ASSESSMENT OF SPATIAL ECOSYSTEM SERVICES VALUE FOR IDENTIFICATION OF SUITABLE AREAS FOR REDD+ BASED ON LOCAL PERCEPTION: EJISU-JUABEN DISTRICT, GHANA

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April, 2013

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ABSTRACT

Benefits from ecosystem services may be identified and achieved through their quantification and valuation. Valuation is important since it increases awareness among communities of the value of services and enhance the basis for communities and decision makers to protect and conserve areas that have high value for ecosystem services. Valuation also helps to identify areas of loss of key services to communities through deforestation and propose locations where REDD+ could contribute its multiple benefits to rural livelihood. The natural ecosystem in the Ejisu-Juaben district of Ghana is made up of forests, water bodies, minerals, plants and animals. However, the past two decades have seen severe threats on resources arising out of expansion of agricultural activities, excessive lumbering, mining, bush burning, sand winning and rapid conversion of forest lands to residential buildings. These have impacted negatively on the effective provision of ecosystem services to people in this area. The objective of the study was to assess the spatial ecosystem services value for identification of suitable areas where REDD+ could actively support livelihoods. The study used Participatory Geographic information systems (PGIS) as a tool in valuing ecosystem services in the Ejisu-Juaben districts of Ghana. Valuation was carried out based on the construction preference method that sought to assign values to ecosystem services and places where the 3 communities collect these services. The most important ecosystem services listed by both low and high income groups in all 3 study communities were mushroom, medicinal plants, bush meat, snails, honey, food (fruits), fuel wood, water and cane. In general, the groups assigned different weights according to the ecosystem services they collect in their respective communities and viewed these as crucial to their livelihood. The results also indicated that forest holds lots of the key ecosystem services followed by fallow, farmland and grass. Low income group use the ecosystem services more for commercial purposes and less for domestic usage across the 3 study communities in contrast to the high income groups, who use more for domestic purposes than for commercial purposes. The result mean that the low income groups' livelihoods depend more on income generated from selling the ecosystem services whilst the high income groups may have other alternative sources of income in addition to the ecosystem services provision. The study found variations in spatial distribution of the ecosystem services across all 3 study communities. High values areas provide large quantity of ecosystem services and low values areas provide least quantity of ecosystem services. The result of the accessibility analyses show that influence of land cover, road infrastructure and slope contribute to how the local people locate and access these ecosystem services. Accessibility was classified as highly accessible, accessible, low access and least access. The vegetation types that hold these ecosystem services are randomly located relative to accessibility because some vegetation types provide abundant ecosystem services in both accessible and inaccessible areas. The lower usefulness and values the locals attached to less accessible areas may be attributed to some physical barriers including rivers or water logged areas and high slope areas. The local people maximise access to and optimise use of ecosystem services in locations close to them and some choose to harvest in inaccessible areas. High values areas attract more direct access to the ecosystem services and are potential for holding large ecosystem services, high carbon stock and other biodiversity stock. These high values areas are suitable for REDD+ implementation programmes because it can contribute multiple benefits to rural livelihoods in the form of financial incentives through carbon credits as a result of conserving biodiversity and carbon storage whilst promoting sustainable use of resources. Low values areas that coincide with high carbon was categorised as a high risk area because tress are cut for firewood and charcoal. These low value areas are suitable for REDD+ implementation programmes because it can mitigate deforestation and offer financial incentives to alleviate poverty through plantation development in fallow and grass lands areas and in the long run benefit from future carbon sequestration.

Key words: Ecosystem services, Participatory GIS, REDD+, Valuation

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TABLE OF CONTENTS

ABSTRACT i
ACKNOWLEDMENT ii
TABLE OF CONTENTS iii
LIST OF FIGURES iv
LIST OF TABLES v
LIST OF PLATES vi
LIST OF ACROYNMS vii
1. Introduction 1
   1.1. Background 1
   1.2. Ghana's forest resource and ecosystems 2
   1.3. Problem statement and Justification 2
   1.4. Research Objective 3
   1.5. Research Framework 5
2. Concepts and definitions 7
   2.1. Ecosystems services 7
   2.2. Valuation of Ecosystem Services 8
   2.3. Provisioning services 9
   2.4. Participatory GIS 10
   2.5. REDD+ 11
   2.6. Land cover classification and change detection 11
3. Materials and Methods 13
   3.1. Study Area: Location and Justification 13
   3.2. Materials 15
   3.3. Methods 16
4. Results 26
   4.1. Land cover classification 26
   Assessment of ecosystem services 29
   4.2. Suitability map for REDD+programme 39
5. Discussion 44
   5.1. Accuracy Assessment and land cover classification 44
   5.2. Land cover change 44
   5.3. Assessment of ecosystem services value 45
6. CONCLUSIONS and RECOMMEDATION 48
   6.1. Conclusions 48
   6.2. Recommendation 50
7. List of references 51
8. Appendix 55
   8.1. Appendix A 55
   8.2 Appendix B 56
   8.3 Appendix C 57
   8.4 Appendix D 58
   8.5 Appendix E 60

LIST OF FIGURES

Figure 1: A research diagram showing the importance of REDD+ in conserving the ecosystem. 5
Figure 2: The ecosystem valuation framework (after Hein *et al*., 2006).. 9
Figure 3: Regional map of Ghana showing the location of Ashanti region and Ejisu-Juaben district with the study communities.. 14
Figure 4: Methodological flow chart 16
Figure 5: The layers as used in the weighted overlay function.. 23
Figure 6: Land cover map of 2002 and 2010 of Ejisu-Juaben districts 26
Figure 7: Key ecosystem services identification and valuation per income group in the 3 communities 34
Figure 8: Spatial distribution of value for ecosystem services 35
Figure 9: The four factors used in the accessibility map (A: land cover, B: slope map, C: Main/Sec road map, D: Footpath map 37
Figure 10: The accessibility map of the study area.. 38
Figure 11: Raster layers of carbon and ecosystem services map of portion of the study area........................ 39
Figure 12: Suitability map for REDD+ implementation 40
Figure 13: Effects of accessibility on ecosystem hotspots... 41
Figure 14: Raster layers of accessibility map and forest change map of the study area 42
Figure 15: Effects of accessibility on forest cover in the study area 43

LIST OF TABLES

Table 1: Ecosystem Services: Millennium Ecosystem Assessment (2003) 7
Table 2: Modified Land cover and travelling speed (km/hr) (Toxopeus, 1996) 21
Table 3: Travelling speed per infrastructure (road) type 21
Table 4: The slope classes and the scale value applied to the travelling speed in Ejisu-Juaben districts.......22
Table 5: The ecosystem services value and carbon maps with their respective assigned scale values 24
Table 6: The accessibility map and suitability map with their respective assigned scale values 25
Table 7: Table 7: Accessibility map and the assigned scale values 25
Table 8: Accuracy Assessment for 2010 image 27
Table 9: Accurate Assessment for 2002 27
Table 10: Land cover class of the study area for the year 2002 and 2010 28
Table 11: Land cover conversion matrix 28
Table 12: Number of participants per income group in the focus group discussion 29
Table 13: Respondent characteristics (Occupation) 29
Table 14: Respondents' level of education 30
Table 15: List of Ecosystem services in three communities 30
Table 16: Purpose of collection of ecosystem services 31

LIST OF PLATES

Plate 1: Field pictures showing mapping and valuation of key ecosystem services found in the study area 57

Plate 2: Field pictures showing the valuation of land cover types in the study area..58

LIST OF ACRONYMS

DEM: Digital Elevation Model

ETM+: Enhanced Thematic Mapper Plus

GDP: Gross Domestic Product

GIS: Geographic Information Systems

GPS: Global Positioning Systems

GSS: Ghana Statistical Services

ISODATA: Iterative Self Organising Data Analysis

ITC: International Centre for Geographic Information and Earth Observation

JHS: Junior High School

LULC: Land Use Land Cover

NTFP: Non-Timber Forest Products

PES: Payment for Environmental Services

PGIS: Participatory Geographic Information System

REDD: Reducing Emission from Forest Degradation and Deforestation

REDD+: Reducing Emission from Forest Degradation and Deforestation plus

RMS: Root Mean Square

TEV: Total Economic Value

UN: United Nations

UTM: Universal Transverse Mercator

WGS: World Geodetic System

WHO: World Health Organisation

1. INTRODUCTION

1.1. Background

Ecosystem services are the conditions and processes that makes it possible for natural ecosystems and their species to sustain and fulfil human life (Daily, 1997). In other words they are a composition and interaction of natural mechanisms resulting in outputs that yield direct benefits to enhance human well-being (Boyd & Banzhaf, 2006). Ecosystem services are made up of benefits people derive from the ecosystem including provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling and carbon that ensures that favourable conditions are created for the maintenance of life on Earth (Millenium Ecosystem Assessment, 2003).

Today, natural ecosystems have come under severe pressure from growing demands arising out of increased population which has translated into converting natural ecosystems into agriculture, industrial and residential use (IUCN, 2004). It has been estimated that nearly 60% of ecosystem services obtained are being degraded or not put to sustainable use (WHO, 2005). The last decade of the 20th century has seen much attention drawn to global-scale degradation of natural habitats and threats to potentially millions of species (Novacek, 2008). Jones-Walters and Mulder (2009) remarked that the lack of efficient systems of valuing environmental services has led to natural resources either getting lost or going extinct in relation to damage caused to their habitats. There has also been an information gap in respect of limited information on values of ecosystem services to all segments of society (Kumar & Kumar, 2008).

Valuation of ecosystem services will form the basis of determining the worth of nature and the amount of benefits we derive from the ecosystem at any given time (Tacconi, 2000). Several methods or approaches have been developed by researchers including (Barkmann *et al.*, 2008; Costanza *et al.*, 1997; Hein *et al.*, 2006; Millenium Ecosystem Assessment, 2003) to value ecosystem services. However, there exists certain insufficiency in these methods regarding the supply of valid information by local communities because they are not directly involved in the process. Therefore, (Nunes & Bergh, 2001) remarked that, the suitability of the stated preference or contingent valuation method is questionable because stakeholders are not deeply involved and lack sufficient familiarity with ecosystem functions to make meaningful preference statements. Any method that involves the local people can improve valuation process. This study uses Participatory Geographic information systems (PGIS) as a tool in valuing ecosystem services in order to fill in this information gap (Jankowski, 2009).

In the light of the growing environmental problems, reducing emissions from deforestation and degradation with sustainable management of forests and the enhancement of forest carbon stocks

(REDD+) has emerged not only to reduce greenhouse gas emissions, but also to preserve ecosystem services through its multiple benefit scheme. Valuation will help to identify areas of high value of key ecosystem services to communities and propose REDD+ intervention. Within this framework, much attention is focused on conservation and sustainable management of forests so as to offset the effect of depleting and reducing ecosystem services habitats to fragments and deserts (CBD, 2012).

1.2. Ghana's forest resource and ecosystems

With a total land area of 238,539 km^2, Ghana is endowed with diversity of landscapes, ecosystems, habitats, plants and animals which form the basis of human survival for especially local populations across the country. Ecosystem services benefits people obtain from the forests include provisioning; freshwater, fuel wood, timber, bush meat, fruits, and genetic resources. Regulating services include climate regulation, disease regulation, water purification, pollination and cultural services which represent spiritual and religious, recreation and ecotourism as well as carbon. Agriculture in general has been identified as taking up to more than 75% of forest land whiles in the northern savannas, it represents about 60%. The last 30 years has seen Ghana's ecosystem and forests being threatened at such an alarming rate arising from unsustainable pressures from fast growing populations, expansion in agricultural and industrial activities and rapid urbanization. These have led to deforestation, land degradation, loss of biodiversity, drying up of watershed areas, frequent drought spells leading to acute water shortage and low quality drinking water. Another devastating effect is the rapid decrease in the forest area into several fragments (Duut, 2005).

As noted by Idinoba *et al.* (2010), between 1985-2000, Ghana's high forest zones were reduced through deforestation from 2,736 km^2, representing 57.6% of land cover to 1,623 km^2 (34.2%) with the moderately close bush forest areas also reducing from 7.4% of land cover in 1972 to 5.9% in 2000. In effect the resilience and integrity of Ghana's ecosystems are reduced in terms of capacity to provide its valuable services to society.

1.3. Problem statement and Justification

The natural ecosystem in the Ejisu-Juaben district of Ghana is made up of forests, water bodies, minerals, plants and animals which provide many services to local communities. However, the past two decades have seen severe threats on it arising out of expansion of agricultural activities, excessive lumbering, mining, bush burning, sand winning and rapid conversion of forest lands to residential buildings, which have impacted negatively and affected the effective provision of ecosystem services to people in this area (Ministry of Local Government, 2006). REDD seeks to conserve forest and tree resources but the intended benefits that will come with REDD+ are far more than REDD and therefore when properly designed, REDD+ will contribute to multiple benefits including poverty alleviation, improved community livelihoods, technology transfer, sustainable use of forest resources and biodiversity conservation (Murphy, 2011).

Apart from forest conservation, REDD+ promotes re-forestation projects in areas with considerable high value for ecosystem services where the vegetation is reduced to shrub, grass and old fallow lands so as to enhance the ecosystem resilience to conserve biodiversity (CBD, 2012). Values communities attach to ecosystem services may as well be influenced by factors like distance and accessibility, income levels, type of service, and for that matter any assessment in this regard should take these into consideration (Thomas *et al.*, 2009). Within the current circumstance, the land cover is altered due to conversions from forests to other activities. These forested areas have high carbon stock and biodiversity and may be considered high value and suitable areas for REDD (Gibbs *et al.*, 2007). Investigating the effect of land cover changes on the ecosystem service will thus be important. The lack of spatial information about the total value of current flows of benefits from the ecosystem services has also informed this research as cited in (Haines-Young, 2009) and for this purpose specific emphasis will be placed on provisioning services and carbon.
The study therefore seeks to assess the spatial distribution of ecosystem services values from community perspective and determine suitable areas (or hotspots) where REDD+ could actively support livelihoods, combat climate change, conserve biodiversity and protect other ecosystem goods and services.

1.4. Research Objective

The main objective of the study is to assess spatial ecosystem services value for identification of suitable areas where REDD+ could actively support livelihoods

1.4.1. Specific Objectives

1. To assess and map the spatial variations of the value of provisioning ecosystem services from community perspective.
2. To analyse income levels in relation to the value local people put on ecosystem services.
3. To determine the amount of forest loss due to land cover conversions.
4. To identify areas that could be suitable for REDD+.
5. To analyse the effect of accessibility on the value of ecosystem services.

1.4.2. Research questions

1. What kind of services/resources does the ecosystem provide to the communities?

2. What is the relation between economic status and value of ecosystem services?
3. What are the spatial variations of the ecosystem service value in the study area?
4. How much forest is lost due to land cover conversions?
5. Where are the suitable areas for REDD+ implementation?
6. What is the effect of accessibility on the value of ecosystem services?

1.4.3. Hypothesis

- Ho: There is no significant difference between the income groups and values assigned to the ecosystem services.
- H1: There is significant difference between the income groups and values assigned to the ecosystem services.

1.5. Research Framework

1.5.1. Research diagram

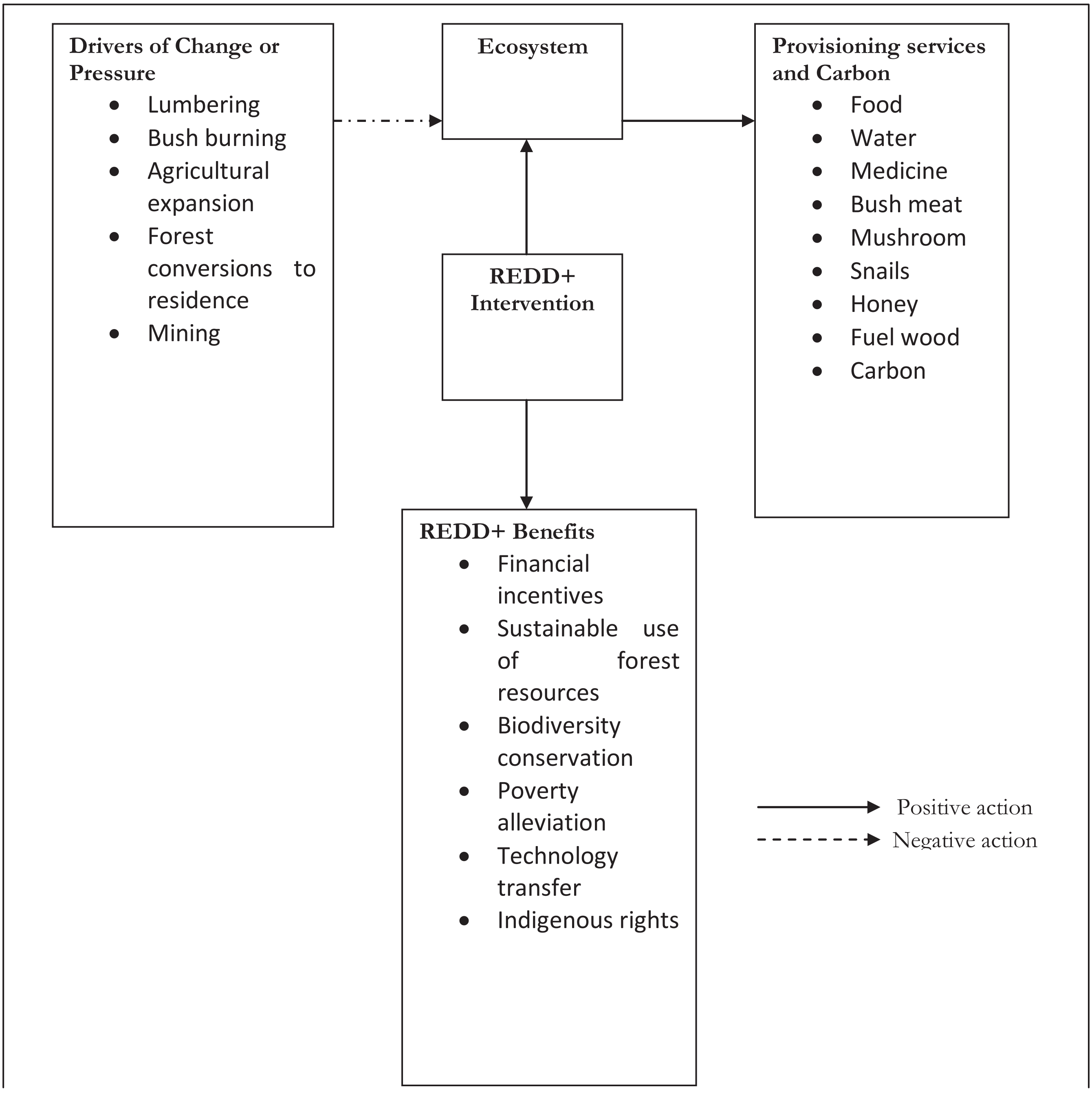


Figure 1: A research diagram showing the importance of REDD+ in conserving the ecosystem.

