Tree plantation	Categorical (dichotomous)	
Main material used for the roof of the house	Categorical (nominal)	Physical Capital
Main material used for the floor of the house	Categorical (nominal)	
Main material used for exterior walls of the house	Categorical (nominal)	
Main source of drinking water for household	Categorical (nominal)	
Kind of toilet facility household members use	Categorical (nominal)	
Electricity in household	Categorical (dichotomous)	
Wall clock in household	Categorical (dichotomous)	
Radio in household	Categorical (dichotomous)	
Colour television in the household	Categorical (dichotomous)	
Mobile telephone	Categorical (dichotomous)	
Main type of fuel used in household	Categorical (nominal)	
Household member possession of - bicycle - motorcycle - animal-drawn cart	Categorical (dichotomous)	
Ownership of livestock, herds and other farm animals and poultry	Categorical (dichotomous)	Financial Capital
Number of animals/poultry (each type)	Numerical (discrete)	
Bank account by any member of the household	Categorical (dichotomous)	
Knowledge resources/systems available to household	Categorical (nominal)	Other (Social and physical)

Table 3.2b Predictor variables - Respondent Characteristics

Respondent characteristics	Type of variable	Type of capital
Relation to Household Head	Categorical (nominal)	Social capital
Sex	Categorical (dichotomous)	
Age	Numerical (continuous)	
Marital Status	Categorical (nominal)	
Ethnic Group	Categorical (nominal)	
Occupation	Categorical (nominal)	Financial Capital
Migration status (last dry season)	Categorical (dichotomous)	Social and financial Capital
Educational status (level reached)	Categorical (ordinal)	Human Capital
Level of knowledge on climate change	Measurement variable	

3.2.4.2 Intermediate Variables

Table 3.3 Intermediate variables - Human activities

Intermediate Variable	Type of variable	Element on Conceptual framework/ Remarks
Access to Woodlands - Reserve woodland - Community Woodland/trees - Tree plantation	Categorical (dichotomous)	Endowment and/or Entitlement Woodlands were categorized into three types to understand any variations in access and use of ES.
Woodland Conservation Practices - Positive practices - Negative practices	Categorical (nominal)	Preferences
On farm adaptation practices	Categorical (nominal)	Preferences
Alternate livelihood options of household members	Categorical (dichotomous)	Other means of livelihood
Types of alternative livelihood options by HH members	Categorical (nominal)	
Type of alternate livelihood options from woodlands	Categorical (dichotomous)	
Importance of other livelihood option on - Household income - Food availability	Categorical (ordinal)	

3.2.4.3 Outcome variables

The outcome variables assessed were benefits derived from woodland ecosystem services and willingness-to-pay for the conservation of the woodland ecosystem. Additionally, the ranking of ecosystem services by respondents to understand the importance of ecosystem service benefits to households was undertaken. As already mentioned, the Wealth index, which measures the "total wealth" of households is both a predictor variable and an outcome variable. The wealth index is a measure of material or economic well-being (Smits & Steendijk, 2013; Rutstein & Staveteig, 2014), as the composite variables evaluate household assets, wealth and health security (number of households on health insurance).

Benefits derived from ecosystem services

The classification of ecosystem service by the Millennium Ecosystem Assessment (2005) was adopted for this study. It was difficult to describe some specific services within the supporting and regulating services categories in the local language or simple terms that the respondents would understand, therefore, proxy descriptions were used. The proxy description may not necessarily fit into the classical description as defined by the Millennium Ecosystem Assessment (2005).

Three types/categories of savannah woodlands accessible to farming households were identified in the Nandom District. These were National Forest Reserve (Reserve woodland) which shares a boundary with the Nandom District; community woodlots and/or scattered trees (community woodland); and household, family, or household member-owned plantations/woodlots (family plantation). These three types of woodlands were grouped as mentioned to explore any differences in access and use as well as hindrances to access and use of ecosystem services.

Statements explaining cultural, regulating, or supporting services were used to explore direct and indirect benefits derived from woodlands. Provisioning services were the easiest to understand and related to by all respondents. The following were the provisioning services investigated: food crops, bush meat, edible vegetables, wild fruits, medicinal plants, fodder, fuelwood, fibre/straw, poles for construction, soil for construction, and water.

Supporting services were the most difficult to define/describe or explain during pretesting. Therefore, questions were narrowed to nutrient cycling, which was easily understood by respondents and could easily be translated into the local language. Table 3.4 describes the Cultural, Regulating, and Supporting Services investigated.

Only households with access to a type of woodland were further asked on the benefit they derived from that woodland, uses of provisioning services and barriers and/or enablers to access to the woodland. This was adopted to prevent and/or minimize responses on perceived benefits household derived from woodlands.

Ranking of ecosystem services (ES) importance

Ranking of the level of importance of ES was done using beads. Respondents were asked to rank, on a scale of 0-10, the level of importance of each ecosystem service derived from Savannah Woodland. The values from ranking were then translated into the standardized Likert Scale's level of importance (Table 3.5). Notably, it was challenging to define the level of importance according to the Likert scale in the local language. Also, ranking in quantitative terms allows for the calculation of measures of dispersion, i.e., mean, mode, and median for each benefit.

Table 3.4 Proxy definitions to describe Cultural, Regulating and Supporting Services

Ecosystem service	**Statements/Proxy definitions or descriptions**	**Type of variable**
Cultural Services		
Spiritual/Religious	Visit specific woodland for traditional rites/prayers/	Categorical- nominal
Aesthetic	Visit specific woodland to admire nature/relax?	Categorical- nominal
Recreational	Visit specific woodland to play/enjoy yourself?	Categorical- nominal
Educational	Visit specific woodland to learn/teach?	Categorical- nominal
Regulating Services		
Air quality maintenance	Enjoy fresh air from trees	Categorical- dichotomous
	Enjoy filtered air during harmattan	
Storm protection	Trees serve as windbreaks	Categorical- dichotomous
	Trees protect close by buildings	
Erosion control	Trees protect farmland soil erosion	Categorical- dichotomous
Supporting Services		
Nutrient cycling	Benefit from fertile woodland/farmland rich in the litter (organic matter from trees)	Categorical- dichotomous
	Benefit from crop yield due to fertile woodland	Categorical- dichotomous
	Save money on fertilizer due to fertile land	Categorical- dichotomous
	Benefit from continuous farming on the same farmland	Categorical- dichotomous

Table 3.5 Grouped Ranking of Ecosystem Services importance and Likert scale equivalent

Grouped Ranking	**Likert scale responses**
0-2	Unimportant
3-4	Of little Importance
5-6	Moderately Important
7-8	Important
9-10	Very Important

3.2.4.4 Confounding variables

Confounding variables that may influence access to woodland ES in the Nandom District included barriers and enablers to ES and migration.

Barriers and enablers to accessing Ecosystem Services

The following categories were assessed for barriers and enablers that influence access to woodland ES: Governance/regulation, geographic factors, and socio-economic characteristics. These categories were adapted from MA (2005) and ASSAR Regional Diagnostic Study for West Africa (Padgham *et al.*, 2015). For each category, specific factors were outlined as in Table 3.6 and respondents/households selected one option among four options- enabler, barrier, both barrier and enabler, and neither barrier nor enabler. This approach was used to assess how each household/respondent perceived each factor within a category and prevent selection bias.

Only households with access to a particular woodland type were asked questions to identify what they considered enablers, barriers, both barriers and enablers, and neither. This approach was to find out the major constraints and/or promoters to the access and use of woodland ecosystem services. Additionally, it was to eliminate or limit the influence of household perceptions on access to woodlands but rather, present real factors that influenced access to woodlands.

For this study, the following definitions are used for analysis:

- Barrier- a factor that limits or prevents access to woodland ES in more than 50% of households.
- Enabler- a factor that promotes access to woodland ES in more than 50% of households.

The 50% limit was used to define a barrier or enabler and identify factors that affect more than 50% of the population.

Table 3.6 Barrier and Enabler categories investigated in this study

Governance/Regulation	**Geographic factors**	**Socio-economic factors**
• Government or Forestry Commission Regulation • Community regulation/rules • Family rules • Community Customs • Access to land/land tenure	• Distance to woodlands • Road condition • Means of transport • Security during travel • Equipment to harvest resources • Transportation of harvested products	• Poverty • Awareness of ES availability • Benefits derived from ES • Personal Protective Equipment • Support from family/friends • Physical challenges • Incentives are given to landowners/leaders • Incentives received from landowners/leaders • Awards or recognition

Migration

Remittance by a migrant household member may influence a household's access and use of woodland ES. Geest (2011) found that the Dagara people (which include people from the Nandom District) migrate to other parts of Ghana during the dry season. Variables on migration in this study are indicated in Table 3.7.

Table 3.7 Variables on Migration investigated in this study

Specific migration variable	Variable type	Remarks
Migration of household member	Categorical	
Frequency of migration of household member(s)	Categorical (ordinal)	This was a grouped variable
Relationship of the migrant to the household head	Categorical (nominal)	Relationship options as defined by the Demographic and Health Survey in Ghana
Common Agro-ecological zone of migration	Categorical (nominal)	Specific destination of migrants coded into one of the six agro-ecological zones of Ghana
Occupation of migrant HH member	Categorical (nominal)	The occupation was coded to 10 common options
Contribution of remittance to: - Household income - Household food security	Numerical (discrete)	Ranking out of 10 with ten being the highest

3.2.5 Sample size and sampling techniques

The sample size was calculated using two primary outcome variables, i.e., benefits derived from ecosystem services and willingness-to-pay for ecosystem services as outlined below.

3.2.5.1 Calculated Sample size

A survey by Boafo *et al*. (2014) conducted in the Guinea Savannah of Northern Ghana was the closest to the research area. Results from this source were used to estimate the sample size even though they reported on provisioning services only. No adjustment was made to incorporate the other three categories (cultural, regulating, and supporting) since there was no scientific procedure to do so.

A sample size of 246 was calculated using the sample size formula, $n_1 = z^2 \left[\frac{p(1-sp)}{(d_1)^2}\right]$ (Watkins, n.d.; Ruohonen, 2011).

Where: n_1 is the calculated sample size; z, the z value at 95% confidence interval for a two-tailed test (1.96); p, the proportion of households benefiting from ES (80% according to Boafo *et al*. (2014); and d_1, the margin of error/difference (5%).

From the 2010 PHC, 85.3% of households in Nandom District are engaged in agriculture (Ghana Statistical Service, 2014a). Of the population involved in agriculture, 98.0% were into crop farming (GSS, 2014a), which implied that 83.6% of the households of Nandom District were engaged in crop farming.

The calculated sample size was adjusted to ensure sampling from the whole population since a list of crop farming households in the district was not available. The computed figure, 294, was again adjusted upwards by assuming an 80% response rate, which gave a final adjusted sample size of 368 households. The lack of a database or list of farming households in the District did not allow for sampling for farming households only.

3.2.5.2 Calculated Sample size- Valuation of Ecosystem Services

In a meta-analysis by Hjerpea, Hussain and Phillips (2015) on willingness-to-pay (WTP) for ES using the contingent valuation method, they found that the adjusted mean WTP was 70.868 United States Dollars (± 87.845).

A sample size of 296 was calculated using the formula, $n_2 = \frac{(sd^2)}{{d_2}^2} z^2$ (Watkins, n.d.; Ruohonen, 2011). Where: n_2 is the calculated sample size; z, the z value of 1.96; sd, the standard deviation; and d_2, the margin of error (10 USD). The calculated sample size was adjusted to 370, assuming an 80% response rate.

3.2.5.3 Sampling technique

A systematic random sampling technique was employed to select households to participate in the study. An updated list, the sampling frame, of all households in all communities of the district was obtained from the Nandom District Assembly. This list was compiled to help identify and track beneficiaries of the Ghana Government's Livelihood Empowerment Against Poverty (LEAP) Initiative in the district. The list contained the community name, household unique identity number, name of household head, residential address (description to locate house), household size, type of residence, and house ownership. There were 9,574 households on the list. Three hundred sixty-eight (368) households were systematically selected across the district using a sampling interval of 26 (9574/370). Selected households were then grouped by sub-district and settlement (the type of community/locality) as shown in Table 3.8.

Table 3.8 Distribution of selected households by sub-district and settlement

Sub-district	Number selected	Settlement		Number of communities/localities
		Rural	Urban	
Nandom Town Council	141	105	36	36 (28 rural)
Ko Area Council	83	83	0	22
Baseble Area Council	73	73	0	25
Puffien Area Council	71	71	0	22
Total	368	332	36	105

Communities referred to in this study would better be described as localities as defined by the Ghana Statistical Service. "A locality is defined as a distinct population cluster (also designated as inhabited place, populated centre, settlement) which has a name or locally recognized status" (GSS, 2012). From this definition, a locality included market towns, villages, towns, and other population clusters that meet the definition (GSS, 2012). Therefore, in this study, locality and community were used interchangeably.

The Nandom District Assembly had classified communities in the district into rural and urban communities. This classification was adopted, the conformity of this classification to guidelines stipulated by the GSS or the Ghana Ministry of Local Government was not verified. However, generally, localities within Nandom Township (with a population of over 5000 inhabitants) were classified as urban.

3.2.5.4 Sampling for Qualitative data collection

Four communities (Table 3.9), one from each sub-district, were purposively selected for focus group discussions. In each community, three focus group discussions were conducted with the following groups: youth group (both female and males less than 50 years old), elderly females (50 years and older) and elderly males (50 years and older). These groups were identified to explore their views on adaptation and coping to climate change as well as changes that may have occurred during the past 30 years at their communities. Six key informant interviews were also conducted among community leaders (four), district officer of the Forestry Commission, and head of a local non-governmental organization with experience implementing climate change adaptation programmes in the district.

Table 3.9 Selected communities for focus group discussion on adaptation or coping strategies to climate change

Community/Locality	**Sub-district**	**Reason**
Bilegang	Nandom Town Council	A community near Reserve woodland
Guo	Ko Area Council	
Kamba	Baseble Area Council	Community members engage in charcoal burning and harvesting fuelwood for commercial purposes
Ketuo	Puffien Area Council	A community near Black Volta River

3.2.6 Pretesting of tools

Tools were pretested using non-selected households in the Nandom Town Council (primarily in the Segru Community). Study tools were then finalized and printed.

3.2.7 Data collection and processing

Of the 368 sampled from the database of the Nandom District, 52 households did not participate in the study. The primary reasons for not participating were: (1) no available adult (18 years or above) or empty house after a second visit; (2) migration of household which was confirmed by community leader/members; and (3) name and address on list could not be identified or verified by community leader or other community members. In one community of the Puffien sub-district, two selected names were from one household. The second respondent of this household was not interviewed.

Furthermore, questionnaires were checked for completeness in the field. Completed questionnaires were transported to Accra for data entry. Data entry clerks recruited to enter data did not have any association with the study area. The statistician had access to questionnaires during data cleaning only.

Data was entered into IBM SPSS Statistics version 16 and stored in a computer (pass worded). Data stored in this computer was backed up on an external hard drive and will be stored for 25 years.

3.2.8 Data analysis

Descriptive analyses and inferential analyses were done using IBM SPSS Statistics version 16. All continuous variables (predictor or outcome variables) were assessed for measures of distribution and normality using Skewness, Kurtosis, and the Shapiro-Willis Test. Notably, all continuous data in the study were not normally distributed. Thus, analysis to determine associations between predictor and outcome variables were done using nonparametric tests. Pearson Chi-Square analysis was used to determine associations between two categorical variables. Analyses to assess differences in continuous outcome variables among independent predictor groups were done using Kruskal-Wallis Test (three or more independent groups of a predictor variable) and the Mann-Whitney U test (for two independent groups of a predictor variable). All statistical tests of significance used the 95% confidence level, i.e., less than 5% ($\rho < 0.05$).

Using Principal Component Analysis in STATA statistical software, the wealth index (socio-economic status) was calculated for all participating households. Fifty (50) socio-economic variables (Appendix II- questionnaire) were used to construct the WI of each household. Each household was classified into five Wealth Index (WI) or socio-economic status (SES) categories: 1- lowest; 2- second; 3- middle; 4- fourth; and 5- highest.

The following considerations were made regarding respondents' characteristics; educational status was the highest educational level attained irrespective of whether the respondent completed that level or not. Educational level was self-reported, and verification on the accuracy of the educational level achieved was not done. Since the age range of respondents is very wide, with respondents having varied experiences, the education level categories as in Table 4.2 are maintained.

The study adopted marital status options as in the Ghana Demographic and Health Surveys. Couples legally married were put together with couples who lived together consensually. Similarly, the divorced were grouped with those separated.

Primary occupation referred to the main occupation of the respondent. The business category comprised informal small businesses and skilled based jobs that provided respondents income. The business category included *"pito"* brewers, market men and women, seamstresses and tailors, mechanics, plumbers, and masons. Student or apprentice category referred to all students in formal educational institutions/ schools and informal skills-based learning (apprenticeship, e.g., seamstress apprentice). Formal employment included respondents who were employed by government agencies or the formal private sector and who may have a contract or other form of job binding agreement with their employers. Other category were mainly respondents who did not fit into any of the groups and included labourer (manual casual worker), watchman and respondent into galamsey (small scale artisanal mining).

It was essential to identify the relationship of respondents to household head, to identify any variation in responses to outcome variables. Also, since it was noticed that people in the District migrated to other parts of the country, it was essential to identify the respondent by their migration status.

3.2.9 Ethical consideration

Ethical approval to conduct this study was obtained from the Ethics Board of the College of Basic and Applied Science, University of Ghana. Permission was also obtained from the District Chief Executive of Nandom District, the Paramount Chief of Nandom, Divisional or Sub-Chiefs of selected communities, family heads in some cases and respondents.

3.2.10 Assumptions

The study had the following assumptions:

1. There were no recall biases by respondents, focus group participants or key informants
2. Respondents provided accurate and correct responses to questions and
3. The views of focus group participants and key informants represented the general views of the sub-district in which the community belongs.

3.3 Contingent Valuation Method (CVM)

3.3.1 CVM Design

The contingent valuation method (CVM) is a hypothetical value-based method to estimate smallholder farmers' WTP for the conservation of the savannah woodland for sustainable use. The approach was selected for this study because of its suitability in determining the demand and implicit prices for ecosystem conservation. As a result, the method can capture non-use values such as bequest and existence value (Hjerpe, Hussain & Philips, 2015), which is the outcome of conservation initiatives. The approach is widely applied to the problem of estimating economic values of ES that are not traded in markets and for which no economic behaviour is observable (Wattage, 2001). These nonmarket characteristics are generally present when the ES in question is in the form of an environmental amenity (Wattage, 2001).

The study used the Open-ended Contingent Valuation design. The following CVM elicitation methods have been argued to be superior to the open-ended format: the bidding game, payment card, the discrete choice (takes it or leave it offer), the discrete choice with follow-up approaches, and modified dichotomous. These recommended approaches have their own share of limitation (TEEB, 2010). For example, with the bidding game researchers are concerned with the starting point bias. For payment card, its bias is associated with the ranges used on the cards and the location of the benchmark. For discrete choice also known as dichotomous choice (take it or leave it), one end's up with a discrete indicator of maximum WTP instead of the actual maximum WTP amounts. These approaches were not found suitable for the study area due to the lack of disposable income among the respondents who are mainly poor smallholder farmers. These people farm to feed their households and only sell when there is a need for money, or they sell off their excesses for income.

3.3.2 Data collection tools and technique

3.3.2.1 Data collection tool

In this study, a questionnaire was used to investigate household willingness-to-pay (WTP) for the conservation of the savannah woodland ecosystem. The questionnaire on the valuation of ES was integrated into that for the cross-sectional survey. The questionnaire contained both open-ended and close-ended questions.

Owing to the high poverty rate in the Nandom District, households selected their most preferred choice of contribution from cash, farm produce, or other (e.g., manpower). These options were to ensure that respondents' or households were free to mention their contribution based on their available resources. Additionally, the purpose was to obtain household contribution without having to make them feel worse or burdened financially. Open-ended questions to assess WTP (or contribution) assessed household's minimum and maximum WTP. The minimum WTP was the lowest amount/contribution households were willing to pay, while the maximum WTP was the household's maximum value and beyond which they were unwilling to pay. Following local market norms known to the people in the district, the minimum and maximum WTP values were negotiated. Respondents provided justification for values quoted and for the maximum WTP, a rationale for why they cannot exceed their stated value.

A post-harvest market survey was conducted in November and December 2017. The purpose was to determine the average amount per unit of farm produce in the dominant market in the study area, the Nandom market. The unit per farm produce in the District was the *"koko laa"* translated literally into "bowl" in English. The *koko laa* was regarded as the standard "bowl" used for measurement of cereals for sale in the Nandom District. The household WTP in cash was calculated by multiplying the minimum or the maximum numbers of "bowls" of each farm produce by the average amount per "bowl."

3.3.2.2 Data collection technique

The valuation of the woodland ecosystem was conducted using the contingent valuation method. The elicitation method employed was an open-ended face-to-face format using a structured questionnaire to collect data. A sampling of households/respondents followed the technique used for the cross-sectional survey, which was systematic random sampling across all sub-districts of the Nandom District. Minimum and maximum willingness-to-pay for woodland conservation were the primary variables assessed. Additionally, respondents' preferred choice of conservation strategy was assessed.

An effort was made to minimize the weaknesses of the open-ended format, by collecting minimum and maximum WTP values, including the option of paying using farm produce and negotiating minimum and maximum WTP. Additionally, a market survey was conducted to collect post-harvest produce prices in the Nandom market as it was necessary to convert WTP using food produce to monetary values. Statistical analysis also applied non-parametric tests as data were not normally distributed, and outliers were noticed.

The open-ended formats have been criticized for being difficult to be understood by the respondent. This problem has been blamed in producing a large number of non-responses to WTP questions (Wattage, 2001). To off-set, this problem in this study, questions were interpreted and administered in the preferred language of the respondent to promote understanding and interest.

3.3.2.3 Market survey to collect prices of food produce

A market survey, conducted in November and December 2017, assessed the prices of fresh farm produce in the Nandom major (Sunday) market, indicated in Table 3.10. Market prices, immediately post-harvest and one-month post-harvest, provided a reference to calculate/convert food produce into monetary values (in Ghana cedis) as these values were added to the values solicited using the cash payment for further analysis. The surveyed market vendors were those selling their produce around the same area of the market. A checklist was used to collect prices of farm-produce from four to five purposively selected vendors per produce. Notably, for the same produce, the prices mentioned by vendors during both surveys were the same. Table 3.10 provides the food produce and the average price per "bowl."

Table 3.10 Average price of food produce sold in Nandom major market between November and December 2017

Farm produce	November 2017 average price per bowl (GH¢)	December 2017 average price per bowl (GH¢)	Reference Average per bowl used to calculate monetary-based WTP (GH¢)
Maize (yellow, red or white)	3.00	3.00	3.00
Guinea Corn	3.00	3.50	3.50
Millet	3.00	3.50	3.50
Rice	8.00	8.00	8.00
Groundnut	10.00	10.00	10.00
Beans (black eye)	7.00	9.00	9.00
Bambara beans	6.00	7.00	7.00

3.3.3 Variables of CVM

The minimum and maximum willingness to pay were the primary outcome variables. These were disaggregated by the most preferred type of contribution and most preferred choice of conservation strategy as in Table 3.11. The proxy definitions for each conservation type as used in the study are tabulated in Table 3.12. Predictor or independent variables of respondents and households are in 3.2.4 (Tables 3.2 a and b).

Table 3.11 Contingent Valuation Variables investigated in this study

Variable	Type of variable	Remarks
Willingness to support conservation efforts	Categorical (nominal)	
Preferred form of contribution	Categorical (nominal)	Farm produce, money or other (manpower)
Minimal WTP	Continuous	Farm produce was converted to cash
Maximum WTP	Continuous	Farm produce was converted into cash
Preferred choice of the conservation strategy	Categorical	Restoration, preservation or both

Table 3.12 Variable definitions for conservation strategy

Conservation strategy	Proxy Definition
Preservation	Maintain current trees
Restoration	Grow more trees
Both	Maintain current trees and grow more trees

3.3.4 Limitation of CVM

Non-monetary WTP values such as the number of bowls are limited to the Geographic area since the market prices may not reflect market prices in other parts of Ghana.

3.3.5 Assumptions

Even though negotiation and probing to arrive at a minimum and maximum WTP was meant to minimize the influence of respondents under or overstating WTP values, the study still assumes that the WTP figures provided by respondents reflected their total actual use and non-use values. Additionally, the study assumed that WTP values provided by respondents represented WTP values for their entire household.

3.4 Mapping Land Cover and its change- Nandom District

Landsat satellite images were downloaded from the United States Geological Survey (USGS) website (http://www.usgs.gov) for the years; 1986, 2001 and 2017. The images were of the dry season and devoid of clouds cover as the presence of clouds could interfere with the classification process of the satellite images. Near anniversary images from January to April were used. These periods were chosen to identify changes in the land cover before the 21st and after the beginning of the 21st century. Table 3.13 presents details of satellite images used.

Table 3.13 Details of Satellite images employed in Study

No.	Year	Sensor	Acquisition Date	Total bands
1	1986	TM	15th February	8
2	2001	ETM+	20th February	8
3	2017	OLI/TIRS	8th March	12
TM: Thematic mapper ETM+: Enhanced Thematic Mapper Plus OLI/TIRS: Operational Land Imager/Thermal Infrared Sensor UTM: Universal Transverse Mercator system WGS: World Geodetic System				

The selection of LANDSAT TM data was based on its availability, suitability, and accessibility. The pre-processing of images followed similar methods described by Hailemariam *et al.* (2016), mainly radiometric correction, layer stacking, and enhancement. Both unsupervised and supervised image classification methods were adopted. The unsupervised classification was first carried out to have an idea of the overall land use, as well as land cover clusters of pixels. The algorithm used for the unsupervised classification was the Iterative Self Organizing Data Analysis (ISODATA) classification to generate a preliminary land use land cover change (LULCC) map for each year. After classifying the images, there was a need for ground-truthing to check the accuracy of the classified imageries.

A field visit, to Nandom, was conducted in November 2017 to identify the LULCC classes on the ground. The geographic coordinates of the observation sites from the Global Positioning System (GPS) reading were recorded, and the locations indicated on the images. For the training points, more than 30 samples per class were randomly assigned through simple random sampling (Tempfli, Kerle, Huurneman & Janssen, 2009; Hailemariam, Soromessa, & Teketay, 2016). Also, information on the historical land cover of the area was documented by interviewing community elders.

A supervised classification using the maximum likelihood algorithm was used in classifying the area into seven classes. The classification scheme used is presented in Table 3.14. The classification scheme was an adaptation of the functional classification of Pabi (2007) for Kintampo and surrounding districts. The result of the supervised and unsupervised classification for the years 1986, 2001, and 2017 were extracted and analyzed using tables and maps in hectares and percentages. The classified land use and land cover maps may contain some errors because of several factors, from classification technique to the methods of satellite data capture. Therefore, an accuracy classification assessment was performed through the standard method (Congalton, 1991).

For the analysis of data, visual comparison of features and matrix analysis (image differencing) were adopted to determine the land use and land cover change detection (Lu *et al.*, 2004). Areas that are converted from each class to any of the other classes were computed and the change directions were also determined. The estimation of the rate of change for the different covers were computed based on the formulae (Kashaigili & Majaliwa, 2010).

Table 3.14 Classification scheme for land use land cover and their description

Cover Type	Description
Farms	Lands with crops grown on them. These crops were annual crops such as Guinea corn, maize, and yam. There were also mango and teak plantations.
Built-up/ bare land	These are non-vegetated lands which have been left bare. They also consist of the physical built environment within the study area. Such as buildings, roads, etc.
Short Fallow	These lands typically have been left uncultivated for about 1-5 years. Predominantly young or short herbivorous growth with tree coppices on abandoned farmland or other areas with isolated or no tree.
Long Fallow	These lands usually have been left uncultivated for six or more years. Predominantly young trees and shrubs with isolated matured trees and dense bush.
Grassland	These are lands with predominant grass cover. There is usually no canopy cover.
Dense Canopy Woodland	These include areas that closely resemble a forest cover and reserved areas; gazette reserve area and natural growth. It has a tree population density of more than 150 trees per hectare of that comprised of plantations, riparian vegetation, and reserve woodland.
Open Canopy Woodland	This cover type is usually not as dense as the dense canopy woodland. But its canopy is denser than the long fallow cover type. Trees typically have space between them.

Source: Adopted from Pabi (2007)

3.5 Leaf litter bag Experiment

The litter bag experiment was conducted following the method stipulated by Coleman *et al.* (2004). For this write-up, the methodology of the leaf litter bag experiment was divided into phases broadly categorized into field experiment, laboratory work, and data management phases. The leaf litter bag experiment was conducted from May 2017 to April 2018 (fieldwork from May to October 2017 and the remaining period for laboratory work and data entry and analysis). May to October 2017 was chosen for fieldwork to coincide with the rainy season. Varying studies have shown that decomposition of organic matter takes place faster in the wet/rainy season than the dry season (Parsons, Valdez-Ramirez, Congdon & Williams, 2014; Hasanuzzaman & Hossain, 2014; Cornelissen, 1999).

3.5.1 Field Experiment

3.5.1.1 Collection and processing of Leaf Samples

The leaves of four dominant tree species of the Guinea Savannah Woodland were used for the leaf litter experiment. These were *Parkia biglobosa (Jacq.) R.Br. ex G.Don* (Dawadawa tree), *Vitellaria paradoxa C.F.Gaertn*. (Shea tree), *Cordia myxa L.* (Tongbo tree) and *Lannea microcarpa Engl. & K.Krause* (Sugeh tree). These species are predominant, resilient to annual bush fires and hold economic and social importance (Teklehaimanot, 2004) to rural households in Northern Ghana. In May 2017, fresh matured leaves of the selected species were pruned and sun-dried to constant weight. The longest drying time to constant weight was two weeks.

The litter bag experiment was conducted according to standard methods described by Coleman *et al*. (2004) to assess decomposition and quantity of nutrients remaining during the rainy season.

3.5.1.2 Bagging leaves

Nylon mesh, 1mm by 1mm pore size, were sewn into 20 cm x 20 cm litter bags. The mesh size of 1mm was chosen to allow for decomposers into the bag and more importantly prevent decomposed leaves from falling out of the litter bag (Cornelissen, 1999). During the purchase of nylon mesh, three colours with the same pore size and produced by the same manufacturer were available on the market. Each colour of nylon mesh was randomly assigned to a species by the method described below. All litter bags were labelled using a thick permanent marker. In total, 144 litter bags were sewn, 36 litter bags for each species. Three grams of each species, as recommended by Coleman *et al*. (2004) were placed in labelled litter bags to avoid overloading the litter bag and breaking leaves in the process (Cornelissen, 1999).

Randomization process

Names of each species and colours of nylon mesh were written on folded pieces of paper and placed in two separate bowls: Bowl A contained the names of species, and Bowl B contained the colours of nylon. Since there were only three colours of nylon mesh (in Bowl B), a fourth paper had the name ‘mix’ written on it to denote a mixture of nylon mesh colours. Each bowl was shaken to mix. With eyes closed and using both hands, a paper was drawn from each bowl. This process was repeated four times. Table 3.15 shows the results of this process.

Table 3.15 Results of randomization of species, the zone of field and colour of nylon mesh used for the litter bag experiment

Zone	Species	Colour of nylon mesh
A	Shea	Green
B	*Tongbo*	Mix of colours
C	*Dawadawa*	Blue
D	*Sugeh*	Yellow

3.5.1.3 Study site, zoning of plot and burial of litter bags

An acre (4046.86 m^2) of farmland provided by a volunteer farmer in Dambolteng - Nandom District was the field site of the litter bag experiment. An area of the farm, 140 feet by 110 feet (that is 42.672 m by 33.528 m) with similar physical features on inspection across the site - uniform soil colour, uniform type of grass growing on farmland and a somewhat levelled ground (without big holes or noticeable depressions) - was selected. The selected plot was zoned off from the remaining farm using nylon ropes and pegs and divided into four zones - A, B, C, and D. Each zone was further divided into 0.914 m by 0.914 m (i.e., 3 feet by 3 feet).

In using a similar randomization process described in 3.5.1.2, each species type was allocated to one zone (Table 3.15).

In each zone, representing each species type, litter bags were buried at 15 cm depth with 3 feet by 3 feet (0.914 m by 0.914 m) spacing between bags. Stones (medium-sized) were placed at each burial point for future identification. One hundred and thirty-two (132) litter bags for all species were buried on 12th June 2017 (between 6:00 and 10:00 am). The remaining 12 unburied bags (three per each species) were day zero samples.

Before the burial of litter bags and using an auger, five soil samples per zone were collected on 12th June 2017 to get a composite sample for [in each zone. The physico-chemical parameters assessed were soil pH, soil moisture content, particle size distribution, bulk density, electrical conductivity, organic carbon, organic matter, phosphorus, potassium, and total nitrogen. Additionally, soil temperature readings (pre-burial) per zone of farmland were taken before burying the litter bags.

3.5.1.4 Collection and transport of samples

For each species, three litter bags were collected before burial, then at ten days interval for the first 30 days, and subsequently at 30-day intervals (Table 3.16). Samples were collected in the early hours (morning) of each sampling day.

Table 3.16 Sampling dates of leaf litter

Sampling day	**Date samples were collected**
Day 0 (unburied)	12th June 2017
Day 10	22nd June 2017
Day 20	2nd July 2017
Day 30	12th July 2017
Day 60	11th August 2017
Day 90	10th September 2017
Day 120	10th October 2017

Collected samples (litter bags) were placed in labelled zip-lock bags, one zip-locked bag per species. All samples were placed in an ice chest and transported to the Ecological Laboratory of the University of Ghana. Transport was over-night travel from Nandom to Accra with samples arriving in the laboratory during the morning hours of the following day (after sampling).

3.5.2 Laboratory Work

3.5.2.1 Sample processing

In the laboratory, the collected leaf samples by species were emptied into a sieve (to obtain a composite sample). Bulk soil particles, small plant roots, and living organisms were removed. A small plastic spoon was used to scrape off gently soil particles attached to big broad leaves. Each cleaned litter, by species, was put into a labelled brown paper envelope and oven-dried at 44 ℃ to constant weight.

Dried leaf litter were removed from the oven and gently poured into a sieve. By gently rocking the sieve, dry sand/soil particles were removed. Each dried clean litter was weighed three times, and weights recorded. Average weight per litter bag was calculated.

$$\text{Average weight of leaf litter remaining per litter bag} = \frac{(W_1+W_2+W_3)}{3}$$

Where W_1, $W_{2,}$ and W_3 are the composite recorded weights (three different weights recorded)

The same process was followed each time samples arrived in the laboratory.

3.5.2.2 Variables assessed and Laboratory investigations

Variables Assessed

Table 3.17 presents the variables assessed to determine the physico-chemical parameters of the soils in the different zones described in section 3.5.1.3. Table 3.18 shows the variables assessed from the leaf litter.

Table 3.17 Physical and chemical parameters of soil from the experimental field

Physico-chemical parameter	Type of variable
Soil pH	Continuous
Soil moisture content	Continuous
Particle size distribution	Continuous
Bulk density	Continuous
Electrical conductivity (Cation Exchange)	Continuous
Organic carbon	Continuous
Total Nitrogen	Continuous
Available Phosphorus	Continuous
Available Potassium	Continuous

Variables in Table 3.17 influence the rate of decomposition of organic matter residues in the soil. Other variables which influence decomposition such as presence or absence of inhibitory substances such as tannins and nature and abundance of micro-organisms in the earth were not assessed.

Table 3.18 Leaf litter variables assessed for results in the study

Variable	Type of variable
The average weight of litter remaining (mass remaining)	Continuous
The proportion of mass remaining	Continuous
Decay constant	Continuous
Rate of decomposition	Continuous
Nitrogen content remaining	Continuous
Phosphorus content remaining	Continuous
Potassium content remaining	Continuous
Carbon-Nitrogen (C/N) ratio	Continuous

Laboratory Investigations

Analysis of soil samples

Each composite sample from the four zones was analysed using standard methods listed in Table 3.19 below.

Table 3.19 Laboratory methods to determine physico-chemical parameters of soil

Physico-chemical parameter	**Standard method used**	**Equipment used**
Soil pH	1:2 (soil: water) suspension	OHAUS ST10 pH meter
Soil moisture content	Gravimetric direct measurement	Oven
Soil particle size determination	Hydrometer method (Bouyoucous, 1962)	USDA textural triangle
Soil bulk density	Bulk density method (Cresswell & Hamilton, 2002)	
Cation exchange capacity of soil	Potassium Chloride method	Atomic Absorption Spectrometer
Soil organic carbon	Wet combustion method (Walkley & Black, 1934)	Not applicable (parameter was calculated using standard formula)
Soil Total Nitrogen	The Kjeldahl method (Hesse, 1971)	Not applicable (parameter was calculated using standard formula)
Available Phosphorus in soil	Bray I method	Spectrophotometer
Available Potassium in soil	Total digestion	Flame photometer

Determination of Potassium (K), Sodium (Na), Calcium (Ca) and Magnesium (Mg) in soil was based on the readings from the Atomic Absorption Spectrometer. Percentage Ca, Na, Mg, and K were calculated using the following formula:

% Ca, % K, % Mg, % Na $= \frac{AAS\ reading}{100}$, where AAS is Atomic Absorption Spectrometer.

Laboratory analysis of Leaf litter samples

Each sample (from different species and sampling dates) were assessed for the mass remaining and analysed for nutrients remaining (Nitrogen, Phosphorus, and Potassium). The proportion of mass remaining, rate of decomposition, and decay constants were calculated as in below.

The proportion of mass remaining

The proportion of mass remaining of each litter sample was calculated by:

$$\text{Proportion of mass remaining} = \frac{(\text{average mass remaining})}{\text{original dry mass of leaf sample}} \times 100$$

Rate of decomposition

The rate of decomposition was calculated using the formula below

$$\text{Rate of decomposition} = \frac{(P_2 - P_1)}{(t_2 - t_1)} \times 100$$

Where P_2 is the proportion of mass remaining at a t_2; P_1 , the proportion of mass remaining at t_1; t_2 the day of sampling giving P_2; and t_1 the day of sampling giving P_1 . The rate of decomposition was multiplied by -1 to obtain a positive figure.

Decay Constant

Decay constants for leaf litter were calculated using the negative exponential decay model by Olson (1963) as follows

$$\text{Decay constant, k} = \frac{ln(X_0/X_t)}{change\ in\ time}$$

Formula from general formula $X_t = X_0 e^{-k\Delta t}$

Where X_t is the mass remaining at time t, X_0 the initial weight, e (exp) is the base of the natural logarithm, k is the decay rate coefficient, Δt is the change in the time between X_t and X_0.

Nutrient concentration in leaf litter

The oven-dried leaf samples of individual species were reduced to powder with the use of a grinding machine and processed using acid digestion. The digested sample extracts were processed according to standard protocols (listed in Table 3.20) at Ecological Laboratory of the University of Ghana. Equipment in the laboratory was used to determine the quantities of Nitrogen, Phosphorus, and Potassium remaining in the leaf litter samples.

