Assessing and Mapping Ecosystem Services in Offinso District, Ghana

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by

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Abstract

Forest and tree based ecosystems provide numerous services that constitute the livelihood of local people. The identification of what are the ecosystem services known and important by local people contributes in giving a better understanding of the relation between the forests and tree based ecosystems and the services that they provide for them. The aim of this study is assessing and valuing the main provisioning services provided by the forest and tree-based ecosystems, based on the community perception and compares this with the potential market value of the locally not recognized or appreciated carbon sequestration. There are five main steps in this study to asses and value the ecosystem services: 1) generating land cover as basic spatial information; 2) identification of the services provided by the ecosystem; 3) identification the criteria and indicators that can be used as the basis for valuation and mapping; 4) GIS techniques to map the ecosystem services valuation; 5) Compare the provisioning services based on people perception and the market value of the locally not recognised carbon sequestration service. Discussion, interviews and questionnaires were done to obtain the information on valuation of the ecosystem services from the local community.

4 main land cover types were identified as service provider: annuals, forest, grass and teak monoculture. Annuals appear in two different land uses types, farmland and agro-forest. From this study reveals that, provisioning services are recognized by all respondents from different gender, education level and villages. The main provisioning services are bush meat, grass, fuel wood, medicinal plants and lumber. One of the supporting services that is recognized by local communities is maintaining soil fertility and the few of regulating services are water and fresh air provision. However, when carbon sequestration knowledge was being explored, none of the respondents recognized carbon sequestration as one of the services provided by the ecosystem.

The criteria that used for the valuation are; 1) the importance of land cover based on its relative importance as collection place for a specific service; 2) the importance of a specific land cover type as the total services provider; 3) the availability of land cover. From the land cover valuation based on its relative importance as a collection place for a specific service, annuals (taungya) receive the highest value as collection place for bush meat, fuel wood, medicinal plants and lumber. As for grass collection, obviously grass land receives the highest value from local people. Regarding the importance of each land cover as total services provider used as the criteria, annuals, again received the highest value, followed by grass, forest and teak monoculture. The land cover valuation map as total services provider (second criterion) is then combined with the third criterion, the walking distance. It can be seen that the further people need to walk to reach the collection place, then the lower the value that they put.

It shows that the dependency of the local people on annuals is high, but it is actually the value of the mixed (taungya) system. Annuals are not only capable of providing the provisioning services but also sequestering the carbon. The total carbon stored in woody biomass in study area is 3,191.46 G g. The highest carbon stored in woody biomass is registered in annuals (1,661 G g), followed by forest (1,281 G g), teak monoculture (206 G g) and grass (43 G g). For the Agro-forest, which is part of a reforestation project the sequestered carbon in 5 years time was prediction, provided that trees are left undisturbed. From the carbon prediction, agro-forest will sequester 1,796 G g carbon in 5 years time if the trees in agro-forest are left undisturbed. It means that agro-forest sequestered 743 G g carbon more from the current carbon stock, which could provide a considerable incentive to local people and convince them to manage trees sustainably.

Key words: Ecosystem services valuation, local people, provisioning services, carbon sequestration.

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Arinta Hapsari
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-I dedicate this piece of work for mamah and papah, the my so-ever-two-persons I love the most in the whole universe-

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1. Introduction

1.1. Background

An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit. Humans are an integral part of ecosystems. Ecosystems provide a variety of benefits to people. For many rural people, the environment and natural resources are keys to their livelihood, and land, agriculture and livestock are often seen as the backbone of development. Figure1 below shows that the livelihood of the people constitutes by the agriculture products and the ecosystems services.

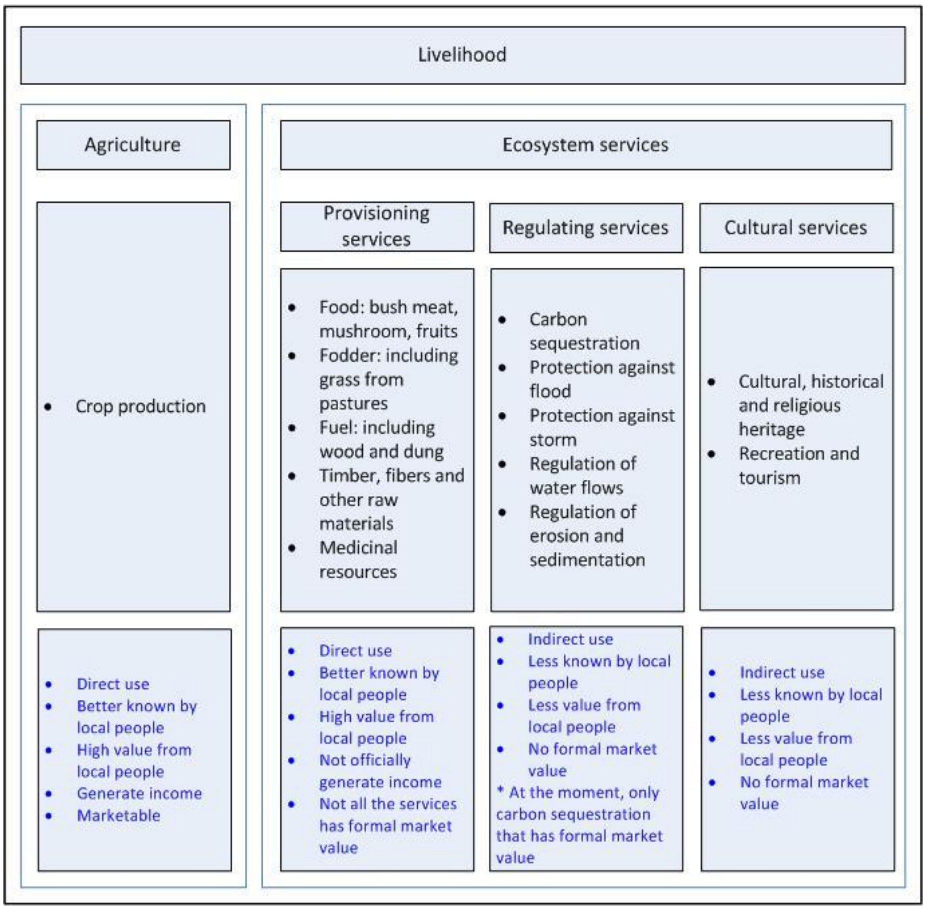

Figure 1 Livelihood of local people

(de Groot et al., 2002, Hein et al., 2006, Jim and Chen, 2009, MA, 2003a, Nasi et al., 2002, Paavola, 2008)

Apiah et al (2007) gives an overview from their research result, by giving the questionnaire to the 431 respondents in randomly selected district in Ghana, reveals that income from sale of agricultural crops and domestic animals constitutes 60% of the average total household income among sample households. However forest products are also important as their livelihood sources, providing 38% of household income of sampled households. And the two percents of household income came from off-farm job.

Ecosystem services research has become an important area of investigation over the past decade. The number of papers addressing ecosystems services is rising exponentially (Fisher et al., 2009). The 2003 Millennium Ecosystem Assessment (MA) found out that globally 15 of the 24 ecosystem services investigated are in a state of decline and this is likely to have a large and negative impact on future human welfare. Thus, the MA was forced to initiate increased and concerted research on measuring, modelling and mapping ecosystem services with respect to human welfare. Furthermore, (Kumar and Kumar, 2008) emphasized that thanks to the understanding that the valuable services provided by ecosystems may be lost and degraded, scientist and decision makers develop an interest to study various aspects of the ecosystem services.

Valuing the ecosystems service itself has been a challenging issue for economists. MA (MA, 2003b) reported that one paradigm of value, known as the utilitarian (anthropocentric) concept, is based on the principle of humans' preference satisfaction (welfare). In this case, ecosystems and the services they provide have value to human societies because people derive utility from their use, either directly or indirectly (use values). However, such values are difficult to objectively measure and quantify, thus, there is a growing concern to develop methodologies to capture the total and incremental changes in services of different types of ecosystems that are mainly, due to human activities (Kumar and Kumar, 2008).

Methodologies in mapping the services provided by the ecosystem have been discussed by among others, (Troy and Wilson, 2006), (Egoh et al., 2008), (Raymond et al., 2009), (Smith and Scherr, 2003) and (Chen et al., 2009). MA (2003) underlined that the spatially defined ecosystem is the basic unit for analyzing the services value provided by the ecosystem. Mapping is considered as the way to spatially define the ecosystem and its services. Visualizing the extent of the ecosystem and the value in each service will give a contribution to understand the current spatial extent and condition of the ecosystem, the quality, quantity, and spatial distributions of services provided by the ecosystems, and who uses and what is the service's use.

The heterogeneity of resources and ecosystem services require spatial visualization to understand the interaction of the biophysical and socio economic. Moreover, (Chen et al., 2009) emphasized that the valuation of ecosystem services will suggest us how wealthy the nature is and how much benefits we can obtain from ecosystem including the benefits we can perceive and those we can not.

1.2. Research Problem

Services provided by forest and tree based ecosystems have a large contribution in supporting the livelihood of the local people live in its surrounding. (Youn, 2009) emphasized more that it is a common fact that people living in remote areas, in this case, surrounding the forest, are dependent on resources available in the area.

The identification of what are the ecosystem services known and important by local people will contribute in giving a better understanding in the relationship between the forests and tree based ecosystems and the services that they provided. Apart from that, the information will also become the basis data for the valuation. However, as (Hein et al., 2006) stated that up to now, local people have more knowledge and experience of the benefits from the services in the provisioning (harvestable goods such as bush meat, fruits, food, fibre, fuel and water).

(Vermeulen and Koziell, 2002), identifies that value that put on the ecosystem services depends upon the views and needs of stakeholders. As local people are considered as one of the stakeholders of the forest and tree based ecosystems, thus they have their own value that they put on the services. However, such values are difficult to measure and quantify (Kumar and Kumar, 2008). Until today there is no certain method in valuing the services provided by ecosystem. There are no widely accepted methods for quantification and valuation of the ecosystem services provided by forest (Jim and Chen, 2009). The criteria and indicators that they put as the basis for their valuation are important in valuing the services. Therefore this study will focus on research to develop method of assessment in valuing and mapping the provisioning services provided by forest and tree based ecosystem based on the criteria and indicators from local people perspective.

Apart from the provisioning services, there are many other services that provided by forest and tree based ecosystems. Supporting, regulating and cultural services are also provided by these ecosystems. Moreover, (de Groot et al., 2002) emphasized that natural ecosystem provide almost unlimited opportunities for spiritual enrichment, mental development and leisure. From regulating services functions, (Jim and Chen, 2009) highlight in their research, that forest ecosystem could generate particular services, such as removing air pollutant, regulating the microclimate and carbon sequestration. All of these services also contribute to improve the quality of environment, and consequently, improve the quality of people’s life. However, most of these services are hardly recognized by local people as they don’t have direct benefit from them, but they are nevertheless essential to human existence on earth, and of course have equally importance or might be more importance value compared to the provisioning services.

One of the regulating services that currently receive many attentions from world wide is carbon sequestration. For many years, carbon sequestration is considered to have little or no economic value, since they are not commercially marketable. However, this has changed with the development of the carbon market and with the increasing understanding of the importance of these services for human’s daily life. From this development of carbon value, perhaps even economic value of this carbon is higher than the value of other services. And maybe by knowing that any carbon has a very important value, it is possible that local people will become aware and not indiscriminate tree felling. Therefore in this study will also assess of the value of this carbon to the value of provisioning services. Therefore becomes important to know the value of the carbon stock and its prediction in the particular years to come.

1.3. Research objective

1.3.1. General objectives

The research objective is assessing and valuing the main services provided by the forest and tree-based ecosystems in the study area, based on people perception and compares this with the market value of the locally not recognised carbon sequestration service.

1.3.2. Specific objectives

1. Identifying and prioritizing the services provided by the ecosystem based on people perspective.
2. Defining the boundaries of the ecosystem and indicators for valuation.
3. Mapping the services from the local people perspective.

4. Valuing the carbon sequestration as one of the services provided by the ecosystem from people perspective, formal value and prediction of prospective yield/value using modelling.

1.4. Research questions

1. What are the land cover type/ecosystems in the study area?
2. What are the services provided by these ecosystems in study area?
3. What can be indicators to measure the value of these services?
4. How it can be mapped?
5. What is the value of the regulating service aboveground carbon stored in woody biomass of the forest and tree based ecosystems in the study area?
6. How the prediction of the (carbon) profit is could be in 5 years time if trees are left undisturbed?
7. How does this relate to the other services as valued by the people?

2. Concepts and Definition

2.1. Ecosystem services

Ecosystem services research is a rapidly growing field , and even the term itself may be relatively new, but an understanding that nature provides services for human welfare has been known since ancient times (Fisher et al., 2009). Despite the history of the concept, the literature does little to distinguish exactly how ecosystem services should be defined (Boyd, 2007; Barbier, 2007). Based on (Fisher et al., 2009), there are three common definitions of ecosystem services that are often cited:

1. The conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life (Daily, 1997a).
2. The benefits human populations derive, directly or indirectly, from ecosystem functions (Costanza et al., 1997).
3. The benefits people obtain from ecosystems (MA, 2005).