Figure 1 shows the impact of anthropogenic action (i.e. drivers of change or pressure) on the ecosystem which results in the degradation of provisioning ecosystem services to communities as well as increasing carbon emissions. However, when REDD+ interventions are introduced, it will restore and sustain the ecosystem services and the carbon stocks.

2. CONCEPTS AND DEFINITIONS

2.1. Ecosystems services

The Millenium Ecosystem Assessment (2003) describes ecosystem services as those benefits people enjoy from the ecosystem which affect them directly, including provisioning, regulating, cultural and supporting services that are needed for the maintenance of other services. The Millennium Ecosystem Assessment refer them as goods and services in addition to cultural values and intangible benefits and categorised them as seen in the Table below.

Table 1: Ecosystem Services: Millennium Ecosystem Assessment (2003)

Provisioning services	Regulating Services	Cultural Services
Products obtained from ecosystems	*Benefits obtained from regulation of ecosystem processes*	*Nonmaterial benefits obtained from ecosystems*
• Food • Fresh water • Fuel wood • Fiber • Bio-chemicals • Genetic resources	• Climate regulation • Disease regulation • Water regulation • Water purification • Pollination	• Spiritual and religious • Recreation and ecotourism • Aesthetic • Inspirational • Educational • Sense of place • Cultural heritage
Supporting services		
Services necessary for the production of all other ecosystem services		
• Soil formation • Nutrient cycling • Primary production		

Robert Costanza *et al.* (1987) refer ecosystem services as a "function" of the ecosystem function (i.e. habitat, biological systems properties or processes of ecosystems) because they represent the benefits human populations derive directly or indirectly from the ecosystem function. The Millennium Ecosystem Assessment assumes a dependency relationship in which a single ecosystem service can be a product of two or more ecosystem functions. The Millennium Ecosystem Assessment grouped ecosystem services into 17 major categories.

In another form, ecosystem services are used to mean the goods and services obtained from nature for which people can express preferences that allow tradeoffs to be evaluated. A distinction is made here from valued end uses and the ecosystem processes from which they are derived with emphasis on the goal of using ecosystem services to balance competing interests and deciding on how best to manage and allocate natural resources (Wainger *et al.*, 2010).

2.2. Valuation of Ecosystem Services

Ecosystem and biodiversity valuation has become an important field of investigation in recent times due to a broader search for arguments in support of conservation policies. Values are considered as norms that allow judging individually or collectively if something is good, beautiful, true, useful and morally upright (Salles, 2011). Valuation studies are needed in order to promote understanding of the biophysical mechanisms that underpin ecosystem services so as to make better analysis of the marginal changes in value that occur in ecosystems as a result of the different pressures and interventions (Haines-Young, 2009). Valuation techniques are therefore developed to set the framework in which benefits and costs can be compared. Among the different perspectives of valuation of ecosystem services are the following: Haines-Young (2009) suggest four broad areas in the context of valuing ecosystem services.

- There is need to determine the total value of the current flow of benefits from an ecosystem, to better understand the contribution that ecosystems make to society.
- The need to value the costs and benefits of interventions that modify ecosystems so as to determine whether the intervention is economically worthwhile.
- Examining how the costs and benefits of an ecosystem (or an intervention) is distributed across society over time. The aim here is to explore social equity issues for ethical and practical reasons
- Finally, identifying potential financing sources for conservation so as to make ecosystem conservation self-sustaining in financial sense.

Salles (2011) remarked that, The Total Economic Value (TEV) framework has been widely employed and seeks to estimate both the use and non-use values that individuals and society gain or lose from marginal changes in ecosystem services. Hein*, et al.* (2006) provides a useful discussion of the steps involved in valuing ecosystem services and their relationship to the TEV framework. Within their framework, four steps are envisaged in the process.

These are;

1. Specification of the boundaries of the ecosystem to be valued;
2. Assessment of the ecosystem services supplied by the system;
3. Valuation of the ecosystem services; and,
4. Aggregation or comparison of the values of the services.

The Hein, *et al*., (2006) framework sets out different profiles in terms of the various TEV categories but then the overall aim is to achieve an aggregated value for the ecosystem that can be used to compare the different sets of circumstances as described in Figure 1.

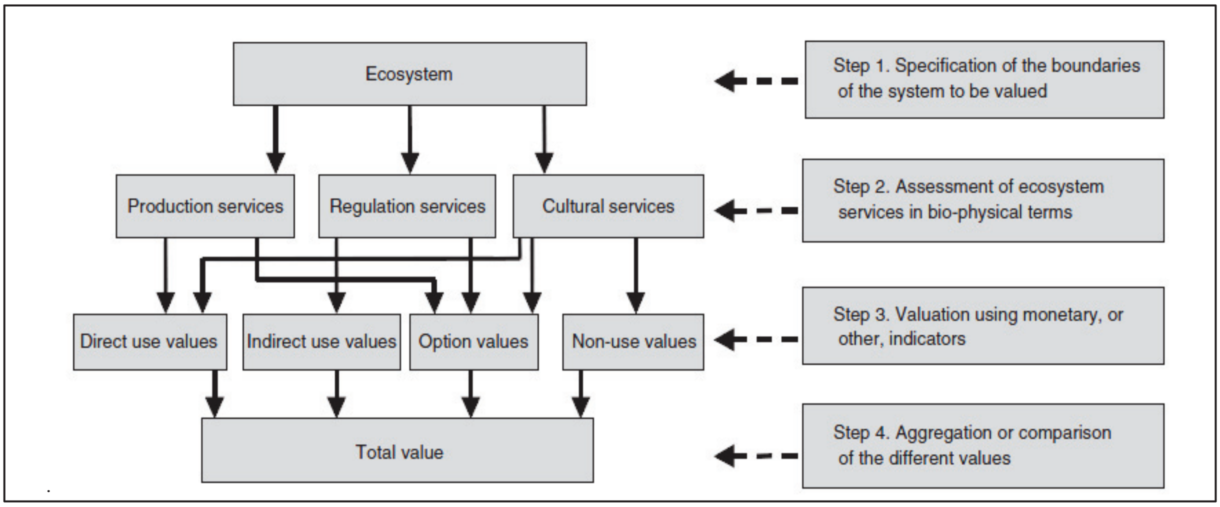


Figure 2: The ecosystem valuation framework (after Hein *et al*., 2006)

Hein *et al*. (2006) method of ecosystem services valuation was adopted and modified for this study because it focuses on natural and semi-natural ecosystems.

2.3. Provisioning services

Provisioning services represents a wide range of products obtained from the ecosystem which are often directly consumed to enhance human wellbeing (Millenium Ecosystem Assessment, 2003). Non-Timber Forest Products (NTFPs) for example have gained prominence in societies and are being promoted by researchers, conservationists, governments and civil society groups due to their significant role in improving the lives of rural livelihoods through food security, nutrition and health (Belcher *et al*., 2005). NTFPs are thus available as a common property resource to most rural poor households and offer support in the form of direct consumption, income and employment and disease control.

In real terms, they are a collection from a wide range of ecotypes such as high forest, fallow lands and farmlands for use as food, medicine and trade and include bush meat, mushrooms, snails, bark, roots, tubers, corms, leaves, flowers, seeds, fruits, sap, resins, honey, fungi, and animal products.

They sometimes represent non-conventional exports and contribute to Gross Domestic Products (GDP) (Ndoye, 2006). In Ghana NTFPs plays a potential role by contributing to alleviate poverty through the improvement of nutrition, health and food security (Ahenkan & Boon, 2011). It is in the light of this that the study seeks to value these key ecosystem services using participatory tools to contribute local spatial knowledge to the proper management of them.

2.4. Participatory GIS

Participatory GIS simply means community application of geographic information technology and is used to refer to the practice of employing geo-spatial information management tools to show indigenous spatial knowledge in the forms maps. PGIS practice takes a multidisciplinary approach and relies on 'experts' with differentiated indigenous knowledge which builds on high levels of stakeholder participation in the processes of spatial learning for decision making and action (IIED, 2009). Thus a system developed out of participatory approaches to generate and communicate spatial information to enhance the capacity of groups in society. McCall (2004) observed that, indigenous technical knowledge is normally more reliable and sometimes accurate because it embodies generations of practical essential knowledge and operates in an interactive and holistic system.
The IIED (2009) further outlines the following ways in which PGIS and Participatory mapping make valuable contributions:

- Spatial specificity: information about local interests & priorities, values and perceptions.
- Social inclusivity: it can be representative of communities, as well as individuals. Local and external knowledge - local, indigenous knowledge, sacred knowledge, gendered knowledge - knowledge that doesn't necessarily conform to state visions of place; integrated with scientific knowledge of e.g. implications of global climate change, globalisation and urbanisation.
- Visual images as "spatial narratives". Pictures are rich in information and shared understanding, and increase information both quantitatively and qualitatively. Visual images often provide the conviction' factor, though this may have negative as well as positive implications.
- Multi-sourcing: involves multiple processes of people's participation in knowledge identification and selection. There are many opportunities for cross-checking and alternative validations.
- Capacity-enhancement: communities groups can be empowered by involvement in PGIS processes – improving self–confidence and technical/ political capacities.

2.5. REDD+

Reducing emissions from deforestation and degradation with sustainable management of forests and the enhancement of forest carbon stocks (REDD+) is an initiative of the United Nations Frame work Convention on climate change that seeks to provide economic incentives to help developing countries reduce deforestation and carbon emissions (Gibbs, *et al*., 2007). This is due to the fact that landscapes with different biophysical and socioeconomic characteristics affect the potential land use/land cover (Etter *et al*., 2006). According to Geist and Lambin (2001), areas with high carbon stock and high ecosystem values become hotspots as these areas are likely to attract frequent human interaction which can affect the total ecosystem value.

As a result of these, Ghana was selected to be a REDD country participant in 2008 and has since been receiving financial assistance from the Readiness Fund of the Forest Carbon Partnership Facility to prepare its Readiness Plan. Ghana has already embarked on a series of forest and natural resource governance initiatives to address these challenges. As such Ghana seeks to explore REDD+ as a potential additional reward mechanism for sustainable forest protection and land use, in support of existing policies (FCPF, 2012). The programme is intended to be implemented across the globe both at national and international levels with focus on assisting countries in their REDD+ efforts through the development of common approaches, analysis, methodologies, tools, data and best practices. Through this programme support is given to indigenous people, forest dependent communities, civil society as well as capacity building, awareness creation and support to governments (UN-REDD, 2011a). REDD+ started as a global initiative with much of the early discussions focused on the global REDD+ architecture and how REDD+ can be included in a post - 2012 climate agreement. At the moment more than 40 countries are developing national REDD+ strategies and policies in addition to hundreds of REDD+ projects initiated across the tropics. The main idea behind REDD+ is to make performance-based payments to forest owners and users to reduce emissions and increase removals. Such payments for environmental (or ecosystem) services (PES) provides strong incentive directly to forest owners and users to manage forest better and clear forestland (Angelsen, 2009).

2.6. Land cover classification and change detection

Land cover changes the most apparent effect of urbanisation, but also the driving forces of many ecological consequences. Before a land use pattern analysis is done, a Land use/Land cover (LULC) classification needs to be conducted (Hung *et al*., 2010). Image classification processes involves conversions of multi-band raster imagery into a single band raster with a number of categorical classes that relates to different types of land cover.

Two classification types are Supervised and Unsupervised classification. In the supervised classification, an image is classified using spectral signatures obtained from training samples i.e. polygons that represent distinct sample areas of the different land cover types to be classified. With the unsupervised classification method, the software finds the spectral classes or clusters in the multi-band image without the analyst's intervention (Nagi, 2011).

Change detection refers to the processes of identifying differences in the state of an object or phenomenon by observing it at different times. Basically, it involves the ability to quantify temporal effects using multi-temporal data sets. Change detection has been identified to be important in the applications of land use change analysis and assessment of deforestation (Ingram *et al.*, 1981).

3. MATERIALS AND METHODS

3.1. Study Area: Location and Justification

The Ejisu-Juaben district is located in the central part of the Ashanti Region and lies within latitude 1.15˚N and 1.45˚N and longitude 6.15˚W and 7.00˚W. The district is one of the 27 administrative and political districts in the Ashanti Region and stretches over an area of 637.2 km^2. The district lies within the semi deciduous forest zone. The economy of the districts is based on agriculture employing 68.2% of the people. The main cash crops grown in the area are cocoa, oil palm and citrus plantation while other crops such as cassava, maize, cocoyam and tomatoes are grown on subsistence basis. Activities such as ecologically unacceptable farming practices, stone quarrying and illegal chain saw operations have resulted in degradation of the natural vegetation cover into secondary forest (Ministry of Food and Agriculture, 2011) thereby affecting the livelihood of local communities who depends more on the forest ecosystem (Benefo, 2008). Figure 2 below identifies the study area.

The topography of the area is flat and undulating, with altitude ranging from 240m to 300m above sea level. The soil types results from pre-cambrian rocks of the Birimian and Tarkwaian formations. The rainfall pattern is bi-modal with the major rainy season lasting from March to July and minor rainy season from September to November. The mean annual rainfall is 1200mm. Mean temperatures normally ranges between 20°C in August and 32°C in March resulting in moderate relative humidity (Ministry of Local Government, 2006). The district is basically rural with a population of 144,272, showing an increase in population compared to previous years and the youth forming 64% of the population (Ministry of Food and Agriculture, 2011).

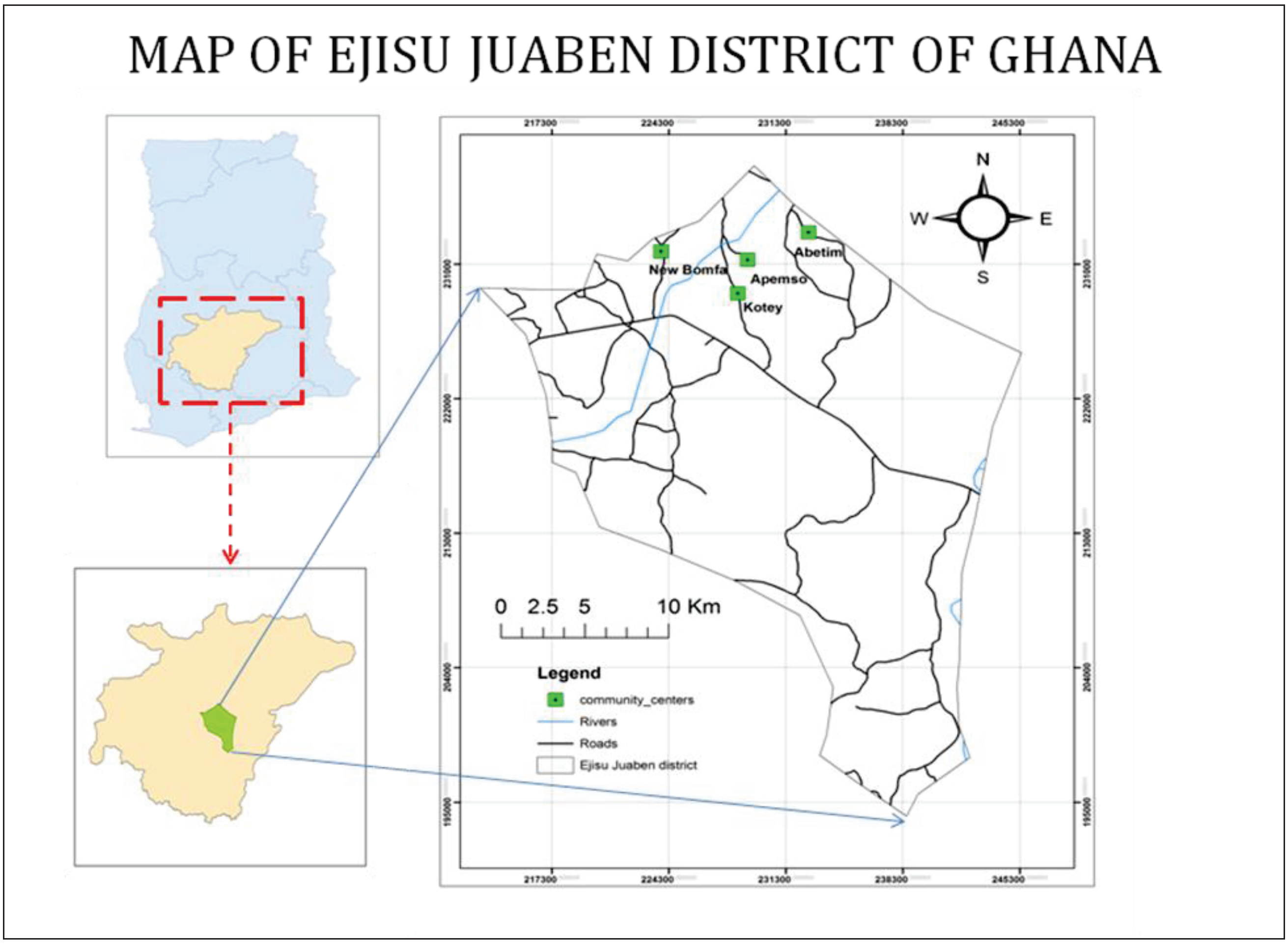


Figure 3: Regional map of Ghana showing the location of Ashanti region and Ejisu-Juaben district with the study communities.