Table 3.20 Laboratory methods to determine nutrient content remaining in leaf litter

Nutrient	**Standard method used**	**Instrument used to read value**
Nitrogen content remaining	Kjeldahl (Block Digestion) method (Bremner, 1965)	Carbon-Nitrogen-Sulphur analyser
Phosphorus content remaining	Total digestion	Spectrophotometer
Potassium content remaining	Total digestion	Flame photometer
Carbon content	Wakley Black Method	Carbon-Nitrogen-Sulphur analyser

3.5.3 Data Management

3.5.3.1 Data entry and cleaning

Laboratory results were entered into Microsoft Excel version 2013. Part of the experimental site was disturbed at day 110 by farmers who disregarded markings. Care was taken to exclude exposed litter bags during day 120 sampling. However, laboratory findings of day 120 samples were presented with caution.

3.5.3.2 Data analysis

The Least significance difference (LSD) was used to test the significance of nitrogen, phosphorus, and potassium mineralization across the four different species. The LSD values, which were computed simultaneously with the variance (F), were used to identify which means were significantly different from each other. This discrimination was adopted because, according to Snedecor and Cochran (1967), when many differences are tested, some values may appear significant whereas the F-test is not significant, which may lead to error in interpretation. A 95% confidence level was used during analysis.

3.5.4 Limitation of leaf litter experiment

Only four dominant species were used for the leaf litter experiment. Thus, the findings and results are limited to the species used.

3.5.5 Assumptions considered

Since burial was at one experimental site, the study assumed that rainfall and temperature patterns which affect litter decomposition were the same in all zones of the experimental field. Additionally, soil decomposers were uniformly distributed in the experimental field.

CHAPTER FOUR

4.0 RESULTS

4.1 Background characteristics of respondents and ecosystem benefits derived from the savannah woodlands

The results of the study showed that there was no significant difference across the sub-districts (ρ = 0.459) and settlement, i.e. rural or urban (ρ = 0.142) of respondents (and households) participating or not participating in the study.

All (316) participants from identified households consented to participate in the study. The response rate was over 85% [85.41% overall (316/370) and 85.87% of sampled households (316/368)]. The response rate was higher than the estimated response rate used to calculate the sample size. Using principal component analysis (PCA), the Wealth index (WI) or socio-economic status (SES) was calculated for all 316 households. It was necessary to assess the SES for all participating households to prevent biases in WI using farming households only. The WI classified the households into five levels (one being the lowest and five the highest).

The research study population was farming households (specifically crop farming households). Thus, 13 non-farming households were excluded from further analysis.

4.1.1 Characteristics of Households and Respondents

4.1.1.1 Sub-district and settlement

The distribution of farming households participating in the study was as in Table 4.1. By sub-district, 37.29% (113) of households were from the Nandom Town Council (or Nandom sub-district), 23.43% (71) from the Ko Area Council (or Ko sub-district), 19.47% (59) from the Baseble Area Council (or Baseble sub-district) and 19.80% (60) from the Puffien Area Council

(Puffien sub-district). Distribution by settlement type showed that, 93.07% (282) farming households lived in the rural area while 6.93% (21) households lived in urban Nandom Township.

Table 4.1 Distribution of households by sub-district and settlement

Characteristic	Frequency	Percentage (%)
Sub-District		
Nandom Town Council	113	37.29
Ko Area Council	71	23.43
Baseble Area Council	59	19.47
Puffien Area Council	60	19.80
Settlement		
Rural	282	93.07
Urban	21	6.93
Total	**303**	**100.00**

4.1.1.2 Respondent characteristics

The age of respondents was from 18 to 100 years. The ages were recorded as reported by respondents in complete years. The actual ages of respondents were not verified using birth records. Two respondents could not give their ages. Age was not normally distributed but positively skewed (Skewness = 0.399, standard error = 0.140; Kurtosis = -0.689, standard error = 0.280; Shapiro-Wilk (301) = 0.966, $\rho < 0.001$). The mean age was 46.81 years with a standard deviation (sd) of 17.672. The median age was 45 years and the modal age of study respondents was 45 years. The ages were grouped as in Table 4.2.

Table 4.2 Respondent Background Characteristics

Characteristic	Frequency	Percentage (%)
Sex of respondent		
Male	202	66.67
Female	101	33.33
Total	303	100.00
Age Group		
< 20	8	2.66
20-29	54	17.94
30-39	58	19.27
40-49	60	19.93
50-59	41	13.62
60-69	41	13.62
70+	39	12.96
Total	301	100.00
Highest Education attained		
No formal education	124	40.92
Pre-Primary	15	4.95
Primary	46	15.18
Middle	19	6.27
JSS/JHS	44	14.52
Secondary (old system)	3	0.99
SSS/SHS	32	10.56
Higher	20	6.60
Total	303	100.00
Marital Status		
Married/ Living together	228	75.25
Divorced/ Separated	6	1.98
Widowed	35	11.55
Never married/ never living together	34	11.22
Total	303	
Tribe/ Ethnic group		
Dagaaba	296	97.69
Sissala	3	0.99
Waala	2	0.66
Others	2	0.66
Total	303	100.00
Primary Occupation		
No formal job or informal job	18	5.94
Farmer	243	80.20
Hunter	3	0.99
Business	14	4.62
Formal employment	8	2.64
Primary Occupation		
Student/Apprentice	14	4.62
Others	3	0.99
Total	303	100.00

Table 4.2 Respondent Background Characteristics (continuation)

Characteristic	Frequency	Percentage (%)
Relationship to the household head		
Head	177	58.42
Wife/ husband	41	13.53
Son/ daughter	39	12.87
Son/ daughter in law	11	3.63
Grandchild	1	0.33
Parent	16	5.28
Brother/ sister	15	4.95
Other relatives	3	0.99
Total	303	100.00
Migrated during last dry season		
Not migrated	236	77.89
Returnee migrant	67	22.11
Total	303	100.00

4.1.1.3 Household characteristics

Results for household characteristics are presented in Table 4.3. The continuous variables such as household size, number of children less than 15 in each household, the number of people living with a disability, and number 65 years or more is categorized into groups. There is no standard categorization/grouping for the size of household, children less than 15 or number of adults 65 years or more. Therefore, these continuous variables were grouped as in Table 4.3. These continuous variables were not normally distributed. For example, household size was not normally distributed: mean = 7.38, standard deviation (sd) = 3.381; median = 7, mode = 6: Skewness = 1.556, standard error = 0.140; Kurtosis = 4.770, standard error = 0.279; Shapiro-Wilk Statistic = 0.893, degrees of freedom (df) = 303, $\rho < 0.001$.

Nonparametric tests to determine the association between household characteristics and dependent variables used both grouped and non-grouped continuous variables.

Table 4.3 Household Characteristics

Characteristics	Sub-district				Settlement		Total Frequency (%)	
	Nandom	Ko	Baseble	Puffien	Rural	Urban	Frequency	%
Gender of household head								
Male	91	65	54	57	248	19	267	88.12
Female	22	6	5	3	34	2	36	11.88
Household size								
1-3	12	6	3	2	21	2	23	7.59
4-6	39	29	22	21	103	8	111	36.63
7-9	38	22	20	24	96	8	104	34.32
10-12	16	13	10	8	45	2	47	15.51
13 and more	8	1	4	5	17	1	18	5.94
Household members that work								
0	23	0	2	1	24	2	26	8.58
1	43	14	10	20	80	7	87	28.71
2	38	50	36	30	143	11	154	50.83
3 or more	9	7	11	9	35	1	36	11.88
Children < 15 years in HH (grouped)								
Yes	100	63	51	56	251	19	270	89.11
No	13	8	8	4	31	2	33	10.89
Adults 65 years or more in HH (grouped)								
Yes	54	38	32	41	152	13	165	54.46
No	59	33	27	19	130	8	138	45.54
Household member living with some form of disability? (grouped)								
Yes	14	11	11	14	49	1	50	16.50
No	99	60	48	46	233	20	253	83.50

Table 4.3 Household Characteristics (continued)

Characteristics	**Sub-district**				**Settlement**		**Total Frequency (%)**	
	Nandom	**Ko**	**Baseble**	**Puffien**	**Rural**	**Urban**	**Frequency**	**%**
Wealth Index (Socio-Economic Status)								
1st Quintile	13	23	15	11	59	3	62	20.46
2nd Quintile	18	14	14	14	59	1	60	19.80
3rd Quintile	19	16	16	12	62	1	63	20.79
4th Quintile	29	11	10	13	59	4	63	20.79
5th Quintile	34	7	4	10	43	12	55	18.15
Total	113	71	59	60	282	21	303	-
Percentage (%)	***37.29***	***23.43***	***19.47***	***19.80***	***93.07***	***6.93***	-	***100.00***

Sex of Household Head

The proportion of female and male-headed households were 11.88% and 88.12%, respectively. The Nandom sub-district had more female-headed households (19.47%, 22) than the other sub-districts (Ko- 8.45%, Baseble- 8.47%, and Puffien- 5.00%).

Household size

Household size was not normally distributed. The average household size was 7.38 (±3.381) persons per household (median 7 and mode 6 persons per household). The average household size among farming households was significantly higher than that found during the 2010 census for the district [$t\ (302) = 7.085$, $\rho < 0.001$].

Household members that work

The average number of household's members that work was 1.72 (sd= 0.934) [median 2, mode 2]. 8.58%, 28.71%, 50.83% and 11.88% households reported zero, one, two, and three or more people that work respectively. Additionally, 20.35% households in the Nandom Sub-district reported no household member that work. Households in other sub-districts reported less than 4% of household members that do not work.

Household Dependents (children less than 15 years and adults 65 years or more)

Nearly 11% of farming households did not have children less than 15 years living in their homes at the time of the survey. The distribution of children less than 15 years was similar across sub-districts. Over two-thirds (68.33%) of the households in Puffien sub-district were households with adults 65 years or more. In the Nandom sub-district, less than 50% of the households had adults 65 years or more.

Households with people living with some form of disability

About 12.4%, 15.5%, 18.6% and 23.3% of households in the Nandom, Ko, Baseble and Puffien sub-districts respectively, had people living with some form of disability. The proportion of people living with disability in rural areas (17.38%) was more than urban areas (4.76%).

Household socioeconomic status/ wealth index

The wealth index of households significantly varied between sub-districts (χ^2 (12) = 32.551, ρ = 0.001) and settlement (χ^2 (4) = 18.844*, $\rho < 0.001$). 55.75% households in the Nandom sub-district were in the upper wealth index (i.e., 4 and 5) as compared with 25.35% in Ko, 23.73% in Baseble and 38.33% in Puffien sub-districts.

4.1.2 Benefits of the woodland ecosystem to farmers of Nandom District

The study reports that, 8.58% (26), 97.03% (294) and 23.43% (71) farming households had access to the reserve woodland, community woodland, and household/family/individually- owned plantation respectively. Six (6) farming households (1.98%) did not have access to all three identified woodland types in the district. These farming households were from the Nandom sub-district.

4.1.2.1 Cultural Services

The results of the four cultural service benefits investigated in this study are presented in Figure 4.1. The percentage of households with access to the woodlands that derived aesthetic, recreational, and educational benefits were high, ranging from 58% to 94% for the woodland types. The spiritual benefit derived by households with access to woodland types investigated was rather low, ranging from 9% to 15%. Details of Figure 4.1 are available in Table A1.1 in the appendix.

Also, the majority, 88.51%, of farming households rated spiritual/religious benefits from woodlands as unimportant, which may be the reason for the results seen in Figure 4.1.

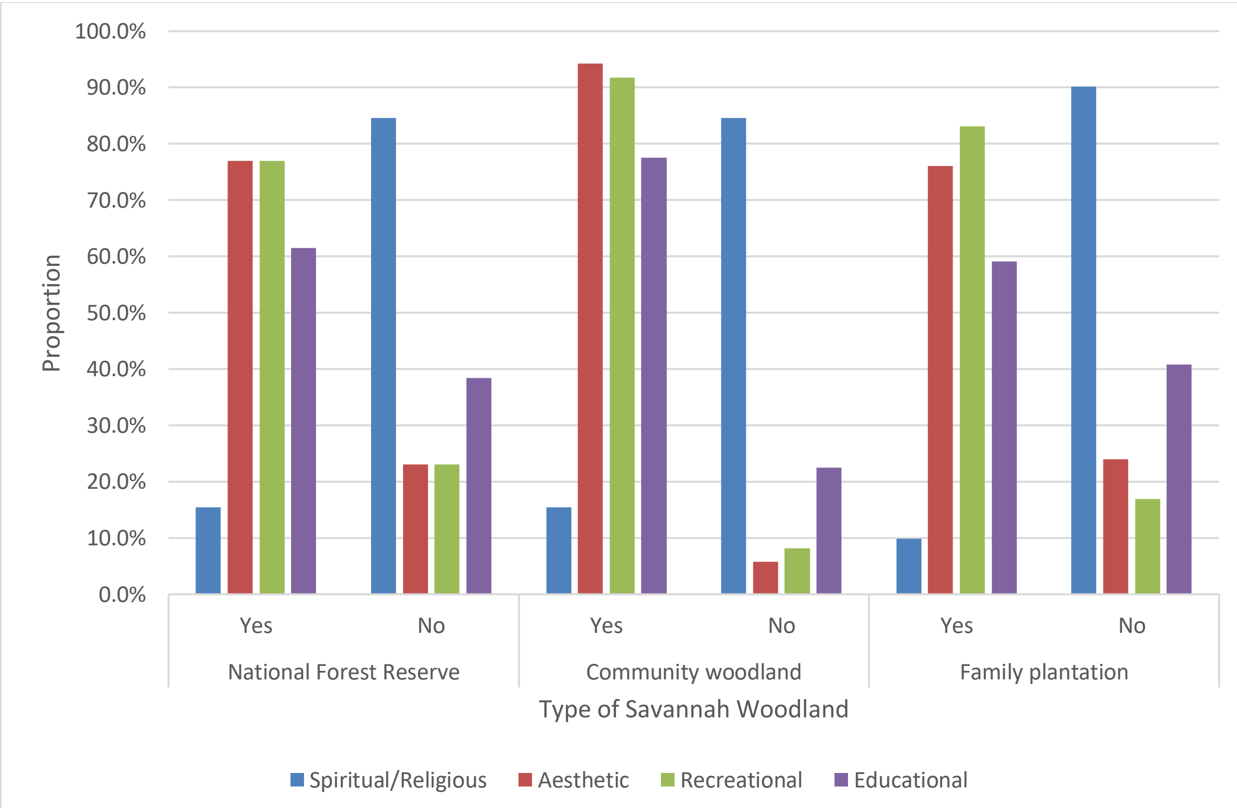


Figure 4.1 Cultural services useful to farming households with access to different woodland types in the Nandom District

4.1.2.2 Provisioning Services

The proportion of farming households benefiting from provisioning service are presented in Figure 4.2. Generally, and except for water and medicinal plants, a greater percentage of households accessed the community woodland for provisioning services as compared with access to the reserve woodland or family plantation.

The key benefits derived from the community woodland recoded a percentage above 80% and were identified as food crops, edible vegetables, wild fruits, fuel wood and soil for construction.

The remaining benefits, less than 80%, were poles for construction, medicinal plants, and fibre.

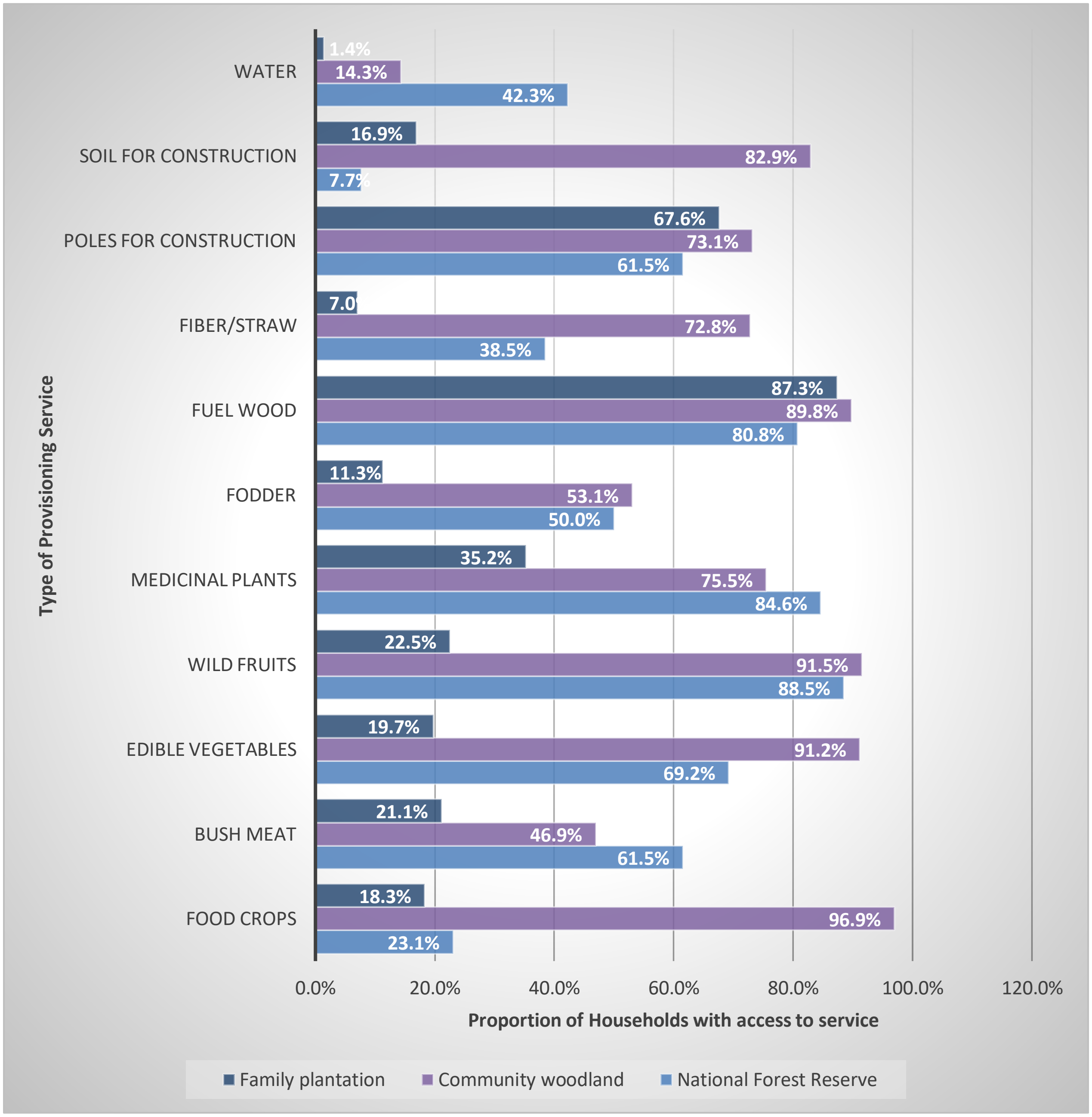


Figure 4.2 Provisioning services useful to farming households with access to different woodland types in the Nandom District

Water obtained from woodlands were ranked as unimportant by 86.8% of households. The result shows that 99.3% of farming households collect water from protected sources of water (piped water source and protected well) for household use. The primary sources of fuel for cooking were firewood (90.76%) and charcoal (8.91%).

4.1.2.3 Regulating Services

The percent of households with access to the different types of woodland that derived regulating service benefits are presented in Figure 4.3. Across woodland types, over 80% of households enjoyed fresh air from trees, enjoyed filtered air during harmattan, and noted that trees served as windbreaks. Less than 50% of households and a little over 50% of households perceived that trees in the Reserve woodland protected close by building and protected soil from erosion respectively.

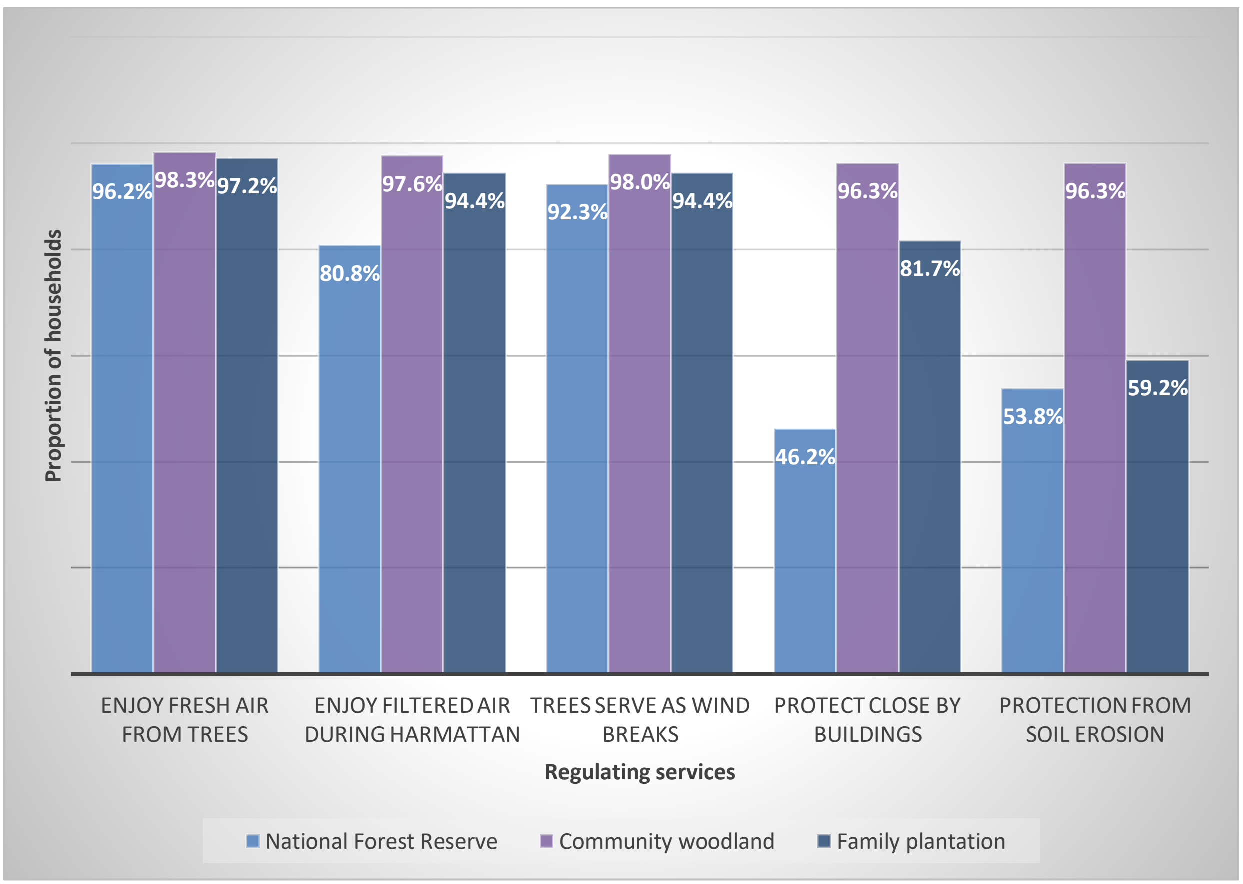


Figure 4.3 Regulating services useful to farming households with access to different woodland types in the Nandom District

4.1.2.4 Supporting Services

The percentage benefits of supporting services presented in Figure 4.4 were high for the community woodland ranging from 92% to 95%. The contribution of leaf litter and organic matter of trees were reportedly low for reserve woodland and family plantation.

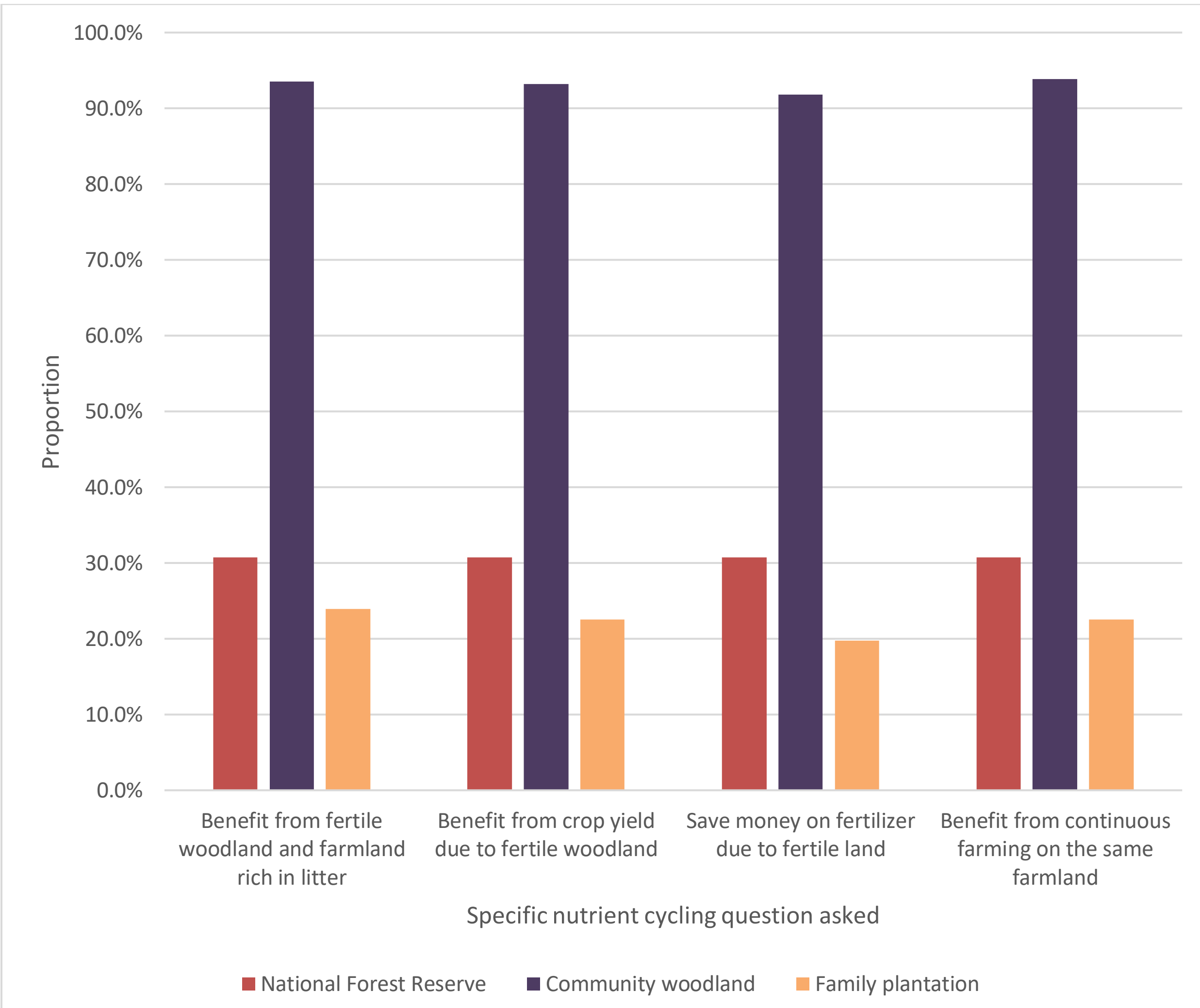


Figure 4.4 Supporting services useful to farming households with access to different woodland types in the Nandom District

4.2 Household factors influencing access and use of savannah woodland ecosystem services (by different social groups)

4.2.1 Location of household and access to woodlands

Table 4.4 shows the relationship between sub-district and settlement of small-holder faming households and access to the different types of woodland. From Table 4.4, sub-district was associated with access to the different woodland types while settlement of households was associated with access to the Reserve Woodland and community woodland but not access to family plantation.

Excluding households living in urban Nandom, analysis of data from rural households did not show any significant difference between access to community woodland and sub-districts (χ^2 (3) = 3.599, $\rho = 0.156$). However, there was a significant association between rural households in sub-districts with access to family-owned plantation (χ^2 (3) = 33.114, $\rho < 0.001$) and access to the reserve woodland (χ^2 (3) = 24.177, $\rho < 0.001$).

Table 4.4 Relationship between location (sub-district and settlement) of households and access to types of woodland

Variable/Characteristic	Reserve woodland (National Forest Reserve)			Access to community woodland			Access to family/own plantation		
	Yes	No	Test result	Yes	No	Test result	Yes	No	Test result
Sub-district									
Nandom	22	91	$\chi^2 = 29.560$	104	9	$\chi^2 = 11.846$*	43	70	$\chi^2 = 28.481$
Ko	0	71	df = 3	71	0	df = 3	3	68	df = 3
Baseble	0	59	$\rho < 0.001$	59	0	$\rho = 0.002$*	12	47	$\rho < 0.001$
Puffien	4	56		60	0		13	47	
Total	26	277		294	9		71	232	
Settlement									
Rural	20	262	$\chi^2 = 11.495$	279	3	$\chi^2 = 51.313$	67	215	$\chi^2 = 0.242$
Urban	6	15	df = 1	15	6	df = 1	4	17	df = 1
Total	26	277	$\rho = 0.005$*	294	9	$\rho < 0.001$*	71	232	$\rho = 0.792$*

* Fisher's Exact Test value

Table 4.5 Relationship between settlement and access to the types of woodland: Nandom sub-district only

Settlement	Access to reserve woodland			Access to community woodland			Access to family/own plantation		
	Yes	No	Test result	Yes	No	Test result	Yes	No	Test result
Rural	16	76	$\chi^2 = 1.363$	89	3	$\chi^2 = 14.942$	39	53	$\chi^2 = 3.952$
Urban	6	15	df = 1	15	6	df = 1	4	17	df = 1
Total	22	91	$\rho = 0.239$*	104	9	$\rho = 0.001$*	43	70	$\rho = 0.047$

* Fisher's Exact Test value

4.2.2 Household characteristics and access to woodlands

Sex of the household head, household with children less than 15 years, and households with persons living with disability were not significantly associated with access to any woodland type (Table 4.6).

Household size was significantly associated with access to family-owned plantation but not access to reserve or community woodland. From the data, the proportion of households with access to family owned-plantation showed an increasing trend with increasing household size, Figure 4.5.

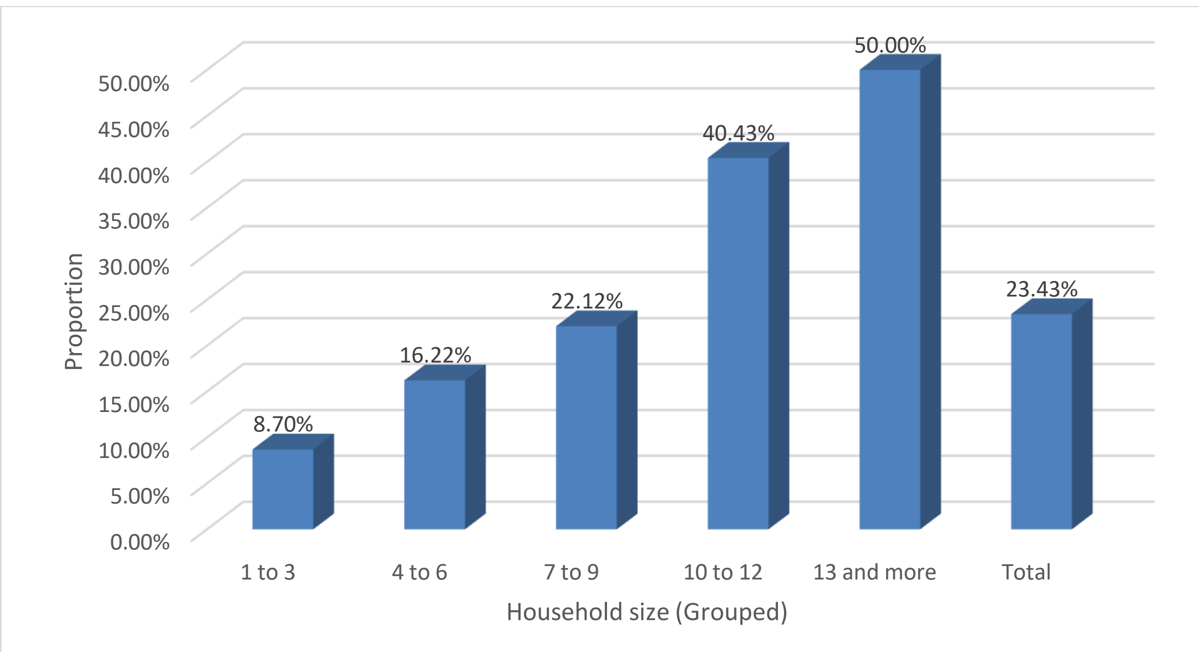


Figure 4.5 Percentage of farming households in the Nandom District with access to family-owned plantation by grouped household size

The number of household members that work was associated with access to reserve woodland and access to family-owned plantation.

The presence of adults 65 years or more was significantly associated with access to reserve woodland but not access to community woodland or family-owned plantation.

The wealth index, a measure of the total wealth of the household, was associated with access to family-owned plantation but not access to reserve or community woodland. A higher proportion of households with agriculture land engaged in plantation farming (27.38%) as compared to households without agriculture land (10.00%), [χ^2 (1) = 5.579, ρ = 0.018]. However, household engagement in plantation farming was not significantly associated with the wealth index of the household (χ^2 (4) = 4.643, ρ = 0.326).

Table 4.6 Relationship between household factors and access to woodland types

Variable/Characteristic	Access to Reserve woodland			Access to community woodland			Access to family/own plantation		
	Yes	**No**	**Results**	**Yes**	**No**	**Results**	**Yes**	**No**	**Results**
Sex of Household Head									
Male	23	244	$\chi^2 = 0.003$	259	8	$\chi^2 = 0.005$	59	208	$\chi^2 = 2.232$
Female	3	33	df = 1	35	1	df = 1	12	24	df = 1
Total	26	277	ρ = 1.000*	294	9	ρ = 1.000*	71	232	ρ = 0.135
Grouped household size									
1-3	3	20	$\chi^2 = 8.231$*	22	1	$\chi^2 = 1.050$*	2	21	$\chi^2 = 19.301$*
4-6	9	102	df = 4	108	3	df = 4	18	93	df = 1
7-9	4	100	ρ = 0.063*	100	4	ρ = 0.931*	23	81	ρ = 0.001*
10-12	7	40		46	1		19	28	
13 or more	3	15		18	0		9	9	
Total	26	277		294	9		71	232	
Grouped number that work									
0	1	25	$\chi^2 = 7.804$*	26	0	$\chi^2 = 2.788$*	13	13	$\chi^2 = 12.313$
1	14	73	df = 3	82	5	df = 3	18	69	df = 3
2	10	144	ρ = 0.038*	150	4	ρ = 0.361*	30	124	ρ = 0.006
3 or more	1	35		36	0		10	26	
Total	26	277		294	9		71	232	
Household with children < 15 years									
Yes	23	247	$\chi^2 = 0.012$	261	9	$\chi^2 = 1.134$	63	207	$\chi^2 = 0.014$
No	3	30	df = 1	33	0	df = 1	8	25	df = 1
Total	26	277	ρ = 1.000*	294	9	ρ = 0.604*	71	232	ρ = 0.907
Households with adults 65+ years									
Yes	7	158	$\chi^2 = 8.693$	160	5	$\chi^2 = 0.005$	40	125	$\chi^2 = 0.133$
No	19	119	df = 1	134	4	df = 1	31	107	df = 1
Total	26	277	ρ = 0.003	294	9	ρ = 1.000*	71	232	ρ = 0.716

Table 4.6 Relationship between household factors and access to woodland types (continued)

Variable/Characteristic	Access to Reserve woodland			Access to community woodland			Access to family/own plantation		
	Yes	**No**	**Results**	**Yes**	**No**	**Results**	**Yes**	**No**	**Results**
Households with persons with some form of disability									
Yes	2	48	$\chi^2 = 1.602$	48	2	$\chi^2 = 0.220$	17	33	$\chi^2 = 3.727$
No	24	229	df = 1	246	7	df = 1	54	199	df = 1
Total	26	277	ρ = 0.275*	294	9	ρ = 0.646*	71	232	ρ = 0.054
Wealth Index									
1st Quintile	3	59	$\chi^2 = 5.269$*	60	2	$\chi^2 = 3.486$*	6	56	$\chi^2 = 9.610$
2nd Quintile	4	56	df = 4	58	2	df = 4	13	47	df = 4
3rd Quintile	10	53	ρ = 0.248	63	0	ρ = 0.496*	18	45	ρ = 0.048
4th Quintile	4	59		61	2		19	44	
5th Quintile	5	50		52	3		15	40	
Total	26	277		294	9		71	232	
*Fisher's Exact Test ρ value									

4.2.3 Household assets and access to woodlands

From Table 4.7, ownership of agriculture land by the household or household member was significantly associated with access to community woodland. Additionally, the presence of trees on farmland was significantly associated with access to community woodland (χ^2 (1) = 39.968, $\rho < 0.001$).

Household/family or household member ownership of tree plantation was significantly associated with access to family plantation (χ^2 (1) = 199.9, $\rho < 0.001$).

In the Nandom District, 80.20%, 34.98%, and 8.58% of farming households owned a bicycle, motorcycle, and animal-drawn cart respectively. Less than 5% of farming households in the district possessed a car/truck (1.65%), a boat without motor (1.98%) and boat with motor (0.33%). Household ownership of a bicycle was significantly associated with access to community woodland and access to family plantation but not access to the Reserve woodland. Ownership of a motorcycle and animal-drawn cart were not associated with access to any type of woodland.

Table 4.7 Household assets and access to woodland types

Variable/Characteristic	Access to reserve woodland			Access to community woodland			Access to family/own plantation		
	Yes	No	Result	Yes	No	Result	Yes	No	Result
Ownership of agricultural land									
Yes	23	240	χ^2 = 0.069	258	5	χ^2 = 7.902	66	197	χ^2 = 3.070
No	3	37	df = 1	36	4	df = 1	5	35	df = 1
Total	26	277	ρ = 1.000*	294	9	ρ = 0.020*	71	232	ρ = 0.080
Ownership of bicycle									
Yes	21	222	χ^2 = 0.006	239	4	χ^2 = 7.466	63	180	χ^2 = 4.253
No	5	55	df = 1	55	5	df = 1	8	52	df = 1
Total	26	277	ρ = 0.939	294	9	ρ = 0.017*	71	232	ρ = 0.039
Ownership of Motorcycle									
Yes	9	97	χ^2 = 0.002	102	4	χ^2 = 0.365	29	77	χ^2 = 1.401
No	17	180	df = 1	192	5	df = 1	42	155	df = 1
Total	26	277	ρ = 0.967	294	9	ρ = 0.724*	71	232	ρ = 0.237
Ownership of animal-drawn cart									
Yes	1	25	χ^2 = 0.813	25	1	χ^2 = 0.076	10	16	χ^2 = 3.581
No	25	252	df = 1	269	8	df = 1	61	216	df = 1
Total	26	277	ρ = 0.711*	294	9	ρ = 0.559*	71	232	ρ = 0.058
Ownership of farm animals									
Yes	23	241	χ^2 = 0.045	258	6	χ^2 = 3.463	69	195	χ^2 = 8.359
No	3	36	df = 1	36	3	df = 1	2	37	df = 1
Total	26	277	ρ = 1.000*	294	9	ρ = 0.096*	71	232	ρ = 0.004
*Fisher's Exact Test ρ value									

4.2.4 Socially differentiated groups and access to woodlands

Table 4.8 summarizes the results from Table 4.4 to 4.7 categorized by socially differentiated groups. The findings are based on the hypothesis mentioned in Chapter One. A rejection of the null hypothesis is an acceptance of the alternate hypothesis and vice versa.