Furthermore, the 2003 Millennium Ecosystem Assessment (MA) grouped ecosystem services into four broad categories:

1. Supporting services, these underpin the provision of other services, e.g. nutrient cycling and soil formation;
2. Provisioning services, harvestable goods such as bush meat, fruits, food, fibre, fuel and water;
3. Regulating services, responsible for maintaining biological diversity itself, including natural purification process and dynamics, such as water purification, biological control mechanisms, carbon sequestration, pollination of commercially valuable crops; and
4. Cultural services, providing a source of artistic, spiritual, religious, recreational or scientific enrichment or non-material benefits.

Another interesting idea comes from (de Groot et al., 2002) that used the term of ecosystem functions which reflects to the goods and services provided by the ecosystems, and grouped the ecosystem functions into four main categories:

1. Regulation functions: this group of functions relates to the capacity of natural and semi-natural ecosystems to regulate essential ecological processes and life support systems through bio-geochemical cycles and other biosphere processes. These regulation functions provide many services that have direct and indirect benefits to humans (such as clean air, water and soil, and biological control services).
2. Habitat functions: natural ecosystems provide refuge and reproduction habitat to wild plants and animals and thereby contribute to the (in situ) conservation of biological and genetic diversity and evolutionary processes.
3. Production functions: Photosynthesis and nutrient uptake by autotrophs converts energy, carbon dioxide, water and nutrients into a wide variety of carbohydrate structures which are

then used by secondary producers to create an even larger variety of living biomass. This broad diversity in carbohydrate structures provides many ecosystem goods for human consumption, ranging from food and raw materials to energy resources and genetic material.

4. Information functions: Because most of human evolution took place within the context of undomesticated habitat, natural ecosystems provide an essential ‘reference function’ and contribute to the maintenance of human health by providing opportunities for reflection, spiritual enrichment, cognitive development, recreation and aesthetic experience.

(Hein et al., 2006) (based upon Ehrlich and Ehrlich, 1981; Costanza et al., 1997; De Groot et al., 2002; Millennium Ecosystem Assessment, 2003) gives more clear and short on the grouping of the ecosystem services. (Hein et al., 2006) grouped the ecosystem services in three categories:

1. Production services, refers to goods and services produce in the ecosystem
2. Regulation services are the result of the services from the capacity of ecosystems to regulate climate, hydrological and bio-chemical cycles, earth surface processes and variety of biological processes.
3. Cultural services relates to the benefits people obtain from ecosystems through recreation, cognitive development, relaxation and spiritual reflection.

All those definitions show the strong relationship between humans and their ecosystems, related to the services provided by the ecosystems to support their life. The conceptual framework for the MA places human well-being as the central focus for assessment. MA (2003) grouped the drivers of change in ecosystems into indirect drivers and direct drivers as shown in Appendix 1.

The figure shows the importance of the relationships among the drivers of change to ecosystem services, both direct and indirect and the ability of ecosystems to provide services to support of the human well being. Human activities are extremely impacted the changes in ecosystems. Demands for ecosystem services, for example timber, food, fuel wood and medicinal resources are increasing, and at the same time degrading the ability of the ecosystems to fill these demands.

Another similar view on the relationship between ecosystem services and human being is given by (Swift et al., 2004) and (Matson et al., 1997), that humans have evolved as part of the world’s ecosystems, depending on them for food and other products and natural ecosystems, as well as those modified by humans, provide many services and goods that are essential for humankind.

(Metzger et al., 2006) furthermore, emphasized that the future and current capability of ecosystems to provide the services is determined mainly by changes in socio-economic characteristics, land use, biodiversity, atmospheric composition and climate. Those changes are mainly happen due to human activities. And as urban population is increase, then natural ecosystems become deteriorated. Land use changes may reduce local species and decline the natural habitat and ecosystem functioning, and thus affecting the capability of the ecosystems to provide the services.

People take decisions concerning ecosystems based on considerations for their own well being. Therefore, it is assumed by (MA, 2003b)that a dynamic interaction exists between people and other parts of ecosystems, and its changes will cause the changes in ecosystems and the human well being itself . At the same time, many other independent factor of the environment, change the human condition and many natural and artificial (industry) forces are influencing ecosystems. The changes in ecosystems will contribute the changes (can be positive and negative) in the human being welfare as well.

This implies that the relation between the human activities and the changes in the ecosystems should be well understood in order to manage the ecosystems and maintain the ability in supplying the services needed by human beings.

2.2. Ecosystem services valuation

Valuation is a set of multiple activities that answer the question ‘how valuable is an ecosystem?’ and ‘how valuable to whom’, and it can be interpreted in many different ways. It has often been argued that a main reason for the failure in conserving the natural ecosystems is that we do not realize how valuable the ecosystems are. Such concerns lead to an effort to value natural ecosystems and the services they provide.

MA (2003) underlines that valuation of the ecosystem services is important since it can be used and or applied in many ways: to assess the total contribution that ecosystems make to human well-being, to understand the incentives that individual decision-makers face in managing ecosystems in different ways, and to evaluate the consequences of alternative courses of action. Assessing the values of ecosystem services play various and important roles in linking human activity and natural systems.

Hein *et al*., (2006) remarked that since the late 1960s, the valuation of ecosystem services has received ample attention in scientific literature. There are many frameworks concerning the valuation of the ecosystem services that have been developed among the scientist (Egoh et al., 2008, Raymond et al., 2009, Troy and Wilson, 2006, Hein et al., 2006, Kumar and Kumar, 2008).

(Cowling et al., 2007) proposed an operational framework for mainstreaming the management of ecosystem services into all resource management sectors. This framework highlights the need to combine assessment of biophysical, economic and social context with considerations of implementation opportunities and constraints into strategy development, implementation and management involving stakeholders. This study addresses the biophysical assessment which is similar in some respects to the assessment phase of systematic conservation planning which deals with the identification of geographic areas to ensure the effective conservation of biodiversity.

(Troy and Wilson, 2006) builds a framework upon the value transfer methodology. The framework consists of five core steps:

1. Spatial designation of the study extent;
2. Establishment of a land cover typology whose classes predict significant differences in the flow and value of ecosystem services;
3. Meta-analysis of peer-reviewed valuation literature to link per unit area coefficients to available cover types;
4. Mapping land cover and associated ecosystem service flows;
5. Calculation of total ESV and break down by cover class;

(Egoh et al., 2008) is present the people values mapping method. The method is considering identifying, measure and mapping the community values and threats towards natural capital assets and ecosystem services in the landscape to inform planning for conservation and environmental management. A Geographic Information System (GIS) was used to map the multiple place-specific values and threats and the spatial heterogeneity was analyzed.

(Chen et al., 2009) developed technical framework of valuation and visualization, and use three key steps, the steps are:

1. Identification of study area, as any other analysis, valuation requires that the object of the valuation should be clearly defined.
2. Data collection, provides a data basis for spatial analysis
3. Mapping, to visualize the result

(Hein et al., 2006) developed framework for the valuation of ecosystem services. This valuation framework is applicable to all ecosystems, but it will be in general being more useful to apply to natural or semi natural systems. The framework grouped valuation of ecosystem services into four steps, namely:

1) Specification of 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 ecosystem services valuation framework from (Hein et al., 2006) is shown in Figure 2.

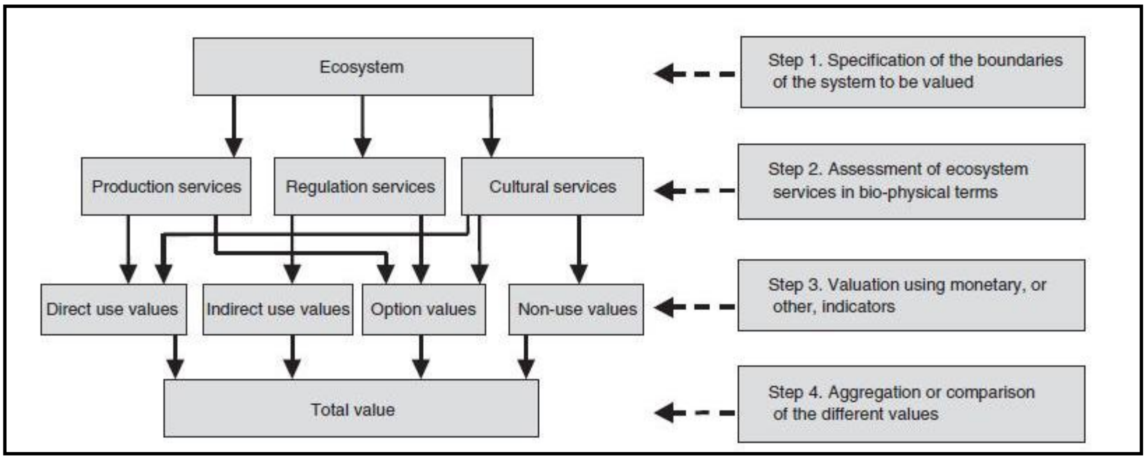

Figure 2 Valuation framework developend by (Hein et al., 2006)

From all the valuation frameworks mentioned above, it can be seen that most of the framework for valuation should start with spatially define the location to be valued. Continue with the assessment, by asking question, “Who is the user?” “What is use?” “and For what purpose?” “Which ecosystem is providing what?” The answer of all those questions will give a good understanding on the relationship between the ecosystem services and their beneficiaries. Then, we can start to assess the value of the ecosystem. The valuation itself can be monetary value, or any other valuation, for example value from local people perspective. Mapping will be the last step to do. Mapping is important to visualize the result of the valuation.

For the purpose of the research in this study, valuation framework developed by (Hein et al., 2006) will be adopted.

2.3. Services provided by forest and tree based ecosystems

MA (2003) stated that forest ecosystems are extremely important refuges for terrestrial biodiversity, a central component of Earth's biogeochemical systems, and a source of ecosystem services that essential for human well-being. The area and condition of the world's forests has, however, declined throughout recent human history. The services provided by forests are numerous and diverse on all spatial and temporal levels, and include provisioning, regulating, cultural, and supporting services.

Moreover, (Vedeld et al., 2007) stated that forest have a very high benefit to the people who live in its surrounding. The benefit is ranging from being a source of agricultural land to non-timber forest products, timber and providing for a range of on-site ecological services.

(de Groot et al., 2002) mentioned that natural and semi-natural ecosystems, in this case related to forest ecosystem, provide many resources, and grouped the services into production services. The services are ranging from oxygen, water, food, medicinal and genetic resources to sources of energy and materials for clothing and building. Although today most foods are derived from cultivated plants and domesticated animals, but a substantial part of the global human food intake still comes from wild plants and animals. Natural ecosystems are an almost unlimited source of edible plants and animals, ranging from game and bush meat, fish and fowl, to vegetables, fungi, fruits, and such exotic items as birds' nests and sponges.

(Jim and Chen, 2009) give another overview on forest services and put the focus on the regulating services. These authors note that the major ecosystem services provided by forest are the regulating services. The forest ecosystems could generate significant services, such as offsetting carbon emission, removing air pollutants, regulating the microclimate, and recreation. These services contribute to improve the quality of environment, life and sustainable urban development.

Cultural services considered as the services that provided by the forest ecosystem as well. As (Hein et al., 2006) note that forest ecosystem provides cultural services through the provision of cultural, historical and religious heritage and opportunities for recreation and tourism. While (de Groot et al., 2002) put the cultural services from the forest as the information functions from the ecosystem. Natural ecosystems, in relation with the forest ecosystem, provide almost unlimited opportunities for spiritual enrichment, mental development and leisure. Therefore it is considered as a vital source of inspiration for science, culture and art.

The compilation of the services provided by forest ecosystem that will be a reference to conduct the research in this study is shown in Table 1.

Table 1 Services provided by forest ecosystem

Provisioning	Regulating	Cultural	Supporting
1. Timber 2. Fuel wood 3. Food (fruits, bush meat, mushrooms etc.) 4. Fodder (including grass from pastures) 5. Medicinal resources	1. Regulation of hydrological cycles 2. Climate regulation 3. Carbon storages 4. Pollination	1. Protection of natural and cultural heritage 2. Recreation and tourism opportunities	1. Generation and preservation of soils and renewal of their fertility 2. Cycling and movement of nutrients

(Hein et al., 2006, MA, 2003b, Boyd and Banzhaf, 2007, de Groot et al., 2002, Jim and Chen, 2009)

However, MA (2003) also considered trees outside the forest, which occur in many formations such as shelterbelts, shade and other elements of agro forestry, roadside plantings, orchards, individual trees on farms and other private land, to have a value to human being welfare. Tree based systems outside the forest also provide important services, including contributing to food security, particularly for the local people lives in it's surrounding.

Food crops that are provided by the agro-forestry systems are not considered as ecosystem services. In agro-forestry, people grow the crop in purpose. They put investment and effort (labour, fertilizer etc.) to ensure that their crop will fulfil their daily consumption and their income. Those investment and effort that they put on their crop in agro-forestry that makes the food provide form the crop is not considered as ecosystem services. Because services that provided by the ecosystems will considered as the ecosystem services if people can directly obtain and or benefit the services from the ecosystem functions (MA, 2003b, Fisher et al., 2009, de Groot et al., 2002, Hein et al., 2006, Costanza et al., 1998).