3.2. Materials

3.2.1. Data

Landsat ETM+ image (04/02/2010, Level 1 B with path/ row 194/55) and Landsat ETM+ (09/07/2002, Level 1 B with path/ row 194/55) with less than 10% cloud cover was obtained and used for the land cover mapping and change detection. A World View-2 image (acquired on 04/01/2011) was selected from ITC database geometrically geo-referenced to UTM Zone 30N coordinates with WGS 84 datum. The World View-2 has a panchromatic band with a resolution of 0.5m and 8 multispectral bands at 2.4m resolution. The high resolution makes it possible to identify individual field boundaries, narrow roads and roofs of houses, so it was used as a reference for the participatory mapping. The area extent of the World view-2 image is approximately 7 x 6 km. The data were chosen based on availability, cost considerations and cloud cover.

Ejisu-Juaben district boundary, developed by the Ghana Lands Commission in 1991 was used in the creation of the image of the study area (Figure 3). The shapefile was used to clip the Landsat ETM+ images to obtain an image of the Ejisu-Juaben district and the study area. A topographic map of scale 1: 25000 and road maps (Ghana Lands Commission, 1991) were acquired and used during the field work for navigation and collection of ground control points for geo-referencing, classification and assessment of 2010 classified map. Other data such as secondary ground truth data of field points collected in 2006 in the study area by Asubonteng (2007) were used for the validation of the 2002 classification.

3.2.2. Instruments and Software used

ERDAS imagine version 2010 was used for image processing, image classification and accuracy assessment. ArcGIS10 was used for GIS operations and Excel software was used for statistical analysis.

In addition, Global Positioning system (GPS) instrument (Garmin 12) was used for field navigation and collection of ground truth data. Digital camera was used for taking pictures during participatory mapping exercise and sample points.

3.3. Methods

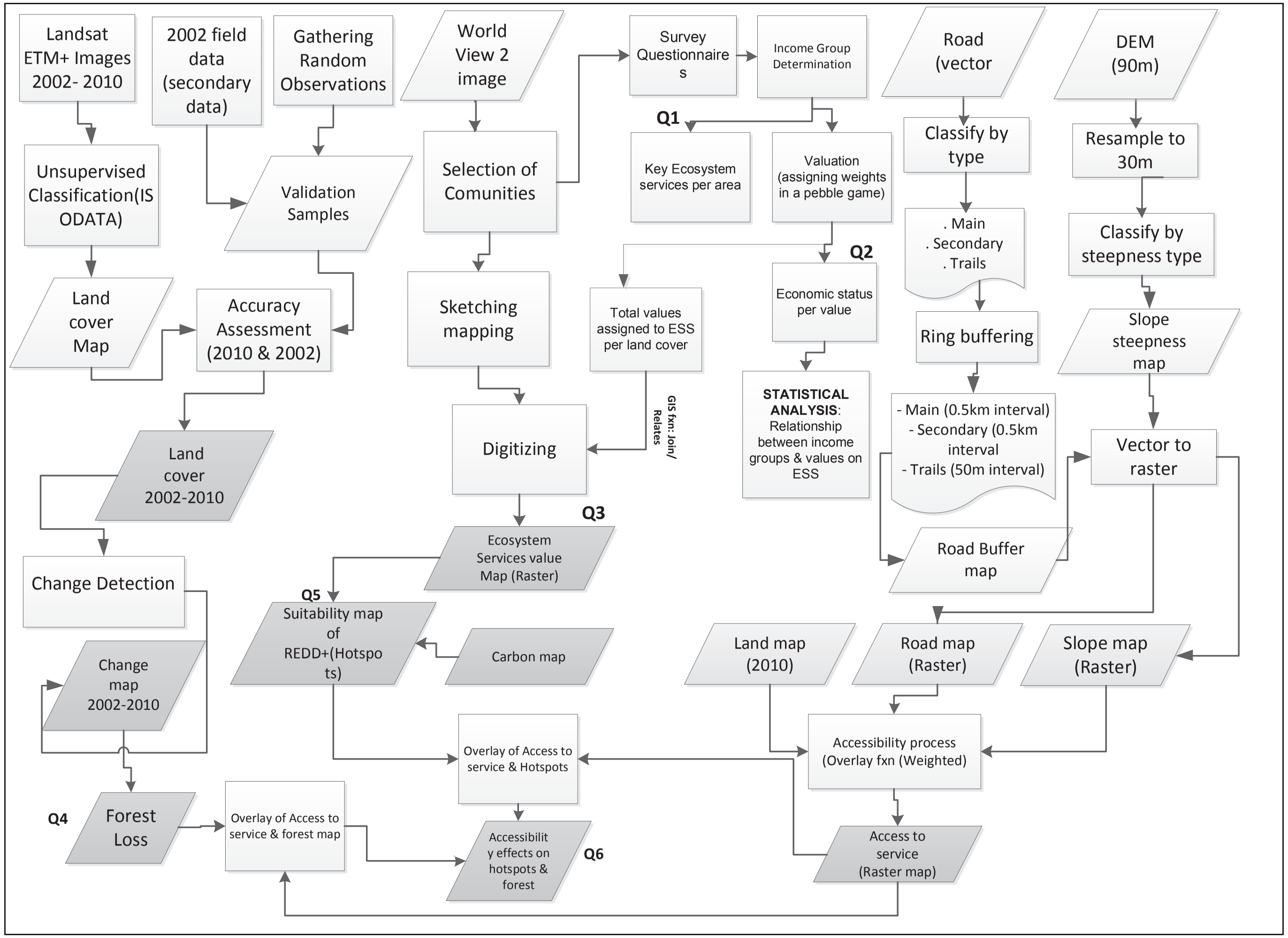


Figure 4: Methodological flow chart

3.3.1. Data pre-processing

The Landsat ETM+ 2010, 2002 images were transformed to conform to Universal Transverse Mercator, Zone 30N, and WGS 84 datum map projection system. The Landsat ETM+ images were geo-referenced with ground control points of recognisable roads intersections in ERDAS IMAGINE 2010 and resulted in Root Mean Square (RMS) error 0.32 less than 0.5 pixels. The World View-2 image was already geometrically co-registered on the basis of six ground control points from road junctions to a RMS error of 0.210 m per pixel size (Mutanga, 2012). The research considered the RMS error of 0.210m reasonable for purpose of participatory mapping because of the spatial resolution of the World View image used. The purpose of geo-referencing was to increase the images geographic coordinate system due geometric distortion as a result of the Earth's rotation and other imaging conditions (Jensen, 1996).
Image classification of Landsat ETM+ 2010 was carried out using unsupervised classification of Iterative Self-Organising Data Analysis (ISODATA) to produce preliminary land cover map for ground truthing. The classification resulted in 20 spectral classes and subsequently merged and labeled to 6 classes. Training samples collected in 2011 (Nooni, 2012) were used to identify the classes and validate Landsat ETM+ 2010 classification before undertaking the field work. The land cover classes were selected to reflect definition used by Benefoh (2008) in the study area. The land cover classes were forest, farmland, fallow, grass, marshy and built-up area. The use of training samples introduced aspects of supervised classification. In order to capture the different land cover classes and increase precision within the study, stratified random sampling was employed to collect ground data (Lillesand *et al.*, 2004).

3.3.2. Field Work

The field work was carried out from September to October 2012 using GPS, Garmin 12, prepared land cover map, printed hard copy of World view-2 image, recording sheet & digital camera. The essence of the field work was to observe and collect data relating to ecosystems services as well as ground truth points in the study area.

A. Determination of income groups

Since income levels affect the value local people put on ecosystem services, they were grouped according to low and high income levels in each community for the valuation exercise. A preliminary questionnaire (see Appendix D) was administered to determine the income level of the respondents. Each respondent information relating to quantity of harvestable ecosystem services and yield from other sources of income were elicited and used to determine the income of each respondent (see sample calculation from Appendix D). The rationales for adopting this approach to determine the income level of respondents in the study area was due to the following reasons. Firstly, the use of Ghana Living Standard Survey (GLSS 5) by Ghana Statistical Service was too general and posed difficulty in placing the respondents in the various income groups. Secondly, the respondents selected were unwilling to provide or discuss how much they earn as it was seen as culturally sensitive. Respondents provided the quantity of services collected per month. The quantity was subsequently multiplied by their respective prices to get the total income per month. This was further divided by the average number of days in a month (i.e. 30 days) to obtain the daily income per respondent. In Ghana, income levels are defined based on the minimum daily wage as set by the Ghana Statistical Service. Low income is defined as people whose income fall below the daily minimum wage of $ 2.40 US and high income refers to those whose income is above the daily minimum wage of $2.40 US (Ghana Statistical Service, 2012). The daily income of the respondents was compared with the daily minimum wage set by the Ghana Statistical Service. Income levels that fell below the minimum daily wage were classified as low income and those that fell above the minimum daily wage was categorised as high income. An exchange rate of GH 1.90 cedis to US $ 1 was used in the calculation (Ojedaa *et al.*, 2007).

Statistical analysis

The study undertook a statistical analysis (Appendix B) specifically, *t-test*, to validate the data collected from the three communities because the information provided by the groups during the questionnaires administration were mainly categorical, hence the need to test its appropriateness.

The hypothesis tested was as follows:

Ho: There is no significant difference between income groups and values assigned to the ecosystem services.

H1: There is significance difference between the income groups and the values assigned to the ecosystem services.

B. Participatory Mapping and Valuation

Maps are important components in rural development and form an essential part of any planning activity. Local people are endowed with great ability to represent their surroundings accurately through village resource maps showing the resources of the village such as land, soil type, land use, watersheds (Mascarenhas & Prem, 1991). The purpose of this section was to spatially locate and assign values to various ecosystem services found in the area. The information in this study was collected through a focus group discussion and interviews together with mapping exercises.

The participatory mapping exercise was based on gender and income levels. Consequently, two major categories of income levels were used for the mapping exercise. In this study 8-10 people from different income levels (categories of poor and rich people) were selected randomly from each of the 3 villages (Apemso, Kotey and New Bomfa) for the community mapping exercise. After which they were asked to identify through ranking, the key ecosystem services and in a pebble game indicate how much value they attach to each ecosystem service (Raymond *et al.*, 2009). The 3 study communities were selected based on their dependence on provisioning ecosystem services. Additionally, these communities were selected due to the pronounced land use/cover transformations that are fast reducing and depleting their sources of livelihoods and calls for REDD+ intervention to offset these trends.

Again valuation was done using the construction preference method that sought to assign values to ecosystem services and places they collect these services in order of importance (Shapansky *et al.*, 2002). In the participatory mapping exercise, the groups were asked to locate and describe places of value by arranging pebbles on a 1: 1,200 scale A1 (600 x 1060mm) size high resolution image of the study area. They were free to move the pebbles until they were satisfied. The groups also had access to a true colour Landsat ETM+ 2010 image of a bigger scale than the high resolution image to show areas they collect ecosystem services outside the range (scale) of the high resolution image.

In order to create value, the groups were given 100 pebbles to assign values to each ecosystem services they identified and collected. This method is in line with studies done by (Brown, 2005, 2006), Raymond and Brown (2006) and Raymond (2008). In a similar fashion, the groups were given 100 pebbles to assign values to the various land cover classes that provide them most of the identifiable ecosystem services. They were asked why the places they value were important to them. Each of the land covers was assigned values for multiple ecosystem services (Raymond, 2008). During the mapping exercise the groups sketched the polygons describing the spatial extent and location of specific values on A1 tracing paper placed on the high resolution image during the mapping exercise.

Preparation of Ecosystem services map

After the participatory mapping exercise, places of values were digitised as multi-pack polygons in ArcGIS 9.3. Digitised polygons ranged in size from very small (e.g. < 1 ha) to very large (e.g. some tracts of farmlands & forested areas). The spatial data structure included many overlapping areas of value. Each polygon's value was the sum of all values of ecosystem services assigned by the groups (Raymond and Brown, 2006). The attribute information associated with each value area was entered in a database using a unique identifier to enable linking with other spatial data layers. Each value area formed a row in the attribute database coded with the relevant ecosystem services. A series of spatial layers were created summarising values for elements of ecosystem services. For example, a layer summarising the spatial distribution of value were created by summing relevant individual values assigned to each ecosystem services. The data structure provided the ease to retrieve data for specific uses and purposes because the database was linked to the spatial value information and queries were built to retrieve specific information.

C. Transect Mapping

Transect mapping represents a spatial cross-section of community depicting geographical features including land use and vegetation zones on an imaginary line, with normally a GPS to capture exact locations of feature on earth (IIED, 2009). Key community members knowledgeable in resource identification were selected and with the aid of a GPS locate actual positions of the main ecosystem services indicated on the drawn maps. This aided in validating the spatial distribution of the ecosystem services and facilitated the production of the land cover maps.

D. Accessibility to Ecosystem services

The ability of humans to reach a particular location in a landscape is termed "accessibility". Accessibility varies with infrastructure (e.g., roads and 'footpaths' or trails) and natural features of the landscape (e.g., slope steepness), different land cover types, distance and the location of the settlements (Trombulak & Frissell, 2000). The rationale behind developing accessibility map is important because the importance or values people attach to resources may be differentially carried out in accessible locations, as a way of reducing costs and increasing the efficiency of ecosystem services collection (Greenwood, 1996). Also, the travel time from a certain settlement to location containing the ecosystem services is related to the slope steepness, road infrastructure and land cover types.

In this study, the factors considered for the accessibility model were; land cover, road infrastructure and slope steepness. Land cover was considered as a factor because some cover types specifically forest, fallow, grass and farmland are the main vegetation types that harbour ecosystem services in the study area. Slope was considered important because higher slopes in the study area make accessibility more difficult. Road infrastructure was considered because all the study communities were located either along the main roads (e.g. New Bomfa community) or secondary roads (e.g. Kotey & Apemso communities). Furthermore, the participants used trails to access the ecosystem services in the vegetation types (Trombulak & Frissell, 2000; Greenwood, 1996).

Geographic information science (GIS) allows data storing, retrieving, displaying data, create buffers, perform overlays and other analytical operations. In spatial analysis, GIS supports the user to define criteria for data and operations of analysis, run models and perform analysis of results. The study employed spatial analyst tools in ArcGIS for preparing layers of slope, land cover map and road infrastructure. Model builder in ArcGIS using weighted overlay function was used to develop the accessibility map.

Preparing the layers for the accessibility model

i. Land cover map

During the participatory mapping exercise, the participants identified the following land covers as where ecosystem services are collected in the study communities: Forest, farmland, fallow, and grass. Land cover map from the 2010 Landsat ETM+ image was used. The purpose of the land cover map is a necessary parameter in the accessibility model because accessibility varies with land cover. The study employed Toxopeus (1996) to assign the scale values as shown in Table 1 to the land cover raster map by creating an attribute table and adding the travel speed values and scale values for each land cover type. For example, participants spend 1 km/hr in accessing a forest cover, so on a scale of 1-6, forest was given a scale value of 6 (highest value) and farmland was given a scale value of 5. A value of 1 was given to settlement & marshy area because very few or almost no ecosystem services were collected in these areas. This means that less time is spent in collecting ecosystem services in forest largely because it holds the highest ecosystem services.