Table 4.8 Association between household factors and access to different woodland types

Variable	Endowment/Entitlement					
	Access to reserve woodland		Access to community woodland		Access to family/own plantation	
	Result	Conclusion	Result	Conclusion	Result	Conclusion
Social Capital						
Sub-district	$\chi^2 = 29.560$ df = 3 $\rho < 0.001$	Reject null hypothesis	$\chi^2 = 11.846$* df = 3 $\rho = 0.002$*	Reject null hypothesis	$\chi^2 = 28.481$ df = 3 $\rho < 0.001$	Reject null hypothesis
Settlement	$\chi^2 = 11.495$ df = 1 $\rho = 0.005$*	Reject null hypothesis	$\chi^2 = 51.313$ df = 1 $\rho < 0.001$*	Reject null hypothesis	$\chi^2 = 0.242$ df = 1 $\rho = 0.792$*	Accept null hypothesis
Sex of household head	$\chi^2 = 0.003$ df = 1 $\rho = 1.000$*	Accept null hypothesis	$\chi^2 = 0.005$ df = 1 $\rho = 1.000$*	Accept null hypothesis	$\chi^2 = 2.232$ df = 1 $\rho = 0.135$	Accept null hypothesis
Household size	$\chi^2 = 8.231$* df = 4 $\rho = 0.063$*	Accept null hypothesis	$\chi^2 = 1.050$* df = 4 $\rho = 0.931$*	Accept null hypothesis	$\chi^2 = 19.301$* df = 1 $\rho = 0.001$*	Reject null hypothesis
Household socio-economic status	$\chi^2 = 5.269$* df = 4 $\rho = 0.248$	Accept null hypothesis	$\chi^2 = 3.486$* df = 4 $\rho = 0.496$*	Accept null hypothesis	$\chi^2 = 9.610$ df = 4 $\rho = 0.048$	Reject null hypothesis
Human Capital						
Household members that work	$\chi^2 = 7.804$* df = 3 $\rho = 0.038$*	Reject null hypothesis	$\chi^2 = 2.788$* df = 3 $\rho = 0.361$*	Accept null hypothesis	$\chi^2 = 12.313$ df = 3 $\rho = 0.006$	Reject null hypothesis
Household with children less than 15 years	$\chi^2 = 0.012$ df = 1 $\rho = 1.000$*	Accept null hypothesis	$\chi^2 = 1.134$ df = 1 $\rho = 0.604$*	Accept null hypothesis	$\chi^2 = 0.014$ df = 1 $\rho = 0.907$	Accept null hypothesis
Household with adult(s) 65 years and more	$\chi^2 = 8.693$ df = 1 $\rho = 0.003$	Reject null hypothesis	$\chi^2 = 0.005$ df = 1 $\rho = 1.000$*	Accept null hypothesis	$\chi^2 = 0.133$ df = 1 $\rho = 0.716$	Accept null hypothesis

Table 4.8 Association between household factors and access to different woodland types (continued)

	Endowment/Entitlement					
	Access to reserve woodland		**Access to community woodland**		**Access to family/own plantation**	
	Result	Conclusion	Result	Conclusion	Result	Conclusion
Human Capital						
Household with person living with some form of disability	$\chi^2 = 1.602$ df = 1 $\rho = 0.275$*	Accept null hypothesis	$\chi^2 = 0.220$ df = 1 $\rho = 0.646$*	Accept null hypothesis	$\chi^2 = 3.727$ df = 1 $\rho = 0.054$	Accept null hypothesis
Natural Capital						
Ownership of agricultural land	$\chi^2 = 0.069$ df = 1 $\rho = 1.000$*	Accept null hypothesis	$\chi^2 = 7.902$ df = 1 $\rho = 0.020$*	Reject null hypothesis	$\chi^2 = 3.070$ df = 1 $\rho = 0.080$	Accept null hypothesis
Physical Capital						
Ownership of bicycle	$\chi^2 = 0.006$ df = 1 $\rho = 0.939$	Accept null hypothesis	$\chi^2 = 7.466$ df = 1 $\rho = 0.017$*	Reject null hypothesis	$\chi^2 = 4.253$ df = 1 $\rho = 0.039$	Reject null hypothesis
Ownership of motorcycle	$\chi^2 = 0.002$ df = 1 $\rho = 0.967$	Accept null hypothesis	$\chi^2 = 0.365$ df = 1 $\rho = 0.724$*	Accept null hypothesis	$\chi^2 = 1.401$ df = 1 $\rho = 0.237$	Accept null hypothesis
Ownership of animal-drawn cart	$\chi^2 = 0.813$ df = 1 $\rho = 0.711$*	Accept null hypothesis	$\chi^2 = 0.076$ df = 1 $\rho = 0.559$*	Accept null hypothesis	$\chi^2 = 3.581$ df = 1 $\rho = 0.058$	Accept null hypothesis
Financial Capital						
Ownership of livestock, herds and other farm animals and poultry	$\chi^2 = 0.045$ df = 1 $\rho = 1.000$*	Accept null hypothesis	$\chi^2 = 3.463$ df = 1 $\rho = 0.096$*	Accept null hypothesis	$\chi^2 = 8.359$ df = 1 $\rho = 0.004$	Reject null hypothesis

*Fisher's Exact Test result

4.3 Relationship between knowledge on climate change and woodland conservation and management practices in the Nandom District

4.3.1 Level and sources of knowledge on climate change

4.3.1.1 Level of knowledge on climate change

Respondents' experience with changes in weather pattern (proxy definition of climate change understood in the Nandom District) revealed the following:

- 93.1% have observed changes in weather, 1.0% have not noticed changes in weather, and 5.9% were not sure of any changes in the weather pattern
- 7.9% observed increasing rainfall patterns, 84.1% observed decreasing rainfall patterns, 1.3% observed no change in rainfall pattern and 6.6% were not sure of any changes in rainfall pattern
- 87.8% observed that the pattern of rainfall was unpredictable, while 8.3% and 6.9% observed that rainfall pattern was predictable and not sure/don't know respectively
- 61.1% of respondents observed an increase in temperature of the weather, 16.5% observed decreasing temperature, 4.0% observed no changes in temperature, and 18.5% were not sure of any changes in temperature
- 79.2% of respondents observed longer periods of drought, 7.6% observed shorter period of drought, 1.3% observed no change, and 11.9% were not sure or did not know
- 38.0% of respondents experienced dry spells frequently during farming over the last couple of years, 41.0% experienced dry spells occasionally, 15.7% observed that dry spells were not frequent, and 5.3% of respondents were not sure.

The level of knowledge on climate change and/or climate variability was assessed using 23 questions. Correct responses were scored out of 100 to obtain a percentage knowledge score of each respondent. Knowledge scores were not normally distributed (Skewness= -0.795, standard error = 0.140; Kurtosis = 1.203, standard error = 0.279; Shapiro-Wilk Statistic = 0.953, df = 303, $\rho < 0.001$).

Knowledge of climate change and/or climate variability was very high. The mean score was 75.85% (standard deviation 13.27), median 78.26%, and mode 78.26%.

From a Mann-Whitney U test, the level of knowledge on climate change did not vary between male and female respondents (U (303) = 9842, Z = -0.503, $\rho = 0.615$). There was no difference in the level of knowledge between returnee migrants and non-migrants (U (303) = 7624, Z = -0.449, $\rho = 0.654$).

A Kruskal-Wallis H test showed that the level of knowledge of respondents was significantly different by sub-district (χ^2 (3) $^=$ 13.306, $\rho = 0.004$) with a mean rank score of 153.00 for Nandom sub-district, 170.39 for Ko sub-district, 117.50 for Baseble sub-district and 162.28 for Puffien sub-district. Respondents' level of knowledge was not statistically significantly different by their age group [χ^2 (6) = 3.426, $\rho = 0.754$]; marital status [χ^2 (3) = 3.458, $\rho = 0.326$]; occupation [χ^2 (6) = 9.340, $\rho = 0.155$]; and relationship to household head [(χ^2 (7) = 5.287, $\rho = 0.625$]. Knowledge was statistically significantly different among different education levels of respondents [(χ^2 (7) = 19.577, $\rho = 0.007$) with mean ranks in the following order: 131.17 for secondary (old system), 137.20 for no formal education, 138.79 for Middle school, 141.64 for JSS/JSS, 157.27 for pre-primary, 164.26 for primary, 170.66 for SSS/SHS, and 220.25 for higher education.

4.3.1.2 Sources of knowledge on climate change

The primary sources of information were recorded into four broad categories: local knowledge and experience; local/community resource persons like community leaders and volunteers; media (radio, television and other sources of information); and external resource persons (staff of Ministry of Agriculture, Forestry Commission and non-governmental organizations and non-community volunteers). Figure 4.6 (a and b) shows the primary sources of knowledge on climate change adaptation (CCA) and woodland conservation.

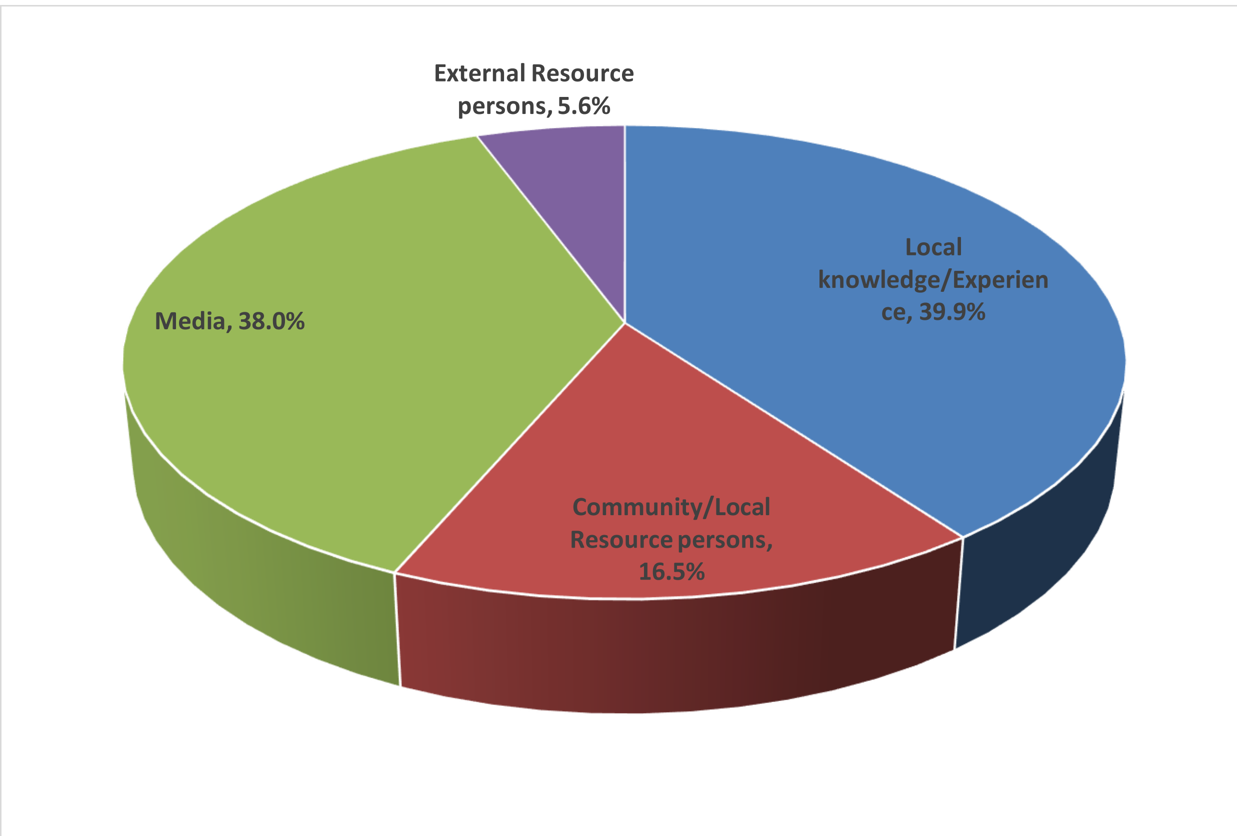


Figure 4.6a Main source of information on Climate Change Adaptation and woodland conservation: Broad categories

Level of knowledge on climate change was not significantly different by broad categories of respondents/household primary source of information [(χ^2 (3) = 1.825, ρ = 0.609].

33.3% of households relied on radio for information on CCA and woodland conservation. More than half (54.13%) of all households possessed radios despite the low access to electricity (42.57%).

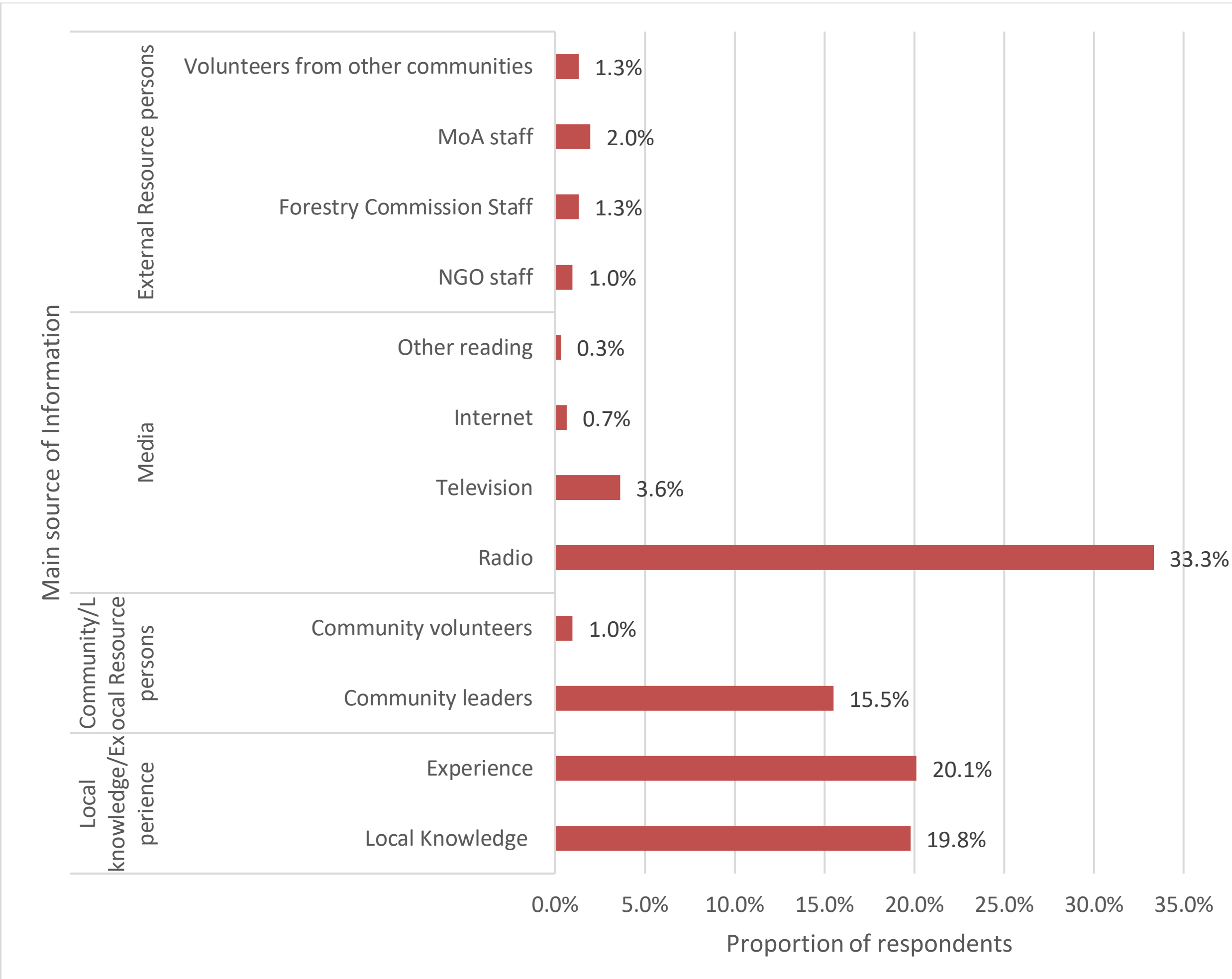


Figure 4.6b Main source of information on Climate Change Adaptation and woodland conservation: Specific categories

4.3.2 Reported woodland management practices in the study area

From the results of the study, communities have laws preventing bush burning (90.10%) and tree felling (85.76%) (Fig. 4.7). From key informant interviews with chiefs, tree cutting of any tree was forbidden. An individual/family has to obtain permission before felling a tree even if the tree was located on the household's farmland. Permission is granted after a team of community leaders has inspected the tree and granted permission for the tree to be felled. Permission is also given to fell trees that do not bear fruits ("so-called male trees" as described in the district) and sometimes very old trees. Farmers are encouraged to plant trees, which led to a relatively high proportion of respondents reporting planting trees as in Figure 4.7.

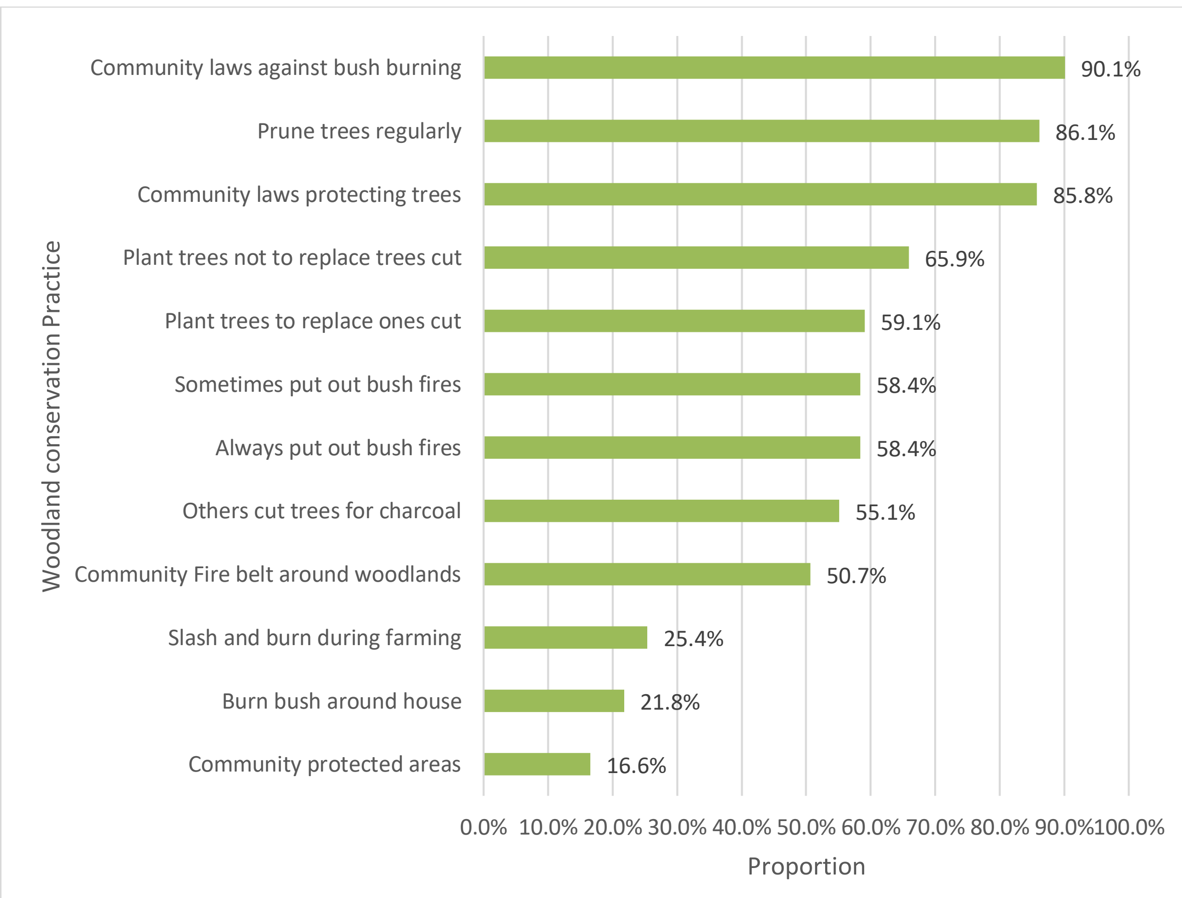


Figure 4.7 Percentage of farming households that reported woodland conservation practices

Even though more than 85% of respondents report regularly pruning trees, the habit of "branch harvesting" not "pruning" was observed in the field. Whole branches were removed from trees usually leaving trees with the trunk and few leaves/branches. The belief was that the branches would regrow.

From the study, 275 (90.76%), 27 (8.91%) and one (0.33%) farming households use firewood/ wood, charcoal and liquefied petroleum gas (LPG) as their main type of fuel used for cooking respectively. Cumulatively, 99.67% of farming households in the Nandom District use wood-based fuels for cooking, which could impact negatively on woodlands and tree cover and may explain the negative practice of branch harvesting observed in the field.

The practice of putting out bush fires was found to be associated with sub-district ($\chi^2 = 31.444$, df $= 6$, $\rho < 0.001$) and settlement ($\chi^2 = 27.093$, df $= 2$, $\rho < 0.001$). Also, reported tree planting to replace cut ones was associated with sub-district ($\chi^2 = 28.459$, df $= 6$, $\rho < 0.001$). These findings may reflect the degree of community and communal law enforcement among sub-districts and not necessarily the presence of these laws.

The perceptions of respondents on who is responsible (persons or institutions) for woodland conservation were also assessed. These perceptions are shown in Figure 4.8. Respondents perceived that it is the responsibility of the household, community leaders, and chiefs and the Forestry Commission to protect trees. Respondents also recognized the importance of conserving trees for future use.

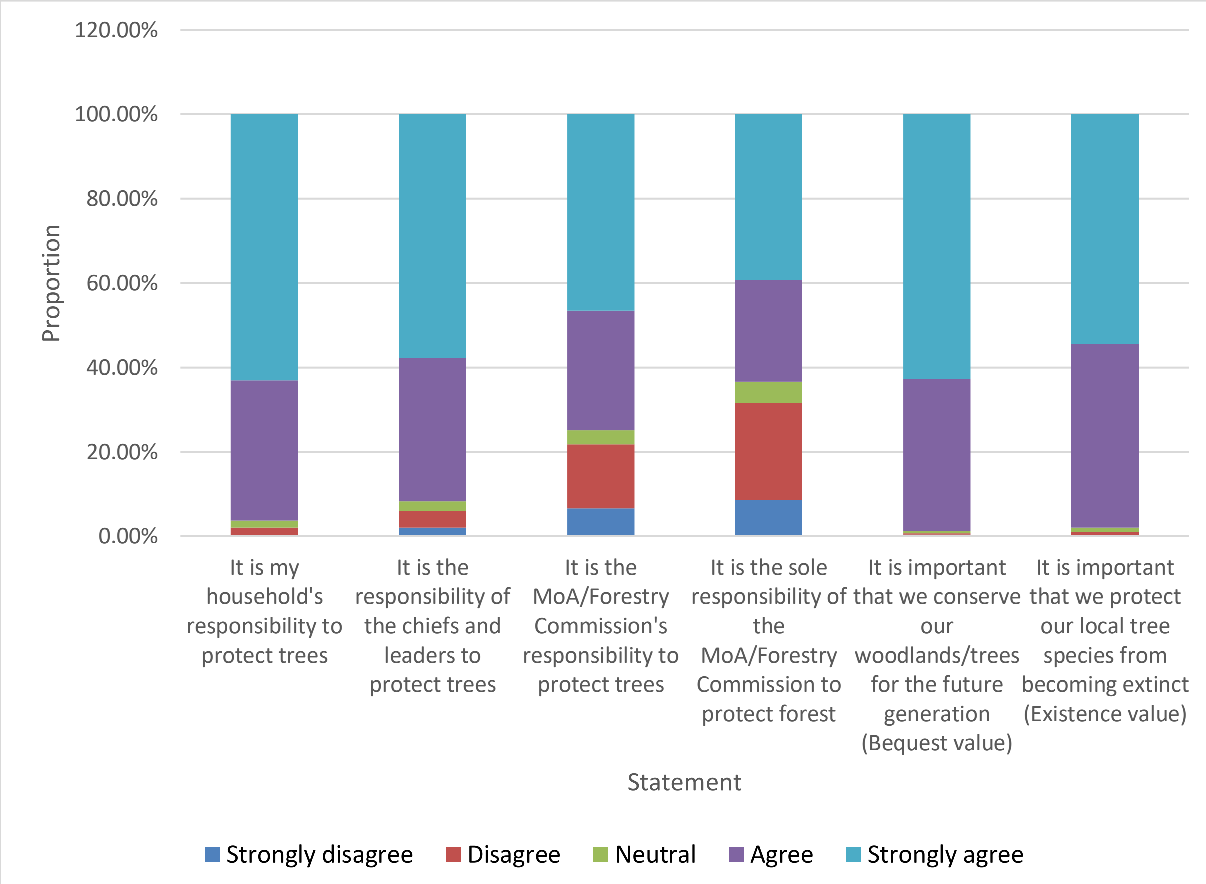


Figure 4.8 Level of agreement of respondents on woodland conservation statements

4.3.3 Knowledge of climate change and woodland conservation practices

Owing to the averagely high level of knowledge on climate change in the Nandom District, level of knowledge was grouped into quartiles. Grouped knowledge level in quartiles was not significantly associated with pruning (χ^2 (6) = 10.272, ρ = 0.073), bush fire control [always (χ^2 (6) = 9.111, ρ = 0.151); sometimes (χ^2 (6) = 8.519, ρ = 0.188)], bush burning around house (χ^2 (6) = 7.142, ρ = 0.227), tree planting/afforestation [to replace felled trees (χ^2 (6) = 7.945, ρ = 0.235); not to replace felled trees (χ^2 (6) = 5.330, ρ = 0.466)], and slash and burn agriculture (χ^2 (6) = 5.731, ρ = 0.425).

4.4 Off-farm adaptation practices that influence the economic wellbeing of smallholder farming households

4.4.1 Off-farm household livelihood options: adaptation, coping or a way of life

4.4.1.1 Findings from key informants

In response to a question on the use of resources from savannah woodlands as an adaptive strategy, coping strategy, or way of life, key informants had this to say:

"The use of the savannah woodland is a mixed box. People resort to cutting wood for fuelwood, and women sell to augment family budget. Diverse reasons account for the use of the woodland'' (key informant from NANDRIDEP, a local non-governmental organization working in climate change).

A chief in a community in the Baseble sub-district explained that the use of the savannah woodland served as a coping strategy, adaptive strategy, or way of life. According to him, both men and women from the sub-district sell firewood to raise money for family expenses in the dry season, a practice, the chief referred to as a coping strategy. The chief referred to the rearing of livestock among the people as an adaptive strategy where fodder from the woodland serves as feed in the dry season. Additionally, the cultural norms of the people in relying on woodlands for medicinal plants, wild fruits, edible vegetables such *kankao, sansang, dumgum and tokora* (examples of edible vegetables using the Dagaaba local names) are ways of life.

In the Ko area sub-district, a retired educationist and spokesperson for the community mentioned that *"borrowing money* (from neighbours) *and dry season gardening"* were coping strategies among the people. Adaptation strategy activities in their community included *"tree harvesting and* *sale, petty trading, pito business, and migration."* Also, "*the culture of the area was one where the people rely on the woodlands for medicinal plants and edible vegetables. Having a room constructed in the local way was compulsory among his people for cultural purposes"*. Traditional houses in the Nandom district included a local storey building. This storey was composed of an adobe covering a layout of logs. Wooden planks (whole logs) supported this superstructure. As per custom/tradition, the announcement of events including marriages took place from the roof of these houses.

In the Puffien sub-district, *"pito brewing by women, fishing along the Black Volta River, harvesting and selling of firewood, plantation farming (Banana) and dry season gardening along the Black Volta"* were regarded as adaptive strategies among the people. The coping strategies were *"harvesting of trees for sale by both men and women and migration."* (Key informant).

From the Nandom sub-district, a key informant had this to say about coping strategies, *"the people sell livestock such as cow, goat, pig to pay children's fees and other expenses, the women sell firewood to raise money for food at home and for the village savings and loan scheme (Susu). The women also engage in shea butter extraction while the men engage in bushmeat hunting for household consumption."* This key informant said that *"the people engage in tree plantation, shea butter extraction, farming in marginal lands, use of roofing sheets to prevent the use of woody material for roofing''* as adaptation strategies. *"Our way of life is such that we don't cut trees like Kakala tree and any fruit-bearing tree''*. The *Kakala* tree is regarded as a totem in the Nandom District.

4.4.1.2 Findings from focus group discussions

Table 4.9 presents the findings on livelihood options that were considered as coping strategies, adaptation strategies, and way of life by the different groups.

Table 4.9 Livelihood options (from the woodland) perceived as coping or adaptation strategies or way of life

	Youth	**Elderly women**	**Elderly men**
Coping strategy	- Sale of firewood - Off-farm work such as -masonry or carpentry - Charcoal burning	- Harvest edible vegetables such as *kalisu, sansang, dugum* for food - Sell wild fruits - Sell pigs - Making and selling dawadawa	- Harvest firewood for sale - Engage in wood carving such as hoe, mortar, pestle - Sale of livestock and guinea fowl
Adaptation strategy	- Rearing of livestock - Engage in tree plantation - Beg for land to farm - Farming- Crop diversification - *Pito* business - Petty trading	- Rearing pigs, goat, and fowls - Basket weaving - Shea butter extraction - Pito business - Soap making	- Rearing of livestock (cattle, goat, sheep) - Farming- crop diversification - Off-farm work such as security job
Way of Life	- Use of medicinal plants - Use local edible vegetables - Use of wild fruits	- The use of medicinal plants (*cogtir, kpamkpara*, *Gaa*, mango, pawpaw) - Use of local edible vegetables at home - Farming - Harvest wild fruits - Tree planting for vegetables	- The use of medicinal plants (*cogtir, kpamkpara*, *Gaa*, mango, pawpaw) - Use of local edible vegetables at home - Pour libation around trees such as *Kakala*

4.4.2 Off-farm household livelihood options: relationship to economic wellbeing, the role of woodland ecosystem services

The analysis of off-farm adaptation options and wealth index are presented in Table 4.10 (a and b). There was a significant association between wealth index of households and the following off-farm livelihood options:

- shea nut picking or oil extraction ($\rho < 0.001$)
- harvesting fuelwood ($\rho < 0.001$)
- harvesting fodder for livestock ($\rho = 0.023$)
- harvesting straw ($\rho = 0.023$)
- logging ($\rho = 0.007$)
- petty trading ($\rho = 0.001$)
- pito brewing ($\rho = 0.007$)
- carving ($\rho = 0.026$)
- office work or other formal employment ($\rho < 0.001$)
- skills based jobs such as tailoring/dressmaking, baking, carpentry, and hair dressing ($\rho = 0.015$).

The wealth index was not associated with gathering fruits and vegetables, charcoal burning, bushmeat hunting, and harvesting medicinal plants. Additionally, the wealth index of households was not associated with basket weaving, pottery, mortar making, motor or bicycle repair works, plumbing, and engagement in construction works.

Notably, households in the highest wealth index category (5) engaged less, when compared with other wealth categories, in shea nut picking (31.5%), gathering fruits and vegetables (63.0%), harvesting fuelwood (63.0%), harvesting straw (25.9%), logging (42.6%), and harvesting medicinal plants (53.7%). Households in category 3 of the wealth index engaged more, compared with other wealth categories, in shea nut picking (72.6%), gathering fruits and vegetables (85.7%), harvesting straw (49.2%), charcoal burning (7.9%), and hunting for bushmeat (50.8%). Over 85% of households in wealth categories 1 to 3 engaged in harvesting fuelwood and over 65% of households in the same wealth categories were engaged in logging.

Further analysis of Table 4.10b reveal that, 35.2%, 40.7% and 48.1% of households in category 5 of the wealth index are engaged in petty trading, office work or formal employment, and skills-based jobs respectively. In comparison, 9.7%, 3.2%, and 19.4% of households in the least wealth index (category 1) engaged in petty trading, office work or formal employment, and skills-based jobs respectively.

Table 4.10a Livelihood option directly from Savannah Woodlands and household Wealth Index

Household Off-farm livelihood options (for sale and/or household use)	Wealth index of household					Results
	1	2	3	4	5	
Shea nut picking/ oil extraction						
Yes	34	43	45	39	17	$\chi^2 = 26.300$
No	28	17	17	24	37	df = 4
Total	62	60	62	63	54	$\rho < 0.001$
Gathering fruits and vegetables						
Yes	49	47	54	47	34	$\chi^2 = 8.937$
No	13	13	9	16	20	df = 4
Total	62	60	63	63	54	$\rho = 0.063$
Harvest fuelwood						
Yes	55	56	55	48	34	$\chi^2 = 23.128$
No	7	4	8	15	20	df = 4
Total	62	60	63	63	54	$\rho < 0.001$
Harvest fodder for livestock						
Yes	22	38	35	30	25	$\chi^2 = 11.338$
No	40	21	28	33	29	df = 4
Total	62	59	63	63	54	$\rho = 0.023$
Harvest straw						
Yes	17	24	31	17	14	$\chi^2 = 11.385$
No	44	36	32	46	40	df = 4
Total	61	60	63	63	54	$\rho = 0.023$
Logging						
Yes	42	44	41	35	23	$\chi^2 = 13.963$
No	20	16	22	28	31	df = 4
Total	62	60	63	63	54	$\rho = 0.007$
Charcoal burning						
Yes	3	3	5	1	1	$\chi^2 = 3.705$*
No	59	57	58	62	53	df = 4
Total	62	60	63	63	54	$\rho = 0.434$*

Table 4.10a Livelihood option directly from Savannah Woodlands and household WI (continued)

Household Off-farm livelihood options (for sale and/or household use)	Wealth index of household					Results
	1	2	3	4	5	
Hunting for bushmeat						
Yes	17	26	32	26	21	$\chi^2 = 7.556$ df = 4 $\rho = 0.109$
No	45	33	31	37	33	
Total	62	59	63	63	54	
Harvesting medicinal plants						
Yes	36	41	43	35	29	$\chi^2 = 4.725$ df = 4 $\rho = 0.317$
No	26	19	20	27	25	
Total	62	60	63	62	54	
*Fisher's Exact Test value						

Table 4.10b Other household livelihood options and household wealth index

Other Household Off-farm livelihood options	Wealth index of household					Results
	1	2	3	4	5	
Petty trading						
Yes	6	7	19	12	19	$\chi^2 = 17.905$
No	56	53	44	51	35	df = 4
Total	62	60	63	63	54	$\rho = 0.001$
Pito brewing						
Yes	30	41	44	46	27	$\chi^2 = 14.116$
No	32	19	19	17	27	df = 4
Total	62	60	63	63	54	$\rho = 0.007$
Basket weaving						
Yes	17	17	18	17	9	$\chi^2 = 2.936$
No	45	43	45	46	45	df = 4
Total	62	60	63	63	54	$\rho = 0.569$
Pottery						
Yes	6	2	4	6	2	$\chi^2 = 3.433$*
No	56	58	59	57	52	df = 4
Total	62	60	63	63	54	$\rho = 0.473$*
Mortar making						
Yes	3	3	3	2	1	$\chi^2 = 1.286$*
No	59	57	60	61	53	df = 4
Total	62	60	63	63	54	$\rho = 0.905$*
Carving						
Yes	0	6	1	4	1	$\chi^2 = 9.243$*
No	62	54	62	59	53	df = 4
Total	62	60	63	63	54	$\rho = 0.026$*
Motor/bicycle repair						
Yes	7	8	12	8	1	$\chi^2 = 8.436$
No	55	52	51	55	53	df = 4
Total	62	60	63	63	54	$\rho = 0.077$

Table 4.10b Other household livelihood options and household wealth index (continued)

Other Household Off-farm livelihood options	Wealth index of household					Results
	1	2	3	4	5	
Plumbing						
Yes	1	0	0	2	2	$\chi^2 = 3.855$*
No	61	60	63	61	52	df = 4
Total	62	60	63	63	54	$\rho = 0.366$*
Building/construction						
Yes	7	13	11	9	11	$\chi^2 = 3.169$
No	55	47	52	53	42	df = 4
Total	62	60	63	62	53	$\rho = 0.530$
Office work/other formal employment						
Yes	2	5	5	10	22	$\chi^2 = 40.237$
No	60	55	58	52	32	df = 4
Total	62	60	63	62	54	$\rho < 0.001$
Skills-based jobs**						
Yes	12	18	16	19	26	$\chi^2 = 12.417$
No	50	42	47	44	28	df = 4
Total	62	60	63	63	54	$\rho = 0.015$

*Fisher's Exact Test value
**Such as tailoring, baking, carpentry and hair-dressing

4.4.3 Off-farm livelihood options and economic wellbeing of households

The results of household off-farm livelihood options and relationship with the wealth index based on the hypothesis, in Chapter 1, are summarized in Table 4.11.

Table 4.11 Association between off-farm adaptation practices from woodlands and wealth index of household

Household Off-farm livelihood options (for sale/household use)	**Wealth index of household**		**Remarks**
	Result	Conclusion	
Shea nut picking/ oil extraction	χ^2 (4) = 26.300 ρ < 0.001	Reject null hypothesis	Livelihood option is an adaptation strategy
Gathering fruits and vegetables	χ^2 (4) = 8.937 ρ = 0.063	Accept null hypothesis	Livelihood option not an adaptation strategy
Harvest fuelwood	χ^2 (4) = 23.128 ρ < 0.001	Reject null hypothesis	Livelihood option is an adaptation strategy
Harvest fodder for livestock	χ^2 (4) = 11.338 ρ = 0.023	Reject null hypothesis	Livelihood option is an adaptation strategy
Harvest straw	χ^2 (4) = 11.385 ρ = 0.023	Reject null hypothesis	Livelihood option is an adaptation strategy
Logging	χ^2 (4) = 13.963 ρ = 0.007	Reject null hypothesis	Livelihood option is an adaptation strategy
Charcoal burning	χ^2 (4) = 3.705* ρ = 0.434*	Accept null hypothesis	Livelihood option not an adaptation strategy
Hunting for bush meat	χ^2 (4) = 7.556 ρ = 0.109	Accept null hypothesis	Livelihood option not an adaptation strategy
Harvesting medicinal plants	χ^2 (4) = 4.725 ρ = 0.317	Accept null hypothesis	Livelihood option not an adaptation strategy

*Fisher's Exact Test values

Ordinal logistic regression (preferred) and multiple regressions could not be performed to estimate the relationships of household wealth index and household livelihood options obtained directly from Savannah Woodlands. This was because the assumption of "no multicollinearity' was not met. Shea nut picking/oil extraction, the gathering of fruits and vegetables, harvesting fuelwood, harvest fodder for livestock, harvest straw, logging, hunting for bush meat, and harvesting medicinal plants showed multicollinearity. Charcoal burning was not collinear with the following: shea nut picking/oil extraction, collection of other foods and vegetables, harvest fuelwood, logging, hunting for bush meat and harvest medicinal plants.