Furthermore, (Nasi et al., 2002) underline in their report that forest and tree-based systems are among the most important providers of ecosystem services for the whole world, since the services provided by them are essential to the survival of human beings. Forest and tree-based systems operate and provide services that cannot effectively replaced by technology.

2.4. Provisioning services

Direct use values are derived from ecosystem services that are used directly by humans. They include the value of consumptive uses, such as harvesting of food products, timber for fuel or construction, medicinal products and hunting of animals for daily consumption (MA, 2003). Those services are so called provisioning services which reflect goods and services produced by the ecosystems (Hein et al., 2006). The provisioning services obtained from the forest and tree based ecosystem have substantial value to the local communities that live in its surroundings.

Therefore, provisioning services considered as the better known services compare to other services. Many examples (such as fruits, timber, and medicinal products) of these services a have a market value, not only because it is needed for daily consumption but also generate income for people. Apart from the market value, people also put the value in the provisioning services based on their importance in supporting their daily consumption (Hein et al., 2006, de Groot et al., 2002, Patterson and Coelho, 2009).

The direct benefits from the provisioning services and the value that local people put on it will be the focus of the research in this study.

2.5. Above-ground woody biomass as one of the carbon pools

Regulating services are the benefits people obtain from the regulation of ecosystem processes, including air quality maintenance, climate regulation, erosion control, regulation of human diseases, and water purification (MA, 2003). These services are indirectly provided support and protection to human activities. Carbon sequestration is considered as one of the regulating services due to the capacity of ecosystems to regulate climate (Hein et al., 2006).

Regulating services is considered having the indirect benefits human life. Therefore, they are often not recognized until they are lost or disturbed, but they are nevertheless essential to human existence on earth. (de Groot et al., 2002).

Carbon is the fourth richest element in the universe (Harrison, 2003), and it is present in the earth atmosphere predominantly as the gas carbon dioxide (CO_2). This cycle consist of several storage pools of carbon and the processes by which the various pools exchange carbon. If more carbon enters a pool than leaves it, that pools is considered a net carbon sink. If more carbon leaves a pool than enters it, that pool is considered net carbon source (Harrison, 2003).

It plays an important role in supporting life. Every organism needs carbon either for structure, energy, or as in the case of humans, for both. It is converted to carbohydrates by the process of plant photosynthesis. Terrestrial plants capture CO_2 from the atmosphere. Plant, soil and animal respiration returns carbon to the atmosphere, as does burning biomass. CO_2 fluxes between the atmosphere and ecosystems are primarily controlled by absorbing through plant photosynthesis and release via respiration, decomposition and combustion of organic matter. Plant biomass, including above-ground and below-ground parts, is the main channel for CO_2 removal from the atmosphere. Large amounts of CO_2 are transferred between the atmosphere and terrestrial ecosystems, primarily through photosynthesis and respiration (Harrison, 2003, IPCC, 2006, MA, 2003b).

Biomass is defined as the total quantity of live and inert or dead organic matter, above and below the ground, expressed in tones of dry matter per unit area, such as hectares. Above-ground biomass is expressed as tones of biomass or carbon per hectare and it is the most important and visible carbon pools, and the dominant carbon pool in forests and plantations, although not in grass and cropland (Ravindranath and Ostwald, 2008).

Above ground biomass is all biomass of living vegetation both woody and herbaceous, above the soil including stems, stumps, bark, seeds and foliage. Biomass is converted to carbon by multiplying it with a carbon fraction of dry matter. The exact value of the fraction varies within a small range for different species and components of plants, and is usually about 0.5 Based on (IPCC, 2006).

2.6. Land cover mapping

Satellite data can contribute to the provision of several types of information needs for assessment of ecosystem condition, including land cover mapping (MA, 2003). The objective of land cover mapping is to mimic the earth surface as much as possible by delineating the different features as they exit in the nature (Campbell, 2002).

Land cover classification is the procedure most often used for quantitative analysis of remote sensing image data. The steps for land cover classification are as follows (adopted and modified from (Han et al., 2002)):

1. Determine the type and number of desired class
2. Choose the representative pixels from each class as training data. Training data can be obtained from field visit, available maps, air photograph, and even from the interpretation of image color composite.
3. Choose the classifier algorithm and use the training data to classify the image.
4. Produce thematic maps that summarize the result of classification

In this research, generating the land cover map is based on the understanding of the ecosystem valuation framework, built by (Hein et al., 2006). In the valuation framework, the first step of the ecosystem services valuation is to spatially define the ecosystem itself. By generating the existing land cover map, this will give a contribution of understanding the basic information to asses the ecosystem services and consequently becomes the boundary of the ecosystem to be valued.

2.7. Spatial multi criteria evaluation

Multi criteria analysis (MCA) is a tool for comparison in which several points of view are taken into account, and therefore is particularly useful during the formulation of a judgment on complex problems. The analysis can be used with contradictory judgment criteria or when a choice between the criteria is difficult. It is developed for complex-multi criteria problems that include quantitative and/or qualitative aspects of the problem (EU, 2009, CIFOR, 1999).

Furthermore, (CIFOR, 1999) indicates that the two simplest MCA methodologies are ranking and rating. *Ranking* involves assigning each decision element a rank that reflects its perceived degree of importance relative to the decision being made. The decision elements can then be ordered according to their rank (first, second etc.) *Rating* is similar to ranking, except that the decision elements are assigned ‘scores’ between 0 and 100. The scores for all elements being compared must add up to 100. Thus, to score one element high means that a different element must be scored lower.

The combination of multi criteria evaluation methods and spatial analysis (GIS) is referred as spatial multi criteria evaluation (SMCE) (Kheirkhah Zarkesh et al., 2005). The most significant difference between multi criteria analysis and spatial multi criteria analysis is the use of spatial components. Therefore, geographical data is requires as the input data on SMCE (Kamruzzaman, 2007).

It is important to understand that the critical aspect of SMCE is the involvement of the geographical events based on the criterion values and the stakeholders’ preferences with respect to a set of evaluation criteria. This implies that the result of the analysis not only depends on the availability of geographical data and its distribution, but also on the valuation given by the stakeholders based on their preferences on a set of criteria.

2.8. Criterion map

Criteria for evaluation can be identified using survey of opinions. Such methods as the key information approach and nominal group process can be used to identify a set of criteria for a particular evaluation.

Layers representing evaluation criteria are referred to as criterion maps. The process of generating the criterion maps is based on GIS functions, which include geographical data input, storage, analysis and output (Malczewski, 1999).

3. Materials and Methods

3.1. Study Area

3.1.1. Location and extent

The study is conducted in Offinso District in Ashanti Region, Ghana. The study concentrated in Afram Headwaters Forest Reserve and the surrounding off reserve (Figure3). Off reserve in this study refers to the area in 1 km buffer from the Afram Forest Reserve boundary. 5 communities are chosen as the source of local people perspective valuation.

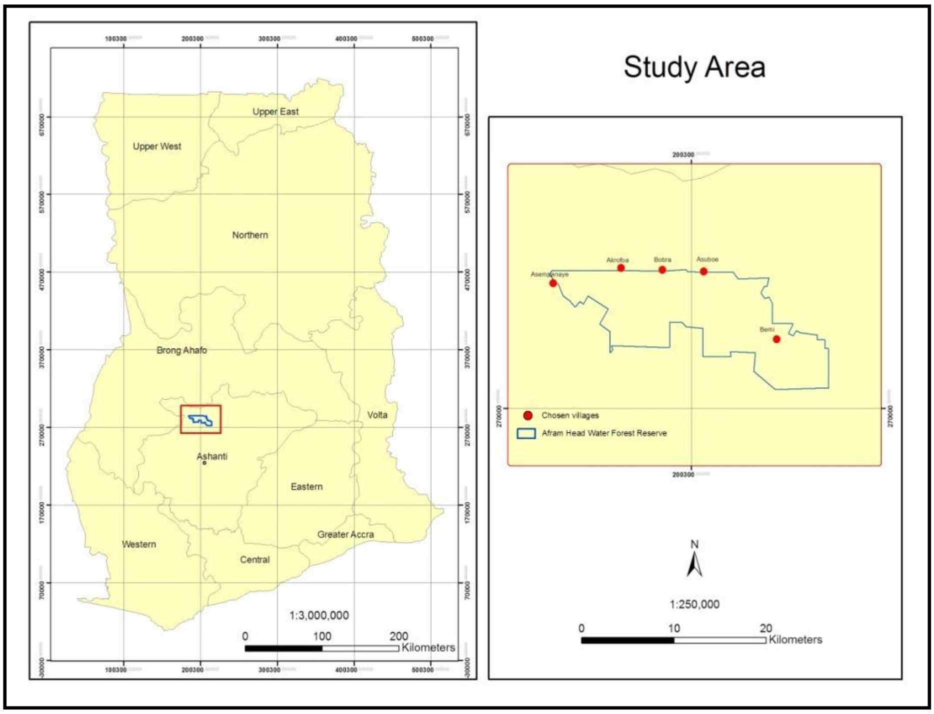

Figure 3 Study area

3.1.2. Vegetation

The area is categorized under the Dry Semi-deciduous forest Fire Zone subtype (DSFZ). It is found within the forest-savanna transition zone of Ghana. It is characterized by sparse woody understory and well illuminated forest floor. Original forest, degraded forest, forest plantations of Teak (*Tectona grandis*) and agro-forests of the *Taungya* system, are the mainly the remains of the present vegetation cover.

In the 1930s, the Government of Ghana launched a plantation development programme under the taugnya system. The taungya system as it was developed in Myanmar, involves farmers in afforestation and/or reforestation. Farmers are given parcels of degraded forest reserve to produce food crops and to help establish and maintain timber trees. The timber trees are interplant with agricultural crops, particularly the local people main food crops production, especially annual crops such as plantain, cocoyam and vegetables. The main purpose of the taungya system is to establish plantation of fast-growing of useful timber species, whilst addressing the shortage of the land for farmers. The timber species are determined by the Forestry Commission; Teak (*Tectona grandis*) and cedrela (*Cedrella odorata*) are examples of the timber species (FAO, 1984, Agyeman et al., 2003).

In 2002, the proposed of revised of taungya system was approved. In the proposed system, farmers would essentially be owners of forest plantation products, with the Forestry Commission, landowners and forest-adjacent communities as shareholders. All participants in the modified taungya system, including farmers, would be eligible for a share of the benefits from the plantation. The consultation process devised a fair benefit-sharing framework based on contributions of the participants.

The farmers would carry out most of the labour, including pruning, maintenance and tending. The Forestry Commission would contribute technical expertise, training for farmers to carry out their functions efficiently, equipment and tools and would be responsible for stock and inventory and auctioning or marketing of products. The landowner would contribute land. The forest adjacent people would provide support services in the form of protection of the investment from fire and encroachment(Agyeman et al., 2003)

3.1.3. Climate

The District experiences semi-equatorial conventional climate. Two rainfall seasons are experienced in the district. The major rains start from April to July and the minor from September Mid-November. Annual rainfall ranges from 1500mm in the north to 1700mm in the south. Relative humidity is high during the major rainy season, reaching its peak of 90% between May and June. A maximum temperature of 30°C is experienced between March and April, near monthly temperature is about 27°C.

3.1.4. Topography

The topography is generally flat or gently undulating (Offinso District Assembly, 2006). Altitude ranges from 300m to 410m above sea level. Limited areas of steep slopes occur in the eastern part of the reserve. The area is drained by two major streams: the Afram located in the east and Brimu found in the western part. Aside these there are a number other water bodies that are largely ephemeral in nature.

3.1.5. Demographic

The population of the district is 138,500 comprising 69,000 mens and 69,500 females. The population density of the area is 63 persons per km^2. There are about 126 settlements in the District. Out of these settlements, five (5) could be described as urban. These are New Offinso (36,190), Akomadan (14,018), Abofour (11,177), Nkenkaasu (10,014) and Afrancho (7,727). The average household size is 5.5. Children under 15 years account for about 46.6%. The economical active population (15-64 years) accounts for 49% and the elderly (65 years and above) account for 1.5% of the total population. There are three main religious groups in the district. These are Christians (75.6%), Islam (15.9%) and Traditional Religion (8.5%).

3.1.6. Economic situation

Agriculture is the main economic activity in the district. Over 70% of the active population in the district are farmers, 25% of this number constitute the youth. Total land area of about 24,000 hectares is put under food crops production each year. The major crops that are cultivated in the district are cassava, maize, plantain, vegetables, oil palm, cocoa, cashew and rice. Cocoa is exported outside the country through the Ghana Cocoa Board. Apart from the agricultural production, there is a small part of animal production. The animal production concentrates only on poultry farming. Poultry production is basically on urban-based agricultural production (www.ghanadistricts.com).