Table 2: Modified Land cover and travelling speed (km/hr) (Toxopeus, 1996)

Land cover type	Travelling speed (km/hr)	Scale value
Forest	1	6
Farmland	2	5
Fallow	1	6
Grass	2	5
Settlement	6	1
Marshy area	6	1

ii. Road map

The road infrastructure in the area was classified by types (i.e. main, secondary, trails/footpaths). Three different road maps were produced using GIS operation (i.e. multiple ring buffering). The multiple buffer operation was used to calculate the ring buffer distance from the road to the closest source of ecosystem services collection. For example, 0.5km distance was the least distance they would move to the closest land cover to access ecosystem service and 3km was the farthest distance to access an ecosystem service. In an interval of 0.5km a ring multiple buffers was performed for main and secondary road. The same procedure was applied to the footpath/trails. For trails, only 50m and 100m ring buffers were performed.

Each road type is kept as a separate vector file. The road maps were then rasterised into two segments maps (i.e., main/secondary and trails/footpaths) and given the output maps the same names as their respective segment. An attribute table was created and assign their respective travelling speed value and scale value to the rasterised map (Table 3). Table 3 shows the different road types with their respective travelling speed used in assigning scale value for the model.

Table 3: Travelling speed per infrastructure (road) type

Road type	Travelling speed (km/hr)	Scale value
On foot	3.0	6
Second road	6.0	3
Main road	6.0	3

iii. Slope map

The DEM data was processed in order to convert it to slope (expressed in percentages). The slope map was classified according to classes corresponding to Table 4. The slope steepness of the area was found to influence the accessibility to the ecosystem services. An attribute table was created and scale values added to the 'slope class map'. The highest slope attracted least scale value because of difficulty to access and the least slope attracted the highest scale value (Newton *et al*., 2011).

Table 4: The slope classes and the scale value applied to the travelling speed in Ejisu-Juaben districts

Slope steepness class	Scale value
0%-5%	6
5-10%	5
10%-20%	4
20%-30%	3

Run the accessibility model

The land cover, slope and infrastructure maps were all projected to conform to Universal Transverse Mercator, Zone 30N, and WGS 84 datum map projection system. These input data for the accessibility model were all prepared in a raster format. All layers were clipped to the study area boundary and had the same 30 m cell size. The model was started by adding the prepared layers (Figure 4).

Then the following steps were followed;

- Weighted overlay:

Weighted overlay is a technique that was used to apply a common measurement scale of values to the factors defined for the model in order to create an integrated analysis. All the raster layers were overlaid in the Model builder. In this operation each layer is weighted in percentages according to its importance to the analysis. The sum of the weighted percentages was 100%. The land cover map was given an influence percentage of 40%; 30% for footpath, 20% for main/secondary and 10% for slope influence (Toxopeus, 1996; Newton *et al*., 2011). According to Toxopeus, (1996) and Newton *et al*., (2011), the output of the accessibility model would not change significantly in relation to the weighting values assigned so long as the order of influence remains the same (i.e. land cover, footpath, main/secondary road and slope). Furthermore, in the model each value of the reclassified raster was scaled according to its associations to accessibility. For example, the very high slope values take the least scale value where the low slope value will take the highest scale. The same process was repeated for land cover and road infrastructure in assigning the scale values in the model.

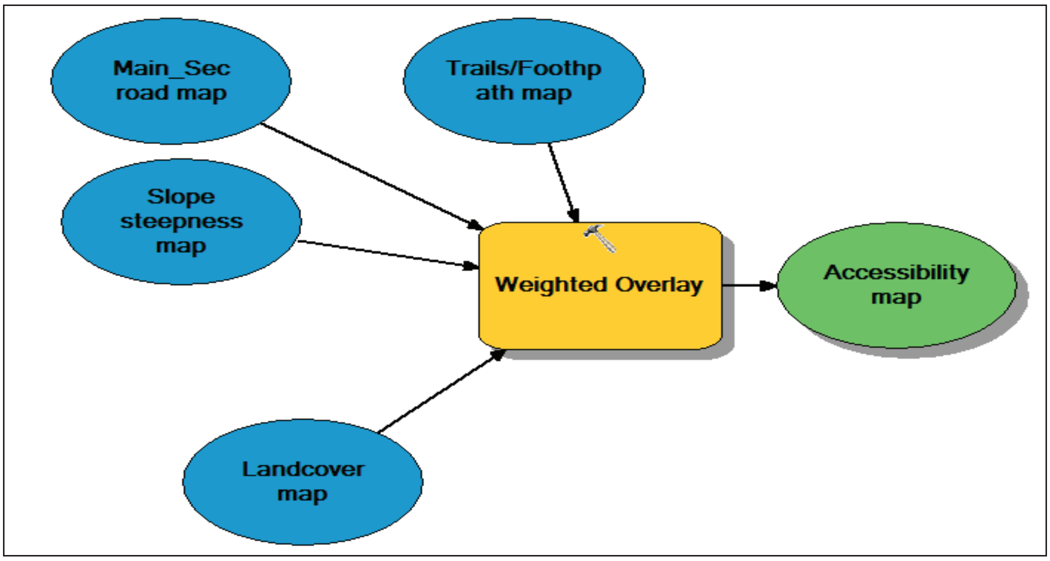


Figure 5: The layers as used in the weighted overlay function

E. Changes in land cover

Human activities over time have resulted in different scales of changes in forest ecosystems. However the acquisition of multispectral satellite data or images in recent times have supported the detection and identification of land cover changes (Coppina & Bauerb, 2009). In order to ascertain the amount of forest loss as a result of land conversions in the study area to inform REDD+ intervention, two dates of Landsat ETM+ images of July 2002 and February 2010 were used to conduct land use/cover change for the study area in Erdas imagine 2010. Two land cover maps of 2002 and 2010 were compared using change matrix extension in Erdas imagine. Thereafter the land use change detection was accomplished and analysed.

F. Determination of REDD+ Areas

The ecosystem services map was overlaid with carbon map in order to investigate and identify areas suitable for REDD+ intervention using Arc GIS overlay function. The carbon map show the distribution of carbon stocks in terms of high and low density areas. The ecosystem services map show high ecosystem services values as high value areas, and low ecosystem services values as low value areas. The output from the overlay function was then used to identify suitable areas where REDD+ could activity be designed to support the improvement of livelihoods and secure biodiversity and other ecosystem services (UN-REDD, 2011b). In order to assess the effects of accessibility on hotspots, the hotspots ecosystem services map (suitability map) and the accessibility map were overlaid using GIS operation. Likewise, the accessibility map and the forest change map were overlaid using the GIS operation to assess the effects of accessibility on forest cover.

G. Further analysis (overlays)

In the model builder, the ecosystem services map and the carbon map (in raster form) were overlaid to produce the suitability map for REDD+ implementation. In this operation each layer was weighted in percentages according to its importance to the analysis. The sum of the weighted percentages was 100%. The ecosystem services map was given an influence percentage of 50% and 50% influence for the carbon map (Toxopeus, 1996; Newton *et al.*, 2011). According to Toxopeus, (1996) and Newton *et al.*, (2011), the output of the suitability model would not change significantly in relation to the weighting values assigned so long as the order of influence remains the same. The equal influence assigned was necessary because, according to Geist and Lambin (2001), high carbon storage areas tend to have high ecosystem services value.

Likewise, in the model each value in the reclassified rasters (Table 5) was scaled according to its association to suitability for REDD+ implementation. For example, ecosystem value of >5 was assigned a scale value of 1 and highest scale value of 5 was assigned to ecosystem value of >40 in order of importance as shown in Table 5. In the same way, the reclassified carbon value map was assigned a scale value of 1 to carbon stock of > 1,9440 kg/tree and a scale value of 6 to carbon stock of >98,303 kg/tree (Table 5). The model was run to produce the suitability map (Geist and Lambin, 2001; Newton *et al.*, 2011).

Table 5: The ecosystem services value and carbon maps with their respective assigned scale values

Ecosystem services value	Carbon map (kg/tree)	Scale value
>5	> 1,9440	1
>11	>5,172	2
>21	>10,946	3
>30	>21,410	4
>40	>47,002	5
>60	> 98,303	6

Furthermore, to determine the effect of accessibility on hotspots (i.e suitability map), the accessibility map and the suitability map were overlaid in the model builder; an influence percentage of 70% and 30% was assigned to the accessibility map and the suitability map respectively (Toxopeus, 1996; Newton *et al.*, 2011). The sum of the weighted percentages was 100%. Accessibility was assigned a high value of 70% because according to Toxopeus (1996), it tends to have high effect on ecosystem services collection.

Each value of both reclassified raster of accessibility and suitability maps were scaled accordingly as shown in Table 6. For example, the scale values were set to range from 1-4 and each scale value was assigned in the model as presented in Table 6. This is because according to Thomas *et al*., (2009) and Newton *et al*., 2011, the communities attach less value to less accessible area due to physical barriers (river or water logged areas, high slope) and tend to maximise access to and optimise use of ecosystem services in locations close to them because they can spend less time to harvest and save time to engage in other activities.

Table 6: The accessibility map and suitability map with their respective assigned scale values

Accessibility map	Suitability map	Scale value
Least accessible	Least suitable	1
Low access	Low suitable	2
Accessible	Suitable	3
Highly accessible	Highly suitable	4

The same processes were repeated for the accessibility map and the forest change map. They were assigned an overall influence of 60% and 40% respectively and at each instance, scale values were allocated as presented in Table 7 in the model. The Forest change map has one class 'forest' and was assigned a scale value of 4 because forest was found to be an important land cover that holds most of the ecosystem services (Newton *et al*., 2011).

Table 7: Table 7: Accessibility map and the assigned scale values

Accessibility map	Scale value
Least accessible	1
Low access	2
Accessible	3
Highly accessible	4

4. RESULTS

4.1. Land cover classification

The land cover maps generated from Landsat ETM+ images of 2002 and 2010 are presented in Figure 6. Six land cover classes were identified: forest, farmland, fallow, grass and marshy area. The cloud cover was mainly found in the land cover map of 2002. Figure 5 showed that agriculture and fallow spreads across the entire study area in both maps. Builtup/bare areas are predominantly pronounced in the south western portion in both maps especially that of the 2010.

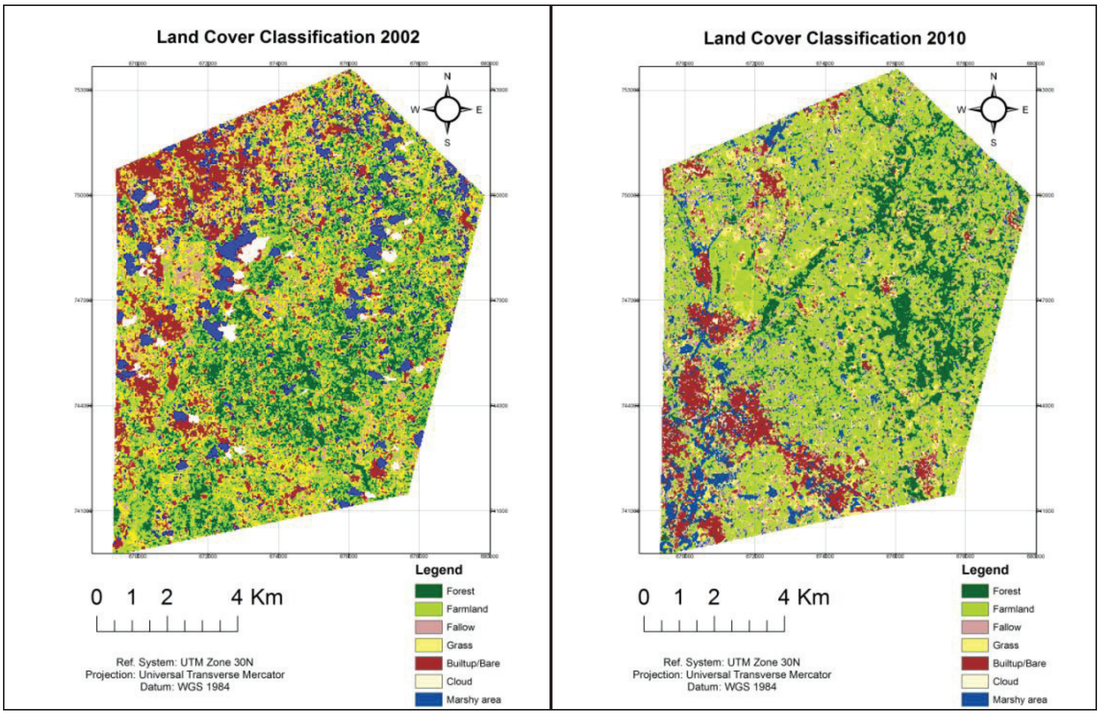


Figure 6: Land cover map of 2002 and 2010 of Ejisu-Juaben districts

Accuracy Assessments

The accuracy of the classified Landsat ETM+ images were assessed using 65 sampling points for the 2010 image and 54 points for the 2002 image. The accuracy assessments for both images are shown in Tables 8 and 9. The producer's accuracies represents the probability of a point in the field being correctly classified whilst the user accuracies shows the probability of a random point on the map being correctly classified. The overall accuracies achieved were 84.6% and 70.3% for 2010 and 2002 images respectively. In general, the class 'forest' and 'built up/bare' have the highest producer accuracies while the class 'builtup/bare and 'Marshy area' have the highest user's accuracies for 2010. Similarly, the class 'builtup/bare' has the highest producer accuracy of 100% while the class 'Marshy area' has the highest user's accuracy for 2002.

Table 8: Accuracy Assessment for 2010 image

Accuracy results 2010						
Class name	**Reference Totals**	**Classified Totals**	**Number correct**	**Producer Accuracy**	**User Accuracy**	**Kappa**
Forest	18	19	18	100%	94.74%	0.93
Farmland	12	17	10	83.33%	58.82%	0.50
Fallow	8	3	2	25%	66.67%	0.62
Grass	5	5	4	80%	80%	0.78
Marshy area	5	4	4	80%	100%	1.00
Builtup/bare	16	16	16	100%	100%	1.00
Cloud	1	1	1	100%	100%	1.00
Total	65	65	55			
Overall Accuracy	84.62%					
Overall Kappa	0.81					

Table 9: Accurate Assessment for 2002

Accuracy totals (2002)						
Class name	**Reference Totals**	**Classified Totals**	**Number correct**	**Producer Accuracy**	**User Accuracy**	**Kappa**
Forest	19	14	11	57.89	78.57%	0.67
Farmland	13	19	12	92.31%	63.16%	0.51
Fallow	3	4	3	100%	75.00%	0.74
Grass	8	6	3	37.50	50.00%	0.41
Marshy area	4	2	2	50%	100%	1.00
Builtup/bare	7	8	7	100%	87.50%	0.86
Cloud	0	1	0	-	-	0.00
Totals	54	54	38			
Overall Accuracy	70.37%					
Overall Kappa	0.62					

Change detection (2002-2010)

Comparing the two different image dates showed different levels of changes in the cover types as a result of conversions between the various cover types in the study area. Table 10 showed that all the 6 land cover classes have experienced changes in size from 2002 to 2010. With regards to forest loss as shown in the land cover conversion matrix (Table 11), forest has been transferred to farmland by 819.9 ha, forest converted to fallow by 417.15 ha, forest loss to Grass was 138.51 ha, forest loss to built-up/bare was 76.32 ha, forest loss to marshy area was 121.05 ha and forest to cloud by 8.01 ha whilst only 425.98 ha remained unchanged. Generally, forest area has decreased from 2005.92 ha to 1480.59 ha representing

26.19%. Challenges of data quality of 2002 image may affect the output from the change detection. However, the overall output from the change detection can contribute to decision making on locating REDD+ to reduce deforestation.

Table 10: Land cover class of the study area for the year 2002 and 2010

Land cover	**2002**	**2010**	**Difference Area**	**+/- (%)**
Forest	2005.92	1480.59	-525.33	-26.19
Farmland	2703.51	4148.73	1445.22	53.46
Fallow	1087.11	1214.09	126.98	11.68
Grass	2200.05	956.70	-1243.35	-56.51
Marshy area	1030.41	935.91	-94.50	-9.17
Builtup/Bare	1630.44	1053.18	-577.26	-35.41

Table 11: Land cover conversion matrix

Land cover type	**Forest**	**Farmland**	**Fallow**	**Grass**	**Marshy area**	**Builtup/bare**
Forest	**425.98**	819.90	417.15	138.51	121.05	76.32
Farmland	474.48	**1061.73**	572.13	210.87	212.67	161.82
Fallow	107.73	451.17	**224.91**	118.62	85.32	94.41
Grass	192.51	847.17	469.26	**224.91**	229.84	223.74
Marshy area	167.58	442.19	216.09	67.86	**94.5**	53.46
Builtup/bare	81.45*	467.01*	275.58*	180.27*	171.09*	**415.8**

Note: '*' Bare areas converted due to illegal logging, bush fires

Assessment of ecosystem services

4.1.1. Respondents characteristics

Out of 73 local respondents interviewed, 37 were males and 36 were females, the average age of male respondents was 47, and that of female respondents was 42 years old. Forty-three respondents fall in the low income group and 30 in the high income group. Table 12 shows the number of participants based on their income status and average age distribution. Results from the interview showed that all respondents had lived in the study area most of their life (i.e. over 10 years) and are engaged in various forms of occupation (Table 13). Majority of the respondents are farmers whilst the rest are involved in occupations such as hunting, palm wine tapping and trading. Table 10 shows the occupational status for the various income groups in the study area. In Table 14, 61 are literates (i.e. respondents who have had at least 6 years of formal education), 12 are illiterates (respondents with no formal education), 34 males and 27 females have had formal education up to secondary level, whilst none of the respondents have had post-secondary education (i.e. tertiary education).