4.5 Changes in the land cover of Nandom District from 1986 to 2017

4.5.1 Accuracy of the classification

The overall accuracy of 74.43% with kappa 0.81, 76.36% with kappa of 0.82, and 71.16% with kappa of 0.78 was found for 2017, 2001, and 1986 respectively. The result of the assessment of the classification accuracy for the year 2017, 2001, and 1986 are shown in Appendix I Section 2 (Tables A2.1, A2.2, and A2.3 respectively).

4.5.2 Extent of land covers classes in Nandom District 1986, 2001 and 2017

Figures 4.9, 4.10, and 4.11 are illustrative maps of LULCC for 1986, 2001, and 2017 respectively. Analysis of each class of land cover in the district is presented in Table 4.12 and Figure 4.12.

Table 4.12 Area of land cover classes in the Nandom District for 1986, 2001 and 2017

Land Cover Class	1986		2001		2017	
	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
Dense canopy woodland	3,404.88	8.45	4,099.32	10.17	2,378.16	5.90
Long fallow	7,054.20	17.51	7,672.05	19.04	8,336.70	20.69
Open canopy woodland	6,993.36	17.36	6,664.50	16.54	7,359.39	18.26
Farmland	6,727.95	16.70	5,646.60	14.01	5,926.59	14.71
Short fallow	6,652.44	16.51	6,147.63	15.26	6,255.54	15.52
Grassland	6,066.09	15.05	6,480.18	16.08	6,332.04	15.71
Built up/bare land	3,395.52	8.43	3,584.16	8.89	3,706.02	9.2

Land cover area summary (from Table 4.12)

1986: long fallow > open canopy woodland > farmland > short fallow > grassland > dense canopy woodland > build-up or bare land

2001: long fallow > open canopy woodland > grassland > short fallow > farmland > dense canopy woodland > build up or bare land

2017: long fallow > open canopy woodland > grassland > short fallow > farmland > built up or bare land > dense canopy woodland

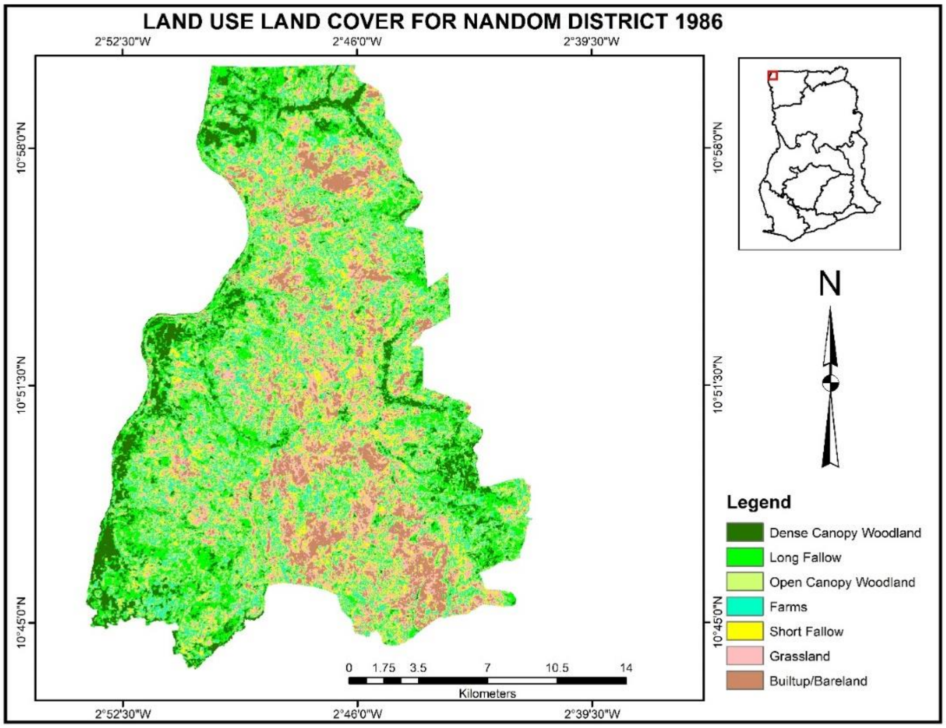


Figure 4.9 Land cover map of Nandom District, 1986

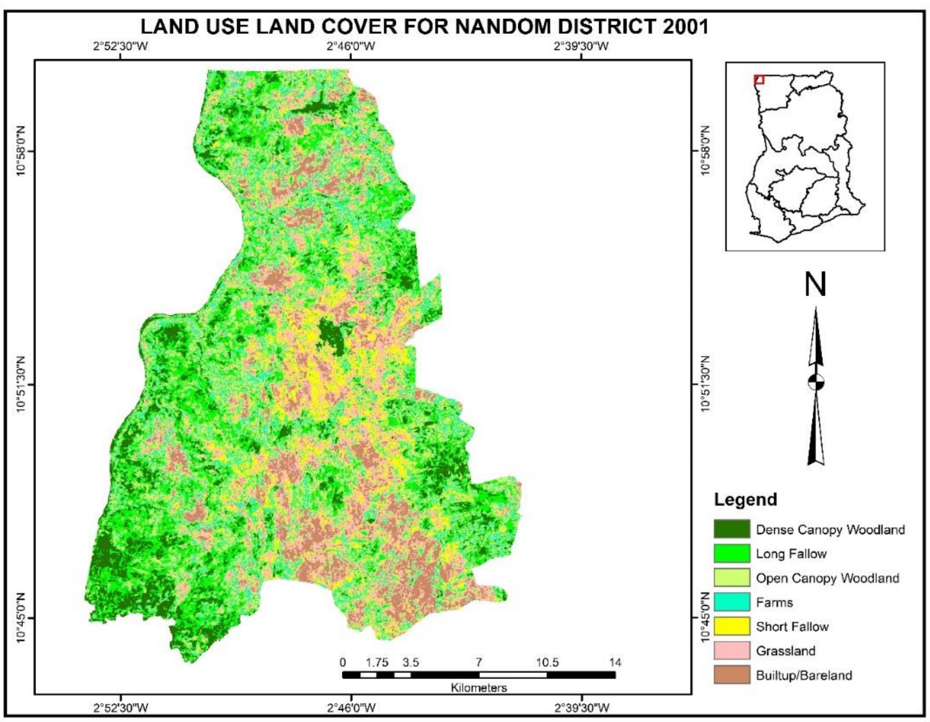


Figure 4.10 Land cover map of Nandom District, 2001

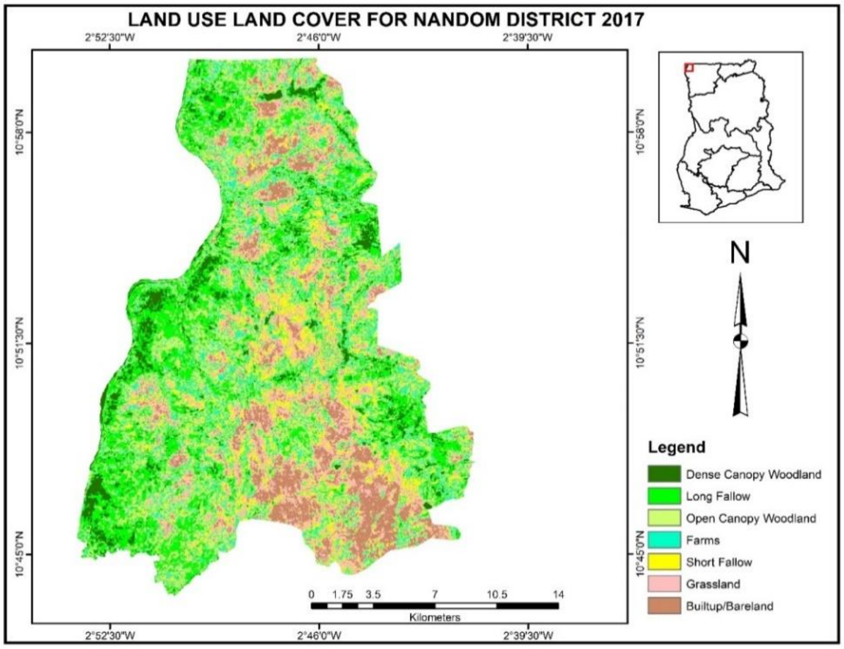


Figure 4.11 Land cover map of Nandom District, 2017

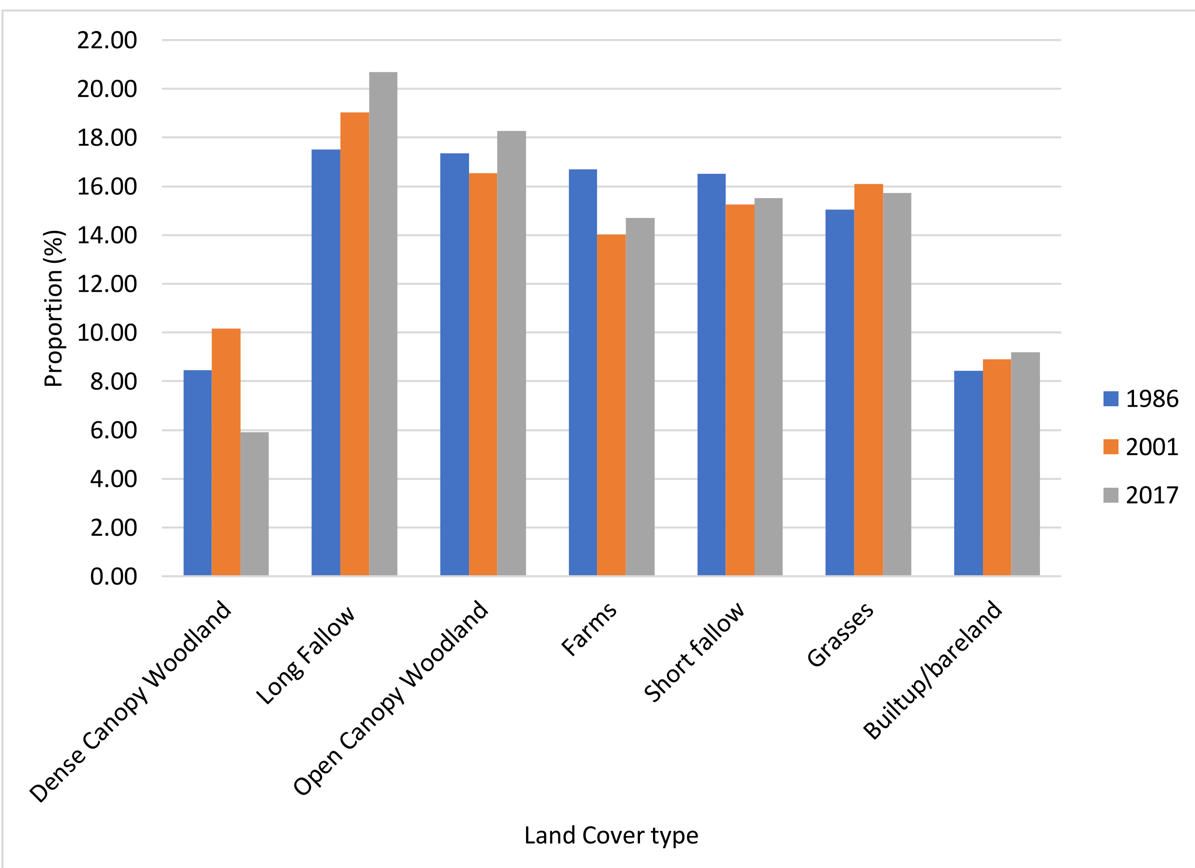


Figure 4.12 Percentage of Land Cover classes of Nandom District (1986, 2001, and 2017)

The extent of land use and land cover classes in 1986

As shown in Table 4.12 and Figure 4.12, the most extensive land cover category of Nandom District, as of 1986, was long fallow area. It covered 7,054.20 hectares representing 17.5% of the land surface of the District. This was followed by open woodland, which covered 6,993.36 hectares (17.36%). Farms covered 6,727.95 hectares (16.7%), which is the third most extensive land cover of the District. The fourth and fifth extensive covers were short fallow area covering an area of 6,652.44 hectares (16.5%) and grassland with coverage of 6,066.09 hectares (15.05%) respectively. Dense woodland was the sixth extensive land cover occupying 3,404.88 hectares (8.45%) while the built-up/bare land was the seventh (least) extensive cover which occupied 3,395.52 hectares (8.43%).

The extent of land use and land cover classes in 2001

Table 4.12 shows the spatial extent of the land cover categories of the District for 2001 which was almost the same as that in 1986, with the most extensive land cover once again being long fallow area. It covered 7,672.05 hectares representing 19.04% of the land surface of the District. This was followed by open woodland, which covered 6,664.50 hectares (16.54%). Here, grasses covered 6,480.18 hectares (16.08%), emerging the third most extensive land cover of the District. The fourth extensive cover was short fallow area covering an area of 6,147.53 hectares (15.26%) while farms covered 5,646.6 hectares (14.01%), representing the fifth extensive land cover. Dense woodland covering 4,099.32 hectares (10.17%) and built-up/bare land covering 3,584.16 hectares (8.89%) were the sixth and seventh extensive land cover area in the district, respectively.

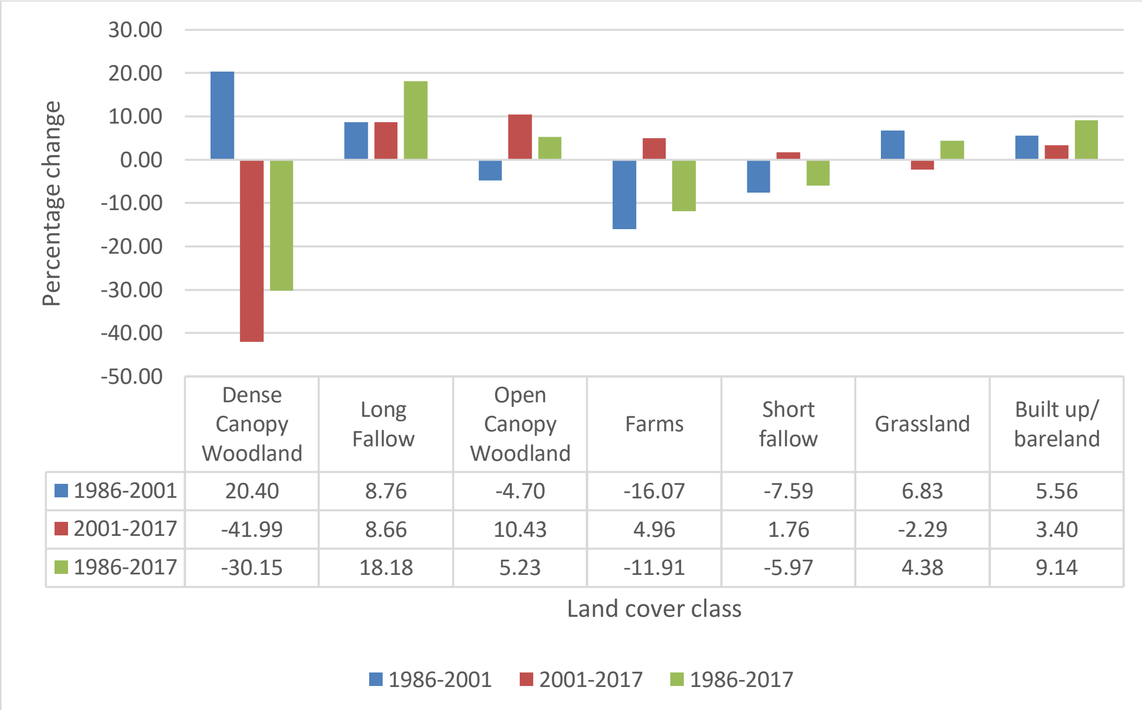
The extent of land use and land cover classes in 2017

As shown in Table 4.12, the order of land cover classes by their spatial extent for 2017 was almost the same as in 2001 except for the slight changes in terms of the last two classes. The long fallow area was the most extensive land cover. Long fallow covered 8,336.70 hectares representing 20.69% of the land surface area of the District. It was followed by open woodland, covering 7,359.39 hectares (18.26%). Grassland covered 6,332.04 hectares (15.52%), being the third most extensive land cover of the District. The fourth land cover was short fallow covering an area of 6,255.54 hectares (15.52%) while the fifth was farmland (covering 5,926.59 hectares, 14.71%). Built-up/ bare land also covered an area of 3,706.02 hectares (9.2%) and was the sixth extensive cover type. The seventh cover type by area was dense woodland land with an area of 2,378.16 hectares (5.9%**).**

4.5.3 Change in land cover in Nandom District over 31-year period

Figure 4.13 presents the proportion of change during the periods 1986 to 2001, 2001 to 2017 and net change from 1986 to 2017.

As presented in Figure 4.13 (and further analysis of areas in Table 4.12), the change in land cover over the period, 1986-2001, reflected a mixed change in area under cultivation and the other cover types. There was a marginal increase in the long fallow area of 617.85 hectares (8.76%) with a decrease in the short fallow area of 504.81 hectares (7.59%) and a decrease in farmland area (by 1081.35 hectares, 16.07%). Dense canopy woodland increased by 694.44 hectares (20.4%), open canopy woodland decreased by 328.86 hectares (4.7%), grassland increased by 414.09 hectares (6.83%) and built-up area increased by 188.64 (5.56%).



	Dense Canopy Woodland	Long Fallow	Open Canopy Woodland	Farms	Short fallow	Grassland	Built up/ bareland
1986-2001	20.40	8.76	-4.70	-16.07	-7.59	6.83	5.56
2001-2017	-41.99	8.66	10.43	4.96	1.76	-2.29	3.40
1986-2017	-30.15	18.18	5.23	-11.91	-5.97	4.38	9.14

Figure 4.13 Percentage change in land cover class during periods 1986-2001, 2001-2017 and 1986-2017

In the period, 2001-2017, short fallow area marginally increased (107.91 hectares, 1.76%). There was also an increase in long fallow area (664.65 hectares, 8.66%) as well as farmland (279.99 hectares, 4.96%) and open canopy woodland (694.89 hectares, 10.43%). There was a decrease in dense canopy woodland cover (1721.16 hectares, 41.99%) and grassland (148.14 hectares, 2.29%). Once again, the built-up area increased by 121.86 hectares (3.40%).

Over a 31 year period of assessment (1986-2017), the change in land cover show a net decrease in dense canopy woodland cover (1,026.72 hectares, 30.15%), a net increase in open-canopy woodland (366.03 hectares, 5.23%), net increase in grassland (265.95 hectares, 4.38%) and net increase in built-up cover (310.50 hectares, 9.14%). The area under cultivation showed a mixed pattern with long fallow area increasing by 1,282.50 hectares (18.18%). There was also a decrease in the short fallow area (396.9 hectares, 5.97%) and farmland (801.36 hectares, 11.91%).

4.6 Household willingness-to-pay for the conservation of woodland ecosystem and preferred conservation strategy

4.6.1 Willingness-to-pay for the conservation of the savannah woodland ecosystem

Out of the 303 respondents participating in the cross-sectional survey, one study participant ended the interview to attend to other business while the remaining 302 participated in the valuation study. Three hundred respondents (99.34%) were willing to support conservation efforts. An 80-year male household head mentioned that he was "old' and "was not in the position to give." The second, a 61-year-old female head of household said, she had "no time."

Of the 300 willing to support conservation efforts, 88.67% were willing to support fully, 10.0% were willing to support partially, while 1.33% were undecided.

4.6.1.1 Preferred mode of contribution for conservation

Two hundred and eighty-four, 284 (94.04%), 12 (3.97%) and six (1.99%) respondents preferred to contribute farm produce, cash/money and other forms of contribution (number of hours work per day) respectively. Since there was no standard in the district to estimate or compute the unit cost per hour of work, the six respondents selecting other/manpower were excluded from further analysis. Figure 4.14 illustrates the specific type of farm produce preferred by 284 households.

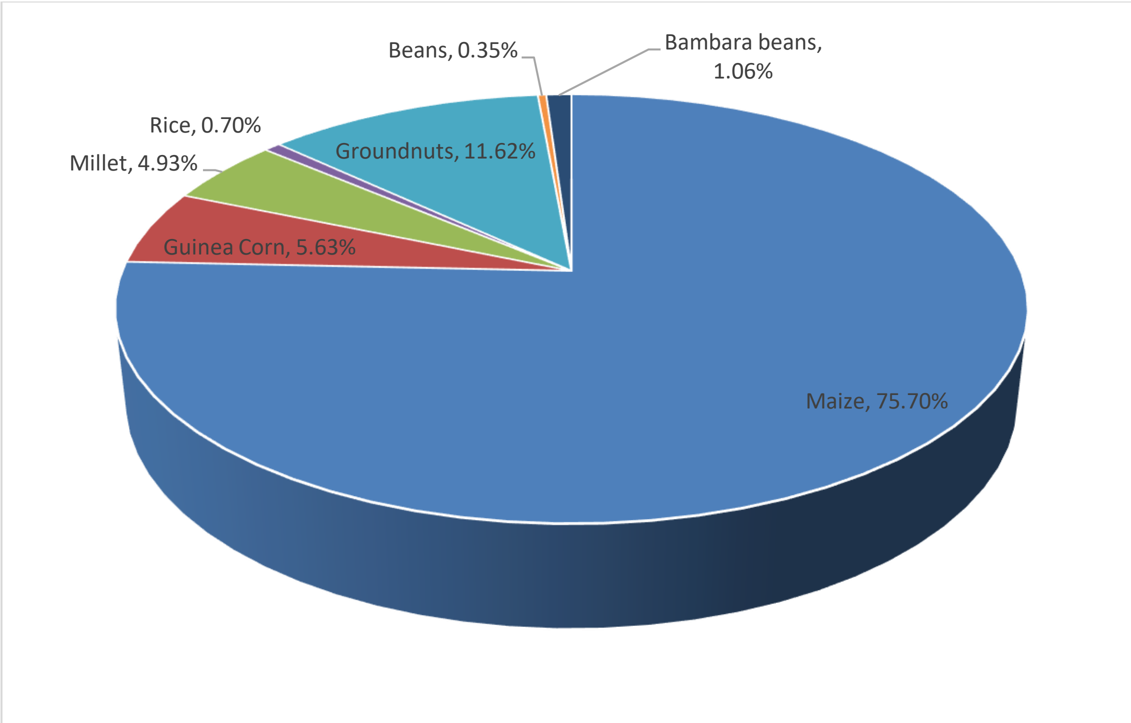


Figure 4.14 Preferred type of farm produce farmers are willing to contribute towards conservation

4.6.1.2 Value of ecosystem service for Nandom District

Two hundred and ninety-six (296) respondents provided minimum and maximum values (farm produce or in monetary terms). The values for farm produce were converted into monetary values, as explained in 3.3.2. Minimum and maximum WTP values (in bowls or cash value) were not normally distributed (as shown in Table 4.13). The conversion of farm produces to monetary value created outliers. Outliers were not excluded from the analysis. Therefore, nonparametric tests were used for further analysis. Table 4.13 presents descriptive statistics on the value of woodland ES in the District.

Table 4.13 Descriptive statistics on the valuation of woodland ecosystem services

		Contribution by farm produce				Contribution by cash (GH¢)		Combined WTP (in GH¢)	
		Farm produce (bowls)		Monetary value (GH¢)					
		Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Number (n)		284	284	284	284	12	12	296	296
Measures of central tendency									
Mean		4.195	9.437	16.580	37.204	9.250	22.667	16.283	36.615
Median		3.00	5.00	10.00	21.00	5.00	15.00	9.50	20.00
Mode		2.00	10.00	6.00	30.00	5.00	3.0/15.0/20.0	6.00	30.00
Measures of dispersion/spread/variation									
Standard deviation		5.347	11.855	22.809	47.397	13.178	27.615	22.531	46.817
Skewness		4.754 (± 0.145)	3.837 (± 0.145)	4.177 (± 0.145)	3.548 (± 0.145)	3.153 (± 0.637)	2.355 (± 0.637)	4.201 (± 0.142)	3.571 (± 0.142)
Kurtosis		27.504 (± 0.288)	17.574 (± 0.288)	22.013 (± 0.288)	16.928 (± 0.288)	10.427 (± 1.232)	5.946 (± 1.232)	22.424 (± 0.282)	17.264 (± 0.282)
Minimum		0.50	1.00	1.50	3.50	2.00	3.00	1.50	3.00
Maximum		40.00	80.00	200.00	400.00	50.00	100.00	200.00	400.00
Range		39.5	79.0	198.50	396.50	48.00	97.00	198.50	397.00
Quartiles	1st	2.00	4.00	6.00	12.00	2.75	5.25	6.00	12.00
	2nd	3.00	5.00	10.00	21.00	5.00	15.00	9.50	20.00
	3rd	5.00	10.00	16.00	39.00	10.00	23.75	15.00	36.00
Others									
95% confidence interval for mean		3.571-4.820	8.052-10.821	13.916-19.2443	31.668-42.7403	0.877-17.6229	5.121-40.2126	13.706-18.8603	31.256-41.9702

Household characteristics and WTP

Minimum WTP did not vary by: relation to household head, $\chi^2(7) = 3.658$, $\rho = 0.818$; migration status, $\chi^2(1) = 1.384$, $\rho = 0.239$; household socioeconomic status/wealth index, $\chi^2(4) = 6.109$, $\rho = 0.191$; or type of settlement, $\chi^2(1) = 2.527$, $\rho = 0.112$.

Similarly, maximum WTP was not significantly different by: relation to household head, $\chi^2(7) = 3.474$, $\rho = 0.838$; SES/WI, $\chi^2(4) = 1.972$, $\rho = 0.741$; or residence, $\chi^2(1) = 2.911$, $\rho = 0.088$. However, maximum WTP was significantly different between respondents who had not migrated and returnee migrants, $\chi^2(1) = 4.853$, $\rho = 0.028$, with mean ranks of 168.68 for returnee migrants and 142.60 for respondents who had not migrated.

The minimum WTP was significantly different by sex of household head $\chi^2(1) = 9.736$, $\rho = 0.002$ with mean ranks of 154.13 for male-headed households and 106.49 for female-headed households; and sex of respondent, $\chi^2(1) = 5.658$, $\rho = 0.017$ (with mean ranks of 156.81 for male respondents and 131.95 for female respondents). The maximum WTP was also significantly different among male and female-headed households, $\chi^2(1) = 11.935$, $\rho = 0.001$ with mean ranks of 154.77 and 101.76 for male-headed and female-headed households respectively; and sex of respondent, $\chi^2(1) = 6.877$, $\rho = 0.009$, with mean ranks of 157.71 for male and 130.17 for female respondents.

Minimum WTP significantly varied by sub-district [$\chi^2(3) = 17.566$, $\rho = 0.001$, mean ranks of 181.08, 164.86, 134.33 and 129.11 for Puffien, Baseble, Nandom and Ko sub-districts respectively. Similarly, maximum WTP was significantly different by sub-district, $\chi^2(3) = 15.251$, $\rho = 0.002$ with mean ranking order of Puffien (182.36), Baseble (158.32), Ko (135.31) and Nandom (133.19).

Total value for woodland conservation in Nandom District

The minimum and maximum median values that smallholder farming households were willing to pay to conserve the woodlands were 9.50 Ghana cedis [GH¢] ($ 2.15) and GH¢ 20.00 ($ 4.53) per year respectively. Thus, using the total household size in the District, the total minimum and maximum values to conserve woodlands in the Nandom District are GH¢ 90,953 ($ 20,614.45) and GH¢ 191,480 ($ 43,398.84) per year respectively.

4.6.2 WTP for the conservation of the woodland ecosystem by preferred conservation strategy

Table 4.14 present the mean minimum and maximum WTP values by conservation strategy.

Table 4.14 Mean minimum and maximum WTP by preferred conservation strategy

Conservation Strategy	Mean WTP (in Ghana cedis)	
	Minimum	Maximum
Preservation	13.7188 (± 10.1476)	28.5000 (± 21.4674)
Restoration	16.9766 (± 25.0720)	37.9346 (± 50.9717)
Both	16.3858 (± 22.3238)	37.3858 (47.0858)

A Kruskal-Wallis H test showed no statistically significant difference in minimum WTP between the different choices of conservation strategies ($\chi^2(2)$ = 0.620, ρ = 0.733) with a mean rank minimum WTP score of 153.88 for preservation, 150.59 for restoration and 143.61 for combined conservation strategy. Similarly, there was no statistically significant difference in maximum WTP among the different choices of conservation strategies ($\chi^2(2)$ = 0.644, ρ = 0.725) with mean rank maximum WTP score of 147.88 for preservation, 151.99 for restoration and 143.57 for both.

4.7 Leaf litter decomposition and quantity of nutrient remaining in select woodland species

4.7.1 Physical and Chemical properties of soil from the experimental site

Table 4.15 shows the physical and chemical properties of the Savannah Ochrosol from the experimental field site, Dambolteng, Nandom Sub-district. Soil texture was found to be loam with 0.13 moisture content. The proportion of silt, sand and clay in soil were 49%, 31% and 20% respectively. Bulk density was 1.06 g/cm^3, organic carbon 0.44%, organic matter 0.76%, total nitrogen, 0.023%, available phosphorus 0.2%, potassium 0.091 Cmol/kg/s, calcium 2.86 Cmol/kg/s, sodium 0.15 Cmol/kg/s and magnesium 1.63 Cmol/kg/s. The Soil pH recorded was 6.3 which is slightly acidic and satisfactory for most crops. The temperature of the soil prior to soil sampling was 33.4℃ and poor in fertility considering percentage content of organic matter of 0.76%.

Table 4.15 Physical and chemical properties of soil from the experimental site

		Demarcated zone			
		Zone A (Shea)	**Zone B (Tonbgo)**	**Zone C (Sugeh)**	**Zone D (Dawadawa)**
Physical properties					
Bulk density (g/cm^3)		1.044	1.035	1.151	1.0042
Textural class		loam	loam	loam	Silt loam
Particle size distribution	Sand (%)	31	30	29	32
	Silt (%)	49	50	48	51
	Clay (%)	20	21	19	20
Micro-climate	Temperature (°C)	32.5	34.5	33.5	34.5
	Moisture	0.13	0.15	0.13	0.14
Chemical properties					
pH (measured in 1:2 soil to water)		6.1	6.3	6.3	6.4
Organic Carbon (%)		0.673	0.6824	0.6732	0.674
Total Nitrogen (%)		0.023	0.023	0.023	0.024
Available phosphorus (mg/kg)		7	6.8	7.2	7
Electrical conductivity (mS/cm)		12.78	10.44	11.43	12.19
Exchangeable base (Cmol (+)/kg)	Ca^{2+}	2.577	2.692	2.207	3.982
	Mg^{2+}	1.583	1.638	1.085	2.222
	Na^{+}	0.168	0.154	0.125	0.149
	K^{+}	0.036	0.072	0.040	0.217

4.7.2 Leaf litter decomposition and nutrient remaining in dominant woodland species

4.7.2.1 Decomposition rate and Mass remaining of common woodland species in Nandom District

Generally, the loss in weight of decomposing leaf litter increased with days for all species as in Table 4.16 and Figure 4.15. Table 4.17 presents the decomposition rates of the different species at different sampling days. *Cordia myxa* was the fastest decomposing species followed by *Lannea microcarpa* and *Parkia biglobosa.*

Table 4.16 Mass remaining of decomposing leaf litter of four tree species

Tree species	Initial mass (g)	Remaining mass (Mean ± SD) (g)					
	Day 0	Day 10	Day 20	Day 30	Day 60	Day 90	Day 120
Parkia biglobosa	3.00	2.703 ± 0.05	2.368 ± 0.23	2.273 ± 0.12	1.155 ± 0.43	0.703 ± 0.26	0.119 ± 0.001
Vitelleria paradoxa	3.00	2.579 ± 0.26	2.483 ± 0.40	2.433 ± 0.15	1.381 ± 0.25	1.047 ± 0.22	0.347 ± 0.00
Lannea microcarpa	3.00	2.440 ± 0.07	2.183 ± 0.22	1.428 ± 1.14	0.846 ± 0.30	0.435 ± 0.32	0.230 ± 0.01
Cordia myxa	3.00	2.233 ± 0.21	2.100 ± 0.07	1.390 ± 0.18	0.675 ± 0.94	0.0037 ± 0.00	0.070 ± 0.1

Table 4.17 Rate of litter decomposition of four common tree species at different sampling times

Litter decomposition rate (g/g/day)				
Days elapsed	***P. biglobosa***	***V. paradoxa***	***L. microcarpa***	***C. myxa***
10	0.989	1.403	1.867	2.556
20	1.053	0.861	1.364	1.5
30	1.212	0.630	1.747	1.786
60	1.025	0.9	1.197	1.292
90	0.851	0.723	0.950	1.11
120	0.784	0.544	0.77	0.803

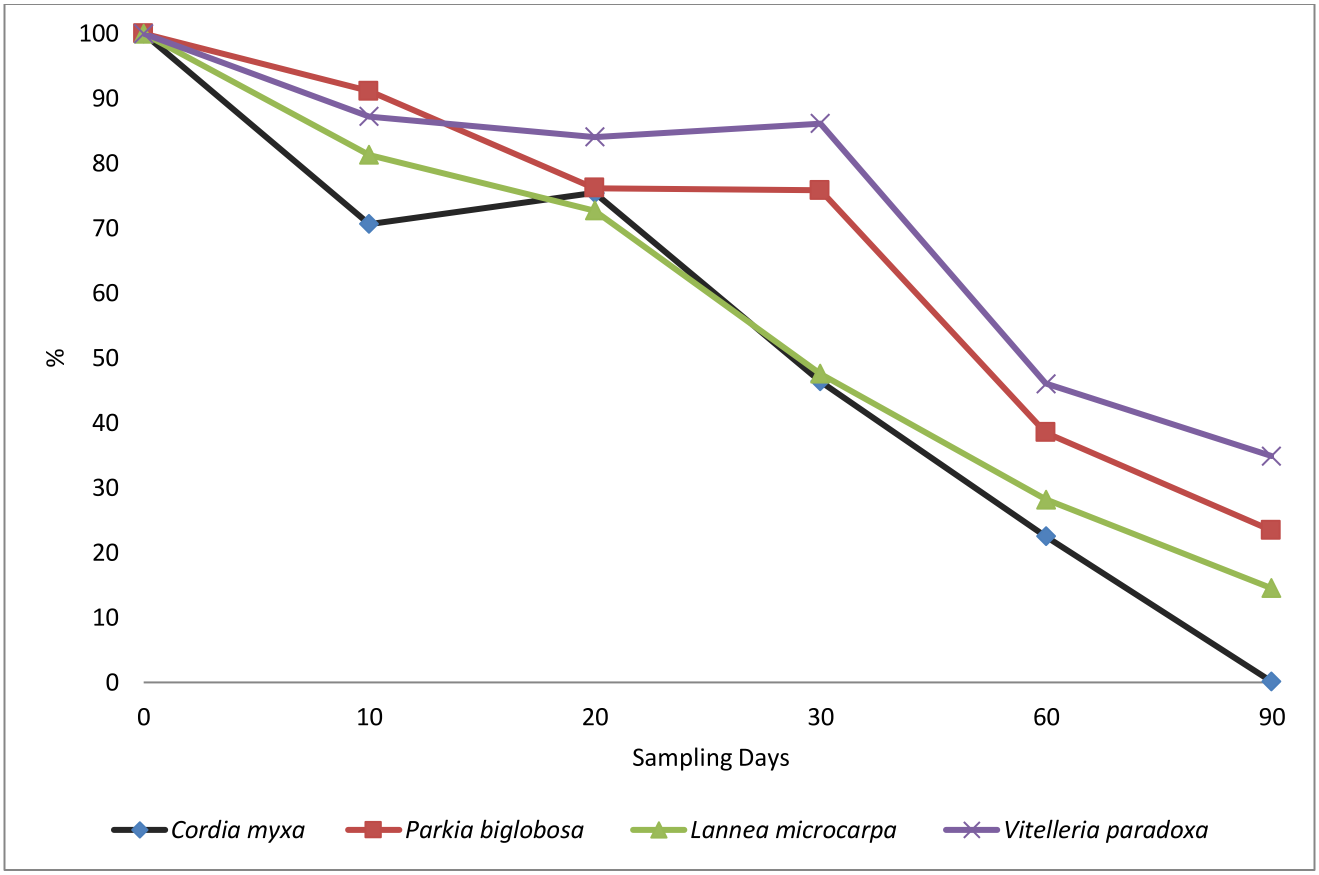


Figure 4.15 Percent of mass remaining at different sampling times

4.7.2.2 Nutrient dynamics during decomposition of common woodland species

Mineral composition of leaf litter

The baseline nutrient content of leaf litter in four common species found in the Nandom District are presented in Table 4.18. The results showed, the nitrogen pattern, in the order of, *C. myxa* > *L. microcarpa* > *P. biglobosa* > *V. paradoxa* with slight variations in the pattern for phosphorus, potassium carbon and sulphur. The C/N ratio was the lowest for *C. myxa* due to high nitrogen and low carbon content followed by *L. microcarpa*, *P. biglobosa* and *V. praradoxa*.

Table 4.18 Mineral content of leaf litter of four dominant species studied

Tree species	Nutrient element					
	Nitrogen (%)	**Phosphorus (%)**	**Potassium (%)**	**Carbon (%)**	**Sulphur (%)**	**C/N**
Vitelleria paradoxa	1.119 ± 0.001	0.105 ± 0.000	0.988 ± 0.0375	39.678 ± 0.001	0.094	35.46
Parkia biglobosa	1.700 ± 0.01	0.142 ± 0.000	0.557 ± 0.029	40.066 ± 0.001	0.161	23.57
Lannea microcarpa	2.249 ± 0.408	0.134 ± 0.01	0.915 ± 0.02	39.33 ± 0.006	0.122	23.01
Cordia myxa	3.608 ± 0.04	0.496 ± 0.000	3.33 ± 0.069	38.074 ± 0.001	0.145	10.55

Decomposition and nutrient dynamics

Figures 4.16, 4.17, and 4.18 present findings on the nitrogen, phosphorus, and potassium content remaining in leaf litter over time. Figure 4.19 presents the proportion of Carbon remaining. The percentage of carbon remaining at different sampling times was used to compute the C/N ratio.

The various mineral elements showed different patterns of decomposition. The initial rate of decomposition was highest for *C. myxa* at day ten, followed by *L. microcarpa*, *V. paradoxa*, and *P. biglobosa*. Also, *C. myxa* recorded the highest initial concentration of nitrogen (N) 3.608%, and potassium (K), 3.33%. The initial phosphorus content (P) was 1.127% and C of 38.074%. The C/N ratio recorded for *C. myxa* was 10.55 the lowest so far, compared to the other species that recorded ratios above twenty (Table 4.18). *C. myxa* was the fastest decomposing species.