3.2. Material

3.2.1. Data

There are three main data type were used in this study. They are satellite data, maps and field data. The data used is listed in Table 2. Satellite data and maps were collected from ITC data base. Field data were obtained from the field work.

Table 2 Data used

Data	
Satellite data	ASTER image acquired on 24th February, 2008; path/row 194/55
Maps	a) Roads b) Rivers c) Villages location d) Forest reserve boundary e) District boundary
Field data	a) Sampling plots b) Ground truth points c) Training sample points d) Questionnaire

3.2.2. Software

ERDAS Imagine is the software used for image pre-processing, classification and accuracy assessment. ArcGIS is used to generate ecosystem services valuation map through multi criteria analysis. CO2FIX is used for modelling and analyst the carbon stock prediction.

3.3. Methods

Overall flow chart of this study is described in Figure 4.

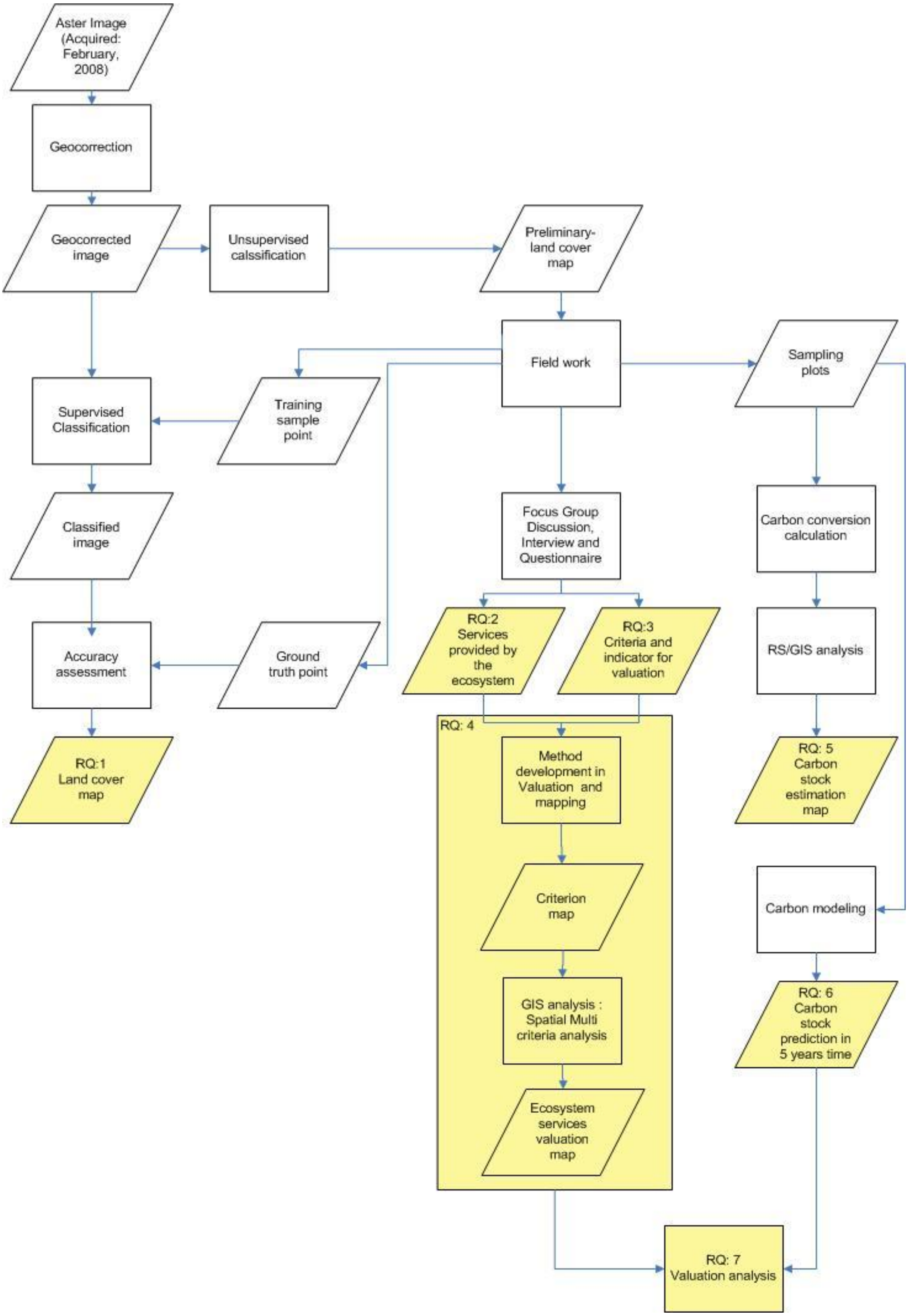

Figure 4 Methodological flow chart

3.3.1. Image pre-processing

3.3.1.1. Radiometric correction

Radiometric correction in this study refers to the noise and haze reduction. The processed was done in ERDAS Imagine. Haze has an additive effect to the overall image, resulting in higher DN values, and as such, it is reducing the contrast. The impact will be different for each band. The highest impact will be in blue range and the lowest impact is in the infrared range. Haze reduction is done by subtracting the DN value that considered as the haze value, which can be seen from the lowest value in the histogram.

3.3.1.2. Image geometric correction

Remotely sensed images usually contain geometric distortions so significant that they cannot be used directly with base map products (Lillesand and Kiefer, 2000). Road and river maps are used as a reference map to register to real world coordinates. The image is geometrically corrected to the local coordinate system, Transverse Mercator projection in Leigon datum. The coordinate system is described in Appendix2.

3.3.2. Field work

Field work was carried out in September-October 2009 at Afram Head waters Forest Reserve in Offinso District. There are three main data types that were collected from the field, namely ground truth points, sampling plots and questionnaire. Stratified random sampling was applied to randomly select the ground truth points and sampling plots.

3.3.2.1. Stratified random sampling

Stratified random sampling in forest inventory has several advantages, namely: separation of estimates mean and variance can be made for each of the forest subdivision; stratification often gives more precise estimated of the forest parameters. However this will achieve if the strata that made has higher homogeneity of the sampling unit within a stratum than for the population as a whole (Spurr, 1952).

The stratification is generated by subdividing the forest area into subdivisions as the basis for criteria, such as topographical features, forest types or density classes. In this study, the stratification was done with basis of the different of land cover type. The preliminary land cover map from the unsupervised image classification was generated to perform the stratification and ensured that the samples are distributed randomly. However due to the complexity conditions in the field, such as accessibility problem, weather conditions, some randomly points that already generated was not visited in the field.

3.3.2.2. Ground truth points

For ground truth points, at each sample point cover type was noted and GPS was used to capture coordinates of the point. The field points were then simply divided into two sets: training sample which needed to perform supervised classification and test sample points which needed for accuracy assessment of the classification.

3.3.2.3. Sample plots

Sample plot was done to obtain information of the parameters needed to be measured in forest area. GPS was used to capture the coordinate of the centre plot. Trees with diameter at breast height (dbh) larger than 10 cm are measured. Sampling sheets can be seen in Appendix 3.

There are two different sample plots that were applied in the field. They are circular and rectangular plot. Circular plot was applied in the forest and teak monoculture. The radius of the circular plot is 12.6m. With the dense in the forest and teak monoculture, circular plot is easy to apply, and the decision regarding whether the tree is in or out from the plot is easier to make. Small circular plot in the forest and teak monoculture is considered enough to capture the parameters needed to measure.

Rectangular plot with size of 30mx30m was applied in the annuals and grass land. Annuals and grass have less dense of trees compared to forest and teak monoculture. Thus, greater of sampling plot in this type of area is needed to ensure the representations of the parameters needed to be measured.

3.3.2.4. Questionnaire

Questionnaire was conducted in the five chosen forest fringe communities surrounding the forest reserve, namely Asempanaye, Akrofoa, Bobra, Asuboe and Bemi. The reconnaissance visit was done to each village, to inform the purpose of the study to the chief of the villages. The date, time and place of the discussion and interview then were set, based on the availability of the local people.

The people from each village then were selected with the help of the chief and the representative assembly. In fact, how they choose the people to be interviewed was not known clearly, as whenever the discussion and interview time settled, the local people were already gathering in settled place.

Questionnaires were given to obtain, not only information for the valuation but also the general information of the characteristics of the respondents. Group of interview and discussion were done to explore more on their perspective and the way they live related with ecosystem services. To obtain the valuation for the services and its collection place, the local people were give 10 clips as a tool to represent their valuation. This method was adopted and modified from (Raymond et al., 2009).This method was easy to apply and understandable for the local people. They could give any number of the clips for each services and the collection place that consequently represent their value based on the criteria that they put for the valuation. Due to the difference in language, interpreters were hired to assist and facilitate the discussion and interview.

Questionnaire is described in Appendix 4 and the situation of the valuation can be seen in Appendix 5.

3.3.3. Image classification

The overall objective of image classification procedures is automatically categorizing all pixels in an image into land cover classes or themes. The image classification used in this research is supervised classification. A requirement of supervised classification techniques is that the analyst has available sufficient known pixels for each class of interest so that representative signatures that can be developed for those classes. These prototype pixels are often referred to as training data. Signatures that are generated from the training data will be different depending on the classifier type to be used. Maximum likelihood classifier is used in this study. Variance and its covariance matrices constitute as the signature (Lillesand et al., 2000). Maximum likelihood classification is a parametric method that has been widely used in land cover mapping, forest (attribute) mapping and other remote sensing applications (Franklin et al., 2003).

3.3.4. Accuracy assessment

The accuracy assessment is carried out by comparing a sample of pixels from the classification results to the accurate geographical data that are usually taken from ground truth data or collected during field visits (Richards & Jia 2006). Classification error matrix indicating overall accuracy, producer's accuracy and user's accuracy were computed to evaluate the classification results. Overall accuracy is calculated by dividing the number of correct pixels for a class with the total number of reference pixels for the class. Omission error (producer accuracy) relates to the probability of a pixel that correctly classified in the interpretation while commission error (user accuracy) refers to the probability that a pixel denotes to the appointed class. Another parameter used for assessing the classification accuracy is kappa (k^) statistics, which determines the extent to which classification results surpass random assignment of pixels (Lillesand et al., 2003).

3.3.5. Ecosystem Services Valuation and Mapping

The assessment of ecosystem services valuation applied in this research is adopted and modified from the valuation framework built by (Hein et al., 2006). There are five main steps that will be done in this study:

1. Generating basic map;
2. Identification of the services provided by the ecosystem;
3. Identification of the criteria and indicator that can be used as the basis of the valuation and mapping;
4. Mapping (visualization) the ecosystem services valuation; spatial multi criteria analysis approach through overlay in GIS was used to facilitate the process in generating the maps.
5. Comparing the assessment of the valuation on the services based on local people perspective.

Figure 5 shows the flowchart of the adopted and modified method that applied in this study.

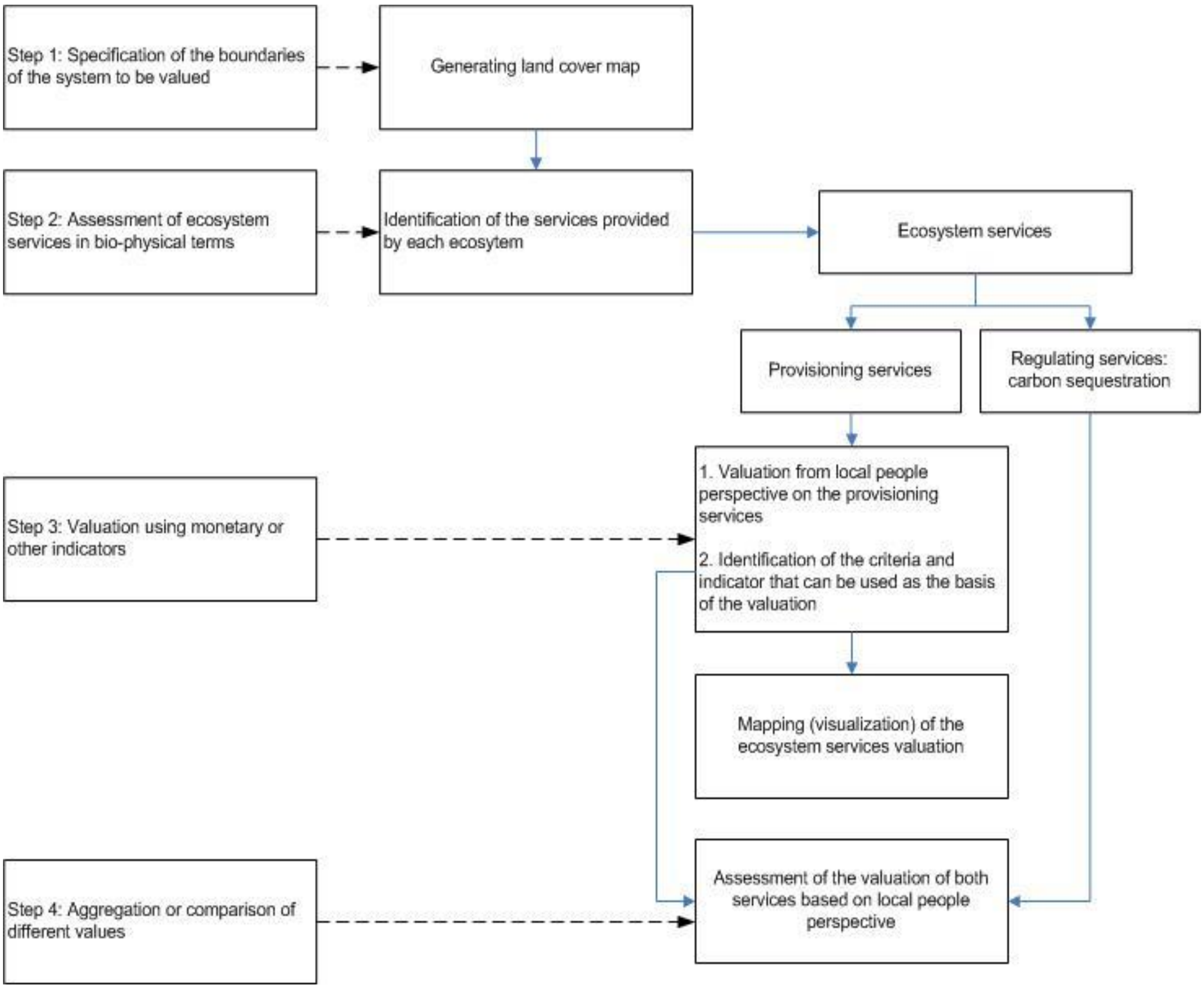

Figure 5 Valuation framework that adopted and modified that applied in this study

Basic map refers to the land cover map. Land cover map was used as the basic information to define the boundary/the extent of the ecosystem. Assessing the services from each ecosystem was done to fulfil the information needed in the second step. From the questionnaire results the list of type of services per ecosystem can be obtained.