Table 12: Number of participants per income group in the focus group discussion

Communities	Income status	No. of respondents			Average age of respondents	
		Total	Male	Female	Male	Female
Apemso	Low income	11	6	5	45	42
	High income	8	4	4	48	44
Kotey	Low income	17	9	8	52	47
	High income	9	4	5	46	38
New Bomfa	Low income	15	7	8	49	43
	High income	13	7	6	44	40

Table 13: Respondent characteristics (Occupation)

Study communities		
New Bomfa	Low income group (%)	High income group (%)
Farmers	57.1	51.7
Hunters	28.1	14.3
Palm wine tapper	14.3	0
Trader	0	28.6
Apemso township	Low income group	High income group
Farmers	50	50
Hunters	16.7	0
Traders	33.3	50
Kotey township	Low income group	High income group

Farmers	55.6	75
Hunters	33.3	25
Palm wine tapper	11.1	0

Table 14: Respondents' level of education

Gender	Illiterate	Literate			
		Primary	J.H.S	Secondary	Tertiary
Male	3	10	17	7	0
Female	9	14	12	1	0

4.1.2. Key ecosystem services

Two (2) income groups (i.e. low income & high income) from three (3) communities were identified and involved in a focus group discussion to list the key ecosystem services. The main ecosystem services found in these communities are presented in Table 15. The respondents provided the purpose of collecting the ecosystem services. Generally, across the 3 communities the results showed that the low income groups use greater proportion of the ecosystem services for commercial purposes whilst the high income group use greater proportion for domestic purposes as shown in Table 16.

Table 15: List of Ecosystem services in three communities

Ecosystem services in study communities	
New Bomfa township	
Mushroom	Fuel wood
Snails	Water
Bush meat	
Medicinal plants	
Apemso township	
Mushroom	Honey
Cane	Food (Fruits)
Bush meat	Water
Medicinal plants	
Kotey township	
Mushroom	Honey
Snails	Food (Fruits)
Bush meat	
Medicinal plants	

Table 16: Purpose of collection of ecosystem services

Communities	**Family use (%)**		**Commercial use (%)**	
	Low income	High income	Low income	High income
New Bomfa	10	70	90	30
Apemso	20	60	80	40
Kotey	15	55	75	45

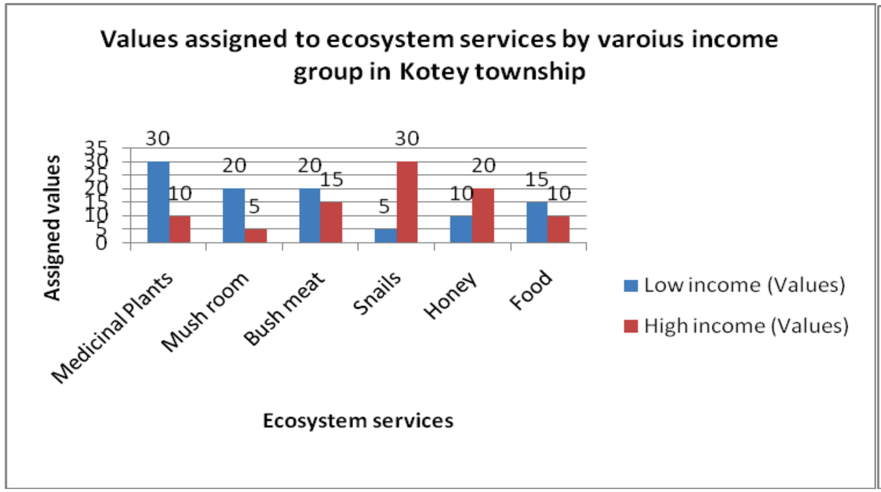
4.1.3. Spatial variations of ecosystem services values

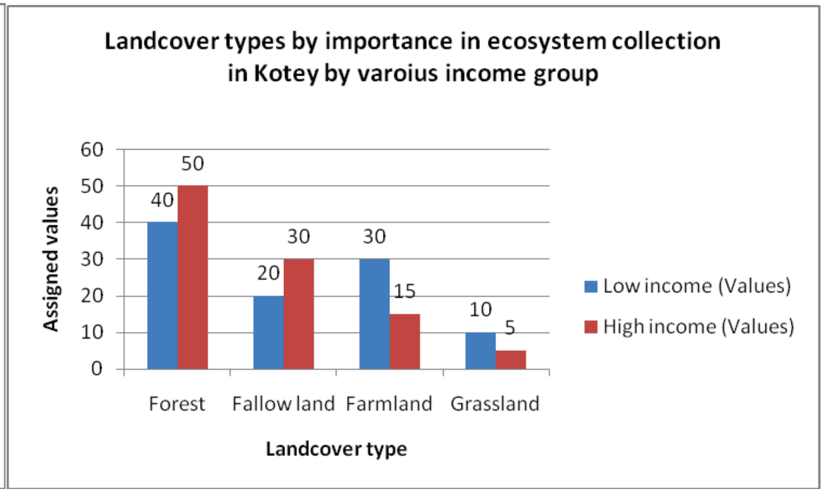
The bar chart in Figure 7 showed the total values allocated to each ecosystem service and the corresponding land cover types. In general, the groups assigned weights according to the ecosystem services they collect more in their respective communities. For instance, in Apemso area, the low income group valued services such as medicinal plants (25 pebbles) and mushroom (30 pebbles) higher than values placed by high income group on the same services (medicinal plants= 15 pebbles), mushroom=5 pebbles). Ecosystems services such as water (10 pebbles), fruits (10 pebbles), and bush meat (15 pebbles) were moderately valued whilst honey (5 pebbles) and cane (5 pebbles) were less valued by the low income groups respectively. Similarly, ecosystems services such as water (15 pebbles), fruits (10 pebbles), honey (12 pebbles), and bush meat (10 pebbles) were moderately valued whilst cane (2 pebbles) was less valued by the high income groups. The t-statistical test of significance relationship between low income and high income group in relation to the values they place on the ecosystem services as presented in Appendix-B showed that the t-statistic value of 1.09 was greater than the P-value of 0.05. This result implied that there was evidence to reject the null hypothesis. This means that values placed on the ecosystem services by the two income groups vary.

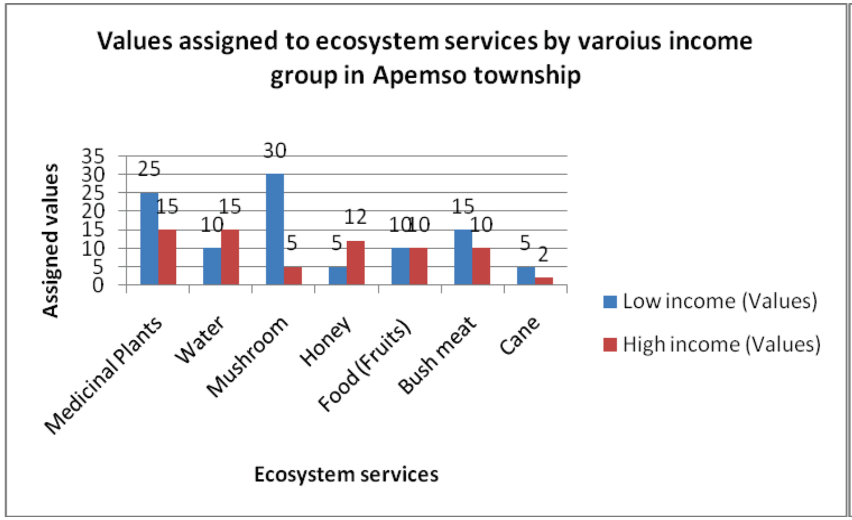
The trend is not different for Bomfa for both income groups as shown in Figure 7. Low income groups tend to place more value on mushroom (30 pebbles) and water (20 pebbles) than high group (Water=10 pebbles, mushroom =12 pebbles). Also, ecosystems services such as fuel wood (10 pebbles), snails (16 pebbles), bush meat (14 pebbles), medicinal plants (10 pebbles) were moderately valued for low income group contrary to bush meat (25 pebbles) and medicinal plants (20 pebbles) for high income group. However, high income groups placed moderate values on snails (10 pebbles), mushroom (10 pebbles), water (15 pebbles) and less value on fuel wood (5 pebbles). Again, the t-test of significance confirmed the values placed on the ecosystems services by the two income groups (Appendix-B). The test result showed that the t-statistic value of 0.48 was greater than the P-value of 0.05. This result implied that there was evidence to reject the null hypothesis.

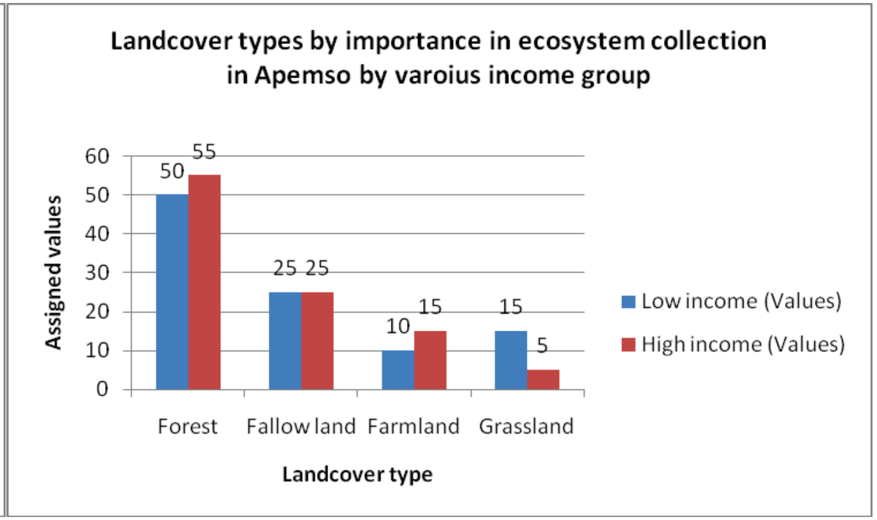
In Kotey, only snails services (5 pebbles) showed less value for low income group but highly valued (30 pebbles) by high income group. This result was confirmed by the t-statistical test (Appendix-B) which gave the t-statistic value of 0.25 greater than the P-value of 0.05. This implied that the total value placed by both the high income and low income groups varied.

The ecosystem services were found to vary in spatial distribution across the various land cover types in all study communities (Figure 8) and this is in line with related studies conducted by Raymond *et al.*, (2009) and Shapansky *et al.,* (2002). From Figure 8 the spatial distribution of ecosystem services and values depicts that, high values areas are places the participants attach more importance due to the large quantity of ecosystem services they collect per land cover. Likewise, low values areas are places that provide least quantity of ecosystem services per cover type.


Values assigned to ecosystem services by varoius income group in Kotey township
Assigned values
0
5
10
15
20
25
30
35
30
10
20
5
20
15
5
30
10
20
15
10
Medicinal Plants
Mush room
Bush meat
Snails
Honey
Food
Ecosystem services
Low income (Values)
High income (Values)


Landcover types by importance in ecosystem collection in Kotey by varoius income group
Assigned values
0
10
20
30
40
50
60
40
50
20
30
30
15
10
5
Forest
Fallow land
Farmland
Grassland
Landcover type
Low income (Values)
High income (Values)


Values assigned to ecosystem services by varoius income group in Apemso township
Assigned values
0
5
10
15
20
25
30
35
25
15
10
15
30
5
5
12
10
10
15
10
5
2
Medicinal Plants
Water
Mushroom
Honey
Food (Fruits)
Bush meat
Cane
Ecosystem services
Low income (Values)
High income (Values)


Landcover types by importance in ecosystem collection in Apemso by varoius income group
Assigned values
0
10
20
30
40
50
60
50
55
25
25
10
15
15
5
Forest
Fallow land
Farmland
Grassland
Landcover type
Low income (Values)
High income (Values)

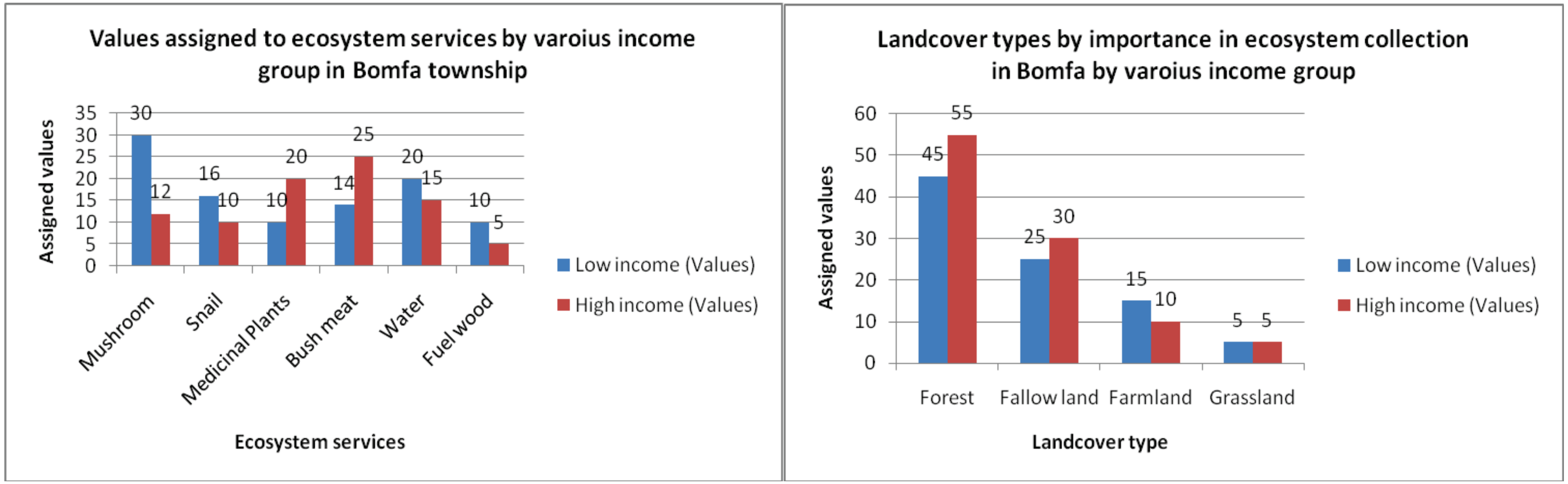


Figure 7: Key ecosystem services identification and valuation per income group in the 3 communities

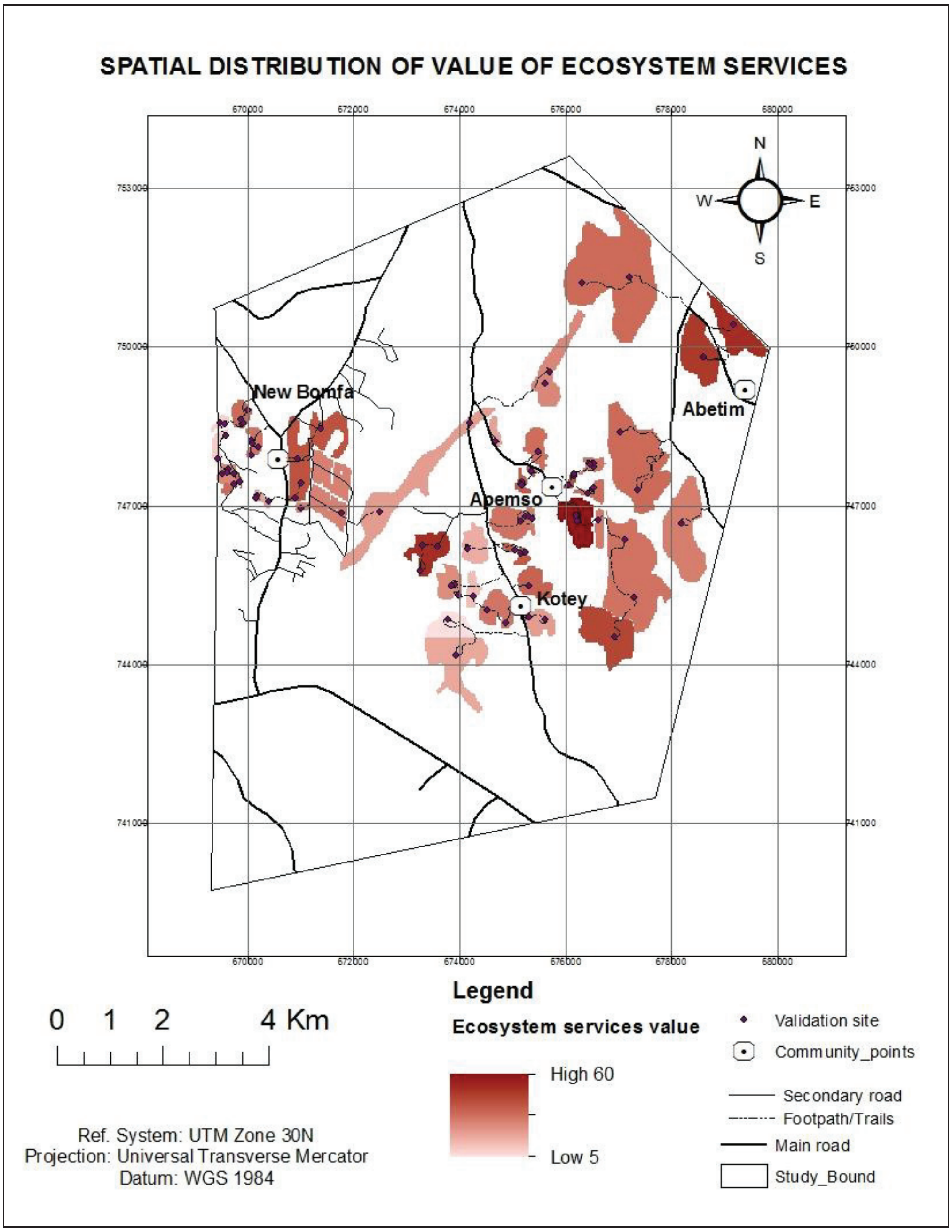


Figure 8: Spatial distribution of value for ecosystem services

4.1.4. Accessibility of ecosystem services in Ejisu-Juaben districts.

The four factors used in the accessibility model development were land cover, main/Sec road, footpath and slope. The land cover map was prepared from 2010 Landsat ETM+ data because it was the most current image data available. However, the accuracy assessment of the classified map was good and was used as a factor to determine the level of accessibility. The results from Figure 8 showed that forest provides the highest ecosystem services followed by fallow, farmland and grass respectively in all selected communities. This means that the ecosystem services were mainly collected in forest, fallow, farmland and grass. These land covers are crucial because they hold most of the ecosystem services the local people collect (Raymond *et al.*, 2009).