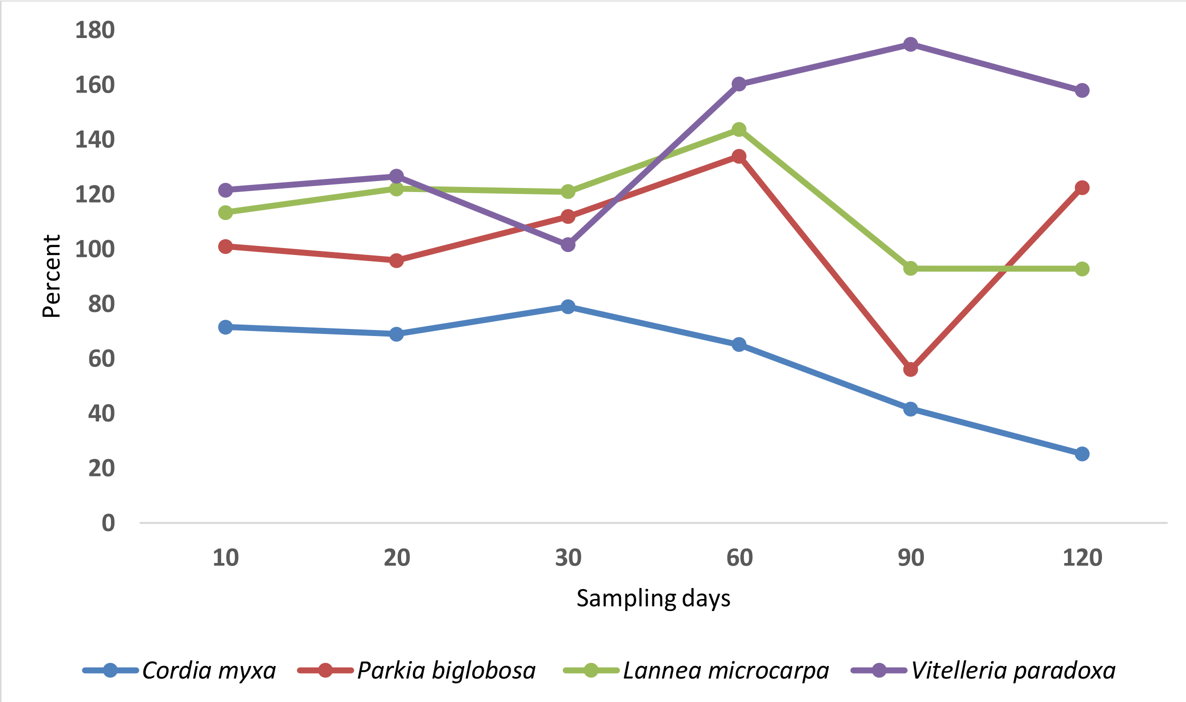


Figure 4.16 Percent Nitrogen retained in leaf litter at different sampling times

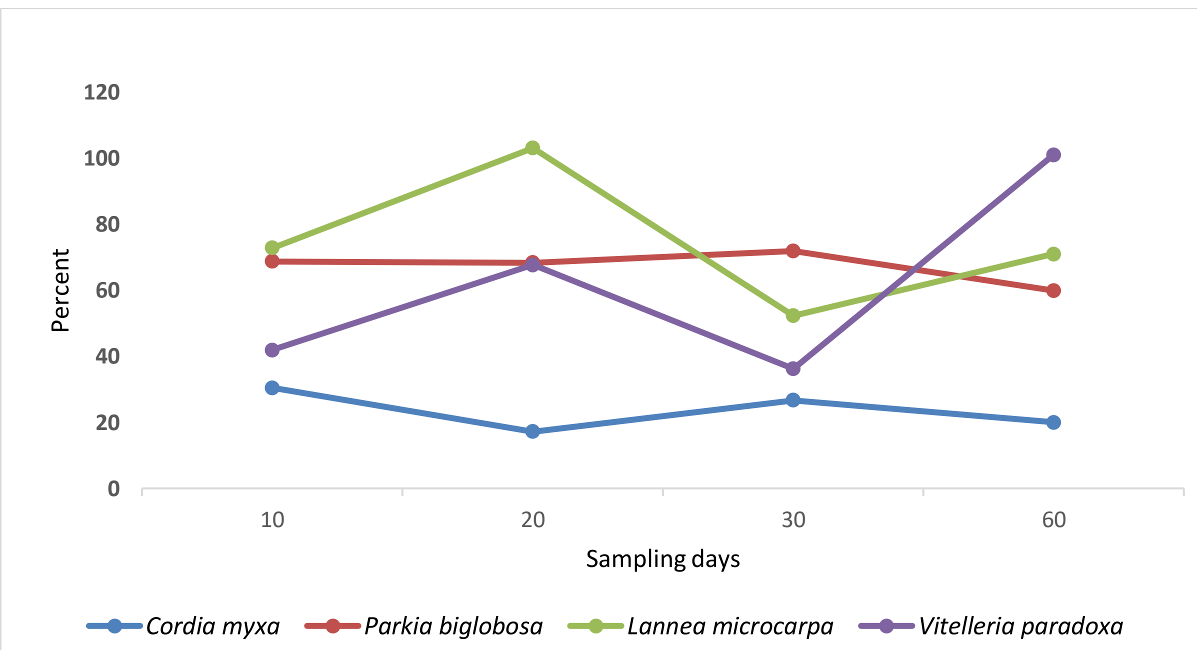


Figure 4.17 Percent Phosphorus retained in leaf litter at different sampling times

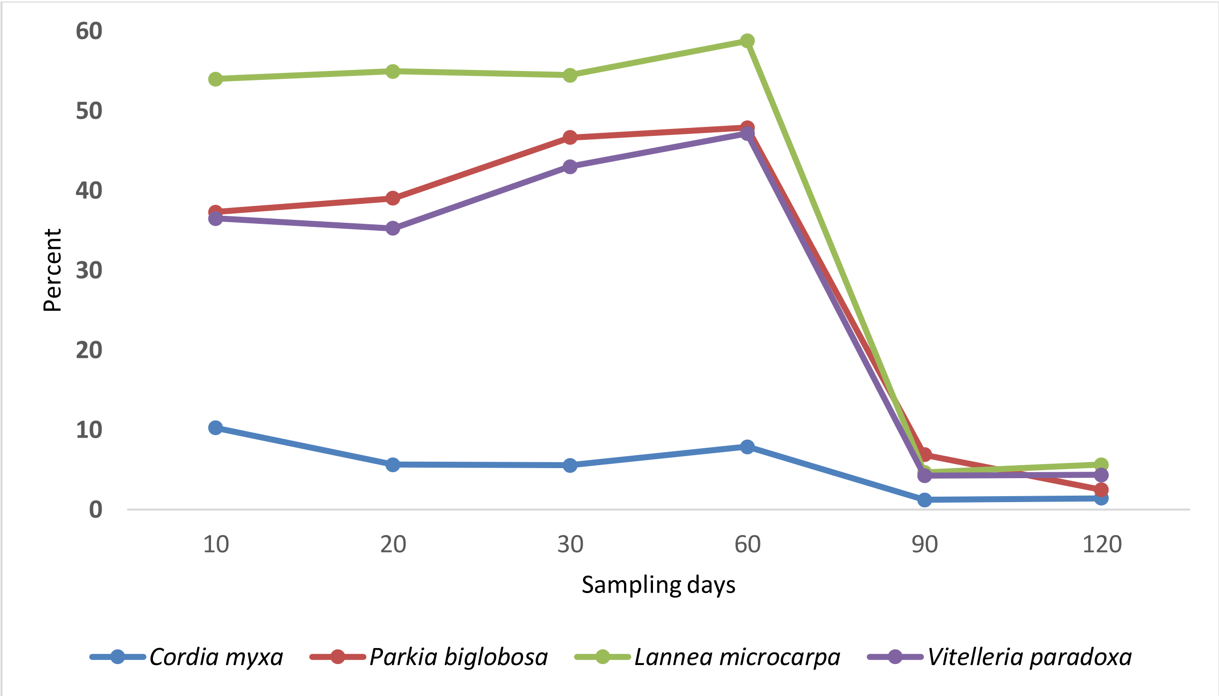


Figure 4.18 Percent Potassium retained in leaf litter at different sampling times

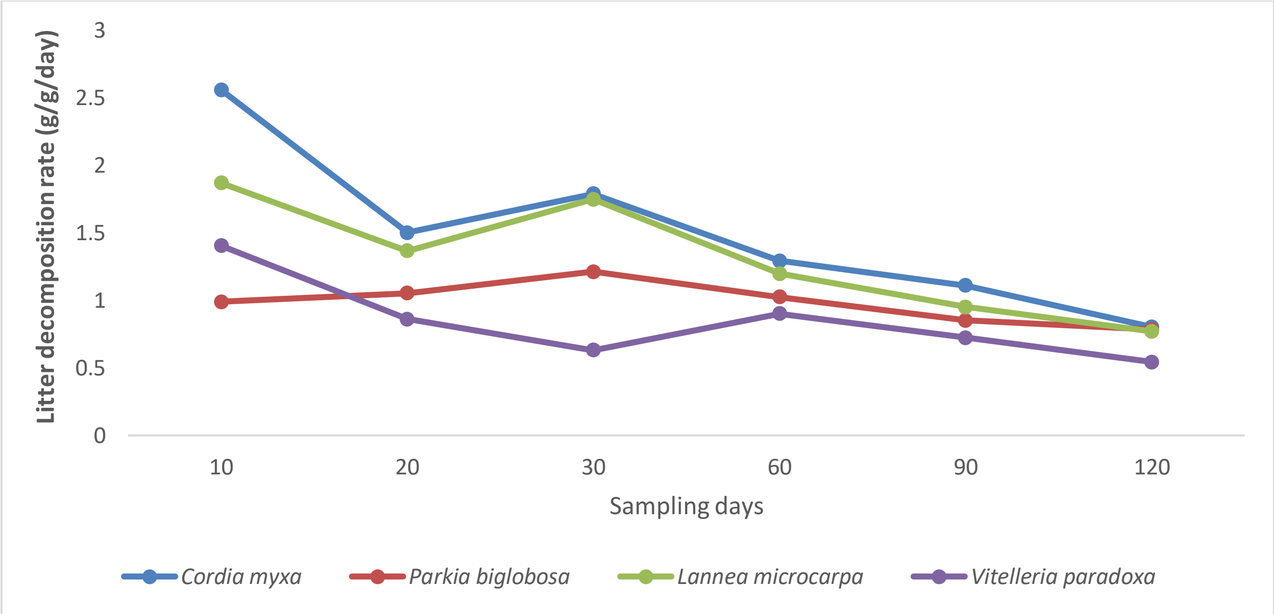


Figure 4.19 Rate of litter decomposition at different sampling times

***Cordia myxa* L.**

C. myxa recorded a decomposition rate of 0.803 g/g/day (Table 4.17) and a decay constant (k) of 0.052. This particular species gained 17.64% in sodium (Na) accompanied by a very high release of potassium (K) of 90 % and calcium (Ca) of 51.27 % on the first ten days. The pattern of nutrients remaining for *C. myxa* on day 90 is in the order N >P >Ca >Mg >S >K >Mn.

The C/N ratio for *C. myxa* was 10.55, which is less than 20, indicating strong mineralization potential. Three patterns of decomposition were observed beginning with a very rapid initial decomposition lasting for ten days with a mass of 74.4 % remaining followed by a slow phase lasting ten days and finally a rapid phase lasting for 70 days with a mass of 0.37 % remaining on day 90.

The decomposition of *C. myxa* was characterized by N and P mineralization and immobilization (Fig 4.16 and 4.17). The percentage change in nitrogen of *C. myxa* showed a three-phase pattern: leaching over the first 20 days, the net gain from day 20 to day 30, and net loss after day 30 to 120.

***Lannea microcarpa* Engl. & K. Krause**

L. microcarpa recorded the second-highest nitrogen content of 1.709 % with a decomposition rate of 0.77 % and a C/N ratio of 23.013, which is above the threshold of 20 which is an indication of immobilization. The nutrient remaining as at day 90 was in the order N >P >Ca >Mg >S >K > Mn. This species also exhibited a three-stage decomposition phase. An initial rapid decomposition was observed for the first ten days followed by a slow phase for another ten days then finally a phase lasting 90 days with a mass of 14.51% remaining. There was a 12.12% gain in Manganese (Mn) and a rapid loss of 85.227% in potassium (K), a further loss in the following: 43.36% of calcium (Ca), 13.40% of Sodium (Na) and 9.79% of magnesium (Mg) for the first ten days. The nitrogen percent change of *L. microcarpa* showed a three-phase pattern: leaching between day 0 and 20, the net gain from day 30 to 60 and, net loss after day 60. In terms of phosphorus decomposition, mineralization occurred after day zero to day 10 and from day 30 to 60, the rest of the days were characterized by immobilization.

***Parkia biglobosa* (Jacq.)**

P. biglobosa recorded the highest carbon content of 40.066 % and nitrogen content of 1.700 % with a decomposition rate of 0.78 % and an initial C/N ratio of 23.57 % which is an indicator of immobilization. *P. biglobosa* gained 41.26% in sodium (Na) but lost 62.68% in potassium (K), 70.3 % in calcium (Ca), 29.02 % in manganese (Mn) and 24.35 % in magnesium (Mg) over the first ten days. This species exhibited a three-stage decomposition phase beginning with an initial rapid decomposition for the first 20 days followed by a very slow decomposition and finally a rapid decomposition with a mass of 0.26 % remaining on day 90. The nitrogen percent change of *P. biglobosa* showed a three-phase pattern: leaching Nitrogen between day 10 and 20, the net gain from day 30 to 60, and a loss after day 60 to 90. In terms of Phosphorus, mineralization and immobilization were alternating over the decomposition period. The order of nutrient remaining on day 90 is as follows P >N> Ca >Mg > Na >S >K > Mn.

***Vitellaria paradoxa* C. F. Gaertn**

V. paradoxa recorded the highest C/N ratio of 35.46 % and the second-highest in the initial carbon content (C) 39.678 %. It recorded the lowest nitrogen content of 1.119 % for day 10 and subsequently for the remaining days up to day 60. *V. paradoxa* recorded the lowest rate of decomposition of 0.544 g/g/day and the lowest decay constant (k) of 0.018. This species depicted a four-pattern decomposition phase. An initial rapid decomposition phase of 10 days, a slow phase of 20 days, another rapid phase lasting for 30 days, and finally a slow decomposition phase of 30 days and finally a prolonged decomposition rate. This species recorded a gain in sodium of 17.63% with losses in the following elements, potassium (K) of 63.11%, calcium (Ca) of 24.81%, and magnesium (Mg) of 11.65%. The percent change in nitrogen of *V. paradoxa* showed a three-phase pattern: leaching from day 20 to 30, net gain after day 30 to 60, and net loss after day 60 to 90. Slow phosphorus mineralization occurred between day 10 and 60, while the rest of the days was characterized with immobilization. At day 90, the nutrient remaining is as follows N > P > Ca > Mg > Na > S > K > Mn.

4.7.3 Comparing concentration of N, P and K by day of sampling among species

Using Fisher's Least Significant Difference (LSD), Tables 4.19, 4.20 and 4.21 show results of significance tests of concentrations at days of sampling between the four species studied. The results indicated values that were relatively the same across different species, an example being two, or three values with the same letter type and those with significant relationship denoted by different litter type.

Table 4.19 Significance test of Nitrogen concentration across four woodland species at different sampling times

Species	Day 0	Day 10	Day 20	Day 30	Day 60	Day 90	Day 120
C. myxa	3.609 c	2.577 d	2.493 d	2.846 d	2.353 c	1.500 b	0.910 a
L. microcarpa	1.708 b	1.938 c	2.085 c	2.067 c	2.455 d	1.589 c	1.587 b
P. biglobosa	1.700 b	1.701 b	1.63 b	2.067 b	2.276 b	0.954 a	2.084 d
V. paradoxa	1.119 a	1.360 a	1.417 a	1.136 a	1.793 a, c	1.956 d, c	1.767 c, a
LSD ($\rho \leq 0.05$)	0.03885	0.02021	0.05300	0.03440	0.0747	0.00765	0.01300

Table 4.20 Significance test of Phosphorus concentration across four woodland species at different sampling times

Species	Day 0	Day 10	Day 20	Day 30	Day 60	Day 90	Day 120
C. myxa	1.127 c	0.924 b	1.461 b	2.753 d	1.448 c	1.263 c	2.738 c
L. microcarpa	0.976 a	0.721 a	0.885 a	1.469 c	0.689 a	1.588 d	1.371 b
P. biglobosa	1.022 b	2.352 d	1.483 c	1.413 b	1.672 d	1.046 a	0.917 a
V. paradoxa	1.259 d	1.874 c	1.578 d	0.956 a	0.993 b	1.155 b	3.606 d
LSD ($\rho \leq 0.05$)	0.001380	0.00783	0.005329	0.003202	0.005521	0.005583	0.001398

Table 4.21 Significance test of Potassium concentration across four woodland species at different sampling times

Species	**Day 0**	**Day 10**	**Day 20**	**Day 30**	**Day 60**	**Day 90**	**Day 120**
C. myxa	3.330 c	0.341 b	0.188 a	0.185 a	0.263 a	0.041 b	0.048 c
L. microcarpa	0.915 b	0.494 c	0.503 d	0.49 d	0.538 c	0.043 c	0.052 d
P. biglobosa	0.557 a	0.208 a	0.217 b	0.26 b	0.273 a	0.038 a	0.014 a
V. paradoxa	0.988 b	0.361 b	0.348 c	0.424 c	0.466 b	0.042 b, c	0.043 b
LSD ($P \leq 0.05$)	0.0848	0.0368	0.0236	0.0292	0.0289	0.0013	0.0008

CHAPTER FIVE

5.0 DISCUSSION

The Nandom District, as well as other semi-arid districts of Northern Ghana, is prone to the effects of land degradation and desertification (EPA, 2002). These are threats to ecosystem services, especially from the woodland ecosystem. The soil fertility in the area is significantly affected, resulting in the use of reserve and marginal lands for farming (Duadze, 2004). Desertification is the primary environmental challenge and impediment to meeting basic human needs in drylands (MA, 2005). Desertification threatens livelihood, improvement in wellbeing, and reverses efforts at reducing poverty due to the reliance of rural households on ecosystem services (EPA, 2002). The provision of ecosystem services protects vulnerable families from external shocks such as food scarcity, providing safety net until the next harvesting season (Oksanen *et al*., 2003).

The study area is currently experiencing the effect of climate change and climate variabilities (Padgham *et al*., 2015). These are prolonged drought, erratic rainfall patterns, and increasing temperatures that are affecting the provisioning of all ecosystem services (Padgham *et al*., 2015). These interlocking factors affect the provisioning of ecosystem services and create challenges for food security and sustainable management of ecosystems (ALP, 2014). The existing poverty situation in the area (GSS, 2014b; GSS, 2015) coupled with reliance on rain-fed agriculture (GSS, 2014a) and poor access to resources and services creates a situation of high vulnerability to smallholder farmers.

5.1 Benefits derived from savannah woodlands

The results showed that community woodlands were commonly accessed (97%) for ES by farming households. The finding is probably due to the closeness of community woodlands to homes as well as the ease of access to community woodland. Furthermore, access to the reserve woodland and tree plantations owned by individuals or families were nearly 9% and 23% respectively. The low percentage of farming households with access to the reserve woodland may be due to community rules and government regulation (Figures A1.1, A1.2 and A1.3). Also, access to the family plantation was low because of ownership/entitlement to plantations. As found by Dittoh (2004), land tenure influenced access to plantations.

The findings of the study suggest heavy reliance on community woodland ecosystem services followed by the reserve woodland and family plantation. The results are broadly in line with previous studies (Asamoah & Wiafe, 2016; Boafo *et al*. 2014; Tugume et al. 2015; Hapsari, 2010; Pullanikkatil et al. 2016). This study, therefore, adds to the body of knowledge by highlighting the community woodland as the dominant source of ecosystem services followed by the reserve woodland and family plantation. Additionally, this study contributes to the body of knowledge by presenting in quantitative terms cultural, provisioning, regulating, and supporting service benefits to households in Northern Ghana. Generally, the findings of the study corroborate the results found in the literature.

5.1.1 Cultural services

Less than 20% of farming households derive spiritual/religious benefits from the different woodland types identified in the Nandom District, with 88.5% ranking spiritual/religious benefits from woodlands as unimportant. According to the Ghana Statistical Service, majority of the people in the Nandom District of Northern Ghana are Christians (85.6%) or Moslem (6.6%) with 5.7% practicing the African Traditional religion (GSS, 2014a). Spiritual/religious benefits from woodlands are common with people practicing the traditional religion (Niangoran-Bouah, 1983 as cited in FAO, 1990). Spiritual benefits are intangible and reflect an individual's beliefs (FAO, 1990). Typically, sacred 'gods,' revered places, and totems are common places in woodlands (FAO, 1990). Even though the *kakala* tree was reported as a totem and this tree is not felled, Christians and Moslems may not offer sacrifices or reverence to these trees in the Nandom District. Similar findings were reported in Nepal by Chaudhary *et al*. (2018), who found that 93% of households attach spiritual and religious values to forest ecosystem services, but only 7% use the forest for traditional cultural practices.

Additionally, 77%, 94%, and 76% of farming households derived aesthetic benefits from the reserve woodland, community woodland, and family plantation, respectively. A little over 60% of households ranked aesthetic benefits derived from Savannah woodlands as important (20.5%) or very important (40.1%) reflecting different levels of appreciation of aesthetic benefits, an intangible benefit (Europe Economics, 2015). This finding shows the importance farming households attach to aesthetics from the woodland ecosystem. This result may be re-emphasizing the important function of aesthetics to rural households as already captured by MA (2005) and TEEB (2009). The Nepal study found aesthetic in the form of, green forest and landscape to be 5%, based on household perception and use. By comparison with 94% from community woodland, the Nepal value is low. The differences may be due to sociocultural practices. In the case of the Nandom district, 78.3% of the farmers engage in skilled agricultural, forestry, and fishery, and work within the private informal sector (GSS, 2010). These livelihood options increase farming households' access to aesthetic as well as recreational and educational benefits associated with the general landscape.

The results further showed that 77%, 92%, and 83% of farming households used reserve woodlands, community woodlands, and family plantation respectively for recreational purposes. The figures are higher than that found in Nepal where 21% of households use the forests for recreational purposes. The reason for the low benefit in the Nepal situation could be due to the social status of the study population who are mostly well educated with occupation and may not require nature for recreational benefits. The poverty situation in the Nandom district leave farming households with no other options but maximise the natural environment for recreational benefits. As such, nearly a little over 50% of these households ranked recreational benefits derived as important or very important.

Again, 62%, 78%, and 59% of farming households derive educational benefits from the reserve woodland, community woodland, and family plantation, respectively. Notably, 48% of households ranked educational benefit as important or very important. The findings in this study are higher than the results by Chaudhary *et al*. (2018), who found that 7% of households in the Mai Pokhari Ramsar site reported using the forest for educational purposes. In the Nandom district, meaningful deductions are made from nature to mark seasonal events which are evident from the responses to questions on the importance of the woodland ecosystem. It was revealed that the sighting of certain species of birds, the shading of some species of trees signified the beginning of the dry or wet season. This information helped the farmer in seasonal farming activities. Knowledge of indigenous tree species which serve as medicine in local treatment of various ailments and conditions for livestock (Tiyumtaba, 2016) and humans. As a result, the aged are economically engaged as they remain the primary service providers in the trade due to their experience or knowledge of the natural vegetation. However, due to advancements in social media and health care delivery, reliance on the natural environment for information is dwindling. These benefits explain the high values attached to educational benefits by household. However, the availability of radio information on climate change and health care delivery may have affected the importance households attach to educational benefits.

5.1.2 Provisioning services

The results of this study illustrate the importance of woodland provisioning services to livelihoods in the Nandom District. Households were reliant on the community or reserve woodland or family plantation for provisioning services. More than 50% of farming households ranked as important or very important food crops (76%), soil for construction (70%), fuelwood (67%), poles for construction (56%), edible vegetables (54%), and wild fruits (51%). Other provisioning services ranked as important or very important were medicinal plants (46%), fodder (29%), fiber/straw (20%), water (9%), and bushmeat (6%). The finding adds to the extensive literature showing that ES is essential for human well-being (MA, 2005; TEEB, 2010).

Similar products were explored by other researchers (Pullanikkatil, Palamuleni & Ruhiiga, 2016; Boafo *et al.*, 2014). These products constitute livelihood options due to their usefulness at the household level, income generation potential, employment opportunities, raw material, and safety net in the lean season, as confirmed by key informants and focus groups during the study. Similar observations were reported in other studies in Ghana by Boafo *et al.*, 2014; Asamoah & Wiafe, 2016, Food crops, wild fruits, and fuelwood were the most frequently accessed products from the community, reserve woodland, and family plantation, respectively.

Contrary to the findings of Ganeshaiah *et al.* (2003) that emphasized the dependence of rural households on reserve woodlands (forest products) for livelihood, this study reported greater reliance on the community woodland than the reserve woodland. The finding of this study may be due to household entitlement to shared resources, enablers to access, and restriction on reserve access as found by Boakye and Baffoe (n.d.). The continuing reliance on provisioning service from community, reserve woodland, and family plantation would enhance food security in the district and promote wellbeing. However, unsustainable harvesting could destroy the safety net of many.

5.1.3 Regulating services

The results of this study demonstrate the perceived importance of regulating service to human well-being in the Nandom District. The perceived benefit of all types of woodlands in air quality maintenance was high (80-98%). Notably, activities such as funerals, marriage ceremonies, festivals, market structures, and meetings do occur under tree or airy places, especially during the day in the District.

The perceived benefits of types of woodlands in storm protection were variable. Households perceived trees from all woodland types to serve as windbreaks (92-98%). Regarding the protection of close-by buildings, over 80% of households perceived community woodland and family plantation to protect close by building while that for reserve woodland was 46%. Community woodlands and some plantations were found to be closer to houses than the reserve woodland. Also, farmers involved in plantation farming mentioned storm protection as a reason for engaging in plantation farming, among other reasons. Community woodlands were found to be important for erosion control than reserve woodland or family plantation in the Nandom District.

Overall, community woodland was perceived as the main provider of regulating services followed by family plantation, due to their proximity to households. Elsewhere in Nepal, similar benefits recorded at the Mai Pokhari Ramsar site were quite low. These benefits were fresh air-31%, water regulation, and purification- 27%, and erosion control- 21% (Chaudhary *et al*., 2018). The location of the Ramsar site may have influenced the perceived benefits derived by households in Nepal. Other regulating benefits identified by local people, through qualitative research methods as found by Hapsari (2010) included water quality maintenance, climate regulation, and carbon sequestration.

5.1.4 Supporting services

The perceived benefit of nutrient cycling was investigated in the study. Largely, community woodlands were perceived by over 90% of households to contribute to soil fertility, with the resultant benefits of high crop yield, cost-saving from fertilizer and continuous farming (intensification) on the same farmland. The perceived contribution of reserve woodland and family plantation to soil fertility was 31% and 24% respectively. Farmers may have noticed increased crop yield around trees as reported from a study in Ethiopia (Tanga, Erenso & Lemma, 2014), as well as increases in soil organic matter/debris which influence soil fertility as published by Osman (2013). The implementation of community bye-laws against tree felling may have also played a role in increasing leaf litter and soil organic matter in community farmlands. Restriction on farming in the reserved woodland except for the degraded portion as reported by Kalame *et al*. (2011) may have also accounted for its low value. Overall, the outcome of these findings emphasises the benefits of ecosystem services and therefore supports this thesis by adding to the body of knowledge.

5.2 Access and use of the savannah woodland by different social groups

5.2.1 Influence of Endowment and Entitlement on access to woodlands

Endowment is defined as the "rights and resources actors have" while entitlements are the "means to use a resource" (Leach *et al*., 1999 as cited in Fisher *et al*., 2014, p. 38). Endowments and entitlement and capital have a significant influence on access to woodlands.

Farming households in Nandom are endowed with woodlands mainly available in their communities, as 97% had access to community woodlands. Fewer than 10% and 25% of farming households in the district had "rights" to the reserve woodland and family-owned plantation respectively. Access to land for farming limited the rights households had to the reserve woodland and family-owned plantation (Appendix, Table A1.1), which confirms the work of Dittoh (2004), who concluded that land tenure systems limit the rights to trees on plots of land and farms.

According to one community chief and confirmed by participants of focus groups, households without rights to woodlands, 'steal' different products from woodlands. Ribot and Peluso (2003) noted that stealing and coercion exist which is also a medium for accessing forestry resources.

5.2.2 Influence of Livelihood assets (capitals) on access to woodlands

5.2.2.1 Social capital and access to woodlands

The following characteristics were identified as social capital: sub-district, settlement type, sex of household head, household size, and household socioeconomic status.

<u>Location of household and access to woodlands</u>

Sub-district was significantly associated with access to all woodland types. From the study, 19.5% and 6.7% of farming households in the Nandom and Puffien sub-districts respectively had access to the reserve woodland. No farming household in the other two sub-districts, Ko and Baseble, had access to the reserve woodland. The proportion of farming households with access to community woodland was 92% in the Nandom sub-district and 100% in the other three sub-districts. Access to family-owned plantations was 38%, 4%, 20%, and 22% in the Nandom, Ko, Baseble, and Puffien sub-districts respectively. The results are not surprising as the Nandom sub-district hosts the district capital, urban Nandom. Additionally, the majority of households in the Nandom sub-district belong to higher wealth quintiles, have access to resources to secure or purchase land for plantation farming.

Settlement (urban or rural) was significantly associated with access to the reserve woodland ($\rho = 0.005$), which confirms the findings of Ganeshaiah *et al*. (2003) who found that communities around the forest margin had access to the forest.

Nearly 29% of farming households living in the urban areas of the district accessed the reserve woodland as compared to 7% rural households. Notably, the reserve woodland is the major woodland type close to the urban settlement of Nandom Township. Settlement was also associated with access to community woodland (99% in rural areas versus 71% in urban areas, $\rho < 0.001$). The settlement was not associated with access to family-owned plantation (24% of rural households versus 19% of urban households, $\rho = 0.792$).

Analysis of data for the Nandom sub-district alone showed that settlement was associated with access to community woodland ($\rho = 0.001$) and family plantation ($\rho = 0.047$) but not the reserve woodland ($\rho = 0.239$). The finding reflects the importance of data at sub-district and local levels in understanding the dynamics of access and use of ecosystem services.

Sex of household head and access to woodlands

Sex of household head was not associated with access to reserve woodland (8.6% of male-headed households, 8.3% of female-headed households, $\rho = 1.000$), community woodland (97.0% and 97.2% of male and female-headed households respectively, $\rho = 1.000$) and family-owned plantation (22.1% of male-headed households versus 33.3% of female-headed households, $\rho = 0.135$).

A study by Coulibaly-Lingani *et al*. (2009) and Chaudhary *et al*. (2018) found that gender influences access to non-timber forest products. Coulibaly-Lingani and colleagues as well as Chaudhary and colleagues referred to the sex of respondents and did not consider the household in totality. This study, however, found that sex/gender of household head was not associated with access to any woodland type confirming similar findings by Tassou (2017). The extended family system (GSS, 2014a) practiced by the people of Nandom may influence access dynamics as the household is regarded as a unit.

Household size and access to woodlands

Household size was not associated with access to reserve woodland (ρ = 0.063) and community woodland (ρ = 0.931) but associated with access to family plantation (ρ = 0.001). Notably, increasing household size correlated with increased access to family-owned plantation. Most likely, the increase in household size increases the propensity to own, or access plantations through social connections. As mentioned by respondents from households with plantations, plantations serve as a form of security against poor yield, provide poles and other benefits and serve as a capital for their children.

A study by Zorondo-Rodríguez (2007), in India, on the determinants of NTFPs collection found that the presence of additional family members increased the household's probability of collecting NTFP. Households' members can also provide labour that may help in collecting NTFPs. The finding also supports the view of Coulibaly-Lingani *et al*. (2009) that a relatively large household size may be the motivation for dependency on forest products.

Household socio-economic status and access to woodlands

Household socioeconomic status was not associated with access to reserve woodland (ρ = 0.248) and community woodland (ρ = 0.496). Household socioeconomic status was associated with access to family-owned plantation (ρ = 0.048).

In Nepal, the wealthy with a high socio-economic status owned plantations (Chaudhary *et al*., 2018) and therefore increased access to plantations. In the Nandom District, however, household wealth was not associated with ownership of family-owned plantations (ρ = 0.326).

A study in Nepal found a significant relationship between household income and land size (Chaudhary *et al*., 2018). Also, in Karnataka state (southwestern region of India) a study found a negative relationship (Ganeshaiah *et al*., 2003) between socio-economic status and dependence on NTFP while a positive relationship (Tugume *et al*., 2015) was reported in Uganda.

5.2.2.2 Human capital and access to woodlands

The number of household members that work was found in this study to be significantly associated with the reserve woodland (ρ = 0.038) and family-owned plantation (ρ = 0.006). This finding points to the theory of access that indicates that "workers may invest in social relations with resource owners or managers to maintain access to both labour opportunities and the resources" (Ribot & Peluso, 2003). Additionally, households would invest in resources (DFID, 1999) to access woodlands to supplement household income and/or prevent household expenditure on ES that could otherwise be obtained from the reserve woodland or plantations.

The variable, household with adults 65 years or more, was significantly associated with access to reserve woodland (ρ = 0.003) but not access to community woodland (ρ = 1.000) or plantation (ρ = 0.716). Notably, four percent of households with adults 65 years accessed the reserve woodland as compared with nearly 14% of households without adults 65 years or more. In Uganda, Tassou (2017) found that the age of the household head was negatively associated with NTFP collection. According to the FAO (1998), "the status of older people in the community is frequently linked to their position as community elders and the repositories of traditional lore" ("Beliefs, knowledge and skills," para. 4), which may explain the results found.

There was no association between households with people living with some form of disability and access to reserve woodland (ρ = 0.275), community woodland (ρ = 0.646) or family plantation ($\rho = 0.054$). Similarly, there was no association between households with children less than 15 years with access to reserve woodland ($\rho = 1.000$), community woodland ($\rho = 0.604$) or family plantation ($\rho = 0.907$). It implies that households with people living with a disability or children less than 15 years are not at a disadvantage in accessing woodlands in the District. Additionally, households with people living with a disability may not be stigmatized (Rohwerder, 2018) or marginalized when it came to accessing woodland types. The finding is very important in the global fight (Eide & Ingstad, 2011; United Nations Convention on the Rights of Persons with Disability, 2016) to alleviate poverty especially targeting households with people living with some form of disability. The household is regarded as a unit (GSS, 2014a) and thus share products harvested. This type of social insurance caters to the needs of socially differentiated groups such as people living with a disability (PWD), young children under fifteen years and the elderly.

5.2.2.3 Natural capital and access to woodlands

Ownership of agriculture land was associated with access to community woodland ($\rho = 0.020$) but not access to reserve woodland ($\rho = 1.000$) or plantation ($\rho = 0.080$). As noted by Dittoh (2004), the land tenure system gives landowners the right and privilege over trees and other products on farms. From qualitative interviews during the study, it was found that farmers begging land to farm from landowners have access to the farmland for farming purposes only. These farmers do not have access to trees and other resources available on the land. Further permission is sought from the landowners to access trees and other resources on the farmland. Therefore, households without access to farmland will "steal" fuelwood and other provisioning services on farmlands. This phenomenon shows the complicated relationship between endowment and entitlement of resources in the Savannah.

5.2.2.4 Physical capital and access to woodlands

Household ownership of a bicycle was significantly associated with access to community woodland ($\rho = 0.017$) and access to family plantation ($\rho = 0.039$) but not access to the reserve woodland ($\rho = 0.939$). Over 80% of households (farming households) owned a bicycle. The bicycle facilitates movement, especially in search of provisioning services, as well as carries products harvested.

Additionally, the use of bicycle facilitates movement to areas inaccessible to motorcycle or vehicle. Its usage among poorer or vulnerable households helps in accessing and conveying provisioning services to the home or for sale. Its use is, therefore, an enabler promoting access to community woodland and family plantation.

Ownership of a motorcycle was not associated with access to reserve woodland ($\rho = 0.967$), community woodland ($\rho = 0.724$) and family plantation ($\rho = 0.237$). Similarly, ownership of an animal-drawn cart was not associated with access to reserve woodland ($\rho = 0.711$), community woodland ($\rho = 0.559$) and family plantation ($\rho = 0.058$). Notably, 35% of households owned a motorcycle, and nearly nine percent of households possessed an animal-drawn cart.

5.2.2.5 Financial capital and access to woodlands

Ownership of livestock, herds and other farm animals was associated with access to family plantation ($\rho = 0.004$) but not access to reserve woodland ($\rho = 1.000$) or community woodland ($\rho = 0.096$). This finding may be related to finance, as households can acquire land for plantations as a form of security or wealth. From the study, farm animals and plantations were identified as forms of financial investment or security against shocks.

5.2.3 Other factors influencing the access and use of woodland ecosystem services

Alternative livelihood options and remittance from migrated relatives influence the access and use of woodlands in the Nandom District. Additionally, there are regulatory, geographic, and socioeconomic barriers and/or enablers that influence access to woodlands by farming households in the district. The discussion of these factors is beyond the scope of this thesis.

5.3 Knowledge on climate change and woodland conservation practices

5.3.1 Level of knowledge on climate change

The level of knowledge of respondents on climate change was high (mean 75.85% ± 13.27). The finding is due to access to radio programmes on climate change and farmers' local knowledge as evident in this study.

The level of knowledge did not vary by sex of respondents ($\rho = 0.615$), migration status ($\rho = 0.654$), respondents' age group ($\rho = 0.754$), marital status ($\rho = 0.326$), occupation ($\rho = 0.155$) and relationship to household head ($\rho = 0.625$). The level of knowledge was, however, significantly different by respondents' educational level ($\rho = 0.007$) and geographic location of household, i.e., sub-district ($\rho = 0.004$). Kabir *et al.* (2016) found that respondents' age group, sex, education, occupation, and household income were significantly associated with knowledge of climate change. In their study, Kabir and colleagues did not assess the level of knowledge as was done in this study, which may have led to differences seen regarding respondents' sex, age group, and occupation.

Furthermore, 93% of respondents observed changes in the weather pattern, 84% observed decreasing rainfall patterns, and nearly 88% observed that rainfall was unpredictable. 61% of respondents observed the increasing temperature of the weather, 79% noticed that the district experienced longer episodes of drought, and 38% experienced dry spells during the farming season. In a cross-sectional study by Kabir *et al*. (2016), 94.5% of respondents in Bangladesh observed changes in weather events, 91.9% observed changes in rainfall, 83.2% observed changes in temperature, and 85.5% observed increased episodes of drought.

The main sources of knowledge on climate change were respondents' local knowledge and experience (39.9%), media (38%), community resource persons (16.5%), and external resource persons (5.6%). Similarly, findings were recorded by Kabir and colleagues (2016) in Bangladesh. In Kenya, Gichuki (2014) found the media to be the most common source of information for climate change. In the Sekyere South District of Ghana, Ansah and Siaw (2017) found that the sources of knowledge about climate change were through indigenous knowledge (which reflected in changes in weather, physical changes on trees and behaviours of animals).

5.3.2 Relationship between the level of knowledge of climate change and woodland management practices

Respondents' level of knowledge was not significantly associated with pruning (ρ = 0.073), bush fire control (ρ = 0.151), re-afforestation (ρ = 0.466) and slash and burn agriculture (ρ = 0.425). Gichuki (2014) found the level of knowledge of students on climate change to be significantly associated with willingness to participate in mitigation activities. In this study, however, the level of knowledge on climate change was not significantly associated with woodland conservation activities such as pruning, bush fire control, and afforestation. Additionally, the level of knowledge was not associated with negative conservation practices such as bush burning and slashes and burn agriculture. As mentioned earlier, community and family rules may have led to the lack of association seen. The implementation of community laws/rules protecting trees and preventing bush burning, among others may eliminate the influences of climate change knowledge on conservation. Thus, households and individuals in the District implement or adhere to community laws/rules irrespective of the level of their knowledge on climate change adaptation and woodland conservation.