The third step is the valuation method. In this study, the value to be mapped is the value given by local people to the services and its ecosystems.

The criteria and indicator that used as basic of valuation given from group of local people on the services and its ecosystems, then was used to generate the criterion map. The criterion map was prepared by assigning criterion score based on the value given from the local people. The flow chart of developing the criterion map is presented in Figure 6.

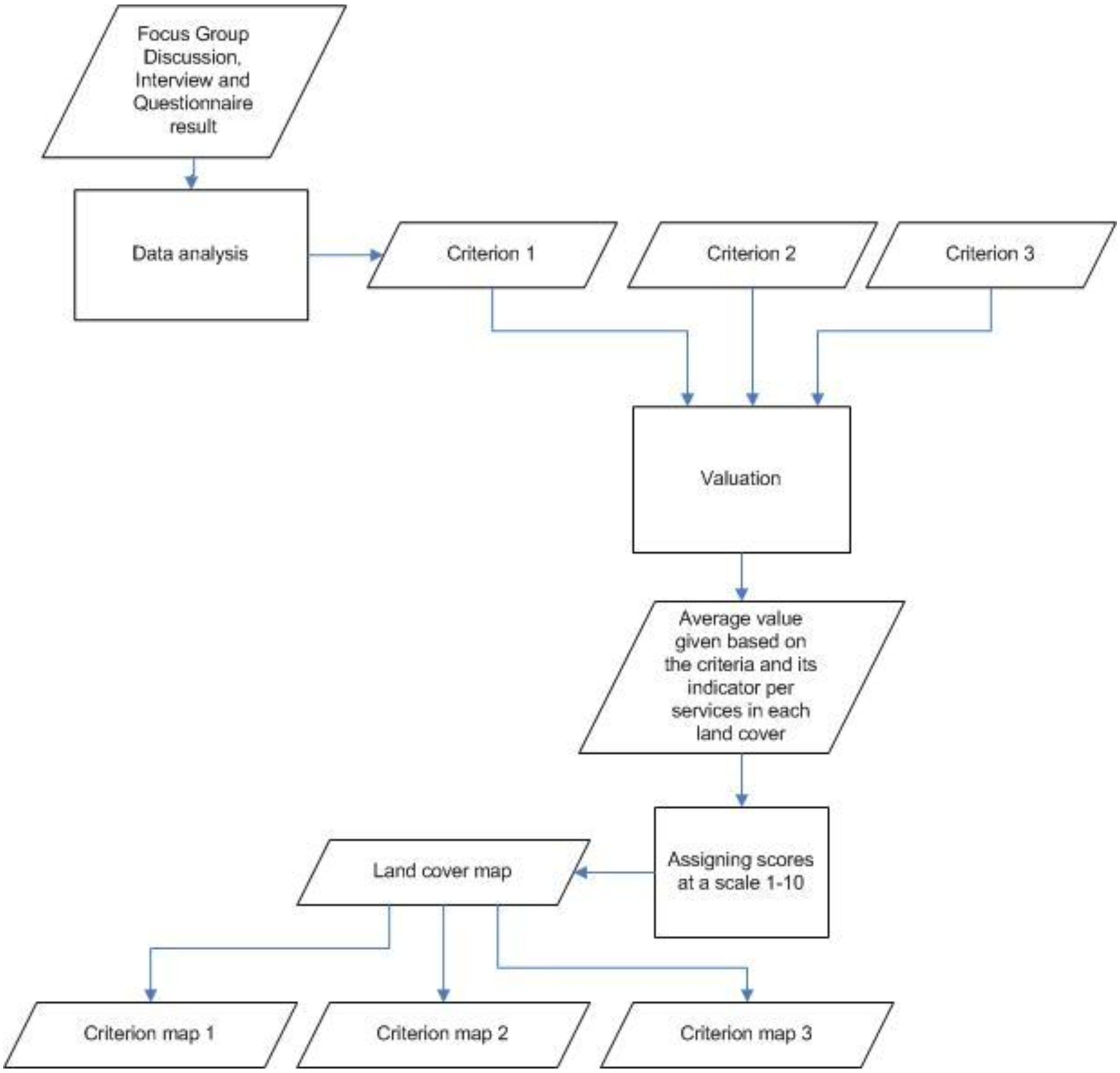

Figure 6 Flow chart of criterion map development

The criterion maps were overlaid to obtain the total value services valuation map (Figure 7). Thus, the total ecosystem valuation map gives information on the total value of land cover given by the forest fringe communities.

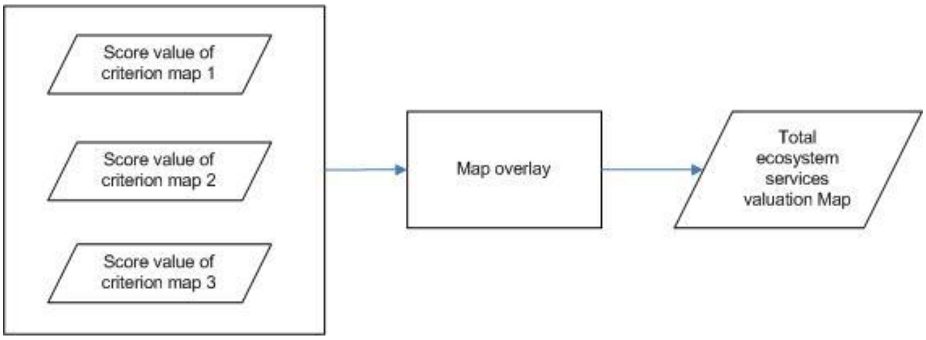

Figure 7 Flow chart of total valuation map

3.3.6. Carbon stocks mapping and modelling

3.3.6.1. Allometric equations

A common method for estimating forest biomass is the use of allometric equations which relate the biomass of individual trees to easily obtainable non-destructive measurements, such as diameter. Estimation of above-ground biomass is an essential aspect of studies of C stocks and the effects of deforestation and C sequestration on the global C balance. Allometric biomass equations are regression equations that provide a relationship between tree fresh weight biomass and a tree dimension(s) such as dbh (Ketterings et al., 2001).

Allometric equations are preferably species specific and locally derived (UNFCCC, 2006; (Ketterings et al., 2001). However, there is currently no local allometric equation developed for Ghana's forests. Thus, aboveground tree biomass was estimated using allometric equation for tropical dry forest (900-1500mm rainfall/year) recommended by Pearson et al. (2005) and Pearson & Brown (2004) as shown in Equation 1.

Equation 1:

$$\text{Aboveground tree biomass (kg/tree) } Y = 0.2035 * DBH^{2.3196}$$

However for biomass in teak (*Tectona grandis*) is estimated using equation presented in Equation 2 that suggested by the IPCC (2003).

Equation 2:

$$\text{Aboveground tree biomass (kg/tree) } Y \text{ of } \textit{Tectona grandis} = 0.153 * DBH^{2.382}$$

3.3.6.2. Carbon sequestration mapping

The woody biomass values then converted to aboveground woody carbon stock (kg.ha-1C) by multiplication with carbon fraction of biomass. (Basuki et al., 2009) stated that carbon stock is typically derived from above-ground biomass by assuming that 50% of the biomass is made up by carbon. This is inline with (Gibbs et al., 2007; IPCC, 2003; Nascimento & Laurance, 2002; Pearson & Brown, 2004) that mention that biomass-to-carbon conversion factor is 0.5.

The average carbon stock value per cover type was obtained by averaging the carbon densities of all sample plots in a particular cover type. Consequently, the total carbon per cover type was estimated by multiplying its average carbon density with total area of that cover type. Therefore, the overall carbon stock of the study area was computed by summing the total carbon stock value of the different cover types (Daniel, 2008, Dwomoh, 2009).

3.3.6.3. Carbon sequestration prediction modelling

Modelling in this study was done with the CO2Fix model. CO2Fix modelling is a user-friendly tool for dynamically estimating the carbon sequestration potential of forest management, agro-forestry and afforestation projects. This model uses a multi-cohort ecosystem-level model based on carbon accounting of forest stands, including forest biomass, soils and products. Cohort is defined as a group of individual trees or species, which are assumed to exhibit similarly growth, and which may be treated as single entities within the model (Alder and Silva, 2000).

Carbon stored in living biomass is estimated with a forest cohort model that allows for competition, natural mortality, logging, and mortality due to logging damage. The cohort approach and the possibility to simulate both age-based and biomass-based tree growth allowed the model flexibility to fit contrasting site conditions and systems (Masera et al., 2003).

Biomass module was used to predict the sequestered carbon in the agro-forestry. In this study, teak (*Tectona grandis*) as one of the determined trees planted in agro-forestry was used as the cohort as function of age. Age (year), current annual increment (CAI) in m3/ha/year, carbon content (MgC/MgDM), wood density (MgDM/m3) and initial carbon (MgC/ha) are the main inputs in this biomass module. Conventional yield table of teak (*Tectona grandis*) is provided as the main source information of the input data. Yield data was obtained from (Nunifu and Murchison, 1999).Teak (*Tectona grandis*) yield table is provided in Appendix 6.

4. Results

4.1. Land cover

The supervised classification image categorized the area in 5 different cover types as describe in Table 3 below. The land cover map fulfilled the first step of the valuation framework, and was used as the basis for spatial information.

Table 3 Land cover type description

Land cover type	Description
Annuals	Land areas under any cultivation. Dominated by annual crops, namely: maize (*Zea mays L*), cassava (*Manihol esculata*), cocoyam (*Xantoshoma tannia*), and plantain and scattered trees with local species.
Grass	Areas that are dominated with grass, namely: spears grass (*Austrostipa wakoolica)* and elephant grass (*Pennistum purpureum*).
Forest	Forested areas, which are predominantly covered by trees with close canopies and showing the area of mixed of natural vegetation.
Teak Monoculture	Forest plantation of teak (*Tectona grandis*) monoculture.
Built up	Areas dominated of infrastructure, residential areas, construction buildings and areas with exposed soil, resulting from human activities or natural cause.

Annual crops consist of two different land use systems, namely agro-forestry and farmland. Agro-forestry is land managed under the Taugnya system which is a collaborative management between Forestry Commission and local people. Agro-forestry is part of the reforestation areas in the forest reserve. Degraded forest areas are converted into agro-forestry. Local people are allowed to grow their annuals crops, but also have to purposively plant trees species which are determined by the Forestry Commission, namely Teak and Cedrela (*Cedrela odorata*).

On the other hand, farmland is privately owned by local people and located outside the forest reserve. Farmland is dominated by annual crops and scattered trees which naturally grow in the location and occur in different densities.

Although in agro-forestry there should be more purposively planted trees, but in the reality there were not many trees planted and those already planted were still very small. Thus, during the image classification the cover type of these two cover classes is considered as one type, which is annual crop area, because the trees were too small to contribute to the reflectance.

However, using expert/field knowledge based, they can be differentiated using the forest reserve boundary. Annual crops located inside the forest reserve are considered as agro-forestry area and annual crops located outside the forest reserve boundary are considered as farmland. The picture of each land cover type is depicted in Appendix 7. The area table of each land cover type is presented in Table 4.

Land cover map is important for further analysis in the valuation. In the land cover valuation, annuals were considered as a land cover with mixed system. The differentiation between the land uses in the annuals was used for further analysis only in carbon prediction. The future carbon stock prediction was focused only in agro-forest.