The slope steepness map was classified into classes based on (Toxopeus, 1996) where the least slope value was scaled the highest value and a higher slope class scaled the least scale value. The main road and secondary infrastructure were created based on buffer creation. In all cases, buffers that were close to road/footpath attracted high values and buffers far from the road attracted low values because locals access easily land covers closer to them than those farther away.

The accessibility map was produced as result of the influence of the 4 factors mentioned above. In effect, the 4 factors maps were overlaid using the weighted overlay function in Arc GIS to generate the overall accessibility map. Figure 10 presents the final accessibility map for the study area. The accessibility map was classified into 4 categories namely, highly accessible, accessible, low access and least access. The white colour background in the accessibility map is the built up areas.

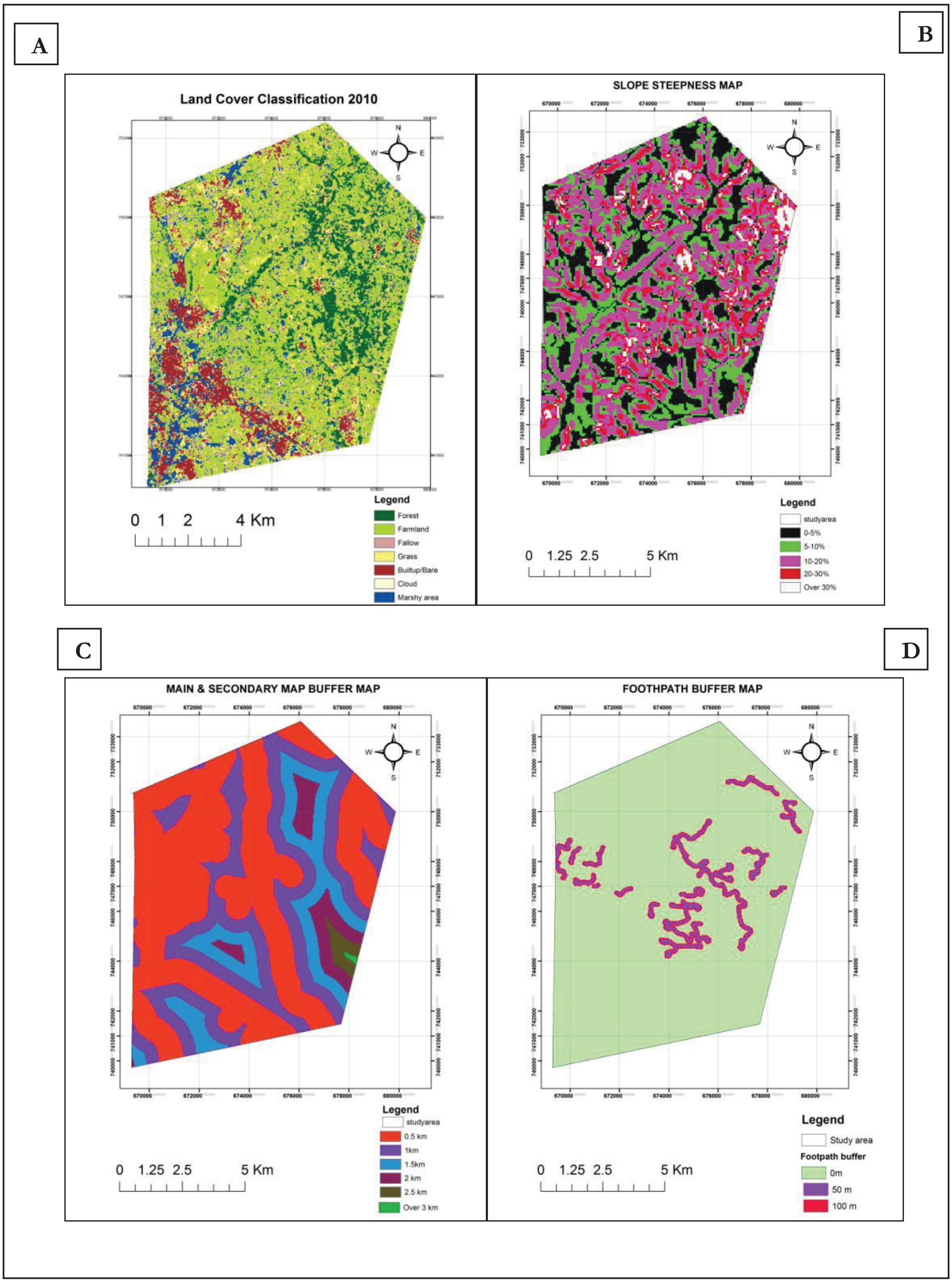


Figure 9: The four factors used in the accessibility map (A: land cover, B: slope map, C: Main/Sec road map, D: Footpath map

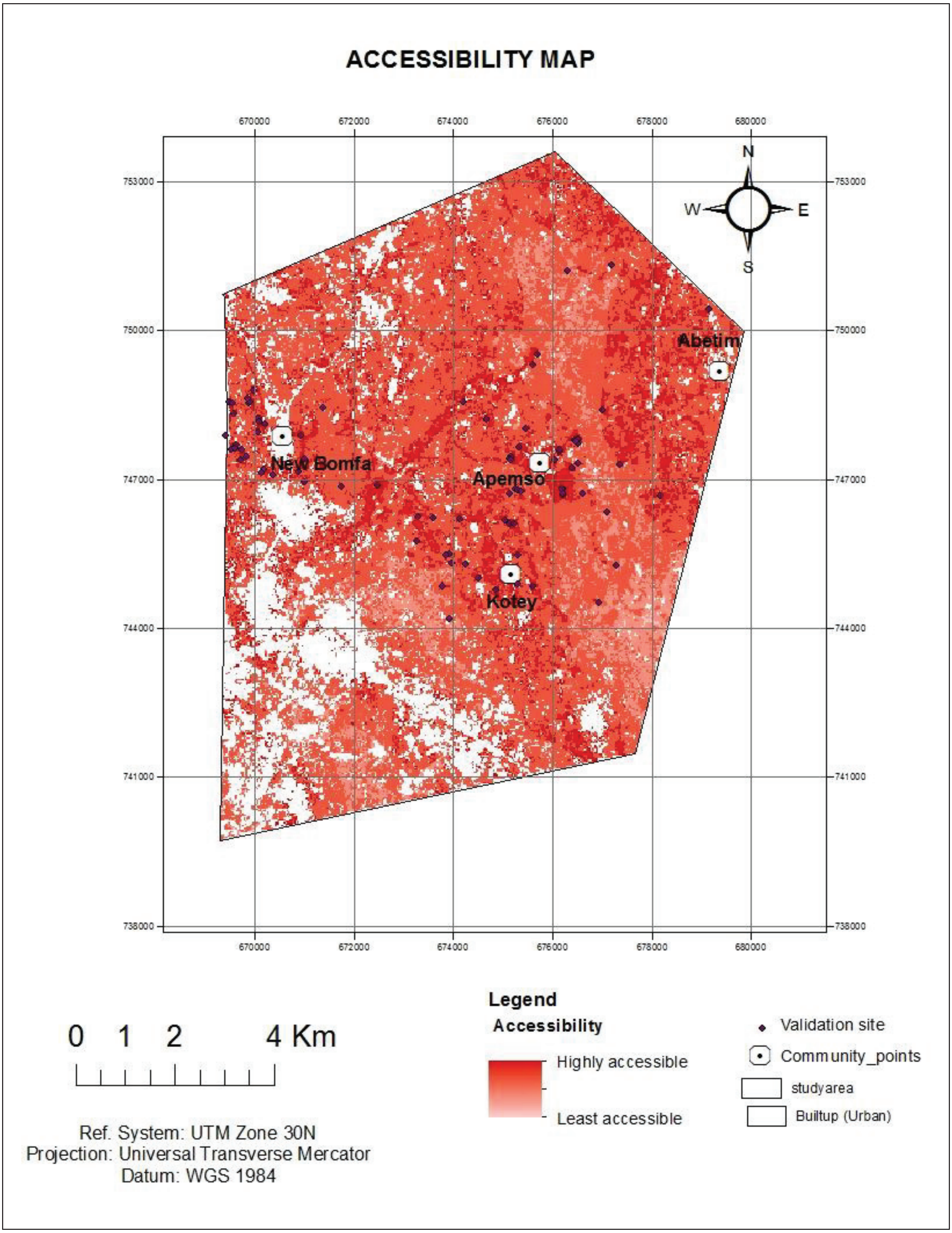


Figure 10: The accessibility map of the study area

4.2. Suitability map for REDD+programme

Figure 11 shows the carbon map and ecosystem services map for portion of the study area. The carbon map was secondary data (Mutanga, 2012) prepared for this portion of the study area. The ecosystem map was prepared and clipped with the portion of the study area for spatial analysis. The carbon map and ecosystem services map were overlaid (Figure 12). From visual interpretation, Figure 12 show high values of ecosystem services coinciding with high carbon. For example, forest and fallow areas that showed high values of ecosystem services were found to coincide with high carbon areas. In some cases, low value areas of ecosystem services were found to coincide with high carbon areas. Some fallow, grass and farmland were areas of low ecosystem services values that coincided with high carbon especially in the south-eastern portion of the map.

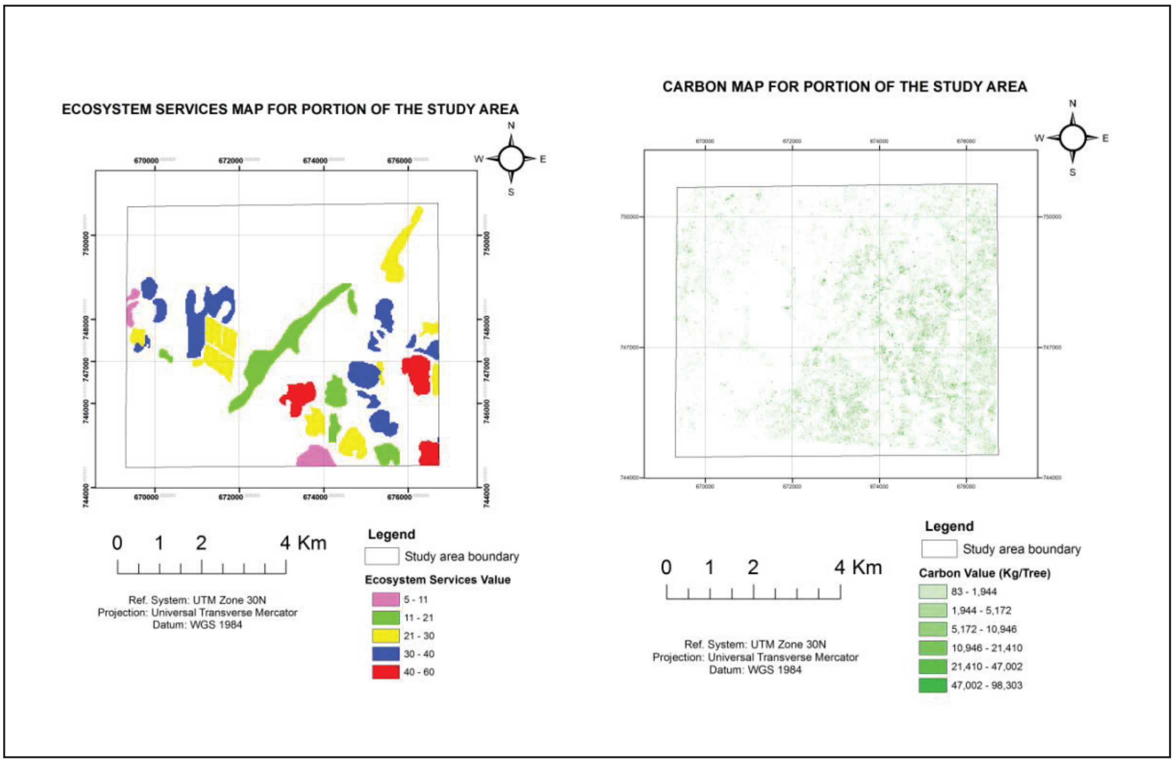


Figure 11: Raster layers of carbon and ecosystem services map of portion of the study area

Figure 11 comprised of areas of ecosystem services and carbon stored in the various types of land cover found in the area.