5.4 Adaptation to climate change and climate variability: influence on the economic wellbeing of smallholder farming households

Livelihood options associated with the use of the woodland have been described in many studies as coping or adaptive strategies to climate change or variability (Eriksen *et al*., 2005; Fisher *et al*., 2010). Even though the distinction between coping and adaptive strategies is often blurred in academic literature, Taylor, Harris, and Ehrhart (2010) provide some guidance on their differences. Adaptation leads to long term benefits while coping responds to short term reliefs to the impact of climate change (Taylor *et al*., 2010).

5.4.1 Adaptation in the context of rural smallholder farmers

Rural smallholder farmers in Nandom District adapt to climate change through off-farm and on-farm adaptation strategies. Off-farm adaptation strategies identified by smallholder farmers in the Nandom District were: rearing of livestock, and off-farm livelihood options such as basket weaving, shea butter extraction, *pito* brewing, soap making, and petty trading. Antwi-Agyei (2012) found that selling livestock to supplement household income was an adaptation strategy. Bawakyillenuo *et al*. (2014) reported livelihood diversification as an off-farm adaptation strategy. Owing to climate change, migration of all or some members of households is common among the people of Nandom (Geest, 2011). However, migration and remittance were not identified by communities as off-farm adaptation strategies as found by Rademacher-Schulz et al. (2012) and Antwi-Agyei (2012), respectively.

On-farm adaptation strategies included crop diversification and tree planting. Crop diversification, an on-farm measure, was identified as an adaptation strategy confirming the work of Ali and Erenstein (2017), and Ndamani and Watanabe (2015). Additionally, tree planting (afforestation) was identified by the youth as an adaptation measure confirming the finding of Muchapondwa (2015), Antwi-Agyei (2012) and Mertz et al. (2010).

5.4.2 Off-farm livelihood options and economic wellbeing of smallholder farming households

A significant association was found between the following livelihood options from woodland ES and household wealth: shea nut picking ($\rho < 0.001$); harvesting fuelwood for sale or household use ($\rho < 0.001$); harvesting fodder for livestock ($\rho = 0.023$); harvesting straw for houses or basket weaving ($\rho = 0.023$); and logging to build local houses or sale ($\rho = 0.007$). These were identified as adaptive strategies to climate change and climate variability in the district.

Households in the Nandom District resort to these activities to reduce climatic and non-climatic effects on agricultural productivity (Antwi-Agyei, 2012; Eriksen *et al*., 2005). These adaptation measures are a combination of the autonomous and planned use of the woodland to improve household wellbeing. Robledo *et al*. (2012) found that, in Mali, shea butter extraction and sale of firewood/fuelwood by farmers were coping strategies. The local context, livelihood options, and capital all contribute to the differences in the results seen.

Gathering fruits and vegetables mainly for household consumption ($\rho = 0.063$), charcoal burning ($\rho = 0.434$), hunting for bushmeat ($\rho = 0.109$) and harvesting medicinal plants ($\rho = 0.317$) were not associated with economic wellbeing as such not adaptive strategies. These were rather mentioned in the focus group discussion by the elderly women and youth groups as coping strategies to climate change. This finding, therefore confirm a study in Zambia where charcoal burning and wild food harvesting were found to be coping strategies (Robledo *et al.*, 2012).

Household off-farm strategies not directly obtained from woodlands and associated with economic wellbeing were petty trading ($\rho = 0.001$), *pito* brewing ($\rho = 0.007$), and carving ($\rho = 0.026$). Others were office work or other formal employment ($\rho < 0.001$) and skilled based jobs ($\rho = 0.015$). Skill-based jobs identified in the district included tailoring, baking, carpentry, and hairdressing. These confirm the conclusion of Bawakyillenuo *et al.* (2014).

5.5 Changes in land cover in Nandom District, 1986 to 2017

This study presented an overall accuracy of 74.43% with a Kappa of 0.81 in 2017, 76.36%, with a Kappa of 0.82 in 2001 and 71.16% with a Kappa of 0.78 in 1986. Other studies in the Upper West Region of Ghana by Duadze (2004), and Prosper and Guan (2015) recorded higher overall accuracies of satellite images. These studies used broader classification schemes. The broader classification scheme adopted by the authors may have contributed to the high overall accuracies obtained.

5.5.1 Changes in land cover in Nandom District

Key informants in the study reported changes in woodland cover in the district over time. Owing to the reliance on woodlands for farming, fuelwood for household use and logs to build houses, there has been a decline in woodland cover. Additionally, *"the gradual urbanization of the Nandom Town as a result of the establishment of the Catholic Church in 1933",* as well as *the* establishment of communities led to tree cutting/felling to make room for buildings. By the early 1990s, the influence of climate change was felt by the communities- erratic rainfall patterns and poor harvest by farmers and increasingly harsh weather conditions. During this time, *"communities noticed the loss of the tree cover at an alarming rate and initiated afforestation programmes and established community bye-laws to limit tree cutting."* These laws at the time were not documented but variably implemented across communities. (Key Informant from a local NGO working in Climate Change Adaptation in Nandom District). Similar stories were provided by other key informants, i.e., community chiefs and opinion leaders.

The environmental consciousness in Nandom, initiation of afforestation programmes and bye-laws in the early 1990s and subsequently over-reliance on woodlands in the 21st century may explain the changes in woodland cover noticed by satellite imaging in 1986, 2001, and 2017.

From the current study, dense canopy woodland cover increased from 1986 to 2001. From key informant interviews, the initiation of afforestation programmes coupled with the establishment of bye-laws around the early 1990s may have contributed to this increase in dense canopy woodland seen in 2001. The impact of climate change in the District coupled with poor fertile lands (Duadze, 2004) experienced before 2001 may have led to migration to other parts of Ghana where fertile arable land was available for farming (Geest, 2011). Migration may in part have contributed to fewer trees cutting/felling, with a resultant decrease in open-canopy woodland, as mainly the youth migrated to Southern Ghana. Geest (2011) found a positive association between out-migration and vegetation cover.

Additionally, migration in search of suitable land for farming may explain the decrease in farmland and short fallow lands as well as increases in grassland and long fallow land from 1986 to 2001. As mentioned in Geest (2011, p22), there was a "significant positive trend in vegetation cover" throughout Northern Ghana between 1982 and 2006 with the Normalized Difference Vegetation Index (NDVI) increasing by 12.1%. According to Geest (2011), "the 'greening of Northern Ghana' probably" resulted "to a large extent from ecosystem recovery after the great Sahelian droughts of the 1970s and early 1980's" (p. 22), which may also explain the changes noticed in the Nandom District.

The turn of the 21st century came with its challenges that influenced the woodland cover in the Nandom District from 2001. Population growth (Duadze, 2004), poverty (EPA, 2002; GSS, 2015), lack of livelihood options (EPA, 2002), worsening soil fertility (Duadze, 2004), climate change and climate variability (MA, 2005), and weak enforcement of bye-laws may have either individually or collectively led to over-dependence on woodlands. The over-dependence on woodlands led to a sharp decrease in dense canopy woodland cover and increased open canopy woodland cover between 2001 and 2017. Farmland cover increased marginally from 2001 to 2017, which may be because of poor soil fertility (Duadze, 2004; EPA, 2002). Thus, smallholder farmers leave the land to lie fallow for extended periods to regain fertility.

Additionally, community members adopted "intelligent," but negative ways of going round bye-laws meant to protect trees. For instance, from focus group discussions, the research showed that complete branch harvesting and not pruning was being practiced. Byelaws prevent tree felling, and only after a tree was proven dead by leaders of the community, will a person be allowed to fell the tree. Harvesting of tree branches, leaving the trunk, may have inadvertently facilitated the death of the trees and thereby promoted felling in the long run.

The net change from 1986 to 2017 in Nandom revealed: a decrease in dense canopy woodland cover (30%), increase open woodland cover (5%), increase in long fallow (18%), reduction of short fallow (6%), decrease in farmland (12%), increase in grassland (4%) and increase in built-up or bare land (9%). From literature, the reduction in the dense woodland cover is due to expansion in agricultural land, built-up, and land cover conversion (Hailemariam *et al*., 2016; Duadze, 2004; FAO, 2016a); or forest fire, extraction of firewood and timber (Pullanikkatil *et al*., 2016). This reliance is usually driven by poverty, as noted by Oksanen *et al*. (2003). The dynamics in Nandom leading to changes in land cover classes may be different. Additional factors such as benefits derived from woodland resources, awareness of ecosystem service availability, and cultural norms ensuring that houses are built with local materials (trees and earth) may have contributed to the overall net reduction in dense woodland cover. The influences of bush fires or forest fires (EPA, 2002) despite laws against bushfires, may also have contributed to the loss in woodland cover.

Owing to poor soil fertility in the district (Duadze, 2004), smallholder farmers kept land fallow for long periods to regain their fertility, which explains the net increase in long fallow cover, a marginal decrease in short fallow cover, and decrease in farmland between 1986 and 2017. The loss of farming opportunities, therefore, promoted migration (Geest, 2011), and off-farm livelihood options, including reliance on woodlands. Notably, smallholder farmers not migrating to the Southern part of Ghana, "*begged to access land for farming*" in the neighbouring Lambussie-Karni District (youth group during focus group discussions). The influence of this district-shift for farming on land cover changes in the Lambussei-Karni District is yet to be investigated.

5.6 Household willingness-to-pay for the conservation of the woodland ecosystem

5.6.1 Willingness-to-pay for the conservation of savannah woodland ecosystem

From the study, 99% of farming households are willing to contribute to support conservation programmes. Of these, 94% are willing to contribute farm produce while 4% are willing to contribute physical cash and 2% willing to use their manpower to support the conservation programmes. The high poverty rates in the district (GSS, 2014b, and 2015) may explain farmers' willingness to pay using farm produce as money is not available. Additionally, for farmers to obtain cash, they may have to sell their farm produce, receive remittance from relations, sell other products harvested from woodlands, and engage in other non-farming livelihood options. In the Sene District of Ghana, Bani and Damnyag (2017), found that poor smallholder farmers were willing to pay using tubers of yam, the major farm produce in the area. Farmers in Nandom, cultivate mainly cereals such as maize, millet, sorghum, and guinea corn. Thus, it was not surprising that over 75% of farmer households were willing to pay to conserve woodlands using maize.

In contrast to the work of Bani and Damnyag (2017), this study applied a local market analysis to convert farm produce to monetary value. Even though this was innovative, smallholder farming households may not have proffered the converted monetary values. Research to understand the relationship between foodstuff (quantities) and proffered amounts as their contribution to conservation is essential, especially in areas with high poverty rates in Sub-Saharan Africa. Research in this area will provide a basis for extrapolation and analysis in contingent valuation studies in poor contexts.

Smallholder farming households were willing to make an annual contribution of GH¢ 9.50 and GH¢ 20.00 (i.e., $ 2.15 and $ 4.53) as the minimum and maximum contribution respectively per household to support conservation of woodlands. The maximum willingness to pay amount is similar to that found by Chukwuone and Okorji (2008). The authors found that households were WTP an annual amount of $4.55 for the systematic management of community forest/woodland. Studies in Ghana and other countries have found different WTP values. For example, Agyemang (2016) found that respondents were willing to pay GH¢45 per month for water quality improvement of the Offin River in Atwima Mponua District of Ghana. Gürlük (2006) found that the average annual WTP ranged from $55 to $80 in Turkey. Ansong and Røskaft (2014) found a monthly mean WTP to be between $1.59 and $1.61 for the sustainable forest management of Subri Forest reserve in the Western Region. Using a choice experiment, Okumu and Muchapondwa (2017) in Kenya found the annual WTP for the conservation of Mau forest to be in the range of \$47.76 and \$80.52. The differences noted may be due to varying reasons. Notably, the weaknesses inherent in each elicitation format (TEEB, 2010) are a major reason for the differences in WTP values.

Additionally, the social, economic, and cultural context (TEEB, 2010) and the intrinsic value placed by respondents/households on woodlands/forests may contribute to the different WTP values. According to TEEB (2010), the boundaries of different ecosystems cannot be compared considering their uniqueness. Again, valuation biases such as design bias, hypothetical bias, starting point, vehicle, question order bias, operational bias, interview and compliance which are inherent in valuation exercise may have also accounted for the differences (TEEB, 2010).

5.6.2 Preferable conservation type in Nandom District

In their meta-analysis using primarily studies conducted in Europe, Canada and the United States of America, Hjerpe *et al*. (2015) concluded that WTP values for preservation were higher than that for the restoration of forest/woodlands. From this study, however, there was no statistically significant difference in minimum WTP for preservation, restoration, or for both preservation and restoration ($\rho = 0.733$). Similarly, there was no statistically significant difference in their maximum WTP by conservation type ($\rho = 0.725$). The reason for the findings of this study may be attributed to the mixed pattern of degradation observed in the district with portions of the landscape being treeless while those with trees are mismanaged. This problem may have influenced respondents in choosing preservation, restoration, and both types of conservation as ways of redeeming on-going ecosystem degradation. The EPA (2002) cited ecosystem degradation in the study area to bush fire, removal of trees for farming and domestic use, and overgrazing, among other reasons. Thus, areas degraded and devoid of vegetative cover will require restoration interventions, whereas preservation strategy may be required for areas with degraded vegetative cover. Preservation and restoration combined strategy may be necessary for places experiencing mixed degradation, especially areas such as reserved woodland.

5.7 Decomposition of leaf litter from trees and nutrient remaining

In the Nandom District, farmers maintain trees on their farmland for several reasons. Reasons mainly relate to benefits derived from these trees: provisioning services (fruits, edible leaves, fuelwood); cultural services (religious, e.g., the '*kakala*' tree); regulating services (air quality control, storm protection); and supporting services (soil fertility). Studies have shown that leaf litter and other organic matter from trees provide nutrients to the soil (Osman, 2013).

Notably, Duadze (2004), EPA (2002), and more recently, Buah and Opoku (2013) reported low contents of nitrogen, phosphorus, and potassium in soils of the Upper West Region. These nutrients are vital nutrients for plant growth. The loss of trees from anthropogenic factors may have contributed to poor soil fertility in the District. Other contributory factors to the poor soil fertility may include leaching and erosion, bush fires, poor agronomic practices, overgrazing and loss of vegetation. Soil from the experimental field was acidic (pH 6.1 - 6.4) and loamy in texture. Total nitrogen content was between 0.023% and 0.024% and available phosphorus in soil measured 6.8mg/kg to 7.2mg/kg.

5.7.1 Decomposition, organic matter remaining and soil fertility

Among the four species studied, *C. myxa* had the highest decomposition rate by day 90 (1.11 g/g/day), which was followed by, in descending order, *L. microcarp*a (0.950 g/g/day), *P. biglobosa* (0.851 g/g/day), and *V. paradoxa* (0.723 g/g/day). The proportion of organic matter remaining was in reverse order to the decomposition rate. The superiority of *C. myxa* over the remaining species may be a result of the carbon-nitrogen (C/N) ratio, polyphenol, and lignin content as indicated by Cotrufo *et al*. (2010). These properties have been argued to influence the decomposition rate (Bayala *et al*., 2005; Semwal *et al*., 2003). Generally, a C/N < 20 is characteristic of fast decomposing species, predominantly leguminous trees. Notably, *C. myxa* (C/N of 10.55), a non-leguminous species, decomposed faster than the leguminous species *P. biglobosa* (C/N of 23.57). What accounted for this variation remains unclear. Knowledge of the influence of microbes and decomposers and the preference of these decomposers for different species in similar conditions is limited. These may have influenced the results seen. Therefore, more studies are required to understand the preferences (choice of leaf litter) of decomposers in nutrient cycling and studies of litter decomposition in the savannah woodlands.

5.7.2 Nutrients remaining and soil fertility

The soils of the Upper West Region of Ghana have poor Nitrogen, Phosphorus, and Potassium (NPK) content, as mentioned above. The laboratory results showed that *C. myxa* differed from the other species in their initial nutrient (N, P, and K) concentration. The other three did not vary significantly by their initial N.P.K contents. Comparing the initial nitrogen content of *V. paradoxa* and *P. biglobosa* used for this study with that used by Bayala *et al*. (2005), the nitrogen content in the species used by Bayala and colleagues was higher- reporting 2.2% for *P. biglobosa* and 1.56% for *V. paradoxa*. The nutrient contents of the soil in Burkina Faso may have, among other factors, contributed to this difference in nitrogen content.

Nutrients remaining or released was a function of the decomposition with *C. myxa* losing high quantities/proportions of its NPK by day 10, which was followed by a gradual loss in nutrients from day 10 to 90. The other species showed different behaviours in nutrients remaining and/or nutrients lost, which could be attributed to microbial or non-microbial immobilization in the residual leaf litter (Semwal *et al*., 2003) and N and P mineralization or immobilization depicting a three-phase pattern. A similar pattern was observed in the work of Semwal *et al.* (2003). At the end of the decomposition process, that is day 90, *C. myxa* released more minerals (N, P, and K) cumulatively. A statistical test using Fisher's protected least significant difference (LSD) showed mixed NPK concentration for the fresh and the decomposed litter across days 0, 10, 20, 30, 60, and 90. In terms of nitrogen concentration, the species recorded significant relationship over the sampling days except day 90. For phosphorus concentration, a significant relation was recorded for days 0, 20, and 30, while the converse was the case for days 10, 60, and 90.

5.8 Woodland ecosystem services and poverty alleviation

From the study, access to woodland ecosystem services presents a complex relationship between endowment, entitlement, preferences, capital, and alternative livelihood options. There would, therefore, be trade-offs when implementing poverty alleviation programmes (Schrenkenberg *et al.*, 2018). Programmes to alleviate poverty among smallholder farmers should, therefore, seek to improve environmental justice (Schrenkenberg *et al.*, 2018; Chaudhary *et al.*, 2018) and provide safe conditions for the sustainable use of the woodland ecosystem (Schrenkenberg *et al.*, 2018).

In assessing the relationships of ecosystem services and poverty alleviation, Schrenkenberg *et al*., (2018) concludes that the links between ecosystem services and poverty are one element of the social-ecological complex system. This complex system is characterised by feedback loops, non-linearities, as well as alternative states (Schrenkenberg *et al.*, 2018). Therefore, there are no apparent straight forward interventions as interventions nearly always lead to unintended consequences (Schrenkenberg *et al.*, 2018). Schrenkenberg *et al.* (2018) recommend that participatory approaches to ensure that all stakeholders are involved as well as approaches that define just and safe outcomes for environmental conditions are required.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 Introduction

This chapter presents the summary and conclusion of the study. It begins by summarizing the study from the introduction through the literature review and methodology as well as the results, analysis and discussion section of the study. Subsequently, the conclusions of the study are drawn from the summary. This chapter ends with a section on recommendations.

6.2 Research Summary

The centrality of the woodland ecosystem for the wellbeing of humanity has been duly acknowledged by environmental agreements such as the United Nations Framework on Climate Change, the Convention on Biological Diversity, the United Nations Conventions to Combat Desertification and the United Nations Forum on Forest (MESTI, 2016). It has been acknowledged by the Millennium Ecosystem Assessment and The Economics of Ecosystem and Biodiversity as well as empirical studies on ecosystem services from developing countries.

Given the importance of ecosystem services, the study generally sought to assess the benefits smallholder farmers derive from the woodland. It identified the household factors influencing access to different types of woodlands in the Nandom District as well as off-farm adaptation practices that influenced the economic wellbeing of smallholder farming households. The study also examined the relationship between knowledge of climate change and management practices employed by farmers to conserve the woodland. Additionally, the study identified shifts in land use and land cover in the district and assessed willingness to pay for the conservation of the woodlands. Lastly, the study assessed the decomposition of leaves of four common woodland species and their nutrients remaining.

Four research designs were employed in this study, cross-sectional survey, imaging, contingent valuation, and leaf litter experiment. The study covered the four area councils of the Nandom district, namely Baseble, Ko, Guo, and Nandom. In all, three hundred and three (303) well-structured pre-tested questionnaires were administered in one hundred and three communities.

Pearson Chi-Square analysis was used to determine associations between two categorical variables. Also, the Kruskal-Wallis Test and the Mann-Whitney U test were employed to assess differences in continuous outcome variables among independent predictor groups.

In addition, Principal Component Analysis in STATA, was used to classify each household into five Wealth Index (WI) or socio-economic status (SES) categories: 1- lowest; 2- second; 3- middle; 4- fourth; and 5- highest.

Generally, the results provided evidence of household reliance on ecosystem services for livelihood. Specifically, the results showed an association between household factors and access to different woodland ecosystem services. Furthermore, the study revealed that group knowledge level in quartiles was not significantly associated with pruning, bush fire control, bush burning around the house, tree planting, slash and burn agriculture. Also, the study revealed that the association between off-farm adaptation practices and the economic well-being of households as a mixed outcome. Notably, shea nut picking/oil extraction, harvest fuelwood, harvest fodder for livestock, harvest straw, petty trading and office work/formal employment were significantly associated with household wealth index. The study further revealed that, over a 31 year period (1986-2017), there have been changes in land cover; with a net decrease in dense canopy woodland cover (1,026.72 hectares, 30.15%), a net increase in open-canopy woodland (366.03 hectares, 5.23%), net increase in grassland (265.95 hectares, 4.38%) and net increase in built-up cover (310.50 hectares, 9.14%). The area under cultivation showed a mixed pattern with long fallow area increasing by 1,282.50 hectares (18.18%). There was also a decrease in the short fallow area (396.9 hectares, 5.97%) and farmland (801.36 hectares, 11.91%).

Again, the study showed that smallholder farming households were willing to make an annual contribution of GH¢ 9.50 and GH¢ 20.00 (i.e., $2.15 and $4.53) as the minimum and maximum contribution respectively per household to support conservation of woodlands. From this study, however, there was no statistically significant difference in minimum WTP for preservation, restoration, or for both preservation and restoration ($\rho = 0.733$). Similarly, there was no statistically significant difference in their maximum WTP by conservation type ($\rho = 0.725$).

Finally, a statistical test using Fisher's protected least significant difference (LSD) showed mixed NPK concentration for the fresh and the decomposed litter across days 0, 10, 20, 30, 60, and 90. In terms of nitrogen concentration, the species recorded significant relationship over the sampling days except day 90. For phosphorus concentration, a significant relation was recorded for days 0, 20, and 30, while the converse was the case for days 10, 60, and 90. Generally, the findings corroborate in a significant way with the results found in the literature.

6.3 Conclusions

A study to assess the benefits farmers and households derive from the savannah woodland ecosystem was reported in this thesis. The following are conclusions drawn from the objectives of this study.

- This study contributes to the conservation of the woodland ecosystem, benefits, adaptation to climate change, and recommendations for stakeholders especially policy makers. Therefore, the outcome of this study falls in line with ASSAR broad objective

- Farming households in the Nandom District derive ecosystem benefits predominantly from the community woodland.
- There is a complex relationship in the household's access to woodlands, which involves determinants such as endowment and entitlement, capital, preferences, and alternative livelihood options.
- In the district, community laws to conserve woodlands are variably implemented.
- The Geographic location of the household, the number of household members that work, and the presence of older adults 65years or more influenced access to the reserve woodland.
- Access to the community woodland was influenced by the geographic location of households, ownership of agricultural land, and ownership of a bicycle.
- Sub-district in which household lives, household size, number of household members that work, household wealth (assessed using household wealth index or socioeconomic status), and ownership of a bicycle and farm animals influenced access to family-owned plantations.
- Notably, sex of household head and households with persons living with disability were not found to influence access to any woodland type
- Awareness and knowledge of climate change and its impact were high among respondents from smallholder farming households. However, knowledge did not influence the behaviours of households concerning woodland management practices. The commonest sources of knowledge were local knowledge or experience, and the media.
- Off-farm adaptation strategies that influenced the economic wellbeing of farming households were shea nut picking, gathering fuelwood, harvesting fodder and straw,

and logging. Others were petty trading, *pito* brewing, carving, getting an employment (white-collar job), and engaging in skills-based jobs.

- Land use land conversion led to a sharp decline in closed-canopy woodland cover between 2001 and 2017 with only marginal increases in farmland cover and the built environment.
- Households were willing to pay between ¢9.50 and ¢20.00 ($2.15 and $4.53) per year to conserve the woodlands.
- The nitrogen, phosphorus, and potassium contents in *Cordia myxa* leaf were relatively higher than that for *Parkia biglobosa*, *Lannea microcarpa*, and *Vitellaria paradoxa.*
- *C. myxa* had the highest decomposition rate as compared to the others by day 90.

6.4 Recommendations

Based on the outcome of the research, the following recommendations are made:

- Policy makers should develop climate change adaptation and programmes focusing on rural smallholder farmers with an environmental justice lens.
- The government should include smallholder farming households in its poverty alleviation programs and provide alternative livelihood options, i.e., training in skills-based jobs.
- Stakeholders such as local government, district assembly and community chief must initiate innovative ways to improve knowledge and practice of woodland conservation
- The district assembly, Lawra forestry office, and local NGOs should initiate local community fund to support and encourage positive woodland management practices
- The district forestry officers, district assembly, community chiefs, NGO's must educate communities on the environmental benefits of trees

- NGOs and the district assembly must develop innovative communication strategies that are participatory to improve the knowledge of smallholder holder farmers on conservation
- The district forest office, district assembly, NGOs must implement innovative approaches that encourage the adoption of positive woodland management practices
- The district forestry department must work with communities and community leaders to set up conservation projects.

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APPENDICES

APPENDIX I- ADDITIONAL RESULTS

Section A1 Additional results from analysing data from cross-section survey

A1.1 Benefits derived from the woodland in Nandom District

A1.1.1 Benefits derived by farming households from woodlands in the Nandom District

Table A1.1 Benefits farming households derive from woodland ecosystem services (All categories)

Ecosystem services	**Benefit derived from:**						**Total per woodland type**
	National Forest Reserve		**Community woodland**		**Family/own plantation**		
	Yes	No	Yes	No	Yes	No	
Cultural Services							
Spiritual/Religious	15.4%	84.6%	15.5%	84.5%	9.9%	90.1%	100.0%
Aesthetic	76.9%	23.1%	94.2%	5.8%	76.1%	23.9%	100.0%
Recreational	76.9%	23.1%	91.8%	8.2%	83.1%	16.9%	100.0%
Educational	61.5%	38.5%	77.6%	22.4%	59.2%	40.8%	100.0%
Provisioning services							
Food Crops	23.1%	76.9%	96.9%	3.1%	18.3%	81.7%	100.0%
Bush Meat	61.5%	38.5%	46.9%	53.1%	21.1%	78.9%	100.0%
Edible vegetables	69.2%	30.8%	91.2%	8.8%	19.7%	80.3%	100.0%
Wild fruits	88.5%	11.5%	91.5%	8.5%	22.5%	77.5%	100.0%
Medicinal plants	84.6%	15.4%	75.5%	24.5%	35.2%	64.8%	100.0%
Fodder for livestock	50.0%	50.0%	53.1%	46.9%	11.3%	88.7%	100.0%
Fuel wood	80.8%	19.2%	89.8%	10.2%	87.3%	12.7%	100.0%
Fibre/Straw	38.5%	61.5%	72.8%	27.2%	7.0%	93.0%	100.0%
Poles for construction	61.5%	38.5%	73.1%	26.9%	67.6%	32.4%	100.0%
Soil for construction	7.7%	92.3%	82.9%	17.1%	16.9%	83.1%	100.0%
Water	42.3%	57.7%	14.3%	85.7%	1.4%	98.6%	100.0%
Regulating services							
Enjoy Fresh air from trees	96.2%	3.8%	98.3%	1.7%	97.2%	2.8%	100.0%
Enjoy filtered air during harmattan	80.8%	19.2%	97.6%	2.4%	94.4%	5.6%	100.0%
Trees serve as wind breaks	92.3%	7.7%	98.0%	2.0%	94.4%	5.6%	100.0%
Protect close by buildings	46.2%	53.8%	96.3%	3.7%	81.7%	18.3%	100.0%
Protection from soil erosion	53.8%	46.2%	96.3%	3.7%	59.2%	40.8%	100.0%

Table A1.1 Benefits farming households derive from woodland ecosystem services (All categories) continued

Ecosystem services	**Benefit derived from:**						**Total per woodland type**
	National Forest Reserve		**Community woodland**		**Family/own plantation**		
	Yes	No	Yes	No	Yes	No	
Supporting services							
Benefit from fertile woodland and farmland rich in litter	30.8%	69.2%	93.5%	6.5%	23.9%	76.1%	100.0%
Benefit from crop yield due to fertile woodland	30.8%	69.2%	93.2%	6.8%	22.5%	77.5%	100.0%
Save money on fertilizer due to fertile land	30.8%	69.2%	91.8%	8.2%	19.7%	80.3%	100.0%
Benefit from continuous farming on the same farmland	30.8%	69.2%	93.9%	6.1%	22.5%	77.5%	100.0%

A1.1.2 Other factors that may influence small holder farmer access to savannah woodlands

A1.1.2.1 Barriers and Enablers to assess and use of savannah woodland ecosystem services

As mentioned in Chapter three, factors that were defined as barriers or enablers are categorized into governance/regulation, geographic and socio-economic.

Figures A1.1, A1.2 and A1.3 present barriers and enablers to access to different types of woodlands in the study area.

<u>Barriers and Enablers to accessing ecosystem services from the Reserve Woodland</u>

From Figure A1.1, community regulation (57.69%) and family rules (69.23%) on the access and use of ES from the Reserve Woodland in the Nandom District were more important barriers than regulation by the Forestry Commission. Communities have rules aimed at protecting trees and limit tree felling in the Nandom District. Even though the Forestry Commission has regulations to limit access to the reserve, households accessing this reserve do not consider their regulation to necessarily influence their access. Regarding trees harvested for fuelwood, households/individuals *"caught will be fined"* as mentioned by a chief in a community close to the Reserve. The fine includes, *"a cock, twenty Ghana cedis and return material harvested"*. This was confirmed by the youth group during the focus group discussion in that community. However, according to this chief, *"they are thieves especially the women"*. He referred to households violating community and family rules to go to the Reserve Woodland at odd hours of the day to harvest fuelwood.

Access to land in the reserve to cultivate crops was also a barrier (65.38%). *"In 2004 Kufour Youth Employment Programme led to tree planting in the forest, where people were given* *portions of forest land to work on in order to care for the planted trees that were growing up. I was part of this programme. When the programme ended in 2010 due to change in the government and I was laid off, we decided to initiate our own laws to encourage community members to grow trees because of too much tree cutting and climate change. The women in the community are fond of cutting trees excessively" (Chief in community near Reserve Woodland).*

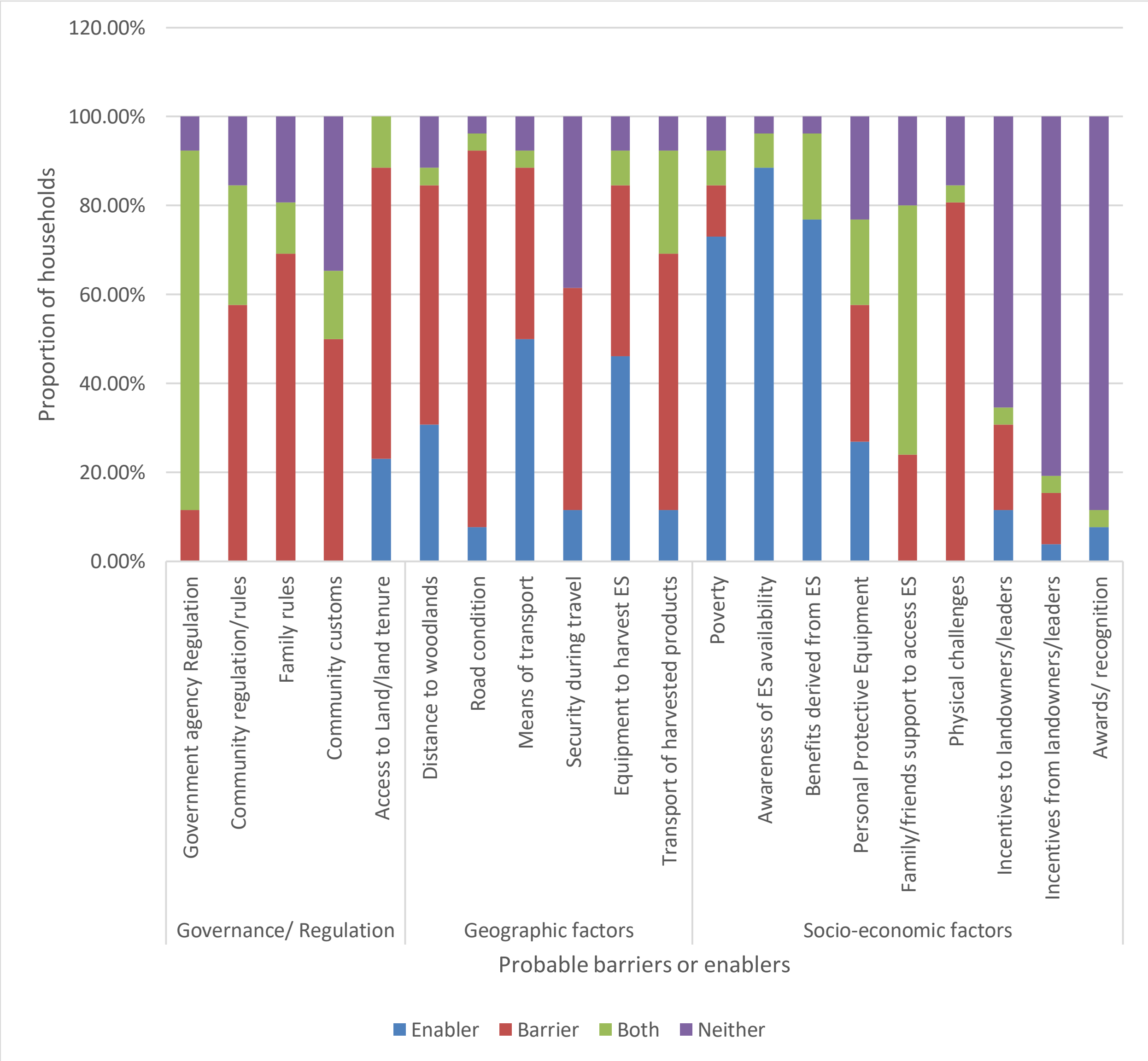

Figure A1.1 Barriers and Enablers: Access to Reserve woodland (Source: Field Survey, 2018)

Geographic factors identified as barriers by households with access to the National Forest Reserve were distance (53.85%) to the forest reserve, road condition (84.62%), and transport of forest products (57.69%). Security during travel to the forest reserve was on the borderline (50.00%).

Additionally, physical challenges (80.77%) by household members, which included old persons and person's living with disability, limited their access to the forest reserve. As presented in Table 4.6, access to the Forest Reserve was significantly associated with presence of adult 65 years or more in household, $\rho = 0.003$.

Despite these geographic and regulatory barriers, awareness of ES available at the reserve (88.46%), benefits derived (76.92%) and poverty (73.08%) were the enablers and driving forces to access the National Forest Reserve. A 45-year-old man (combined male and female youth group FGD) at a community close to the forest reserve said, *"women harvest firewood, sell to pay school fees and health insurance"*. According to a 52-year-old woman (elderly women FGD), they go to the forest reserve to harvest *"edible vegetables for sale and use at home"*. Another elderly woman (who could not give her age) said, *"at dawn, I go to the forest to harvest young trees from the base, sell to get money for food and use at home"*. The older women however, are reported to also, *"call association meeting every Tuesday, borrow money to pay school fees, health insurance and do dawadawa business" (64-year-old woman).*

<u>Barriers and Enablers to accessing Ecosystem services from Community woodland</u>

Awareness of ecosystem service availability (91.50%), benefits derived from ES (91.16%), poverty (89.12%), equipment to harvest ES (62.59%) and access to land (57.82%) were identified as enablers to access and use of community woodlands. No barrier, to accessing community woodland was identified (as none was more than 50%).

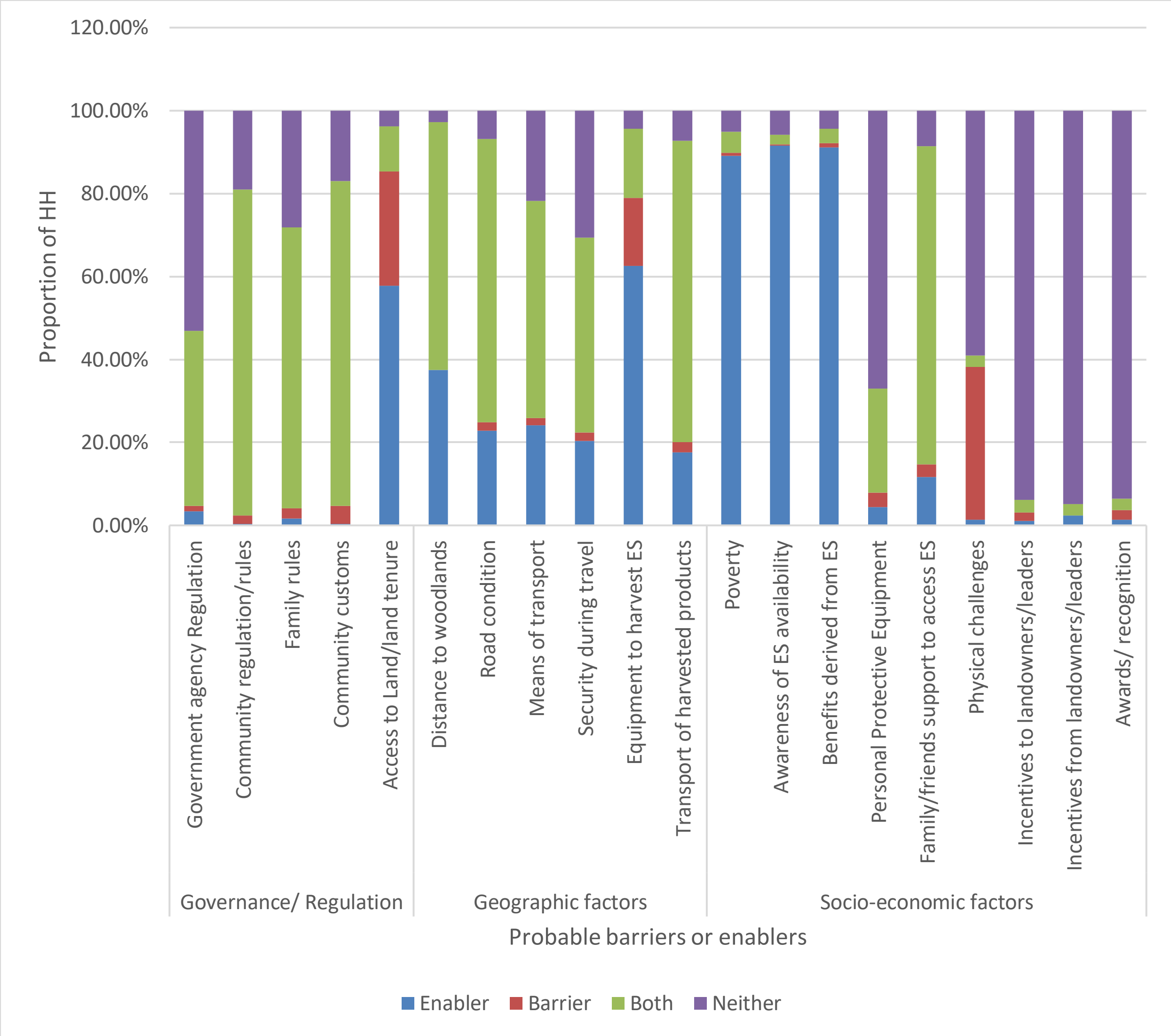

Figure A1.2 Barriers and Enablers: Access to Community Woodland (Source: Field Survey, 2018)

In all communities that focus group discussions were held, community leaders mentioned that they had rules and regulations to preserve trees. These rules limited tree cutting/felling. However, male trees and non-fruit bearing trees were allowed to be felled after inspection by a committee set up to regulate tree cutting. An 80-year old man said, *"I fell some trees which are not useful to sell to pito brewers every dry season"*. These community rules/regulations, encourages a bad practice observed in the field- branch harvesting not pruning. Even though pruning was mentioned in FGDs, what was observed is whole branch harvesting. A 50-year old man in one community remarked, *"I go to my farm, harvest firewood for sale"*. When asked further he opined, *"I barber the trees and kill the male trees"*. In same community, a 23-year old said, "*I cut branches from trees on farmland for sale and use at home"*. A chief in a community of Puffien sub-district said, *"The tree is harvested by cutting the branches to avoid killing it"*. Owing to the effective implementation of the community rules on trees, community regulation (78.57%), family rules (67.69%) and community customs (78.23%) were identified as both barriers and enablers to access to community woodlots. Additionally, distance (59.86%), road condition (68.37%), means of transport (52.38%) and transport of harvested products (72.76%) and support from family or friends (76.71%) were identified as both barriers and enablers to access community woodlands.