Table 4 Land cover type area

Land cover type	Land use	Reserve		Off Reserve	
		Ha	%	Ha	%
Annuals	Agro-forestry	11,873	57.9	-	74.2
	Farmland	-	-	6,849	
Built up		63	0.3	6,213	2.3
Grass		767	3.9	324	3.5
Forest		5,696	28.6	1,016	11
Teak Monoculture		1,494	7.5	833	9
Total Area		19,891	100	9,235	100

Land cover map is shown in Figure 8 below.

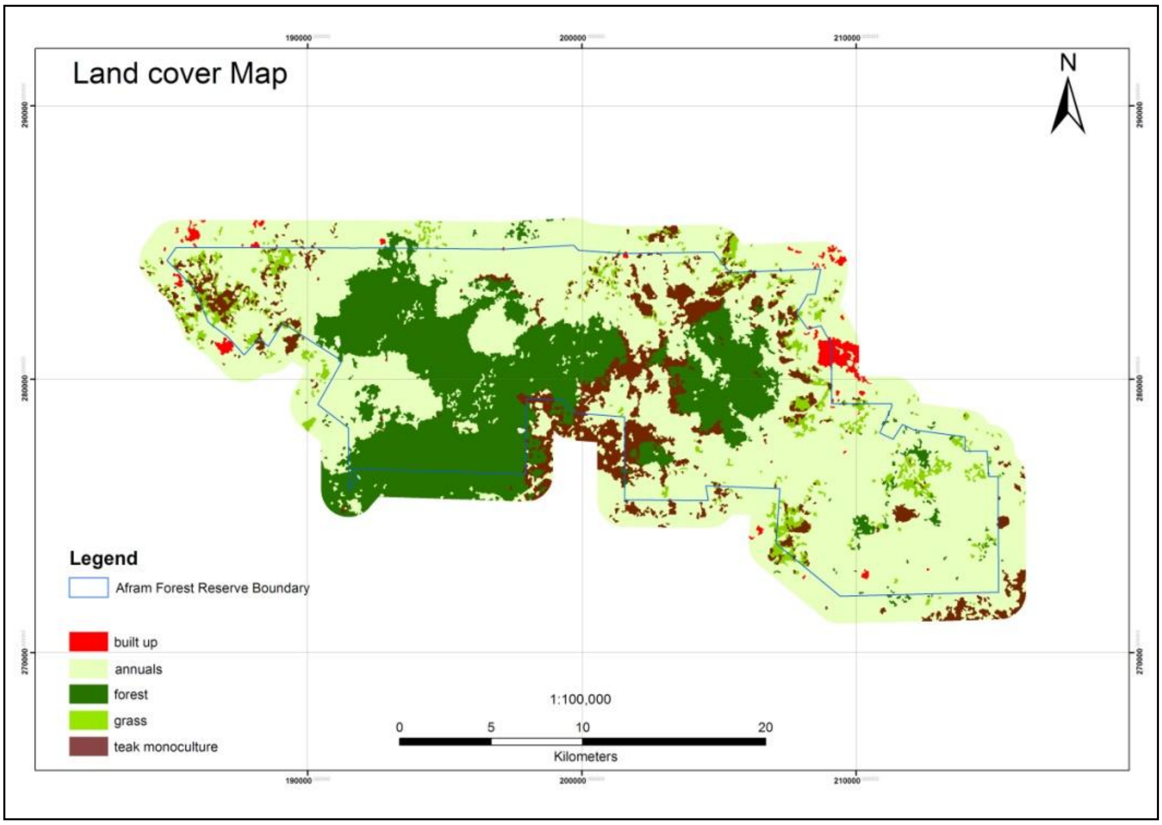

Figure 8 Land cover map

4.1.1. Accuracy assessment

Table 5 is shown the result of the accuracy for image classification.

Table 5 Accuracy assessment report

Class name	Reference Totals	Classified Totals	Number Correct	Producer's accuracy (%)	User's Accuracy (%)	Kappa
Annuals	46	49	40	86.96	81.63	0.54
Forest	10	12	7	70	58.33	0.52
Grass	7	4	4	57.14	100	1
Teak Monoculture	8	8	6	75	75	0.72
Built up	6	4	4	66.7	100	1
Totals	77	77	61			
Overall Classification Accuracy = 79.22 %						
Overall Kappa Statistic = 0.64						

The class "annuals" has the highest producer accuracy which is 86.96%, followed by teak monoculture, forest, built up and grass land. It means that "annuals" has the highest probability of a reference site being correctly classified. It is calculated by dividing the number of correct pixels for a class by the actual number of ground truth pixels for that class.

However, for user's accuracy, the class "grass" and "built up" has the highest which is 100% and followed by, annuals, teak monoculture and forest. It implies that grass land and built up has the highest probability that a pixel on the map actually represents the category on the ground. It is calculated by dividing the number of correct classification by the total number of the classifications in the category. The overall accuracy achieved is 79.22%, while the Kappa coefficient is 0.64. From the Kappa coefficient it implies that 64% of the classification agrees with reference data.

4.2. Ecosystem services valuation

4.2.1. Characteristic of respondents

Questionnaires were given to 80 respondents; however there were 10 of questionnaires were not included in the analysis because they did not provide a complete reliable answer. The total number of the respondents in each village with its characteristic is listed in Table 6.

Table 6 Number of respondents and their characteristic

Villages name	Gender		Education Level				Total Respondents
	Male	Female	Illiterate	Literate	Primary	Secondary	
Asempanaye	4	6	6	-	4	-	10
Akrofoa	9	2	3	4	2	2	11
Asuboe	13	2	5	2	5	3	15
Bemi	11	8	6	3	6	3	19
Bobra	11	4	13	-	1	1	15

All respondents' main occupation is farmer. They have land under the taungya system (agro-forestry) or privately owned land outside the forest reserve. For further analysis in this study, the definitions and number of the respondents based on the difference on the educational level are explained in Table 7.

Table 7 Definition of each educational level and number of the respondents

No	Level of education	Number of respondents	Definition
1	Illiterate	31	Illiterate respondents are those who do not have both ability in writing and reading and no educational background
2	Literate	10	Literate respondents are those who have the ability in writing and reading but do not have educational background
3	Primary	18	Respondents with primary education, are those who had attended the primary school
4	Secondary	9	Respondents with the secondary education, are those who had attended the secondary school

4.2.2. Identification of the services

The identification of the services provided by the ecosystems that recognized by local people, completed the second step of the valuation framework and answered the question of what are the services provided by the ecosystems.

4.2.2.1. Provisioning services

Provisioning services are the services recognized by all respondents. 5 main provisioning services were identified, based on different gender, education level and different villages. The 5 main provisioning services are; bush meat, grass, fuel wood, medicinal plants and lumber. Examples and the uses of the services are listed in Table 8. The picture of each service is depicted in Appendix 8.

Table 8 Servises's usage

Services	Examples	Uses
Bush meat	Grass cutter, rat, ground squirrel, monkey;	Meat for daily consumption; partly sell
Grass	Spears grass, elephant grass (*Pennisetum purpureum*)	Roofing, feeding the animal
Fuel wood	Teak (*Tectona grandis*), york (*Broussonetia papyrifera*) and any kind of tree branches. They take mostly only the falling branches.	Fuel for daily cooking
Medicinal plants	Mahogani (*Khaya ivorensis*): for chest pain, stomache Nwamma (*Ricinodendron heudelotii*): waist pain, blood tonic Dunsikro: ear pain Kakapenpen (*Rauvolfia vomitoria*): waist pain, rushes in skin	Cure sick people; partly sell, mostly for personal use
Lumber	Odum (Milicia excelsa), wawa (*Triplochiton scleroxylon*), mahogany (*Khaya ivorensis*), framo (*Terminalia superba*), kasia	For housing, and storage of their crops and animal. It is not for selling

4.2.2.2. Non-provisioning services

There are two non-provisioning services that are recognized by local people. They are regulating and supporting services. The detail services are listed in Table 9.

Table 9 Non-provisioning services that were recognized by the local people

Non-provisioning services	
Regulating services:	Supporting services:
• Water • Fresh air	• Maintaining soil fertility

The distribution of the knowledge about the non-provisioning services among the respondents based on different education levels is presented if Figure 9.

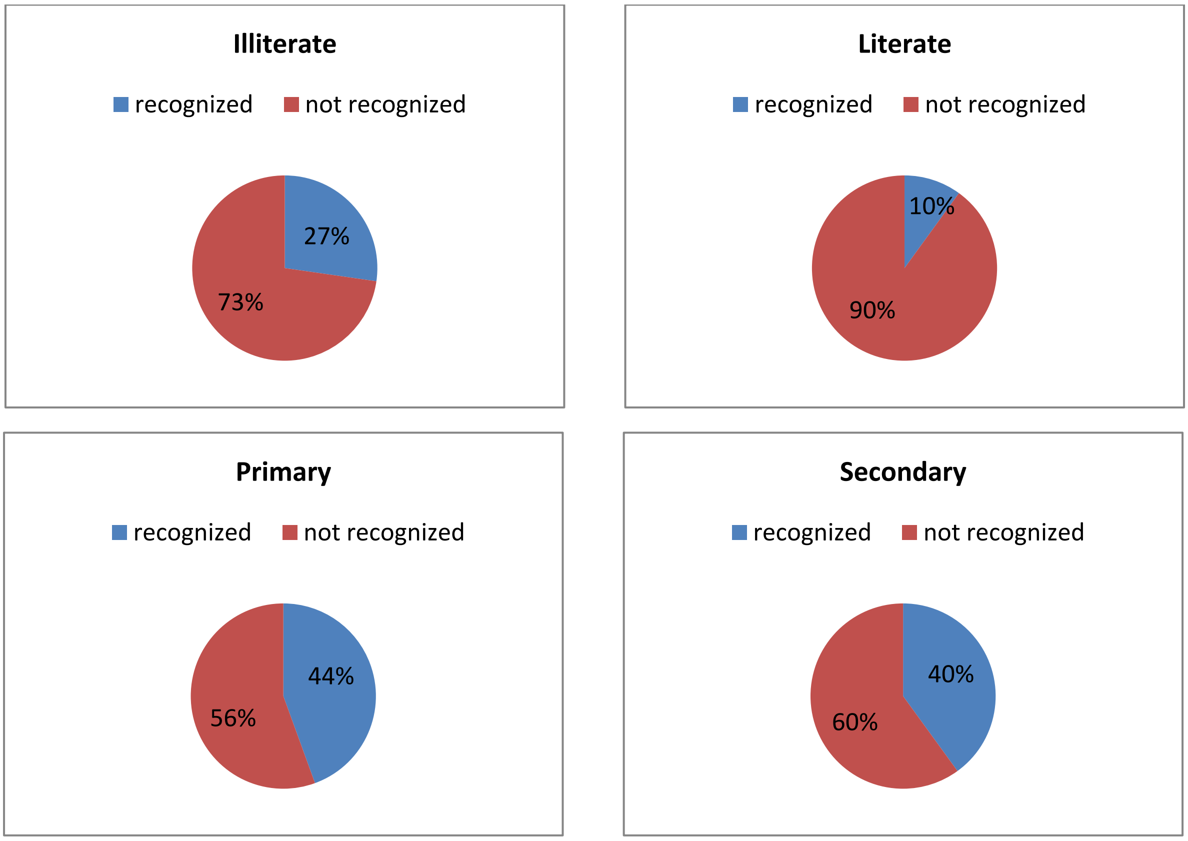

Figure 9 Number of the respondents (in percentage) related to their knowledge about the non-provisioning

The knowledge of respondents in non-provisioning services is very poor. Moreover, carbon sequestration as regulating service is not recognized by all the respondents as one of the services of the ecosystem. Because of people's poor knowledge of non-provisioning services, the questionnaires and this study focussed on the provisioning services only.

4.2.3. Provisioning Services Collection

Although all respondents admitted recognizing all the provisioning services, however not all of them collect the services. The services collection by the respondents from different genders, education levels and villages was explored and explained as follows.

4.2.3.1. Provisioning services collection from different genders

The number of the respondent and its percentage is listed in Table 10. The percentage was obtained from the number of the respondents in each group of gender that collect a specific service divided by the total respondents in that group and multiplied by 100.

Fuel wood is the service that collects by all respondents, while other are vary depending on their needs.

Table 10 Number of the respondent from different gender that collect a specific service

	Female (22 respondents)*		Male (48 respondents)	
	No*	%	No	%
Bush meat	12	77.4	45	93.7
Grass	21	90.3	45	93.7
Fuel wood	31	100	48	100
Medicinal plant	22	77.4	40	83.3
Lumber	25	80.6	40	83.3

: total respondents from different gender; No: number of respondents that collect a specific service

4.2.3.2. Provisioning services collection per different education levels

Table 11 is shown the number of respondent related to the collection of a specific service. From the table it shows that only respondents from the secondary education level that collect all the services. Fuel wood is the service that collects by all respondents from different education level.