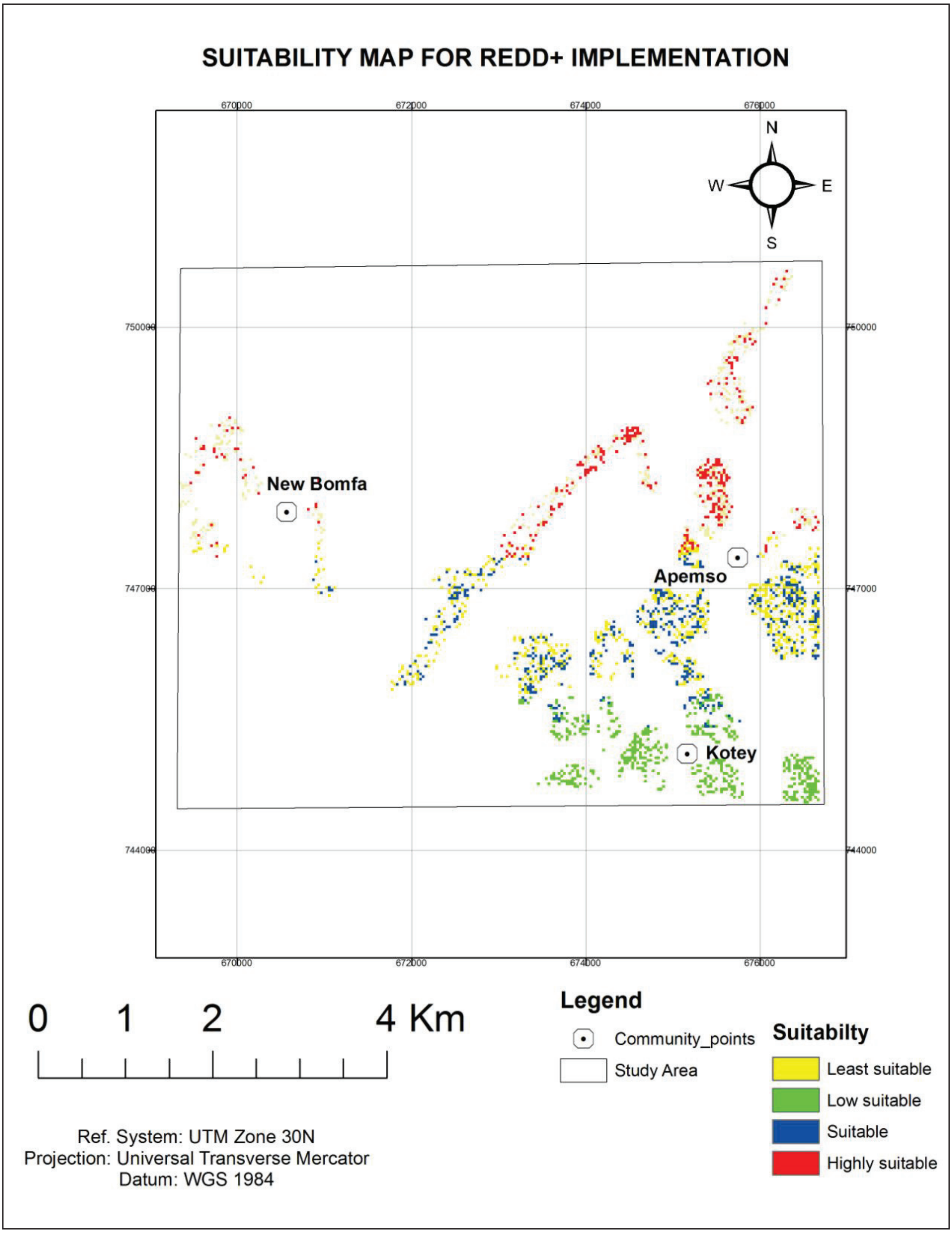


Figure 12: Suitability map for REDD+ implementation

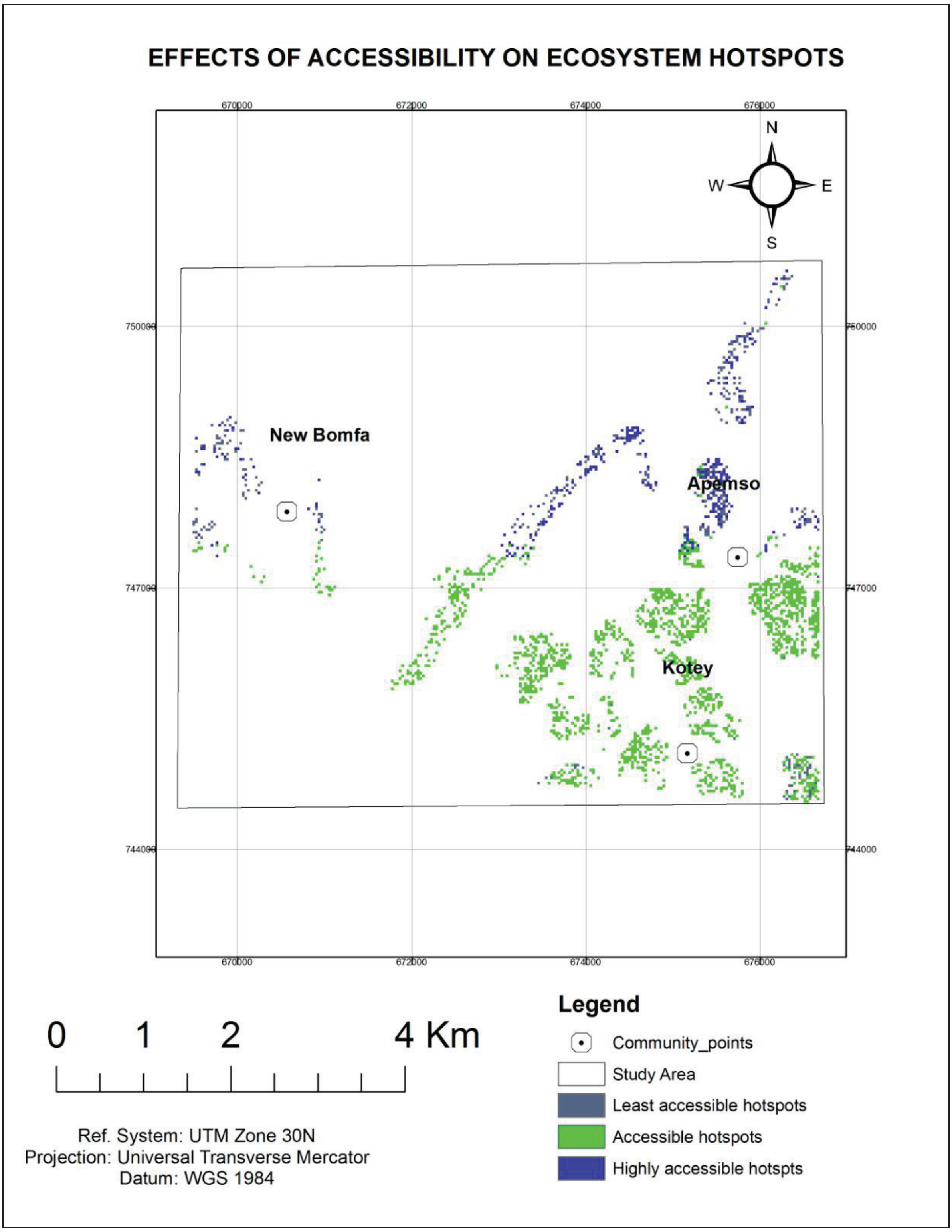


Figure 13: Effects of accessibility on ecosystem hotspots

The overlay of suitability map for REDD+ intervention (comprised of ecosystem values and carbon maps) and accessibility map was done to produce the effects of accessibility on ecosystem hotspots map. The hotspots used in these context means areas with high concentration of ecosystem values and high carbon storage which are prone frequent human visits or interactions. These hotspots are more suitable for REDD+ interventions so as to conserve these areas.

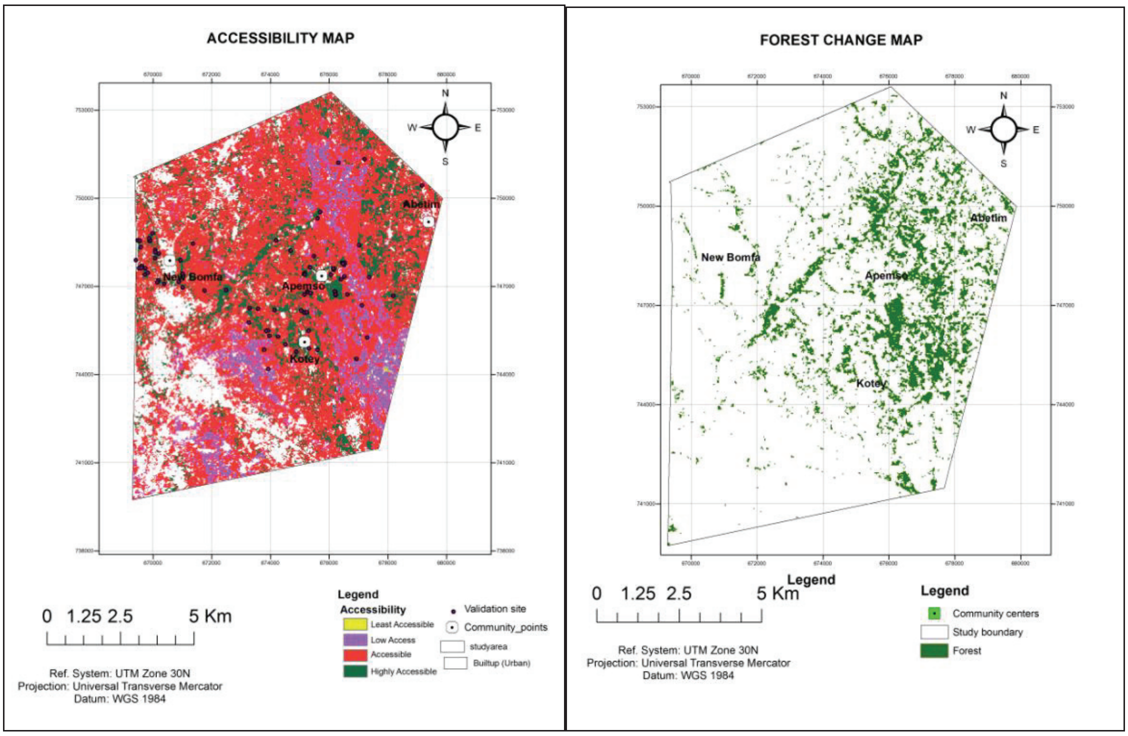


Figure 14: Raster layers of accessibility map and forest change map of the study area

Figure 15 depicts effects of accessibility on forest change map. The result from Figure 15 showed forests closed to settlements are more disturbed than forest further away.

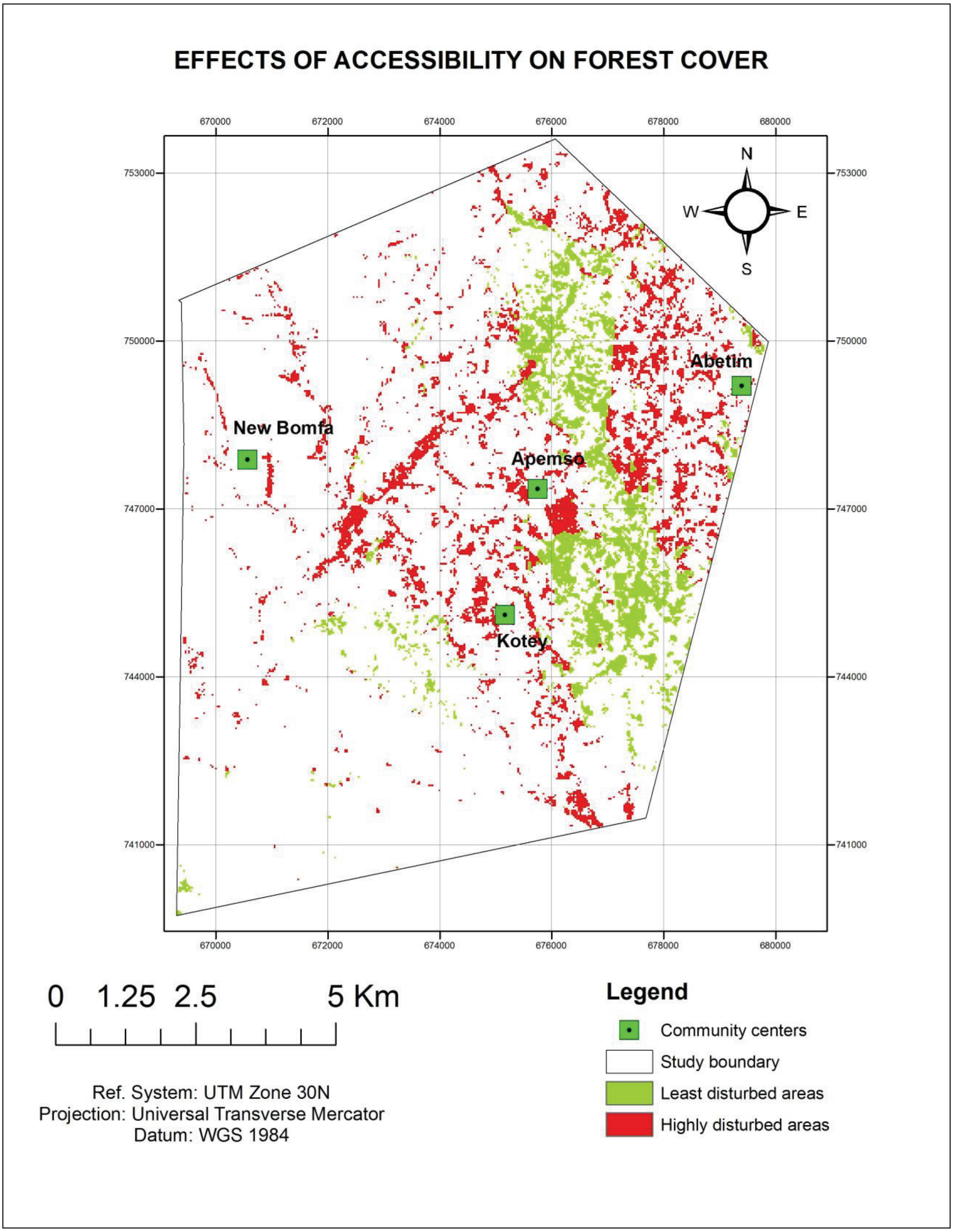


Figure 15: Effects of accessibility on forest cover in the study area

5. DISCUSSION

5.1. Accuracy Assessment and land cover classification

The 2002 Landsat ETM+ image was assessed using field validation data collected in 2007. The overall accuracy assessment of the 2002 image was 70.4% which was lower than the recommended 85% by Campbell (2002). The lower accuracy could be attributed to difference in the date of image acquisition and when the field validation data was collected. Also, the cloud cover on the 2002 image could contribute to the low accuracy recorded. This means that data quality of 2002 image may render the output less appropriate to reflect all the difference of the land covers. The overall accuracy assessment of the 2010 Landsat ETM+ image was 84.6%. The relatively high accuracy recorded could be attributed to the quality of 2010 image and quality of the field validation data collected for the study. The overall accuracy assessment of 2010 is considered good and thus reflects the difference of land covers in the study area.

5.2. Land cover change

The study area has experienced some land cover conversions over the period of 2002 to 2010. For instance, in Table 11, agricultural expansion has seen more conversions than any land cover. Forest conversion to farmland may be due to the intensity of agricultural activities (i.e. shifting cultivation and soil management practices) in the area (Boakye *et al*., 2012). Also forest conversion to fallow and subsequently to grass may be as a result of illegal logging and lumbering activities of timber companies (Boakye *et al*., 2012; Kusimi, 2008). Forest, fallow and farmland conversions to builtup/bare in the study area was less. This may be attributed to the selection of the study communities which are rural based and the data quality of 2002 land cover map. From Table 10, the huge difference (**1243.35 ha**) in grass conversions from 2002 to 2010 could be attributed to the oil palm expansion project initiated by the Government of Ghana and World Bank in 1998 and 2004 where younger oil palm plantation usually intercropped with grass or *peurera* undergrowth as a way of improving soil fertility.

In Table 11, bare areas as a result of illegal logging, bush fire and farming after a period of time has been transferred to forest, farmland, fallow and grass (Boakye *et al*., 2012; Kusimi, 2008). For example, such abandoned bare areas within forest are sometimes overtaken by forest canopy in later stages. Also, bare areas due to bush fires at different stages transferred to forest (through plantation development), farmland, grass (for purposes of grazing) and fallow. Table 11 also showed that farmland was converted to forest by **474.48ha**. This phenomenon rarely happens but from the field observation, land owners claimed their lands from the farmers and converted them into *Teak* plantations as means of securing their lands and later harvested for financial gains. In general there was an overall forest loss of 26.19%.

5.3. Assessment of ecosystem services value

Socio-demographic characteristics in the study area indicate that majority of the participants were slightly educated (up to secondary education). All participants have lived/stayed for more than 10 years in the study area. The level of education, average age of respondents and length of stay in the communities shows that the local people have reasonable knowledge of the natural resource around them. This was reflected in the participatory mapping because the groups were able to identify and map specific area with ecosystem services they collect. Applying participatory tools to map ecosystem services and places they collect them have contributed to knowledge and provided understanding of the links between human interactions with their environment.

For example, based on the construction preference method, values assigned to ecosystem services in order of importance revealed that the participants valued the key ecosystem services in Kotey, New Bomfa and Apemso for several reasons. The locations of the communities showed different patterns with respect to values assigned to the various ecosystem services and important places which provide most of the ecosystem services.

Since income levels affect the value local people put on ecosystem services, the participants were grouped into low and high income levels for the valuation exercise. Ecosystem services such as Mushroom, Medicinal plants, Bush meat, Snails, Honey, Food (Fruits) and Cane were identified and associated with forest, fallow, farmland and grass. This is consistent with previous studies by Raymond*, et al.* (2009) and Jobe & White (2009). The ecosystem services were found and collected mainly from forested areas which tend to hold most of such services in all study communities (Newton *et al.*, 2011) and perceived to be more useful to their livelihood (Thomas*, et al.*, 2009) and determines their quality of life (Geurs & Eck, 2001; Kim *et al.*, 2005). This is consistent with studies done by (Mayers, 2006) that forestry is known to contribute to poverty reduction and this had been shown through its multiple uses or benefits of forest resources (Sunderlin, 2005).

Fallow also hold considerable amount of ecosystem services including bush meat, honey and fruits. Farmland especially oil palm fields prominent in the study area holds more mushrooms and snails due to the favourable conditions it provide for such ecosystems services.

The results from Table 16 shows that the low income group use the ecosystem services more for commercial purposes and less for domestic usage across the 3 study communities in contrast to the high income groups, who use more for domestic purposes than commercial purpose. The results mean that the low income groups' livelihoods depend more on income they gain from selling the ecosystem services whilst the high income groups may have other alternative sources of income in addition to the ecosystem services provision.

Furthermore, the use of GIS and Remote sensing application here allows for spatial representation of ecosystem services, access to these resources locations and its effects on land cover patterns. The integration of the two technologies provides good data analysis and presentation of results for the study

The variations found in spatial distribution of the ecosystem services across the various land cover types in all study communities may attest to the level of importance the local people attach to such services. High value areas tend to provide large quantity of ecosystem services and low value areas provide least quantity of ecosystem services (Figure 8). The lower usefulness and values the locals attached to certain less accessible areas may be attributed to some physical barriers (i.e. rivers or water logged areas, high slope areas) within the study communities (Thomas*, et al.*, 2009). The vegetation types that hold these ecosystem services are randomly arranged relative to accessibility because some vegetation types provide abundant ecosystem services in both accessible and inaccessible areas (Figure 8). For example, the local people tend to maximise access to and optimise use of ecosystem services in locations close to them because they can spend less time to harvest and save time to engage in other activities (Figure 8). On the other hand, some may choose to harvest in inaccessible areas because the probability of finding undisturbed ecosystem services may be high (Figure 8).

Therefore, modelling the potential significance of accessibility simplifies and enhances understanding of human interaction with their environment with respect to the effect of accessibility on ecosystem services. The model used in this study presents the influence of the land cover (vegetation types), slope and road infrastructure as factors in accessing ecosystem services. Several studies employing such factors have been demonstrated in literature (Gragson, 1997; Newton*, et al.*, 2011; Toxopeus, 1996; Turner *et al.*, 2003).