"We don't cut some trees because we will get lost" (chief of community in Nandom District). Community rules also allow for tree felling for construction of houses. As mentioned by a 66-year old opinion leader in Ko sub-district, *"it is compulsory to have one sand decking room in your house for traditional purposes"*. Customs like announcing a marriage of a woman from the roof (sand decked) are important to these communities. Trees used for construction include *Terminalia macroptera, Anogeissus leiocarpus, Diospyros mespiliformis and Azadirachta indica.*

As reported in Table 4.7, ownership of agriculture farms was significantly associated with access to the community woodland (ρ = 0.020). From key informant interviews with community leaders, trees on farmlands belong to the owners of these farmlands. Therefore, farmers who beg to farm on these farmlands will need approval from their land owners to harvest tree branches, fruits and other products. A 50-year old lady from Ko sub-district mentioned that, *"we steal firewood from peoples' farms to sell to buy food"*. Women were noted to be the principal people engaged in tree harvesting.

Barriers and Enablers to accessing ecosystem services from family owned plantation

From Figure A1.3, access and use of family plantation were enabled by short distance to plantations (78.57%), motorable road (61.43%), and equipment to harvest ES (57.14%), poverty (62.86%), awareness of plantation (66.67%) and benefits derived from plantation (67.14%).

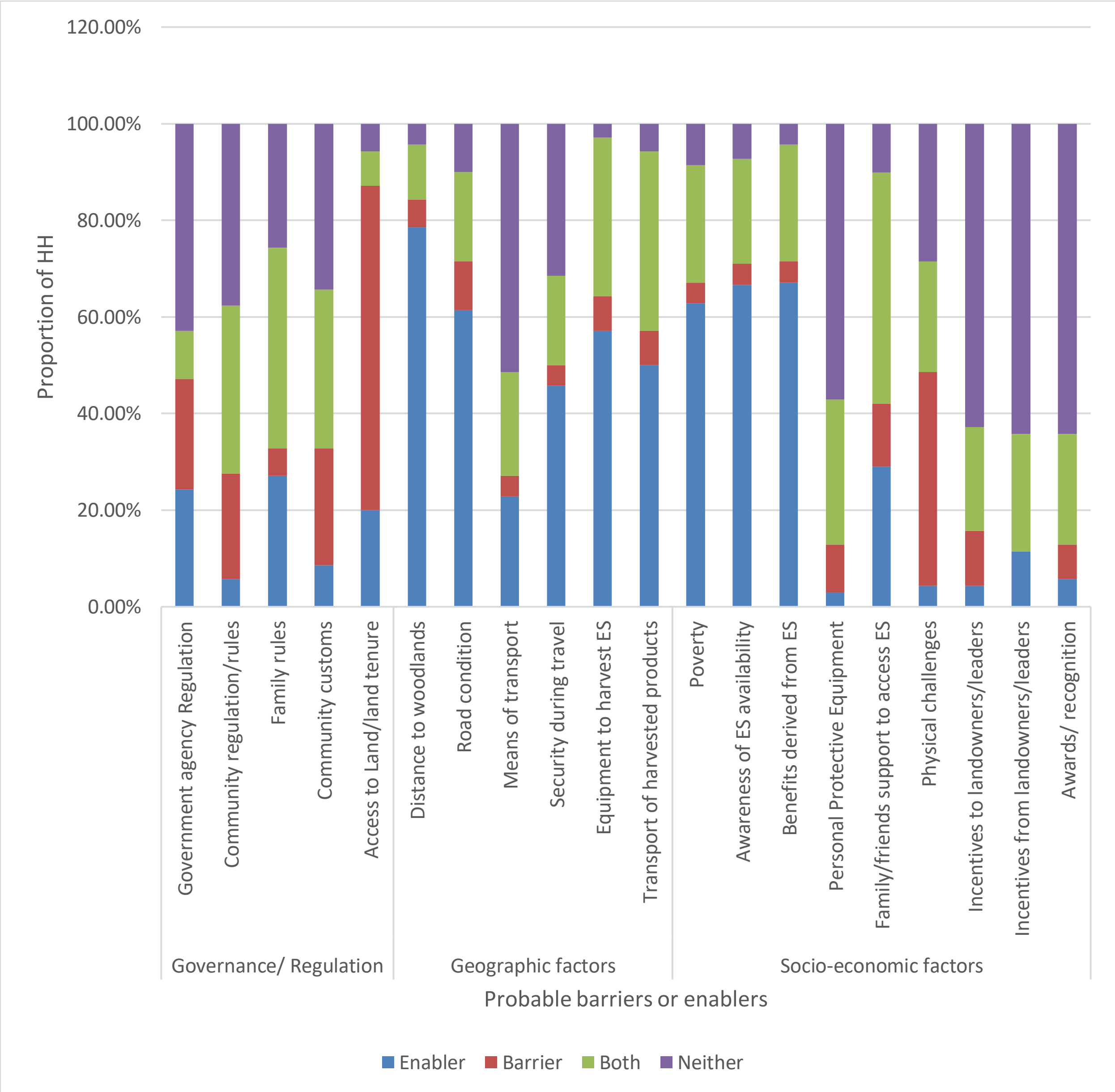

Figure A1.3 Barriers and Enablers: Access to family owned plantation (Source: Field Survey, 2018)

The only barrier identified to accessing family plantation was access to land (67.14%). Notably ownership of agriculture land by households was significantly associated with households engaging in plantation farming [χ^2 (1) = 5.579, ρ = 0.018]. Reasons for owing plantation farms included logs for construction of houses, extra form of income; fruits from trees, trees serve as wind breaks and security against poor harvest.

Table A1.2 presents a summary of barriers and enablers to different types of savannah woodlands. Details are available in Appendix I.

Table A1.2 Colour coded summary of barriers and enablers to different types of woodlands

		Access to Reserve woodland	Access to community woodland	Access to family/ own plantation
Governance / Regulation	Government regulation			
	Community Regulation			
	Family rules			
	Community customs			
	Access to land/ land tenure			
Geographic factors	Distance to woodland			
	Road condition			
	Means of transport			
	Security during travel			
	Equipment to harvest ES			
	Transport of harvested products			
Socio-economic factors	Poverty			
	Awareness of ES availability			
	Benefits derived from ES			
	Personal Protective Equipment			
	Family/ friends support to access ES			
	Physical challenges			
	Incentives to landowners			
	Incentives from landowners/ leaders			
	Awards/ recognition			

Legend

	Colour code
Barrier	
Enabler	
Both	
Neither	

Source: Field Survey, 2018

Common woodland species in Nandom District

Data from farming households on the trees left on their farms showed that the four dominant tree species present on farmlands were *Parkia biglobosa* (Dawadawa tree, 61.5%), *Vitelleria paradoxa* (Shea tree, 71.1%), *Cordia mycoxa* (Tongbo tree, 65.5%) and *Lannea microcarpa* (Sugeh tree, 60.8%). Figure 4.15 presents the 15 common trees species available on farmlands of farmers in the Nandom District.

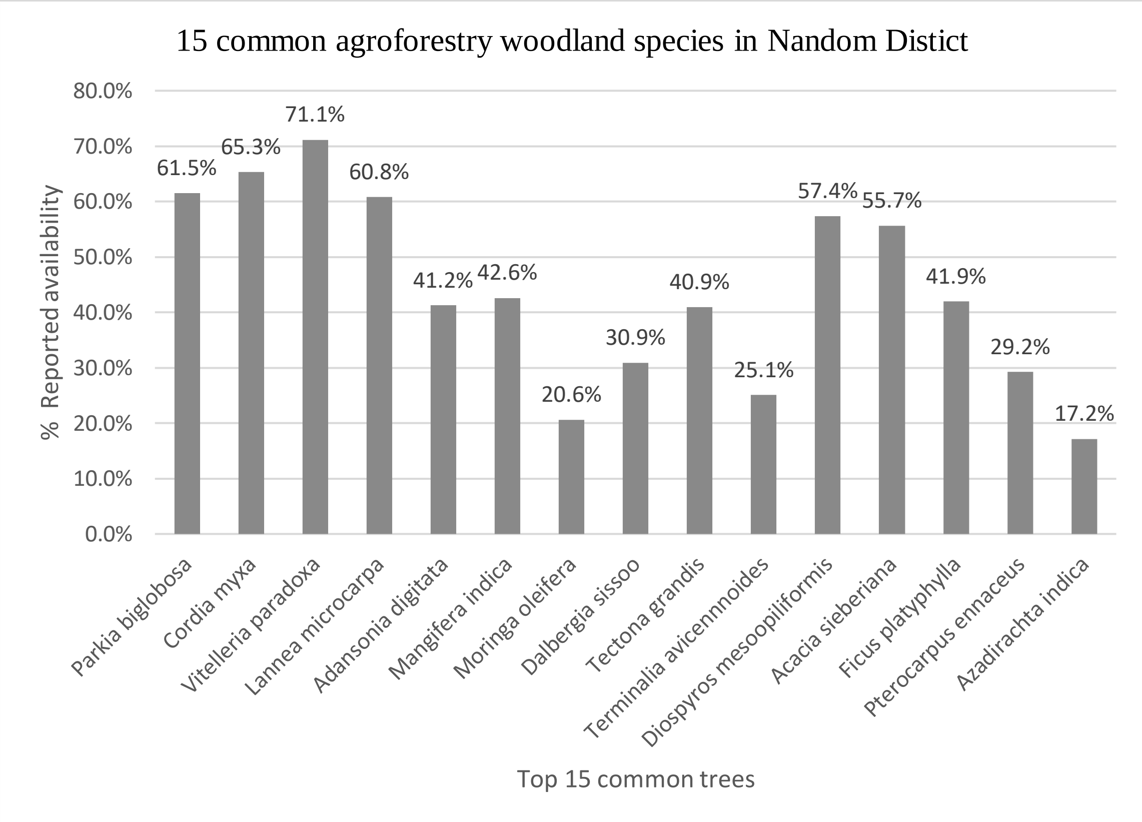

Figure A1.4 Common woodland species retained on crop fields by farmers in Nandom District (Source: Field survey, 2018)

Section A2 Land Use Land Cover error matrices for 1986, 2001, and 2017

Table A2.1 Land cover map error matrix for 2017

Class	**Dense/ closed Woodland**	**Open savannah Woodland**	**Long fallow**	**Farms**	**Short fallow**	**Grasses**	**Built-up/ Bare land**	**Row Total**	**User Accuracy (%)**
Dense/ closed Woodland	26424	0	0	0	0	0	0	**26424**	100.00
Open savannah Woodland	29922	62708	0	0	0	0	0	**92630**	67.70
Long fallow	0	27103	54630	38	0	0	0	**81771**	66.81
Farms	0	0	7507	50594	7750	0	0	**65851**	76.83
Short fallow	0	0	0	123	47115	22268	0	**69506**	67.79
Grasses	0	0	0	0	0	50595	19761	**70356**	71.91
Built up/bare land	0	0	0	0	0	0	41178	**41178**	100.00
Column Total	**56346**	**89811**	**62137**	**50755**	**54865**	**72863**	**60939**	**447716**	
Producer Accuracy (%)	46.90	69.82	87.92	99.68	85.87	69.44	67.57		

$$\text{2017 Overall accuracy} = \frac{(26424+62708+54630+50594+47115+50595+411788)*(100)}{447716} = 74.43\%$$

2017 Kappa = 0.8073

Table A2.2 Land cover map error matrix for 2001

Class	**Dense/ closed Woodland**	**Open savannah Woodland**	**Long fallow**	**Farms**	**Short fallow**	**Grasses**	**Built-up/ Bare land**	**Row Total**	**User Accuracy (%)**
Dense/ closed Woodland	45548	0	0	0	0	0	0	**45548**	100.00
Open savannah Woodland	23540	61705	0	0	0	0	0	**85245**	72.39
Long fallow	0	21379	52351	320	0	0	0	**74050**	70.70
Farms	0	0	5066	48198	9476	0	0	**62740**	76.82
Short fallow	0	0	0	135	44238	23934	0	**68307**	64.76
Grasses	0	0	0	0	0	49990	22012	**72002**	69.43
Built up/bare land	0	0	0	0	0	0	39824	**39824**	100.00
Column Total	**69088**	**83084**	**57417**	**48653**	**53714**	**73924**	**61836**	**447716**	
Producer Accuracy (%)	65.93	74.27	91.18	99.06	82.36	67.62	64.40		

2001 Overall accuracy = $\frac{(45548+61705+52351+48198+44238+49990+39824)*(100)}{447716}$ = 76.36%

2001 Kappa = 0.8221

Table A2.3 Land cover error matrix for 1986

Class	**Dense/ closed Woodland**	**Open savannah Woodland**	**Long Fallow**	**Farms**	**Short fallow**	**Grasses**	**Built-up/ Bare land**	**Row Total**	**User Accuracy (%)**
Dense/ closed Woodland	37832	0	0	0	0	0	0	**37832**	100.00
Open savannah Woodland	11091	64701	2588	0	0	0	0	**78380**	82.55
Long fallow	0	1	49764	27939	0	0	0	**77704**	64.04
Farms	0	0	37104	37651	0	0	0	**74755**	50.37
Short fallow	0	0	0	0	41573	32343	0	**73916**	56.24
Grasses	0	0	0	0	0	49356	18045	**67401**	73.23
Built up/bare land	0	0	0	0	0	0	37728	**37728**	100.00
Column Total	**48923**	**64702**	**89456**	**65590**	**41573**	**81699**	**55773**	**447716**	
Producer Accuracy (%)	77.33	100.00	55.63	57.40	100.00	60.41	67.65		

$$1986 \text{ Overall accuracy} = \frac{(37832+64701+49764+37651+41573+49356+37728)*(100)}{447716} = 71.16\%$$

1986 Kappa = 0.7819

Section A3 Reference values of nutrient concentration in plants

Table A3.1 Reference values of nutrients in plants

Element and its concentration in plant						
N	P	K	Ca	S	Mn	Mg
1-6%	0.05-1%	0.3-6%	0.1-3%	0.05-1.5%	5-500 ppm	0.05-1.5%

Source: Peter & Laboski (2011)

APPENDIX II QUESTIONNAIRE

Serial number: ________________

Institute for Environment and Sanitation Studies,

College of Basic and Applied Sciences

University of Ghana

Research Area: **Ecosystem Services Benefits to Farmers from Savannah woodlands in Northern Ghana**

Informed Consent

I am ____________________________, a research assistant working with the investigator on this project.

The investigator, Ophelia Kaba-Ayamba (Mrs.), is a PhD student of the University of Ghana. She is carrying out her research work on **Ecosystem Services Benefits to Farmers from Savannah Woodlands in Northern Ghana** and would like you to participate in the study. The student and study are non-political and not linked to government or any institution.

Participation is voluntary and you may choose not to answer a question or decide to end the interview at any time. The discussion will take approximately **one to two hours.** You will not be affected in any way if you decline to participate in the study.

I am here to learn from you especially on the way and manner you use the savannah woodlands (areas of trees) as well as your farm management practices. So you will be my teacher by providing information that will meet the objective of this study. The information gathered is purely for research purposes which will also contribute to knowledge on the Adaptation at Scale in Semi-Arid Regions [ASSAR] of Northern Ghana by providing information on knowledge and discussions on impact of human and natural influences on ecosystem services in semi-arid regions of Ghana.

We would also gather information that will help the student assess the worth (value, how much) of preserving the savannah woodland.

All information you provide is confidential and available to the research team. Your personal details are available to the researcher and statistician only. We shall not share any information containing your personal details to any third party.

For more information on the research, kindly contact Ophelia Kaba-Ayamba on 0268204800/ 0505785220.

If you have any issues on your rights as a participant, kindly contact:
Administrator, Ethics Committee for Basic and Applied Sciences, College of Basic and Applied Sciences, University of Ghana, P. O. Box LG 68, Legon – Accra. Tel: + 233 277493259. Email: ekacquaah@ug.edu.gh

D00	Would you like to participate in the study?	Yes …………………… No …………………… Not sure ………………	1 2 3	 → *End* → *End*

D01	District	Nandom …………………………	1
D02	Area Council/ sub-district	Nandom Area Council ………..….. Ko Area Council ……………..……… Baseble Area Council ……..……… Puffien Area Council …………….	1 2 3 4

D03	Community name	___________												
D04	Is community Rural or Urban *(see listing)*	Rural ………………. ………….. 1 Urban ……………… ………….. 2												
D05	Household ID *(check listing)*	1	0	-	1	0	-				-			
T01	Interview start time *(HH:MM)*			:			*Example 14:21*							

D06	Name of respondent?	
D07	Phone contact *(any phone number person can be reached by)*	

Socio-demographic characteristics

ID #	Question and instructions	Coded responses/categories		Skip
D08	Age *(age in completed years-probe)*?	[ ] *later group during analysis*		
D09	Gender *(see for yourself and tick)*?	Male ……………………… Female ……………………	1 2	
D10	*(What is the)* highest educational level you have attained?	No formal Education …….. Pre-primary …………….. Primary …………………. Middle ………………….. JSS/JHS ………………….. Secondary (old system) ….. SSS/SHS ………………… Higher ……………………	0 1 2 3 4 5 6 7	
D11	Marital status	Married/Living together …. Divorced/Separated ……… Widowed ………………… Never married/ never living together …….	1 2 3 4	
D12	Tribe/ ethnic group	Dagaaba ………………… Sissala …………………… Waala …………………… Lobi ……………………… Other (specify) ……………	1 2 3 4 5	
D13	Migrated during last dry season (respondent)? *(enquire on migration during the previous dry season)*	Not migrated …………….. Returnee migrant …………	1 2	
D14	What work do you do for a living	No formal or informal job …. Farmer ………..…………… Hunter ……………………..… Business (specify) ………… Formal employment ……….. Other (specify) ……………..	0 1 2 3 4 5	
D15	Ask, household head? If no, Relation to household head?	Head ……………………….. Wife/Husband …………….... Son/Daughter ……………… Son/ daughter-in-law ……… Grandchild ………………… Parent ……………………… Parent-in-law ……………… Brother/Sister …………….... Other relative ……………… Adopted/foster/stepchild …… Not related ………………….. Don't know …………………..	01 02 03 04 05 06 07 08 09 10 11 98	→W01
D16	Sex of household head, if not respondent	Male ………………………… Female ………………………	1 2	

SECTION A: Household Characteristics to determine Wealth Quintiles

Now we move to the section where I would want to ask about your household assets (what you have). Household is define as you and members of your family that eat from the same pot.

Wealth quintile questions: W01-W50.
Others to help with analysis of value: X01-X04

ID #	Question and instructions	Coded responses/categories		SKIP
W01	What is the **main** source of drinking water for members of your household?	Piped Water		
		Piped Into Dwelling/Indoor	11	
		Piped To Yard/Plot	12	
		Public Tap/Standpipe	13	
		Tube Well Or Borehole	21	
		Dug Well		
		Protected Well	31	
		Unprotected Well	32	
		Water from Spring		
		Protected Spring	41	
		Unprotected Spring	42	
		Rainwater...	51	
		Tanker Truck	61	
		Cart with small Tank	71	
		Surface Water (River/ Dam/ Lake/ Pond/ Stream/ Canal/Irrigation Channel)	81	
		Boiled water	91	
		Sachet water	92	
		Other	96	
W02	What kind of toilet facility do members of your household **usually** use?	Flush or Pour Flush Toilet		
		Flush to piped sewer system	11	
		Flush to Septic Tank	12	
		Flush to pit latrine	13	
		Flush to somewhere else	14	
		Flush, don't know where	15	
		Pit latrine		
		Ventilated Improved pit latrine	21	
		Pit latrine with slab	22	→ W04
		Pit latrine without slab/open pit	23	
		Bucket/Pan	31	
		Composting Toilet	41	
		Hanging toilet/hanging latrine	51	
		No facility/ Bush/ Field	61	
		Other	96	
W03	Do you share this toilet facility with other households?	Yes, other households only	1	
		Yes, public	2	
		No	3	

ID #	Question and instructions	Coded responses/categories	Yes	No	Skip
	Does your household have:		Yes	No	
W04	Electricity?	Electricity ……………………..	1	2	
W05	A wall clock	A wall clock …………………..	1	2	
W06	A radio?	A radio ………………………..	1	2	
W07a	A black/white television?	A Black/white television ……...	1	2	
W07b	A colour television	Colour Television …………….	1	2	
W08	A mobile telephone?	A mobile telephone …………...	1	2	
W09	A landline telephone?	A landline telephone ………..	1	2	
W10	A refrigerator?	A refrigerator ……………….	1	2	
W11	A freezer?	A freezer …………………….	1	2	
W12	Electric generator/Invertor(s)?	Electric generator/Invertor(s) …	1	2	
W13	Washing machine?	Washing machine …………….	1	2	
W14	Computer/ tablet computer?	Computer ……………………...	1	2	
W15a	Digital photo-camera?	Digital photo-camera ………..	1	2	
W15b	Non-digital photo-camera?	Non-digital photo-camera …….	1	2	
W16a	Video deck?	Video deck …………………..	1	2	
W16b	DVD/VCD?	DVD/VCD …………………..	1	2	
W17	Sewing machine?	Sewing machine …………….	1	2	
W18	Bed?	Bed …………………………..	1	2	
W19	Table?	Table ………………………..	1	2	
W20	Cabinet/Cupboard?	Cabinet/Cupboard …………….	1	2	
W21	Access to internet in any devise?	Internet ………………………..	1	2	

ID #	Question and instructions	Coded responses/categories		Skip
W22	What type of fuel does your household **mainly** use for cooking	Electricity …………………..	01	
		LPG ………………………...	02	
		National Gas ……………….	03	
		Biogas ……………………..	04	
		Kerosene …………………..	05	
		Coal, Lignite ……………….	06	
		Charcoal ……………………	07	
		Wood/firewood ……………..	08	
		Straw/Shrubs/Grass …………	09	
		Agricultural crop residue …...	10	
		Animal dung ……………….	11	
		No food cooked in household.	95	
		Other ………………………..	96	
W23a	Is the cooking usually done in the house, in a separate building, or outdoors?	In the House ……………….	1	
		In a separate Building ………	2	
		Outdoors ……………………	3	
		Other ………………………..	6	→ *W24*

ID #	Question and instructions	Coded responses/categories	Skip
W23b	Do you have a separate room which is used as a kitchen?	Yes .... 1 No 2	
	NB W23 analysis: Add response 2 in W23a and response 1 in W23b		

ID #	Question and instructions	Coded responses/categories	Skip
W24	What is the **main** material of the floor in your household? *RECORD OBSERVATION*	Natural Floor Earth/Sand .... 11 Dung .... 12 Rudimentary Floor Wood planks .... 21 Palm/Bamboo .... 22 Finished Floor Parquet or polished wood .... 31 Vinyl or Asphalt strips .... 32 Ceramic/Marble/Porcelain tiles/ Terrazzo .... 33 Cement .... 34 Woollen carpet/Synthetic carpet .. 35 Linoleum/Rubber carpet .... 36 Other *(specify)* 96	

ID #	Question and instructions	Coded responses/categories	Skip
W25	What is the **main** material of the roof in your household? *RECORD OBSERVATION*	Natural roofing No roof .... 11 Thatch/Palm leaf/Sod .... 12 Rudimentary roofing Rustic mat .... 21 Palm/Bamboo .... 22 Wood Planks .... 23 Cardboard .... 24 Finished roofing Metal .... 31 Wood .... 32 Calamine/Cement fibre .... 33 Ceramic tiles/Brick tiles .... 34 Cement .... 35 Roofing shingles .... 36 Asbestos/Slate roofing sheets ..... 37 Other 96	

ID #	Question and instructions	Coded responses/categories		Skip
W26	What is the **main** material of the exterior walls in your household? *RECORD OBSERVATION*	Natural walls		
		No walls ………………………...	11	
		Cane/Palm/Trunks ……………...	12	
		Dirt/Landcrete …………………	13	
		Rudimentary walls		
		Bamboo with mud ……………..	21	
		Stone with mud ………………..	22	
		Uncovered adobe ………………	23	
		Plywood ……………………….	24	
		Cardboard ………………………	25	
		Reused wood ……………………	26	
		Finished walls		
		Cement ………………………….	31	
		Stone with lime/cement ………...	32	
		Bricks …………………………..	33	
		Cement blocks ………………….	34	
		Covered adobe …………………	35	
		Wood planks/Shingles …………	36	
		Other ……………………………………	96	
W27	How many rooms in the household are used for sleeping?	Rooms ………………….. ________ ________		

ID #	Question and instructions	Coded responses/categories	Yes	No	Skip
	Does any member of this household own:				
W28	A wrist watch	Wrist watch ………..	1	2	
W29	A bicycle?	Bicycle ………………	1	2	
W30	A motorcycle or motor scooter?	Motorcycle/ motor scooter ……….	1	2	
W31	An animal-drawn cart?	Animal-drawn cart ….	1	2	
W32	A car or truck?	Car/ truck ……………	1	2	
W33	A boat with a motor?	Boat with motor …….	1	2	
W34	A boat without a motor	Boat without motor …	1	2	
W35	Does any member of this household own any agricultural land	Yes …………………………...		1	
		No ……………………………		2	→ W37
W36	How many hectares, acres or poles of agricultural land do members of the household own? *If 99.5 or more acres, record in hectares (100 acres= 1 hectare)*	Hectares ……..... 1 [ ][ ].[ ]			
		Acres …..……… 2 [ ][ ].[ ]			
		Plots ……..…… 3 [ ][ ].[ ]			
		95 or more hectares ……...	9995		
		Don't know ……..…….	9998		

ID #	Question and instructions	Coded responses/categories			Skip
W37	Does this household own any livestock, herds, other farm animals, or poultry?	Yes .... 1 No 2			→ W49
	How many of the following animals does this household own?	If none, enter '00'. If more than 95, enter '95'			
W38	Cattle?	Cattle ………….. _______ _______			
W39	Milk cow or bulls?	Milk cow/bulls … _______ _______			
W40	Horses, donkeys or mules?	Horses/ donkeys/ mules _____ _____			
W41	Goats?	Goats ………….. _______ _______			
W42	Sheep?	Sheep ………….. _______ _______			
W43	Pigs?	Pigs ……………. _______ _______			
W44	Rabbits?	Rabbits ………… _______ _______			
W45	Grasscutter?	Grasscutter …….. _______ _______			
W46	Chickens?	Chickens ……… _______ _______			
W47	Other poultry?	Other poultry …... _______ _______			
W48	Other?	Other …………… _______ _______			
W49	Does any member of this household have a bank account?	Yes ……………………….. 1 No ………………………... 2			
W49a	How many household members are covered by health insurance? *If none record '00'*	Persons ……………… Don't know/ not sure ... 98			
W50	How many people live in your household?	Number of People ….			
X01	Of the people living in your household, how many work for money?	Number working ……			
X02	Of the people living in your household, how many are less than 15 years?	Number less than 15 years			
X03	Of the people living in your household, how many are 65 years and more?	Number 65 and more			
X04	Of the people living in your household, how many have some form of disability?	Number with disability			

Section B: Agroforestry Woodland species ***(For farming households only, if respondent/household not a farmer(s) please skip to Section C)***

ID #	Question and instructions	Coded responses/categories		Skip
F00	Do you or members of you household engage in farming?	Yes …………………………. No …………………………..	1 2	 →*A01*
F01	How long have you/household been farming in this community? *(in years, 99 if don't know)*	Farming duration ………		
F02	Do you have trees on your/household's farmland(s): trees left deliberately/ on purpose?	Yes …………………………. No …………………………. Don't know ………………..	1 2 3	 →*A01* →*A01*
F03.01 F03.02 F03.03 F03.04 F03.05 F03.06 F03.07 F03.08 F03.09 F03.10 F03.11 F03.12 F03.13 F03.91 F03.92 F03.93	What trees are on your farmland(s) currently? *(select all that apply, tick with X or √)*	Dawadawa …………………. Tongbo …………………….. Shea ………………………... Sugeh ………………………. Baobab …………………….. Eucalyptus …………………. Mango ………………………. Moringa ……………………. Black berry/other berry ……. Rosewood ………………….. Acacia ………………………. Mahogany ………………….. Teak ………………………... Others (specify) ……………. Others (specify) ……………. Others (specify) ……………		
F04.01 F04.02 F04.03 F04.04 F04.05 F04.06 F04.07 F04.91 F04.92 F04.93	What is/are the **reason(s)** for leaving these trees on farm(s)? *(select all that apply, tick with X or √)*	Trees provide shade ……….. Edible fruits/nuts/leaves …… Medicinal purposes ………… Leaves enriched soil ……….. Serve as a boundary between farms/land ……………….. Trees are not to be cut down/belief …………….. Place for other insects/animals e.g., bees ……………….. Others (specify) ………..…. Others (specify) ……………. Others (specify) …………….		

SECTION C: Access and Use of Savannah Woodland Ecosystem Services and barriers/enablers encountered

Now let us find out what you and/or your household derive from Savannah Woodlands (collection of trees and shrubs).

Definition

ACCESS to woodland: refers to any woodland available to the disposal of the participant and/or household members irrespective of whether they go there (woodland) or not OR derive any benefits directly from the woodland

DERIVE from woodland: refers to services (categorized) directly obtained (and harvested for provision services) from woodland and not what is purchased from another individual/household/market (i.e. what you get from woodlands)

FOOD CROP: any crop cultivated-millet, maize/corn, sorghum, legumes (beans, soya been etc.), rice, yam etc.

ENABLER: promote

BARRIER: limit or prevent

ID #	Question and instructions	Coded responses/categories	Yes	No	Skip
	Which savannah wood land do you have access to *(Endowment, social, capital).*		Yes	No	
A01	National forest reserve	National Forest ……….	1	2	
A02	Community plantations/woodlot	Community woodlot ….	1	2	
A03	Own or family plantation/woodlot	Family/Own woodlot …	1	2	
A04	Scattered vegetation in or around the community	Scattered vegetation …..	1	2	

A01: Access to National forest Reserve

ID #	Question and instructions	Coded responses/categories				Skip
A01	Do you/household have access to National Forest Reserve? *(confirm)*	Yes .... 1 No 2				 →*A02 (N/A for all below)*
	What do you derive from the National Forest Reserve? *(Go through each type of service and select as appropriate)*					
A01C	Cultural Services?		Yes	No	n/a	
A01C01	- Visit forest for Traditional rites/prayer?	Traditional rites/ prayer	1	2	3	
A01C02	- Visit forest to admire nature/relax?	Admire/Relax	1	2	3	
A01C03	- Visit forest to play/enjoy yourself (recreation?	Play/enjoy	1	2	3	
A01C04	- Visit the forest to learn/teach?	Learn/Teach	1	2	3	
A01P	Provisioning Services?		Yes	No	n/a	
A01P01	- Food crops (i.e. cultivated)	Food crops	1	2	3	
A01P02	- Bush Meat	Bush Meat	1	2	3	
A01P03	- Edible vegetables	Edible vegetables ..	1	2	3	
A01P04	- Wild fruits	Wild fruits	1	2	3	
A01P05	- Medicinal plants	Medicinal plants ...	1	2	3	
A01P06	- Fodder for livestock	Fodder for livestock.	1	2	3	
A01P07	- Fuel wood (firewood/stalks)	Fuel (firewood)	1	2	3	
A01P08	- Fibre/ straw (broom/roofing)	Fibre	1	2	3	
A01P09	- Poles for Construction	Poles for Construction.	1	2	3	
A01P10	- Soil for construction	Soil for construction..	1	2	3	
A01P11	- Water	Water	1	2	3	
A01R	Regulating Services?		Yes	No	n/a	
A01R01	- Enjoy fresh air from trees	Enjoy fresh air	1	2	3	
A01R02	- Enjoy shade provided by trees	Enjoy shade	1	2	3	
A01R03	- Trees serving as wind-brakes	Wind-brakes	1	2	3	
A01R04	- Produce healthy crops due to absence of pest and disease	Produce healthy crops.	1	2	3	
A01R05	- Trees protect farmland soil erosion	Protection soil erosion	1	2	3	

ID #	Question and instructions	Coded responses/categories				Skip
A01R06	- Enjoy filtered air during the harmattan	Enjoy filtered air …	1	2	3	
A01R07	- Protect close by building	Protect close by building …………….	1	2	3	
A01S	Supporting Services?		Yes	No	n/a	
A01S01	- Benefit from fertile forest farm land rich in litter	Benefit: fertile farmland	1	2	3	
A01S02	- Benefits from crop yield due to fertile forest land	Benefit: Crop yield …	1	2	3	
A01S03	- Save money on fertilizer due to fertile land	Save money on fertilizer ……………	1	2	3	
A01S04	- Benefit from continuous farming on the same farmland	Benefit: continuous farming ……………	1	2	3	

U01: Use of Ecosystem Services (ES) derived from National Forest Reserve

ID #	Question and instructions	Coded responses/categories	
	OPTIONS	Primarily for household use (excess not sold) ...	**1**
		Primarily household use but excess is sold ……	**2**
		Primarily for market (none kept at home) ……..	**3**
		Primarily for market but unsold used at home ...	**4**
		Both household use and sold in market (in similar quantities) …………………………………..	**5**
		Not for household use or Market ….…………	**6**
		Not applicable/not obtained …………………..	**7**
U01	What do you use the above services (provisioning services) from the woodlands for: SELECT ONE OPTION ABOVE		
	Provisioning Services		Predominant Use
U01FC	- Food crops ……………………………		
U01BM	- Bush Meat ……………………………		
U01EV	- Edible vegetables ……………………..		
U01WF	- Wild fruits ……………………………		
U01MP	- Medicinal plants ……………………..		
U01FL	- Fodder for livestock …………………		
U01FW	- Fuel wood (firewood/stalks) ………..		
U01FS	- Fibre/ straw (broom/roofing) ……….		
U01PW	- Poles for Construction ………………		
U01PP	- Poles for other purposes/unknown purpose		
U01SC	- Soil for construction ………………		
U01WA	- Water ………………………………		

B01: Barriers and Enablers to Access and use of ES derived from National Forest Reserve

ID #	Question and instructions	Coded responses/categories			
B01	For each of the following, please select which answer best describes the way it affects access and use of woodlands by you and/or members of your household	Promote	Limit/ Prevent	Promote and Limit	Neither
B01R	Governance/Regulation				
B01R01	- Government/ FC regulation …	1	2	3	4
B01R02	- Community regulation/rules ..	1	2.	3	4
B01R03	- Family rules …………………	1	2	3	4
B01R04	- Community customs ………..	1	2	3	4
B01R05	- Access to land/land tenure ….	1	2	3	4
B01G	Geographic factors	1	2	3	4
B01G01	- Distance to woodlands ………	1	2	3	4
B01G02	- Road condition ………………	1	2	3	4
B01G03	- Means of transport (bicycle, motorbike, vehicle) …………	1	2	3	4
B01G04	- Security when travelling …….	1	2	3	4
B01G05	- Equipment to harvest resources.	1	2	3	4
B01G06	- Transport of harvested products.	1	2	3	4
B01S	Socio-economic	1	2	3	4
B01S01	- Poverty ………………………	1	2	3	4
B01S02	- Awareness of ES availability ..	1	2	3	4
B01S03	- Benefits derived from ES ……	1	2	3	4
B01S04	- Personal protective equipment .	1	2	3	4
B01S05	- Support from family and friends to access ES …………………	1	2	3	4
B01S06	- Physical challenges (living with disability) ……………………	1	2	3	4
B01S07	- Incentives given to landowners or leaders …………………………….	1	2	3	4
B01S08	- Incentives received from landowners or leaders ……..	1	2	3	4
B01S09	- Awards or recognition (from any source) ……………………	1	2	3	4
FC: Forestry Commission, ES: Ecosystem services					

A02: Access to Community Woodlot (including scattered trees/vegetation in and around community) ***i.e. bush/forest but not protected national forests***

ID #	**Question and instructions**	**Coded responses/categories**				**Skip**
A02	Do you/household have access to Community Woodlot? *(confirm)*	Yes …………………………… No …………………………….	1 2			 →*A03 (N/A for all below)*
	What do you derive from the community woodlot? *(Go through each type of service and select as appropriate)*					
A02C	Cultural Services?		Yes	No	n/a	
A02C01	- Visit forest for Traditional rites/prayer?	Traditional rites/prayer	1	2	3	
A02C02	- Visit forest to admire nature/relax?	Admire/Relax ………	1	2	3	
A02C03	- Visit forest to play/enjoy yourself (recreation?	Play/enjoy …………	1	2	3	
A02C04	- Visit the forest to learn/teach?	Learn/Teach ………..	1	2	3	
A02P	Provisioning Services?		Yes	No	n/a	
A02P01	- Food crops	Food crops ……….	1	2	3	
A02P02	- Bush Meat	Bush Meat ……….	1	2	3	
A02P03	- Edible vegetables	Edible vegetables …	1	2	3	
A02P04	- Wild fruits	Wild fruits ……….	1	2	3	
A02P05	- Medicinal plants	Medicinal plants …	1	2	3	
A02P06	- Fodder for livestock	Fodder for livestock	1	2	3	
A02P07	- Fuel wood (firewood/stalks)	Fuel (firewood) ….	1	2	3	
A02P08	- Fibre/ straw (broom/roofing)	Fibre ……………..	1	2	3	
A02P09	- Poles for Construction	Poles for Construction	1	2	3	
A02P10	- Soil for construction	Soil for construction .	1	2	3	
A02P11	- Water	Water ………………	1	2	3	
A02R	Regulating Services?		Yes	No	n/a	
A02R01	- Enjoy fresh air from trees	Enjoy fresh air ……	1	2	3	
A02R02	- Enjoy shade provided by trees	Enjoy shade ………	1	2	3	
A02R03	- Trees serving as wind-brakes	Wind-brakes ……..	1	2	3	
A02R04	- Produce healthy crops due to absence of pest and disease	Produce healthy crops	1	2	3	

ID #	Question and instructions	Coded responses/categories				Skip
A02R05	- Trees protect farmland soil erosion	Protection soil erosion	1	2	3	
A02R06	- Enjoy filtered air during the harmattan	Enjoy filtered air …	1	2	3	
A02R07	- Protect close by building	Protect close by building …...............	1	2	3	
A02S	Supporting Services?		Yes	No	n/a	
A02S01	- Benefit from fertile forest farm land rich in litter	Benefit: fertile farmland	1	2	3	
A02S02	- Benefits from crop yield due to fertile forest land	Benefit: Crop yield …	1	2	3	
A02S03	- Save money on fertilizer due to fertile land	Save money on fertilizer …………..	1	2	3	
A02S04	- Benefit from continuous farming on the same farmland	Benefit: continuous farming……………	1	2	3	

U02: Use of Ecosystem Services derived from Community woodlot

ID #	Question and instructions	Coded responses/categories	
	OPTIONS	Primarily for household use (excess not sold) ……...	**1**
		Primarily household use but excess is sold …………	**2**
		Primarily for market (none kept at home) …………..	**3**
		Primarily for market but unsold used at home ……...	**4**
		Both household use and sold in market (in similar quantities) ………………………………………..	**5**
		Not for household use or Market ……………………	**6**
		Not applicable/not obtained …………………………	**7**
U02	What do you use the above services (provisioning services) from the woodlands for: SELECT ONE OPTION ABOVE		
	Provisioning Services	Predominant Use	
U02FC	- Food crops ……………………………………..		
U02BM	- Bush Meat ……………………………………..		
U02EV	- Edible vegetables …………………………….		
U02WF	- Wild fruits …………………………………….		
U02MP	- Medicinal plants ……………………………..		
U02FL	- Fodder for livestock ………………………….		
U02FW	- Fuel wood (firewood/stalks) …………………...		