Table 11 Number of respondents from different education level that collect a specific service

	Illiterate (31 respondents)*		Literate (10 respondents)		Primary (18 respondents)		Secondary (9 respondents)	
	No*	%	No	%	No	%	No	%
Bush meat	24	77.4	8	80	14	77	9	100
Grass	28	90.3	10	100	17	94.4	9	100
Fuel wood	31	100	10	100	18	100	9	100
Medicinal plant	24	77.4	8	80	17	94.4	9	100
Lumber	25	80.6	10	100	14	77.8	9	100

: total respondents in different education levels; No: number of respondents that collect a specific service

4.2.3.3. Provisioning services collection per different villages

The number of the respondents in each village, related to the services that they collected is listed in Table 12. The table shows that fuel wood is the most sought services for all the respondents in different villages. While others are may vary depending on the interests and needs.

Table 12 Number of the respondents in each village related to the services that they collected

	Asempanaye (11 respondents)*		Asuboe (15 respondents)		Akrofoa (11 respondents)		Bemi (19 respondents)		Bobra (15 erspondents)	
	No**	%	No*	%	No*	%	No*	%	No*	%
Bush meat	4	40	9	81.8	9	94.7	18	73.3	11	73.3
Grass	7	70	15	100	11	100	18	94.7	15	100
Fuel wood	4	40	15	100	10	90.9	17	89.5	15	100
Medicinal plant	11	100	15	100	11	100	19	100	15	100
Lumber	8	10	12	80	11	100	19	100	14	93.3

: total respondents in each village; No: number of respondents that collect a specific service

4.2.4. Importance of the services

Apart from the foods that produce from their agricultural land, which are not considered as ecosystem services, the five main ecosystem services that are identified as important services were ranked based on the importance for supporting the local people livelihood.

The importance of the services from gender perspective, education level and different villages was explored. Regression analysis was applied to see the correlation and Anova one way with single factor was applied to see the significant differences among groups and within the groups.

4.2.4.1. Importance of the services from different gender perspectives

The respondents were asked to rank the services on the scale of 1-10. The average value was obtained from the total value given by group of respondents from different genders then divided by the number of the respondents in each group. The value is listed in Table 13.

Table 13 the Importance of the services from different gender perspectives

Services	Value of the importance services (in average)	
	Female	Male
Bush meat	1.41	2.96
Grass	2.95	3.10
Fuel wood	7.45	5.88
Medicinal plants	2.64	2.04
Lumber	2.27	2.19

Figure 10 shows a clear comparison on relative (in %) importance of the services from female and male. Both female and male give the highest value to fuel wood. For female respondents, they give the lowest value to bush meat, and for male respondents, they give the lowest value to medicinal plants.

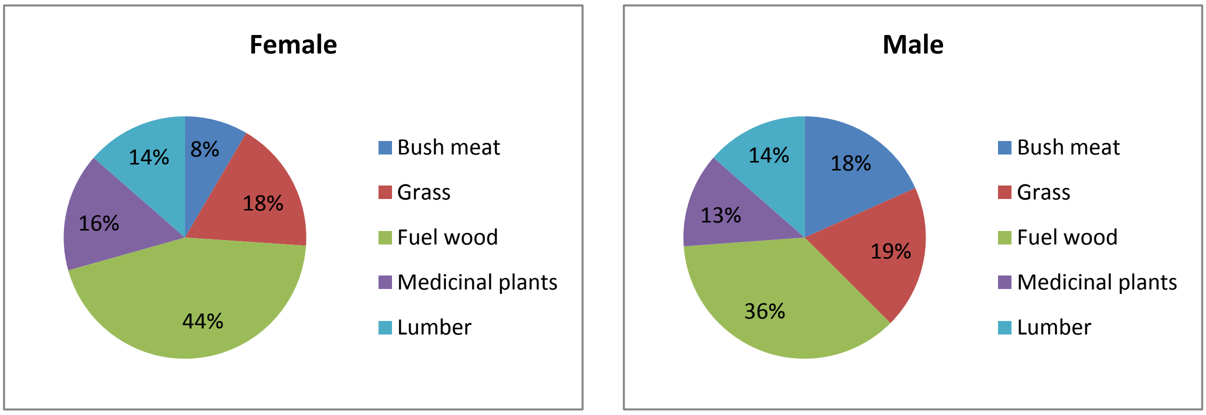

Figure 10 the importance of services based on different gender perspectives

The importance of the services from the gender perspectives shows the same pattern between female and male respondents. From the regression analysis, it shows that statistical test shows that female and male are highly correlated (R^2=0.8). It means that there is no significant difference from female and male in given the value based on the importance of the services. From the Anova test, the result (Appendix 9) shows that at α=0.05, fuel wood is significantly different from other services, that both female and male give this value higher than the other services.

4.2.4.2. Importance of the services from different education level perspective

The value of the importance of the services from different education level is listed in Table 14.

Table 14 Value of the importance of the services from different education level

Services	Value of the importance services (in average)			
	Illiterate	Literate	Primary	Secondary
Bush meat	2.1	2.5	2.8	3.4
Grass	2.9	3.2	3.3	3.1
Fuel wood	6.8	6.1	6.2	5.8
Medicinal plants	1.3	2.9	3.1	3.2
Lumber	1.7	2.6	2.6	2.8

From the table and Figure 15, it shows that all respondents give the highest value to fuel wood. Illiterate respondents give the lowest value to medicinal plants, while literate respondents give to bush meat. And the respondents with primary and secondary education give the lowest value to bush meat.

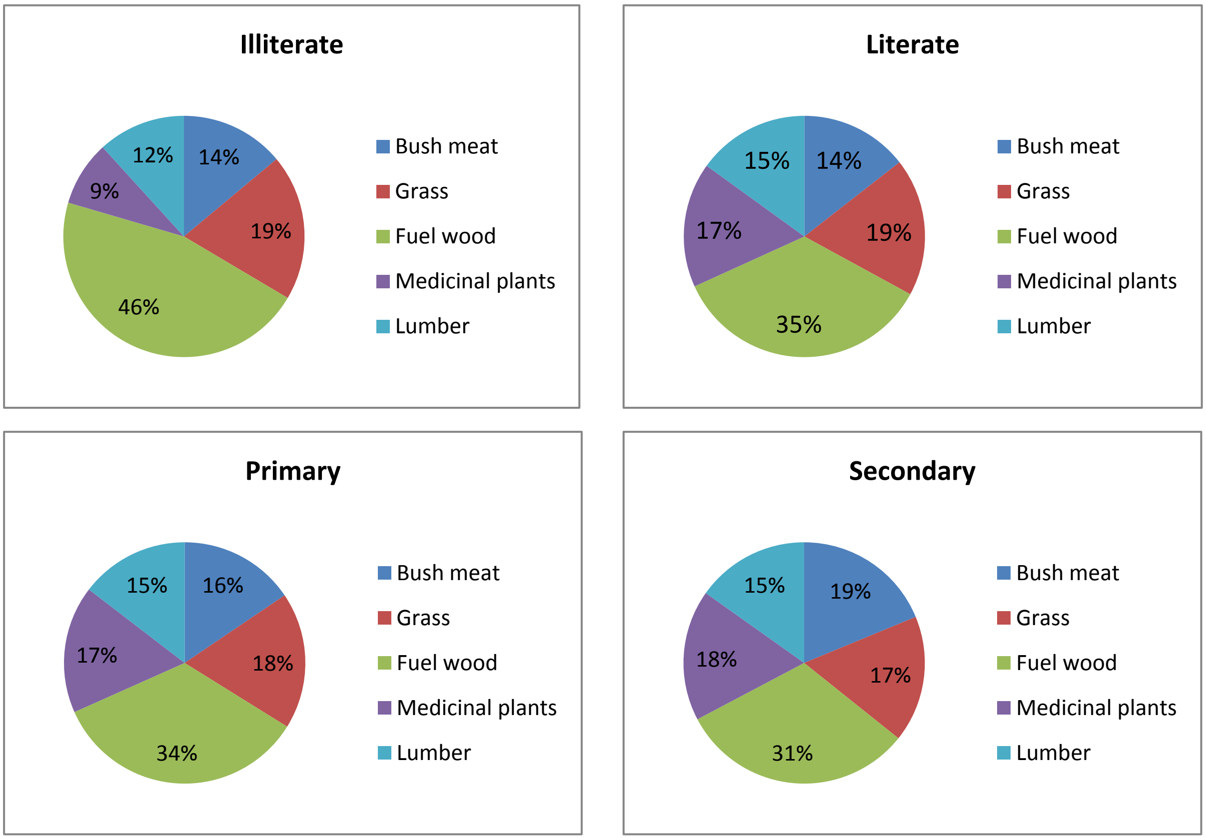

Figure 11 the importance of services based on different education level perspective

From the Anova test result (Appendix 10), it confirms that at $\alpha=0.05$, fuel wood is significantly different from other services, that all respondents from different education levels give higher value to fuel wood than the other service. Apart from that, the result also shows that there is no significant difference of the valuation given by the respondents based on the different education levels.

4.2.4.3. Importance of the services from different villages

The value of the importance of each service from different villages is listed in Table 15.

Table 15 Value of the importance of the services from different villages

Services	Value of the importance services (in average)				
	Akrofoa	Asempanaye	Asuboe	Bemi	Bobra
Bush meat	3.00	1.7	3.0	2.4	1.2
Grass	3.7	2.5	3.5	2.8	3.5
Fuel wood	6.4	6.6	6.4	5.0	7.3
Medicinal Plants	2.4	1.5	2.4	1.9	1.0
Lumber	1.7	0.5	2.3	1.8	1.8

All respondents give higher value to fuel wood. For respondents from Akrofoa, Asempanaye, Asuboe and Bemi, they give the lowest value to lumber. And for respondents from Bobra, they give the lowest value to medicinal plants. Figure 16 shows the different value of the importance of the services from the five chosen villages.

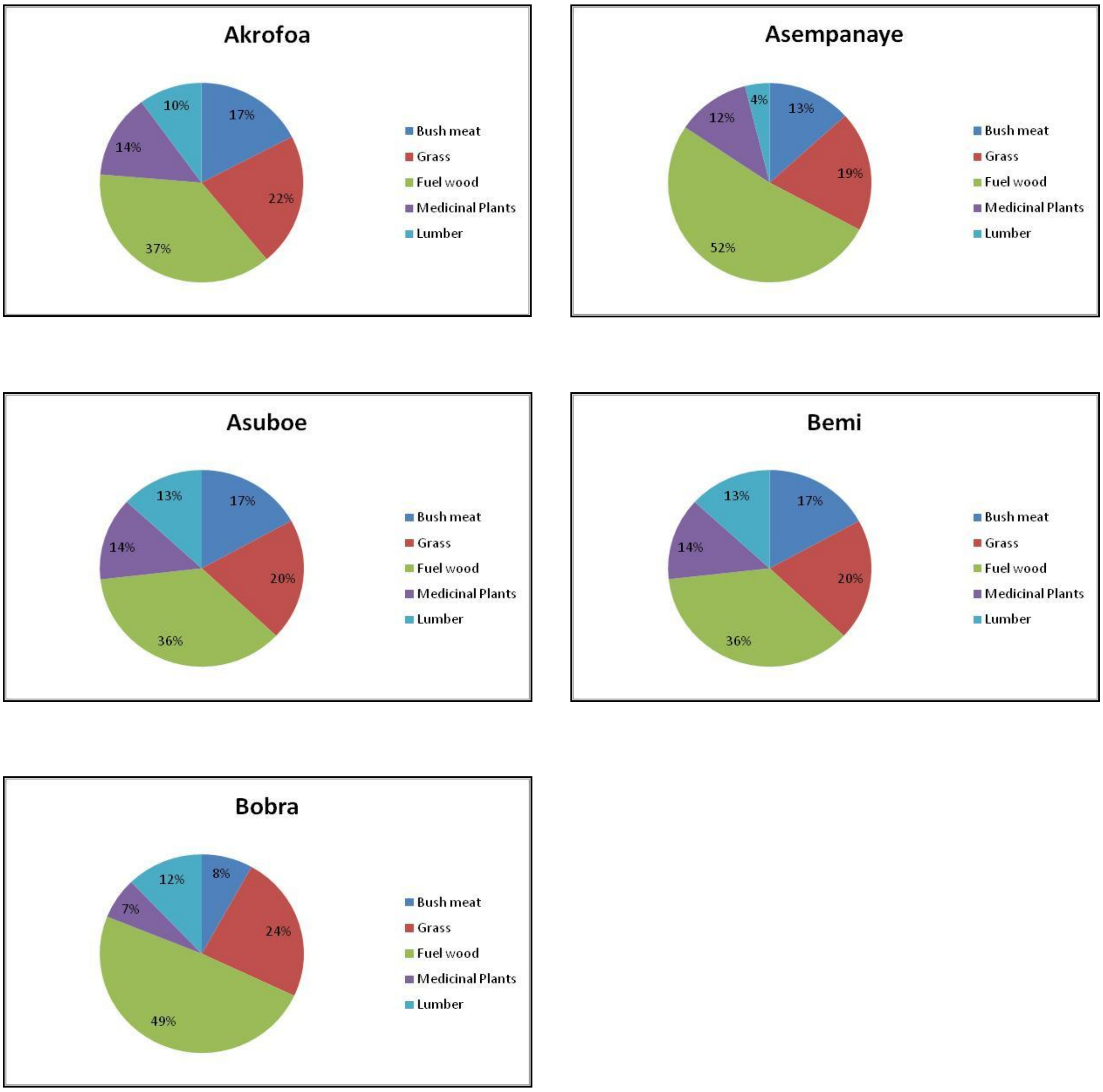

Figure 13 the Importance of services based on different village perspective

From the Anova test (Appendix 11), at α= 0.05, fuel wood is proofed to be significantly different from other services, as the most important service for all respondents in different villages. The result also shows that there is no significant difference among the groups of villages in giving the value.