The accessibility model (Figure 10) indicates that ecosystem services that occur near to roads and in less steep areas are more accessible and perceived as more useful by the local people and this is in line with Toxopeus (1996) and Newton *et al.*, (2011). This is shown in the accessibility model as highly accessible and accessible. This is consistent with the result of effects of accessibility on hotspots in Figure 13. This means that the local people may first want to access these services using footpaths of radius 50m and 100m and main roads within 0.5 km radius and in certain cases 1 km range to harvest. However, these areas can be prone to high competition and could lead to over exploitation and become a risk zone (Kuffour, 2000). Also, places over 3km radius to the main road show least access in certain cases but where it is identified as high values areas may be attributed to the type of vegetation cover that holds the ecosystem services. The effect of accessibility on forest cover (Figure 15) further confirms that resources close to them are more important than resources farther away. On the other hand, consistent pressure on these forest resources close to them could lead to disturbances on the entire forest ecosystem through biodiversity loss and deforestation. The result of forest loss for the period of 2002-2010 shows dramatic reduction of 26.19% providing enough bases for introduction of REDD+ measures to reduce deforestation in the study area and sustain the local people' livelihood of harvesting ecosystem services.

Combining carbon and ecosystem services map, could help the study on how REDD+ measures can influence the local people attitude towards sustainability of these resources without compromising their livelihoods, conservation and climate change control objectives. For instance, overlaying the carbon map and ecosystem services map (Figure 12) revealed interesting results. For example, high values areas attract more direct access to the ecosystem services. Meanwhile these high values areas are potential for holding

large ecosystem services, high carbon stock and other biodiversity stock. These areas are more suitable to design REDD+ programmes. They are suitable for REDD+ implementation programme because it contributes multiple benefits to rural livelihoods by conserving biodiversity and carbon storage, mitigating deforestation, promoting sustainable use of resources and offer financial incentives to alleviate poverty.
Also, where low values areas coincide with high carbon then it is considered a high risk area because the local people may be tempted to cut the trees for firewood and charcoal. This is another probable area to design a REDD+ programme and may thus be important to incorporate the development of other livelihood income ventures into the design of any REDD+ activity (Angelsen, 2008; UN-REDD, 2011b).
However, the suitability map also shows some inconsistencies especially from the lower right corner. These map area present mixed results because highly suitable areas are mixed up with low or least suitable areas. This inconsistency occurs in same location where patches of forest were identified as giving high carbon and high ecosystem services as well as low ecosystem services and low carbon. This is attributed to the freehand sketching during the participatory mapping where the local people included fragmented land covers because they derived certain peculiar ecosystem services from these areas. Fragmentation is defined as a dynamic process of change that occurs when large areas of vegetation are incompletely cleared leaving multiple smaller areas that are separated from each other (Bennett, 2003). Forest fragment in this context refers to an isolated patch of forest cover resulting from disconnected deforestation (Zipperer, 1993). Changes to landscape patterns arising from fragmentation can be readily identified in Ejisu-Juaben where most pressure arises out of the transfer of forest to other land cover types (Nagendra *et al.*, 2004).

From figure 15, effects of accessibility on forest cover change shows interesting results. For instance, from the figure, easy access to forested areas may lead to deforestation where ecosystem services collection is high, making these areas vulnerable or high risk zones. REDD+ implementation to conserve the forest cover will be appropriate. On the other hand, high carbon areas and easy access coupled with low ecosystem services collection may lead to deforestation, therefore introducing REDD+ may be an incentive for locals whose interest is to cut down trees for other purposes. However, areas with high carbon, with difficult access due to physical barriers coupled with low ecosystem services has less risk and therefore REDD+ implementation may not be appropriate (Thomas *et al.*, 2009; Newton *et al.*, 2011; Raymond *et al.*, 2009).

6. CONCLUSIONS AND RECOMMEDATION

6.1. Conclusions

The general objective of the study was to assess spatial ecosystem services value for identification of suitable areas where REDD+ could actively support livelihoods. This has been demonstrated through the use of remote sensing and GIS technology. The following are the study conclusions.

Question 1: What kind of services/resources does the ecosystem provide to the communities?

- Six provisioning ecosystem services were identified in Kotey community (Medicinal plants, Mushroom, Bush meat, Snails, Honey and Food (fruits)). Seven (7) provisioning ecosystem services were identified in Apemso community (Medicinal plants, Mushroom, Honey, Food (fruits), Water, Bush meat and Cane) and six (6) provisioning ecosystem services were collected in New Bomfa community (Medicinal plants, Mushroom, Bush meat, Snails, Water and Fuel wood)
- The overall ecosystem services listed in all 3 study communities were Mushroom, Medicinal plants, Bush meat, Snails, Honey, Food (Fruits) and Cane.

Question 2: What is the relation between economic status and value of ecosystem services?

- In all 3 study communities, the low income groups use greater proportion of the ecosystem services for commercial purposes (82%) than for domestic purposes (18%). The high income group use greater proportion for domestic purposes (62%) than for commercial purpose (38%). This means that the low income groups' livelihoods depend more on income they gain from selling the ecosystem services whilst the high income groups might have other alternative sources of income in addition to the ecosystem services provision.
- The t-statistical test of significant relationship between low income and high income groups in relation to the values they place on the ecosystem services showed that there was enough evidence to reject the null hypothesis in all three study communities. This suggested that values placed on the ecosystem services by the two income groups vary.

Question 3: What are the spatial variations of the ecosystem service value in the area?

- The spatial distribution of communities showed different patterns with respect to values assigned to the various ecosystem services and viewed these ecosystem services as crucial to their livelihood. The spatial distribution of ecosystem services and values depicts that, high value areas were places the participants attach more importance due to the large quantity of ecosystem services they collect and low value areas are places that provide least quantity of ecosystem services.

- Forest provides the highest ecosystem services followed by fallow, farmland and Grass respectively.

Question 4: How much forest is lost due to land cover conversions?

- Forest area decreased from 2005.92 ha to 1480.59 ha representing 26.19%. Forest was transferred to farmland by 819.9 ha, forest converted to fallow by 417.15 ha, forest loss to Grass was 138.51 ha, forest loss to built-up/bare by 76.32 ha, forest loss to marshy area by 121.05 ha and 424.98 ha remained unchanged during the study period.

Question 5: Where are the suitable areas to design REDD+ programme?

- Places of high ecosystem services value coinciding with high carbon stock were found to be hotspots for REED+. These areas are potential for holding large ecosystem services, high carbon stock and other biodiversity stock hence suitable to design REDD+ programme.
- Places of low ecosystem services value that coincide with high carbon stock. These areas are prone to tree cutting and may be described as high risk zone. Alternative livelihood schemes including plantation development in areas where forest is lost to fallow and grass.

Question 6: What is the effect of accessibility on the value of ecosystem services?

- Ecosystem services that occur near to roads and in less steep areas are more accessible and useful to the local people. These areas may as well be prone to competition and risk of being over exploited.
- Ecosystem services located at places farther than 2km radius to the main road show least access and less pressure.

Limitation

The data quality of a cloud free Landsat ETM+ (2002) limited the study with respect to the land cover accuracy assessment to reflect what is on the ground. However, this did not have effect on the overall conclusion but instead assessment of the spatial ecosystem services values guided the identification of suitable areas where REDD+ could be implemented to support livelihoods.

6.2. Recommendation

The study provides a tangible method for planning and identifying in the national context, information for making management decisions where REDD+ could actively support livelihoods in Ghana. Further studies should consider the extent of threats due to land cover conversion and their effects on ecosystem services and in general on local people's quality of life. This will form the basis for communities to express their disgust about loss of their natural resources.

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8. APPENDIX

8.1. Appendix A

8.1.1. Confusion matrix (2010)

Class name	Forest	Farmland	Fallow	Grass	Marshy area	Built-up/bare	Cloud	Totals	Error of commission %
Forest	18	1	0	0	0	0	0	19	5.26
Farmland	0	10	5	1	1	0	0	17	41.17
Fallow	0	1	2	0	0	0	0	3	33.33
Grass	0	0	1	4	0	0	0	5	20.00
Marshy area	0	0	0	0	4	0	0	4	0.00
Builtup/bare	0	0	0	0	0	16	0	16	0.00
Cloud	0	0	0	0	0	0	1	1	0.00
Totals	18	12	8	5	5	16	1	65	
Error of omission	0.00	16.65	25.00	20.00	20.00	0.00	0.00		

8.1.2. Confusion matrix (2002)

Class name	Forest	Farmland	Fallow	Grass	Marshy area	Built-up/bare	Cloud	Totals	Error of commission %
Forest	11	1	0	2	0	0	0	14	21.43
Farmland	4	12	0	1	2	0	0	19	36.84
Fallow	1	0	3	0	0	0	0	4	25.00
Grass	3	0	0	3	0	0	0	6	50.00
Marshy area	0	0	0	0	2	0	0	2	0.00
Builtup/bare	0	0	0	1	0	7	0	8	12.50
Cloud	0	0	0	1	0	0	0	1	0.00
Totals	19	13	3	8	4	7	0	54	
Error of omission	0.00	7.69	0.00	62.50	50.00	0.00	0.00		

8.1.3. Change detection matrix (2010-2002)

Land cover type	Forest	Farmland	Fallow	Grass	Marshy area	Builtup/bare
Forest	**425.98**	819.90	417.15	138.51	121.05	76.32
Farmland	474.48	**1061.73**	572.13	210.87	212.67	161.82
Fallow	107.73	451.17	**224.91**	118.62	85.32	94.41
Grass	192.51	847.17	469.26	**224.91**	229.84	223.74
Marshy area	167.58	442.19	216.09	67.86	**94.5**	53.46
Builtup/bare	81.45	467.01	275.58	180.27	171.09	**415.8**
Cloud	31.86	79.56	38.97	16.66	21.42	27.63

8.2 Appendix B

Bomfa (Statistical Analysis Results)

t-Test: Paired Two Sample for Means		
	High income Values(Bomfa)	*low income Values(Bomfa)*
Mean	14.5	16.66666667
Variance	51.5	57.06666667
Observations	6	6
Pearson Correlation	-0.110676746	
Hypothesized Mean Difference	0	
Df	5	
t Stat	-0.483341516	
P(T<=t) one-tail	0.32463788	
t Critical one-tail	2.015048372	
P(T<=t) two-tail	0.64927576	
t Critical two-tail	2.570581835	

Apemso (Statistical Analysis Results)

t-Test: Paired Two Sample for Means		
	Low income Values (Apemso)	*High income values (Apemso)*
Mean	14.28571429	9.857142857
Variance	95.23809524	23.80952381
Observations	7	7
Pearson Correlation	0.0325	
Hypothesized Mean Difference	0	
Df	6	
t Stat	1.088110092	
P(T<=t) one-tail	0.159155671	
t Critical one-tail	1.943180274	

P(T<=t) two-tail	0.318311342	
t Critical two-tail	2.446911846	

Kotey (Statistical Analysis Results)

t-Test: Paired Two Sample for Means		
	Low income Values (Kotey)	*High income Values (Kotey)*
Mean	16.66666667	15
Variance	76.66666667	80
Observations	6	6
Pearson Correlation	-0.766130878	
Hypothesized Mean Difference	0	
Df	5	
t Stat	0.245440347	
P(T<=t) one-tail	0.407935742	
t Critical one-tail	2.015048372	
P(T<=t) two-tail	0.815871484	
t Critical two-tail	2.570581835	

8.3 Appendix C

Field pictures

Plate 1: Field pictures showing mapping and valuation of key ecosystem services found in the study area

Plate 2: Field pictures showing the valuation of land cover types in the study area

8.4 Appendix D

Determination of income groups of respondents

Questionnaire						
Date:						
1	**General Information**					
	Field enumerator:	Village:				
2	**Respondent Information**					
	Name:	Gender:	F ( )	M ( )		
	Occupation:	Farmer	Hunter	Palm wine Tapper	Trader	Other (specify
3	**Provisioning Ecosystem Services (Harvestable)**					
a	What quantity of the following items do you usually collect per month?					
	Medicinal plants (no. of sacks) [ ] Fuel wood (no. of bunches) [ ] Snail (small baskets) [ ] Mushroom (kilos) [ ] Fruit [ ] Bush meat [ ] Water [ ] Other (Specify)					
b	How long does it take to sell all the ecosystem services collected?					
	One week [ ] Two weeks [ ] Three weeks [ ] Four weeks [ ] Other (Specify)					
c	Do you have any other source of income other than the selling of harvestable ESS? Yes [ ] No [ ]					
	If Yes, indicate your occupation Farming [ ] Trading [ ] Hunting [ ] Other (Specify)					
d	If farming, what type of crop you grow? Cocoa[ ] Oil palm [ ] Citrus [ ] Other (Specify)					
4	**Price valuation**					
a	Price list of items?					

Services (Harvestable)	Unit of Measurement	Price (cedis)	Remarks
Mushroom	½ kilo	1	

Snail	4kilos	20	
Medicinal Plants	1 meter long sack	10	
Bush meat	5kilos	20	Medium size
Water	25litres	0.3	30 pesewa per container
Honey	1 beer bottle	20	
Fruits	100 pieces per basket	15	Pear and oranges
Fuel wood	1Bunch	3	Small Bunch
Cane	1Bunch	10	

Alternative source	Unit of Measurement	Price (cedis)	Remarks
Cocoa	60 kilos	212	I sack
Oil palm	1 ton	160	
Citrus farm	1 meter long sack	50	
Other (specify			

Sample of income determination

1. **Respondent A (Trades only harvestable ESS)**

Harvestable ESS	Quantity collected per month (kilos)	Estimated cost per month (cedis)
Mushroom	10	20
Snails	10	50
Bush meat	15	60
Total		130

Total cost per month for Respondents A: 130 cedis
Minimum daily wage (GSS): 4.48 cedis ($ 2.4 US)
Average days per month: 30 days
Estimated daily wage for Respondents A: 130/30 days ; 4.30 cedis ($ 2.2 US)
Comparing Estimated daily wage to Minimum daily wage (GSS): 4.30 cedis ($ 2.2 US): 4.48cedis ($ 2.4 US).
Respondents A is categorised as low income group.

2. **Respondents B (Trades in harvestable ecosystems and other income sources)**

Sale of Cocoa
Number of hectares of cocoa farm: 5
Average number of bags per 5 hectares: 26 bags (1560 kilos)
Sells cocoa beans quarterly (3 months)
60 kilos (1 bag) of cocoa beans: 212 cedis
Estimates cost of cocoa per 3 months: 5512 cedis
Estimated daily wage (sale of cocoa): 61.2 cedis ($ 32.2 US

Harvestable ESS	Quantity collected per month (kilos)	Estimated cost per month (cedis)
Medicinal plants	5sacks	50
Honey	5bottles	100
Total		150

Total cost per month for Respondents B (Harvestable ESS): 150 cedis
Minimum daily wage (GSS): 4.48 cedis ($ 2.4 US)
Average days per month: 30 days

Estimated daily wage for Respondents B (Harvestable ESS) : 150/30 days ; 5 cedis ($ 2.6 US)
Total daily wage of Respondents B: Estimated daily wage of harvestable ESS + Estimated daily wage from sale of cocoa: (61.2 + 5) cedis: 66.2 cedis ($ 34.8 US)
Comparing Estimated daily wage to Minimum daily wage (GSS): 66.2 cedis ($ 34.8 US): 4.48cedis ($ 2.4 US).
Respondents B is categorised as high income group

8.5 Appendix E

Respondent's questionnaires

Questionnaire						
Date:						
1	**General Information**					
	Field enumerator:	Village:				
2	**Respondent Information**					
	Name:	Gender:	F ( )	M ( )		
	Age:	Income group	Low ( )	High ( )		
	Level of Education:	Illiterate [ ]	Literate [ ]	Primary [ ]	Secondary [ ]	Tertiary [ ]
	Occupation:	Farmer	Hunter	Palm wine Tapper	Trader	Other (specify
3	**Provisioning Ecosystem Services (Harvestable)**					
a	Which of the following items do you usually collect for use?					
	Medicinal plants [ ] Fuel wood [ ] Snail [ ] Mushroom [ ] Food [ ] Bush meat [ ] Water [ ] Other (Specify)					
b	For what purpose do you collect them?					
	Family use/food [%] Commercial purpose [%] Other (Specify)					
c	Where do you usually collect them?					
	Forest [ ] Fallow lands [ ] Farmlands [ ] Grassland [ ] Other (Specify)					
d	Could you indicate these areas on the map/image?					

4	**Valuation**
A	Given 100 pebbles how many would you assign to the following services by importance?

Services (Harvestable)	Values	%	Remarks
Mushroom			
Snail			
Medicinal Plants			
Bush meat			
Water			
Honey			
Food			
Fuel wood			
Cane			

B	Given 100 pebbles how many would you assign to the following Land covers based on their importance for collection?

Land cover	values	%	Remarks
Forest			
Fallow land			
Farmland			
Grassland			

C	Please indicate areas where each service is collected on the map and give values to these locations in order of importance. 5 [ ] 10 [ ] 20 [ ] 30 [ ] 40 [ ] 50 [ ] Above 50 [ ]
D	How far do you walk to collect these things? Kilometers ( ) Hours ( )