U02FS	- Fibre/ straw (broom/roofing) …………………..		
U02PW	- Poles for Construction …………………………		
U02PP	- Poles for other purposes/unknown purpose ……		
U02SC	- Soil for construction ……………………………		
U02WA	- Water ……………………………………………		

B02: Barriers and Enablers to Access and use of ES derived from Community woodlot

ID #	Question and instructions	Coded responses/categories			
B02	For each of the following, please select which answer best describes the way it affects the access and use of woodlands by you and/or members of your household	Promote	Limit/ Prevent	Promote and Limit	Neither
B02R	Governance/Regulation				
B02R01	- Government/ FC regulation …	1	2	3	4
B02R02	- Community regulation/rules ...	1	2	3	4
B02R03	- Family rules …………………	1	2	3	4
B02R04	- Community customs ………..	1	2	3	4
B02R05	- Access to land/land tenure ….	1	2	3	4
B02G	Geographic factors				
B02G01	- Distance to woodlands ………	1	2	3	4
B02G02	- Road condition ………………	1	2	3	4
B02G03	- Means of transport (bicycle, motorbike, vehicle) …………	1	2	3	4
B02G04	- Security when travelling ……	1	2	3	4
B02G05	- Equipment to harvest ES ……	1	2	3	4
B02G06	- Transport of harvested products	1	2	3	4
B02S	Socio-economic				
B02S01	- Poverty ………………………	1	2	3	4
B02S02	- Awareness of ES availability …	1	2	3	4
B02S03	- Benefits derived from ES …….	1	2	3	4
B02S04	- Personal protective equipment ..	1	2	3	4
B02S05	- Support from family and friends to access ES ……………………..	1	2	3	4
B02S06	- Physical challenges (living with disability) ……………………..	1	2	3	4
B02S07	- Incentives given to landowners or leaders …………………………….	1	2	3	4
B02S08	- Incentives received from landowners or leaders …………	1	2	3	4
B02S09	- Awards or recognition (from any source) ………………………..	1	2	3	4
FC: Forestry Commission, ES: Ecosystem services					

A03: Access to Family/Own Plantation/Woodlot

ID #	**Question and instructions**	**Coded responses/categories**				**Skip**
A03	Do you/household have access to Family or own plantation/Woodlot? *(confirm)*	Yes ………………………… 1 No ………………………… 2				 →*A04 (N/A for all below)*
	What do you derive from your family or own plantation/ woodlot? *(Go through each type of service and select as appropriate)*					
A03C	Cultural Services?		Yes	No	n/a	
A03C01	- Visit forest for Traditional rites/prayer?	Traditional rites/prayer	1	2	3	
A03C02	- Visit forest to admire nature/relax?	Admire/Relax ………	1	2	3	
A03C03	- Visit forest to play/enjoy yourself (recreation?	Play/enjoy …………..	1	2	3	
A03C04	- Visit the forest to learn/teach?	Learn/Teach …………	1	2	3	
A03P	Provisioning Services?		Yes	No	n/a	
A03P01	- Food crops	Food crops …………	1	2	3	
A03P02	- Bush Meat	Bush Meat …………	1	2	3	
A03P03	- Edible vegetables	Edible vegetables …..	1	2	3	
A03P04	- Wild fruits	Wild fruits …………	1	2	3	
A03P05	- Medicinal plants	Medicinal plants ……	1	2	3	
A03P06	- Fodder for livestock	Fodder for livestock …	1	2	3	
A03P07	- Fuel wood (firewood/stalks)	Fuel (firewood) …….	1	2	3	
A03P08	- Fibre/ straw (broom/roofing)	Fibre ……………….	1	2	3	
A03P09	- Poles for Construction	Poles for Construction.	1	2	3	
A03P10	- Soil for construction	Soil for construction …	1	2	3	
A03P11	- Water	Water ………………..	1	2	3	
A03R	Regulating Services?		Yes	No	n/a	
A03R01	- Enjoy fresh air from trees	Enjoy fresh air ………	1	2	3	
A03R02	- Enjoy shade provided by trees	Enjoy shade …………	1	2	3	
A03R03	- Trees serving as wind-brakes	Wind-brakes …………	1	2	3	
A03R04	- Produce healthy crops due to absence of pest and disease	Produce healthy crops	1	2	3	

ID #	Question and instructions	Coded responses/categories				Skip
A03R05	- Trees protect farmland soil erosion	Protection soil erosion	1	2	3	
A03R06	- Enjoy filtered air during the harmattan	Enjoy filtered air ……	1	2	3	
A03R07	- Protect close by building	Protect close by building ………………..	1	2	3	
A03S	Supporting Services?		Yes	No	n/a	
A03S01	- Benefit from fertile forest farm land rich in litter	Benefit: fertile farmland	1	2	3	
A03S02	- Benefits from crop yield due to fertile forest land	Benefit: Crop yield …	1	2	3	
A03S03	- Save money on fertilizer due to fertile land	Save money on fertilizer …………….	1	2	3	
A03S04	- Benefit from continuous farming on the same farmland	Benefit: continuous farming …………….	1	2	3	

U03: Use of Ecosystem Services derived from Family/Own Plantation/woodlot

ID #	Question and instructions	Coded responses/categories	
	OPTIONS	Primarily for household use (excess not sold) ………	**1**
		Primarily household use but excess is sold ………..	**2**
		Primarily for market (none kept at home) …………	**3**
		Primarily for market but unsold used at home ………	**4**
		Both household use and sold in market (in similar quantities) ………………………………………..	**5**
		Not for household use or Market ………………….	**6**
		Not applicable/not obtained ………………………..	**7**
U03	What do you use the above services (provisioning services) from the woodlands for: SELECT ONE OPTION ABOVE		
	Provisioning Services	Predominant Use	
U03FC	- Food crops ………………………………………		
U03BM	- Bush Meat ………………………………………		
U03EV	- Edible vegetables ………………………………		
U03WF	- Wild fruits ………………………………………		
U03MP	- Medicinal plants ………………………………..		
U03FL	- Fodder for livestock ……………………………		
U03FW	- Fuel wood (firewood/stalks) ……………………		

U03FS	- Fibre/ straw (broom/roofing) ……………………		
U03PW	- Poles for Construction …………………………		
U03PP	- Poles for other purposes/unknown purpose ……		
U03SC	- Soil for construction ……………………………		
U03WA	- Water ……………………………………………		

B03: Barriers and Enablers to Access and use of ES derived from Family or Own plantation

ID #	Question and instructions	Coded responses/categories			
B03	For each of the following, please select which answer best describes the way it affects the access and use of woodlands by you and/or members of your household.	Promote	Limit/ Prevent	Promote and Limit	Neither
B03R	Governance/Regulation				
B03R01	- Government/ FC regulation …	1	2	3	4
B03R02	- Community regulation/rules …	1	2	3	4
B03R03	- Family rules …………………	1	2	3	4
B03R04	- Community customs ………..	1	2	3	4
B03R05	- Access to land/land tenure …	1	2	3	4
B03G	Geographic factors				
B03G01	- Distance to woodlands ………	1	2	3	4
B03G02	- Road condition ………………	1	2	3	4
B03G03	- Means of transport (bicycle, motorbike, vehicle) ………..	1	2	3	4
B03G04	- Security when travelling …….	1	2	3	4
B03G05	- Equipment to harvest ES ……	1	2	3	4
B03G06	- Transport of harvested products	1	2	3	4
B03S	Socio-economic				
B03S01	- Poverty ……………………..	1	2	3	4
B03S02	- Awareness of ES availability ..	1	2	3	4
B03S03	- Benefits derived from ES ……	1	2	3	4
B03S04	- Personal protective equipment	1	2	3	4
B03S05	- Support from family and friends to access ES …………………	1	2	3	4
B03S06	- Physical challenges (living with disability) ……………………..	1	2	3	4
B03S07	- Incentives given to landowners or leaders …………………………….	1	2	3	4
B03S08	- Incentives received from landowners or leaders ..……..	1	2	3	4
B03S09	- Awards or recognition (from any source) ……	1	2	3	4
FC: Forestry Commission, ES: Ecosystem services					

Ranking all ES services obtained from woodlands based on level of importance to household

ID #	Question and instructions	Coded responses/categories		
R01	On a scale of 0 to 10 *(with 0 being least and 10 being highest)* rank the level of importance of **EACH** ecosystem services derived from woodlands to your household. *Please do not guess but think through to rank level of importance.*			
	Instructions: state 00, 01, 02 etc. to 10 in boxes for example		***0***	***8***
R01C	Cultural Services?			
R01C01	- Visit forest for Traditional rites/prayer?	Traditional rites/prayer ……..		
R01C02	- Visit forest to admire nature/relax?	Admire/Relax ………………		
R01C03	- Visit forest to play/enjoy yourself (recreation)?	Play/enjoy …………………		
R01C04	- Visit the forest to learn/teach?	Learn/Teach ………………..		
R01P	Provisioning Services?			
R01P01	- Food crops	Food crops …………………		
R01P02	- Bush Meat	Bush Meat …………………		
R01P03	- Edible vegetables	Edible vegetables …………..		
R01P04	- Wild fruits	Wild fruits …………………		
R01P05	- Medicinal plants	Medicinal plants ……………		
R01P06	- Fodder for livestock	Fodder for livestock ………..		
R01P07	- Fuel wood (firewood/stalks)	Fuel (firewood) …………….		
R01P08	- Fibre/ straw (broom/roofing)	Fibre ………………………..		
R01P09	- Poles for Construction	Poles for Construction ……..		
R01P10	- Soil for construction	Soil for construction ……….		
R01P11	- Water	Water ………………………		
R01R	Regulating Services?			
R01R01	- Enjoy fresh air from trees	Enjoy fresh air ………………		
R01R02	- Enjoy shade provided by trees	Enjoy shade …………………		
R01R03	- Trees serving as wind-brakes	Wind-brakes ………………...		
R01R04	- Produce healthy crops due to absence of pest and disease	Produce healthy crops ………		
R01R05	- Trees protection farmland soil erosion	Protection soil erosion ……...		
R01R06	- Enjoy filtered air during the harmattan	Enjoy filtered air ……………		
R01R07	- Protect close by building	Protect close by building …….		
R01S	Supporting Services?			
R01S01	- Benefit from fertile forest farm land rich in litter	Benefit: fertile farmland …….		
R01S02	- Benefits from crop yield due to fertile forest land	Benefit: Crop yield …………		

R01S03	- Save money on fertilizer due to fertile land	Save money on fertilizer ….		
R01S04	- Benefit from continuous farming on the same farmland	Benefit: continuous farming …		

SECTION D: Climate Change Adaptation, Woodland Conservation and Value of Woodlands

Experience on climate variability

ID #	Question and instructions	Coded responses/categories		Skip
K01	Have you observed changes in the weather pattern over the last two decade	Yes …………………… No …………………… Don't know/not sure …	1 2 3	
K02	What are your main observations of rainfall patterns over the last two decade?	Increasing …………….. Decreasing …………… No change …………… Don't know/ not sure …	1 2 3 4	
K03	What are your main observations on the predictability of rain fall patterns?	Unpredictable ……….. Predicable ……………. Don't know/ not sure …	1 2 3	
K04	What are your main observations in terms of temperature	Increasing …………… Decreasing …………… No change …………… Don't know/ not sure …	1 2 3 4	
K05	What are your observation in terms of drought	Longer than before …… Shorter than before …… No change …………….. Don't know/ not sure ….	1 2 3 4	
K06	Over the last few years, are droughts predicable? Unpredictable?	Unpredictable ……….. Predictable ……………. Don't know/ not sure ….	1 2 3	
K07	Do you experience droughts and dry spells during the farming season?	Yes ……………………… No …………………………	1 2	 → *K09*
K08	How often do you experience droughts and dry spells?	Frequently …………… Occasionally …………… Not common …………… Don't know/ not sure ……	1 2 3 4	
K09	Have you or your household experienced floods over the last couple of years?	Yes ………..…………… No ………………;…….. Don't know …………….	1 2 3	

ID #	Question and instructions	Coded responses/categories	Yes	No	Don't know	Skip
K10	What do you think are the reasons for the changes in rainfall and temperature patterns		Yes	No	Don't know	*If **no** to K01, **no change** to K02, K04 and K05 and **no** to K07 skip to K10*
K10A	- Too much tree cutting	Too much tree cutting	1	2	3	
K10B	- Less Tree cutting	Less Tree cutting ….	1	2	3	
K10C	- Too much charcoal burning	Too much charcoal burning ……………	1	2	3	
K10D	- Less charcoal burning	Less charcoal burning	1	2	3	
K10E	- Frequently clearing trees to plant crops	Frequently clearing trees to plant crops …	1	2	3	
K10F	- Growing trees	Growing trees ……...	1	2	3	
K10G	- Planting crops whilst leaving trees around farm	Planting crops & leaving trees around farm ……………...	1	2	3	
K10H	- Bush burning	Bush burning …….	1	2	3	
K10I	- Preventing bush fires	Prevent bush fires ….	1	2	3	
K10J	- The gods are angry	The gods are angry ..	1	2	3	
K10K	- Sins of the world	Sins of the world …	1	2	3	
K10L	- The gods are happy	The gods are happy..	1	2	3	
K10M	- Livestock overgrazing	Livestock overgrazing ………	1	2	3	
K11	What can we do to stop the changes in rainfall and temperature patterns		Yes	No	Don't know	
K11A	- Cut more trees	Cut more trees ……	1	2	3	
K11B	- Plant more trees	Plant more trees …..	1	2	3	
K11C	- Burn more charcoal	Burn more charcoal..	1	2	3	
K11D	- Burn less charcoal	Burn less charcoal …	1	2	3	
K11E	- Bush burning	Bush burning ……...	1	2	3	
K11F	- Protect existing trees from wildfires	Protect existing trees from wildfires …….	1	2	3	
K11G	- Pray to God	Pray to God ………	1	2	3	
K11H	- Perform rites to appease the gods	Perform rites to appease the gods ….	1	2	3	
K11I	- Overgraze the land	Overgraze the land …	1	2	3	
K11J	- Minimize overgrazing	Minimize overgrazing …..	1	2	3	
K12A	Score out of 23 *(calculate manually for data entry)*					
K12B	Percentage score *(K11K/23)x100%*	●			%	

Sources of Knowledge

ID #	Question and instructions	Coded responses/categories		Skip
K13	What is your **main source** of knowledge on changing weather pattern? *Where do you usually get information from? Select one*	Local knowledge ……………	01	
		Community members/leaders ..	02	
		Community volunteers ………	03	
		Radio ………………………	04	
		Television ……………………	05	
		NGO staff ……………………	06	
		Forestry Commission staff ….	07	
		MoA- Agric Staff ……………	08	
		Volunteers from other districts	09	
		Others *(specify)*……………..	91	

Practices: Conservation of woodlands

Now let us discuss trees and what you do currently to conserve the trees

ID #	Question and instructions	Coded responses/categories		
P01	Reply true or false to the following statements? (What do you do to protect trees)	True	False	N/A
P01C01	I prune trees around my house/farm/community regularly …………………………………………	1	2	3
P01C02	I always put out bush fires ………………………	1	2	3
P01C03	I sometimes put out bush fires …………………..	1	2	3
P01C04	Do some in your community or nearby communities cut down trees for charcoal ………………………	1	2	3
P01C05	I burn bushes around my house/home ……………	1	2	3
P01C06	I plant trees to replace ones I cut down ……………	1	2	3
P01C07	I plant trees sometimes but not to replace trees I cut.	1	2	3
P01C08	I cut down trees and shrubs to make room for farming activities (slash and burn) …………………………..	1	2	3
P01C09	My community has laws to prevent bush burning …	1	2	3
P01C10	My community has laws to protect trees (determine which to cut and which not to cut) …………………	1	2	3
P01C11	My community has protected areas (lands) where grazing is forbidden ………………………………	1	2	3
P01C12	My community put a fire-belt around forests, plantations or trees in/around community ………..	1	2	3
P01C13	We are not allowed to farm in the forest …………	1	2	3
P01C14	We plant trees in the forest ………………………	1	2	3
P01C15	It is my responsibility to protect tree crops ………	1	2	3
P02	Please indicate your level of agreement with the following statements *(state if you strongly disagree, disagree, neutral/not decided, agree, or strongly agree)* *INSTRUCTION: please use codes on Right, write in box below*	Strongly Disagree . 1 Disagree ……….... 2 Neutral …………. 3 Agree …………… 4 Strongly Agree ….. 5		

P02C01	- It is my responsibility (me and household) to protect trees in and around my community including forests …………………………		
P02C02	- It is the responsibility of the chiefs and leaders to protect trees in/around community (including forests) …………….............................		
P02C03	- It is the Ministry of Agriculture/Forestry Commission's responsibility to protect trees in my communities …………………………		
P02C04	- It is the sole responsibility of MoA/Forestry Commission's to protect forest near my community ………………………………		
P02C05	- It is important that we conserve our woodlands/trees for the future generation (Bequest value) …………………………..		
P02C06	- It is important that we protect our local tree species from becoming extinct (Existence value) …………………………………….		

Adaptation practices (Now let us discuss your/household responses to changing weather pattern)

ID #	Question and instructions	Coded responses/categories				Skip
F00	Do you or members of household engage in farming activities	Yes ………………… 1 No …………………. 2 Don't know ……….. 3				*2/3 skip to P01*
F01	Which are your **on-farm** practices adopted to adapt to changing weather patterns		Yes	No	Don't Know	
F01	Irrigation farming?	Irrigation? ………..	1	2	3	
F02	Planting drought resistant crops?	Drought resistant crops? ……………..	1	2	3	
F03	Planting early maturing seeds?	Early maturing seeds? .	1	2	3	
F04	Shifting to newer crops?	New crops? ………..	1	2	3	
F05	Integrate crops and livestock?	Crops and livestock? .	1	2	3	
F06	Rain water harvesting?	Water harvesting? …	1	2	3	
F07	Planting different crops?	Plant different crops?	1	2	3	
F08	Relying on weather information to start planting?	Rely weather information? ………	1	2	3	
F09	Engage in tree planting/ afforestation?	Re-afforestation? …	1	2	3	
F10	Application of compost	Application of compost	1	2	3	
F11	Application of fertilizer/pesticides	Fertilizer/pesticides .	1	2	3	

F12	Expansion of farmland into forest reserve	Expansion of farmland into forest reserve? …	1	2	3	
F13	Agroforestry practice	Agroforestry practice	1	2	3	
F14	Using mounds and ridges	Mounds and ridges ..	1	2	3	

Other on-farm jobs

ID #	Question and instructions	Coded responses/categories			Skip
P01	Are you/members of household engaged in plantation farming (mango, teak, etc.)	Yes ………….. 1 No …………... 2 Don't know …. 3			2/3 skip to
P02 P03 P04	Why are you/household into plantation farming? *(select the most important reasons- 3 choices from below as respondent answers question e.g., 92)*	1st Reason ………… 2nd Reason ………... 3rd Reason ………...			
	Reasons Extra form of income/ alternate source of income ... 01 Logs for household construction/ fuel-wood ……... 02 Security against poor harvest …………………….. 03 Other colleagues are into it/ encouraged by community…... 04 Instruction of leaders (and/or forestry commission and agric staff) ………………………………….. 05 Wood, fruits etc. from plantation ………………… 06 Secure land for future use ……………………… 07 Land no longer good for farming ……………… 08 Used as support for other plants e.g., yam …….. 09 Reduce changing weather pattern ……………… 20 Control deforestation/ afforestation …………….. 21 Purify the air …………………………………… 22 Control erosion/ hold soil together ……………… 23 Tree leaves provides nutrients to the soil ……… 24 Trees help hold water in soil …………………… 25 Serve as Windbreaks/control winds …………… 26 Other 1 *(specify)* ………………………………. 91 Other 2 *(specify)* ………………………………. 92 Other 3 *(specify)* ………………………………. 93				

Off-Farm adaptation practices

ID #	Question and instructions	Coded responses/categories	Yes	No	Don't know
G00	Which of the following other off-farm jobs/ practices do you/household engage in to respond to changing weather and poor.		Yes	No	Don't know
G01	Petty trading	Petty trading …………	1	2	3
G02	Pito brewing	Pito brewing …………	1	2	3
G03	Basket weaving	Basket weaving ……..	1	2	3
G04	Pottery	Pottery ………………	1	2	3
G05	Mortar making	Mortar making ………	1	2	3
G06	Carving	Carving ……………..	1	2	3
G07	Shea nut picking and/or oil extraction	Shea nut pick/oil extract	1	2	3
G08	Collection of other fruits/food and vegetables for sale/household use	Collection of other edibles ………………	1	2	3
G09	Harvest fuel-wood (sale/household)	Harvest fuel-wood ….	1	2	3
G10	Harvest fodder for livestock	Fodder for livestock …	1	2	3
G11	Harvest straw (broom, roofing, basketry)	Harvest straw ………..	1	2	3
G12	Logging (wood/ poles for houses, sale)	Logging ……………..	1	2	3
G13	Charcoal burning	Charcoal burning ……	1	2	3
G14	Hunting for bush meat	Bush meat …………..	1	2	3
G15	Harvesting medicinal plants	Medicinal plants …….	1	2	3
G16	Motor/bicycle repair	Motor/bicycle repair ..	1	2	3
G17	Plumbering	Plumbering …………	1	2	3
G18	Building/construction	Building/construction .	1	2	3
G19	Office work/ other formal employment (teaching, nursing, security etc.)	Formal employment …	1	2	3
G20	Skill based jobs (tailoring, bakery, hairdressing)	Skill based jobs ………	1	2	3
	BEAD GAME (●●●●● ●●●●●)				
G21	Rank the importance of off-farm practices to household **income** [in comparison to on-farm practices or other sources of income] *(give respondent 10 beads, respondent will give you the number of beads they feel contribute to household income, e.g., 00)*				
G22	Rank contribution of off-farm practices to food provisioning (food security) in the household *i.e. how much does off-farm practice contribute to food availability in the household (using beads to rank)*				

Migration (possible confounding variable)
Now let's talk about the effect of changing weather on you and/or your household and your work (livelihood)? What are the social implications of the changing weather pattern on livelihoods?

ID #	Question and instructions	Coded responses/categories	Skip
M01	Cast your mind to past 10-15 years, did you or any member of your household migrate (travel outside the community) during the dry season or "bad years"?	Yes ………………… 1 No ………………… 2 Don't know/not sure . 3	2/3 skip to V01
M02	If yes, how often do you or members of household migrate in the last 10-15years/seasons?	Every year ……………….. 1 Less than 5 times/seasons .. 2 5 to 9 times/seasons ……… 3 10 and more times/seasons.. 4	
M03	If yes, which member of your household **usually** migrate *(in relation to household head)*	Head …………………….. 01 Wife/Husband ……………. 02 Son/Daughter …………….. 03 Son/ daughter-in-law …….. 04 Grandchild ………………. 05 Parent ……………………. 06 Parent-in-law ……………. 07 Brother/Sister ………….... 08 Other relative ……………. 09 Adopted/foster/stepchild … 10 Not related ……………….. 11 Don't know ………………. 98	
M04	Typically, where do you/members of your household migrate to (name the main place)? *NB INST: Please locate place on agro-ecological map attached and code*	Reference Eco-zone Sudan Savannah ………… 1 Guinea Savannah ……….. 2 Transitional zone ………… 3 Deciduous Forest ………… 4 Rain forest ………..……… 5 Coastal Savannah ……….. 6	
M05	What job do you/members of household **usually** do when they migrate to (as above)?	Don't know ……………. 01 Farming ……………….. 02 Rearing of animals ……. 03 Fishing ………………… 04 Trading- petty ………… 05 Apprenticeship (learn a trade) ………………… 06 Hawking …………….... 07 Office work ………..…. 08 Other jobs ……….……. 09 To live with another relation …..................... 10 Education ……..……… 11	
	(BEAD GAME) Rank the contribution of migration of you or member of households to the following		

M06 M07	Household income Household food availability	Household income …… Food availability ……..			
M08	Do you think that, a member of your household will migrate during this/coming dry season?	Yes …………………… No …………………… Not sure ………………	1 2 3		

Value of Woodland Ecosystem Services

ID #	Question and instructions	Coded responses/categories		Skip
V01	How important do you feel it is to keep/protect trees/bushes/forests **1. Very important 2. Not important 3. Not sure**			
V01	Are you willing to support keep/protect these trees/bush/forests?	Yes ………………………….. No …………………………...	1 2	→*V03*
V02	If no, why are you not willing to support keep these trees/bushes/forests	I/we do not derive any benefit To prevent others from benefiting at the disadvantage of rest of community …………………… I/we are not from here (part of country) ……………………… No money/poverty ………….. Not my responsibility (government or other agencies responsibility) .. Other (specify) …………………..	1 2 3 4 5 6	
V03	Are you willing to support government agencies, community leaders, NGOs, or the Forestry commission in preserving the forest/bushes/ trees for future use	Yes, fully support ……………… Yes, partially support …………. No, with reservation …………… No, not at all …………………... Undecided/don't know ……………………	1 2 3 4 5	
V04S01 V04S02 V04S03 V04S04 V04S05 V04S06 V04S07 V04S08 V04S09 V04S10 V04S11	Which of the following support can you give to preserve the trees/forest/bushes for future use *(Tick all that apply, indicate reason if other selected)*	Financial support ……………… Farm produce ………………….. Manpower ……………………... Play key roles in community to solve problem ………………... Prevent bushfires ………..…… Report over logging of trees …. Minimize or avoid tree cutting .. Obey laws …………………….. Minimize hunting …………… Other ………………………... Other ………………………..		

Scenarios

					skip
	Scenario 1				skip
V05	Trees provide us with several benefits. Some trees such as shea, dawadawa, sugeh etc. provide fruits and products that can be used to make other foods items. Parts of other trees/plants are used as medicine. In times past, these trees were many but as time goes by you would have noticed a decrease in the number of trees as people use these trees for various purposes. Taking a look at some years back (two decades plus ago) and the current situation and considering that if these trees are destroyed, we lose a form of livelihood (benefits). We can help change the current trend if we contribute to make a difference. Contribution can be in money or farm produce or other kind you can suggest.				
V05	Which type of contribution would you prefer		Farm produce ………… 1 Money ………………… 2 Other (specify) ………... 3		
	Please enquire of at least two (farm produce or other against money). Let us see how much of the farm produce, money or other you would contribute in one year (or end of season)				
	Farm produce	Indicate:			
V06M1 V06N1		Specify (one kind only):	Minimum (bowls) ………. Maximum (bowls)		
V06M2 V06N2	*(Use market price to calculate this)*	Market value	Minimum (GHS) Maximum (GHS)	• •	
V07M V07N	Money in Ghana cedis		Minimum ……. Maximum …….	• •	
V08M1 V08N1	Other	Specify (one kind only):	Minimum ...…... Maximum ……		
V08M1 V08N1	*(Use market price to calculate this)*	Market value	Minimum …... Maximum ….	• •	
V09	Your contribution can be used for any of the following, select the one you would prefer		Grow more trees/forests …. 1 Maintain current trees/ forests …………………… 2 Grow and maintain trees/ forests …………………… 3 None …………………….. 4		
V10	Once you have made contributions together with others from community, who (which body/group) would you prefer (or have trust in) to manage your contributions to ensure that it is put into good use in restoring/conserving trees/bushes/forests		Community group ………. 1 Chief and leaders in community ……………… 2 Local/zonal Assembly …. 3 Forestry Commission …… 4 District Assembly ……..... 5 Other (specify) …….....….. 6		

V11	What in your opinion will enhance community participation and ownership of trees/forests/bushes *(tick all that apply, specify others)*	Education on environmental degradation		
		Support from Forestry Commission		
		Encouragement from community leaders		
		Making available land for tree planting		
		Incentives to community members		
		Use tree planting to create jobs for us		
		Others …………………………… ……………………………		
		Others …………………………… ……………………………		

Scenario 2

	Scenario 2			Skip
V12	Trees provide us with shade and fresh air etc. Some trees such as shea, dawadawa provide fruits and products that can be used to make other foods. Other trees/plants are used as medicines. Let us take it that you or members of your household are engaged in tree cutting for charcoal production, logging for sale (and construction), bush burning and other activities that destroy trees, bushes and forests. Since these activities destroy the trees and as time goes on, there would be no trees to provide us with shade, fresh air, fruits, vegetables and medicinal products, the government decides to pay you off to stop cutting and destroying further trees.			
V13	Would you be interested in Government paying you so that you stop cutting trees?	Yes …………………… No …………………….. Not sure ………………..	1 2 3	 →V19 →V19
V14	What kind of payment would you prefer	Farm produce ………… Money ………………… Other (specify) ………...	1 2 3	
V15	How often would you want payment to be?	Weekly ……………….. Monthly ……………….. Yearly ………………… Other (specify) …………	1 2 3 4	
V16M V16N	What amount per …? *(frequency above)* would you accept *(below if other or farm produce)*	Minimum (GHS) ……… Maximum (GHS) ………	1 2	

V17M1	If, farm produce	Specify (one kind only):	Minimum (bowls) ….				
V17N1			Maximum (bowls) ….				

V17M2	*(Use market price to calculate this)*	Market value	Minimum (GHS)				●			
V17N2			Maximum (GHS)				●			
V18M	Calculate yearly amount of money in Ghana cedis (frequency X amount/market price of value)		Minimum …….				●			
V18N			Maximum …...				●			
V19R1	If no/ not sure, what is your reason for not accepting payment?		Prefer alternative form of livelihood							
V19R2	*(tick all that apply, indicate reason if other)*		Prefer relocation of household							
V19R3			Government cannot be trusted							
V19R4			Any agency preferred to make payment							
V19R5			Other							
V19R6			Other							
V19R7			Other							

Thank you

Name of research assistant ………………………………………………………	Signature ……………………………………………
Date of interview:	Time interview ends:

APPENDIX III KEY INFORMANT INTERVIEW GUIDE

Institute for Environment and Sanitation Studies,

College of Basic and Applied Sciences

University of Ghana

Research Area: **Ecosystem Services Benefits to Farmers from Savannah woodlands in Northern Ghana**

Informed Consent

I am Ophelia Kaba Ayamba (Mrs.), a PhD student of the University of Ghana. I am carrying out a research work on the topic: **Ecosystem Services Benefits to Farmers from Savannah Woodlands in Northern Ghana**. The study and I are non-political and not linked to the government of Ghana or other state institutions.
You were selected as a key informant to participate in this study. Participation is voluntary and you may choose not to answer a question or decide to end the interview at any time. The discussion will take approximately **45 minutes.** You will not be affected in any way if you decline to participate in the study.
I am here to learn from you the effects that climate change and climate variability has had on woodlands in the District as well as on smallholder farming households. So you will be my teacher by providing information that will meet the objective of this study. The information gathered is purely for research purposes which will also contribute to knowledge on the Adaptation at Scale in Semi-Arid Regions [ASSAR] of Northern Ghana by providing information on knowledge and discussions on impact of human and natural influences on ecosystem services in semi-arid regions of Ghana.
All information you provide is confidential and available to the research team. Your personal details are available to the researcher and statistician only. I shall not share any information containing your personal details to any third party.
For more information on the research, kindly contact Ophelia Kaba-Ayamba on 0268204800/ 0505785220.

If you have any issues on your rights as a participant, kindly contact:
Administrator, Ethics Committee for Basic and Applied Sciences, College of Basic and Applied Sciences, University of Ghana, P. O. Box LG 68, Legon – Accra. Tel: + 233 277493259. Email: ekacquaah@ug.edu.gh

KII01	Would you like to participate in the study?	Yes ……………. 1 No ……………… 2 Not sure ……….. 3	*If NO or NOT SURE, **thank participant and end interview***
KII02	Would you mind me recording our discussion?	Yes ……………. 1 No ……………… 2 Not sure ……….. 3	*If YES or NOT SURE, **do not record discussion***

Transcribe all responses verbatim (in English) on separate sheets provided.

KD01	Name:	
KD02	Community or place of work:	
KD03	Role in Nandom/community:	
KD04	Sex of Key informant:	
KD05	Phone number (where applicable):	
KD06	Address (where applicable):	
KII03	How has delays of rains and weather changes affected farmers in the Nandom District *(or community where Key Informant lives)*	
KII04	Do you have rules to control people accessing woodland at the community level? When did it start and why that?	
KII05	What can you say regarding the harvesting of branches for firewood and other uses?	
KII06	When there are food shortages what do you (or farmers) normally do to ensure you have food or money until the next harvesting season? *(probe further to differentiate between adaptation and coping)*	
KII07	What practices do your people engage in to ensure continuous supply of food, meat, money, fuelwood, logs for construction each year? *(probe further to differentiate between adaptation and coping)*	
KII08	Which activities or practices do your people engage in? Which are cultural practice handed to you by your fathers especially with regards the use of the trees on your farm and surrounding environment? (probe further)	

Thank participant and request to leave after interview

APPENDIX IV FOCUS GROUP DISCUSSION GUIDE

<table>
<tr><td colspan="4">Institute for Environment and Sanitation Studies,
College of Basic and Applied Sciences
University of Ghana
Research Area: Ecosystem Services Benefits to Farmers from Savannah woodlands in Northern Ghana</td></tr>
<tr><td colspan="4"><u>Informed Consent</u>

I am Ophelia Kaba Ayamba (Mrs.), a PhD student of the University of Ghana. I am carrying out a research work on the topic: Ecosystem Services Benefits to Farmers from Savannah Woodlands in Northern Ghana. The study and I are non-political and not linked to the government of Ghana or other state institutions.
You were selected to participate in focus group discussions at ……………… community. Participation is voluntary and you may choose not to answer a question or decide to end or leave the discussion at any time. The discussion will take approximately <u>45-60 minutes.</u> You will not be affected in any way if you decline to participate in the study.
I am here to learn from you the effects that climate change and climate variability has had on woodlands in the District as well as on smallholder farming households. So you will be my teacher by providing information that will meet the objective of this study. The information gathered is purely for research purposes and will also contribute to knowledge on the Adaptation at Scale in Semi-Arid Regions [ASSAR] Project.
All information you provide is confidential and available to the research team. Your personal details are available to the researcher and statistician only. I shall not share any information containing your personal details to any third party.
For more information on the research, kindly contact Ophelia Kaba-Ayamba on 0268204800/ 0505785220.

If you have any issues on your rights as a participant, kindly contact:
Administrator, Ethics Committee for Basic and Applied Sciences, College of Basic and Applied Sciences, University of Ghana, P. O. Box LG 68, Legon – Accra. Tel: + 233 277493259. Email: ekacquaah@ug.edu.gh</td></tr>
<tr><td>FGD01</td><td colspan="3">Would you like to participate in the study? Please indicate in the sheet your acceptance to participate in this study</td></tr>
<tr><td>FGD02</td><td>Would you mind me recording our discussion? ALL respond individually (if any one says Yes or not sure, do not record discussion.</td><td>Yes …………….. 1
No ……………… 2
Not sure ……….. 3</td><td>if any one person says Yes or not sure, do not record discussion</td></tr>
</table>

Transcribe all responses verbatim (in English) on separate sheets provided.

Agree on ground rules for focus group discussion and encourage all to contribute

List of participants for FGD

Community: …………………………………………	Sub-district: ………………………………………………
Point of contact name: ……………………………………………	Point of contact phone number: ………………………………………
Type of group (elderly, youth, women only etc.): ………………………………………………………………………………………………	

	Name of participant	Consent (Y/N)	Approximate Age (completed years)	Sex
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

FGD03	How has delays of rains and weather changes affected farmers in your community?
FGD04	When there are food shortages what do you (or farmers) normally do to ensure you have food or money until the next harvesting season? *(probe further to differentiate between adaptation and coping)*
FGD05	What practices do your people engage in to ensure continuous supply of food, meat, money, fuelwood, logs for construction each year? *(probe further to differentiate between adaptation and coping)*
FGD06	Which activities or practices do your people engage in? Which are cultural practice handed to you by your fathers especially with regards the use of the trees on your farm and surrounding environment? *(probe further)*
FGD07	Any questions for me? Any comments?

Thank participants and request to leave after interview

APPENDIX V

COPY OF ETHICAL APPROVAL OF STUDY

UNIVERSITY OF GHANA
ETHICS COMMITTEE FOR BASIC AND APPLIED SCIENCES (ECBAS)
P. O. Box LG 1195, Legon, Accra, Ghana

Ref. No: ECBAS 014/17-18

5th March, 2018.

Mrs. Ophelia Kaba-Ayamba
IESS
University of Ghana
Legon, Accra

Dear Mrs. Kaba-Ayamba,

ECBAS 014/17-18: ECO SYSTEM SERVICES BENEFITS TO FARMERS FROM SAVANAH WOODLAND IN NORTHERN REGION

This is to inform you that the above reference study has been presented to the Ethics Committee for Basic and Applied Sciences for a full board review and the following actions taken subject to the conditions and explanation provided below:

Expiry Date:	4/02/19
On Agenda for:	Initial Submission
Date of Submission:	27/10/2017
ECBAS Action:	Approved
Reporting:	Bi-Annual

Please accept my congratulations.

Yours sincerely,

Very. Rev. Dr. Maxwell Aryee
Ag. ECBAS Chairperson

APPROVED

Tel: +233-207684121 Email: eoghartey@ug.edu.gh / ethicsebas@ug.edu.gh