4.2.5. Criteria and indicator for land cover valuation based on the ecosystem services provided

The identification of the criteria and indicator that local people put is important in valuing the ecosystem services. The result of the identification of the criteria and indicator is fulfilled the third research question in this study. The criteria and indicator are presented in Table 16.

Scoring of the criteria is based on the value for each of the indicators given by the local people on scale 1-10. To normalize the value given that comes from different number of group of people, then the average value was calculated. The range of the average value is 0-10, which represents the lowest value to the highest value. After obtaining the average value from each land cover, then its percentage is calculated to see the relative importance of each land cover in providing the services. The percentage value of each land cover then is used for the mapping. The scale ranges from 0-100 which represents the lowest value to the highest value.

Table 16 Criteria and Indicator

Criteria	Indicator
Land cover as collection place for a specific service	1. The capability of each land cover in providing each services : a) number of animal (for bush meat); b) number of bundle (for grass and fuel wood); c) number of medicinal plant species (medicinal plants); d) type of the allowable cutting trees species (lumber)
Land cover as total services provider	1. Number of services 2. The importance of the services for their daily life
The availability of land cover	Walking distance

4.2.6. Valuation mapping

Valuation mapping was done to visualize the value given by the local people in the ecosystems based on the criteria and indicators. This was done as the fourth step of the valuation framework and answered the research questions of how the valuation can be mapped.

4.2.6.1. Valuation of land cover based on its relative importance for a specific service

The valuation of land cover based on its relative importance for a specific service shows the capability of each land cover in providing a specific service. The value given by local people is listed in average and percentage in Table 17.

Table 17 Valuation of land cover based on its relative importance for a specific service (in average and percentage)

Land cover type	Bush meat		Grass		Fuel wood		Medicinal plants		Lumber	
	A*	%	A*	%	A*	%	A*	%	A*	%
Annuals	5.9	71.2	2.8	29.6	7.6	79.2	4.8	57.2	6.6	77.9
Grass	0.5	5.9	6.6	69.5	1.4	15.0	0.5	5.6	1.3	15.8
Forest	1.9	22.7	0.1	0.9	0.5	5.3	3.1	37.2	0.5	6.4
Teak Monoculture	0	0	0	0	0.04	0.4	0	0	0	0
Total	8.3	100	9.5	100	9.6	100	8.3	100	8.5	100

A*=average

From the table it shows that annuals receive the highest value as collection place for bush meat, fuel wood, medicinal plants and lumber. Grass land receives the highest value as collection place for grass.

And teak monoculture receives the lowest value for all services. Figure 14 shows the relative importance of each land cover in providing each service.

The valuation of land cover based on its relative importance as collection place for a specific service is mapped in Figure 15.

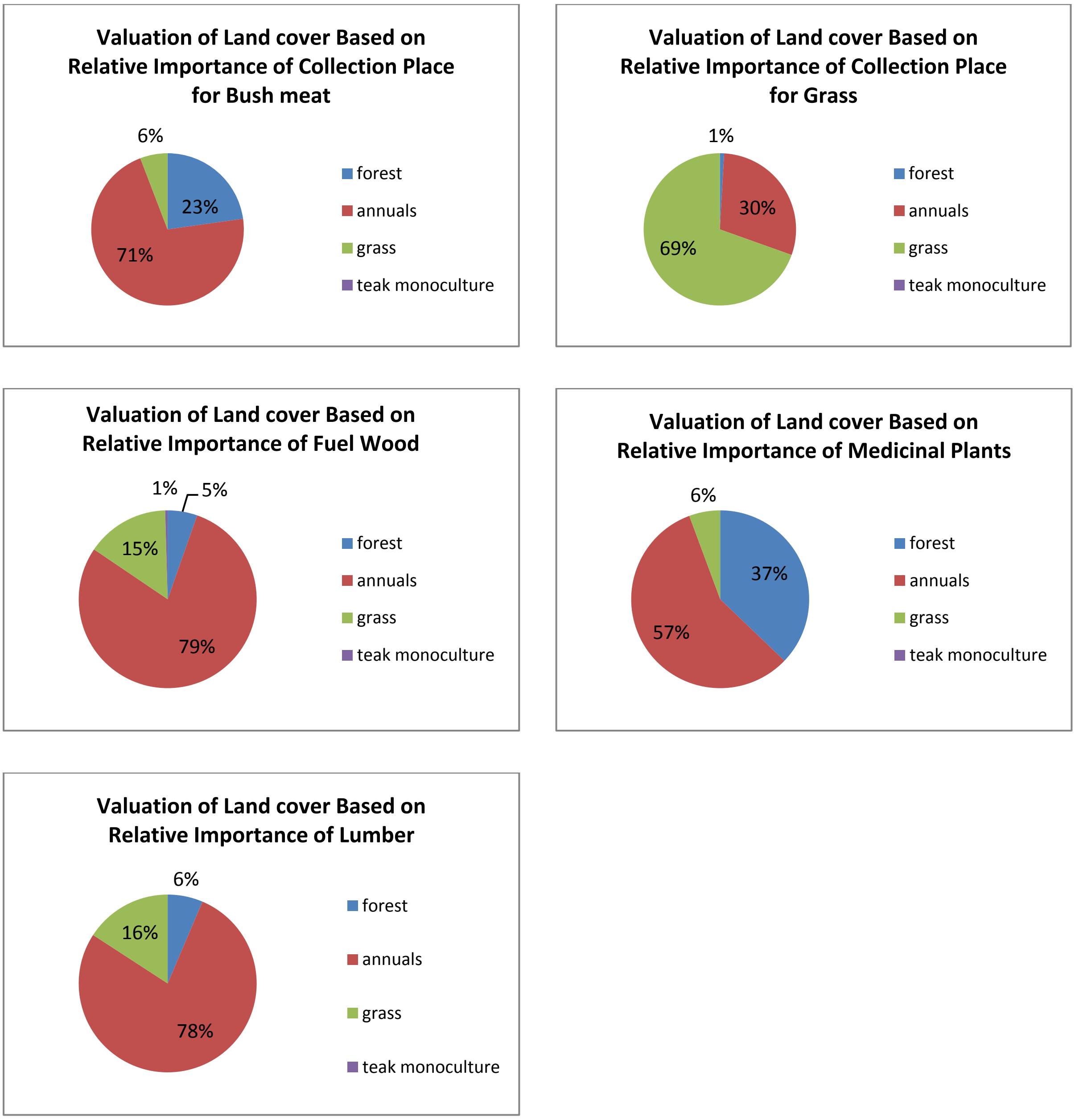

Figure 14 valuation of land cover based on its relative importance for a specific service

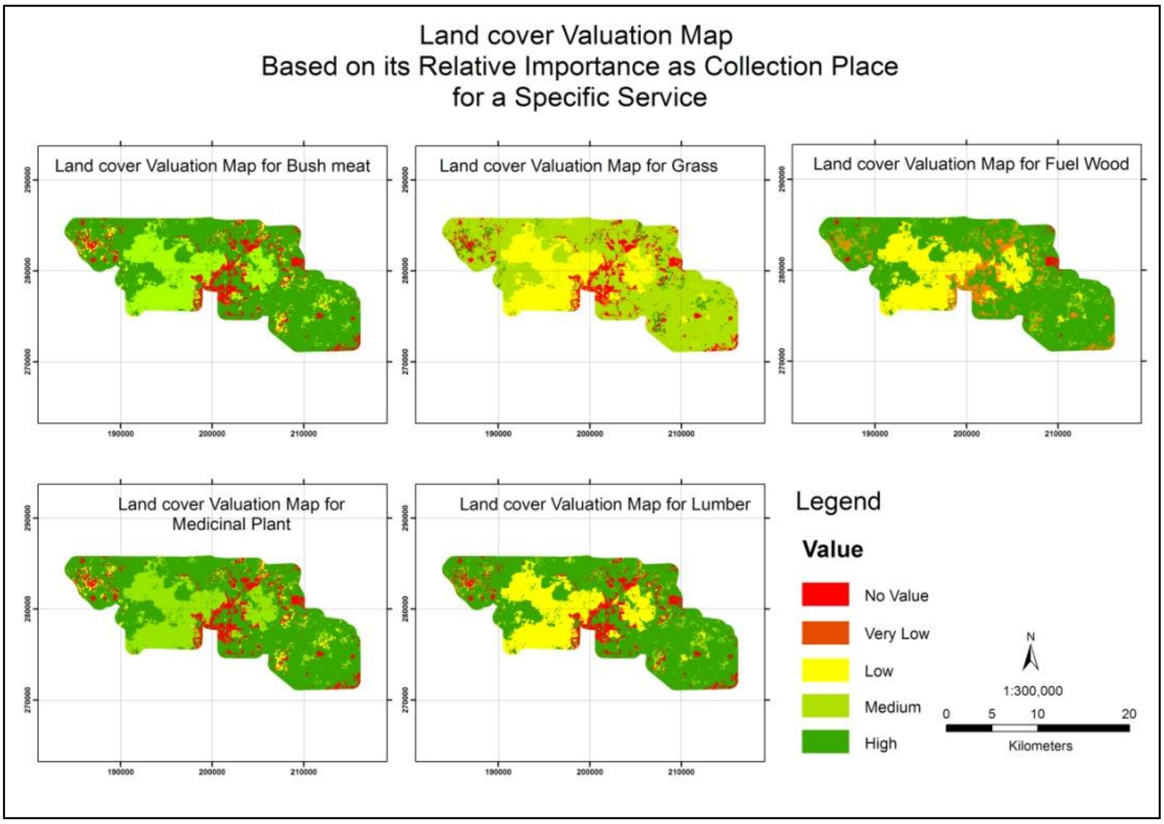

Figure 15 Land cover valuation map based on its relative importance as collection place for a specific service

4.2.6.2. Valuation of land cover based on its relative importance as collection place for a specific service on different gender perspective

Furthermore, the value placed on land cover based on its relative importance as collection placed for a specific service from different genders was also explored. Table 18 shows the value given by female and male respondents.

From the table, it shows that annuals always receive the highest value as collection place for bush meat, fuel wood, medicinal plants and lumber.

Grass land receives the highest value as collection place for grass. Even in forest grass is hardly found, however male respondents still give small value to forest as collection place for grass, while female respondents give no value.

Teak monoculture receives no value for all services from female respondents. However male respondents still give small value to teak monoculture as collection place for fuel wood.

Table 18 Valuation on land cover based on its relative importance as collection place for a specific service

Services	Gender	Value of each land cover (in average)			
		forest	annuals	grass	teak monoculture
Bush meat	Female	1.1	5.5	0.2	0
	Male	2.3	6.6	0.1	0
Grass	Female	0.0	2.6	6.9	0
	Male	0.1	2.8	6.4	0
Fuel wood	Female	0.6	7.9	1.4	0
	Male	0.6	7.6	1.6	0.13
Medicinal plants	Female	2.6	5.1	0.5	0
	Male	3.3	4.9	0.5	0
Lumber	Female	0.1	5.9	1.2	0
	Male	0.7	6.9	1.5	0

From the regression analysis, it shows that the correlation between female and male in valuing the land cover based on its relative importance as collection place for a specific service is highly correlated (Table 19). It shows that there is no significant difference between female and male in valuing the land cover based on its relative importance as collection place for a specific service.

Table 19 R^2 of the value of each land cover for each service between female and male

Services	R^2
Bush meat	0.97
Grass	0.99
Fuel wood	0.99
Medicinal plants	0.97
Lumber	0.99

4.2.6.3. Valuation of land cover based on its relative importance as total services provider

Valuation of land cover based on its relative importance as total services provider represents the value given by local community based on two indicators, number of the services and the importance of the services for their daily life. The average value was calculated by summing the total value given by the respondents and divided by the number of the respondents, and then converted into percentage to capture the contribution of each land cover as total services provider. The percentage value consequently is the value to be mapped to visualize the valuation of each land cover. The value of each land cover in average and percentage is listed in Table 20.

Table 20 Value of land cover based on its relative importance as total services provider

Indicator	Land cover type	Value	
		Average	%
	Annuals	77.5	62.702
1. Number of services	Forest	17.2	13.91
2. The importance of the services for their daily life	Grass	28.8	23.3
	Teak Monoculture	0.1	0.08
Total		123.6	100

The valuation is mapped in Figure 16.

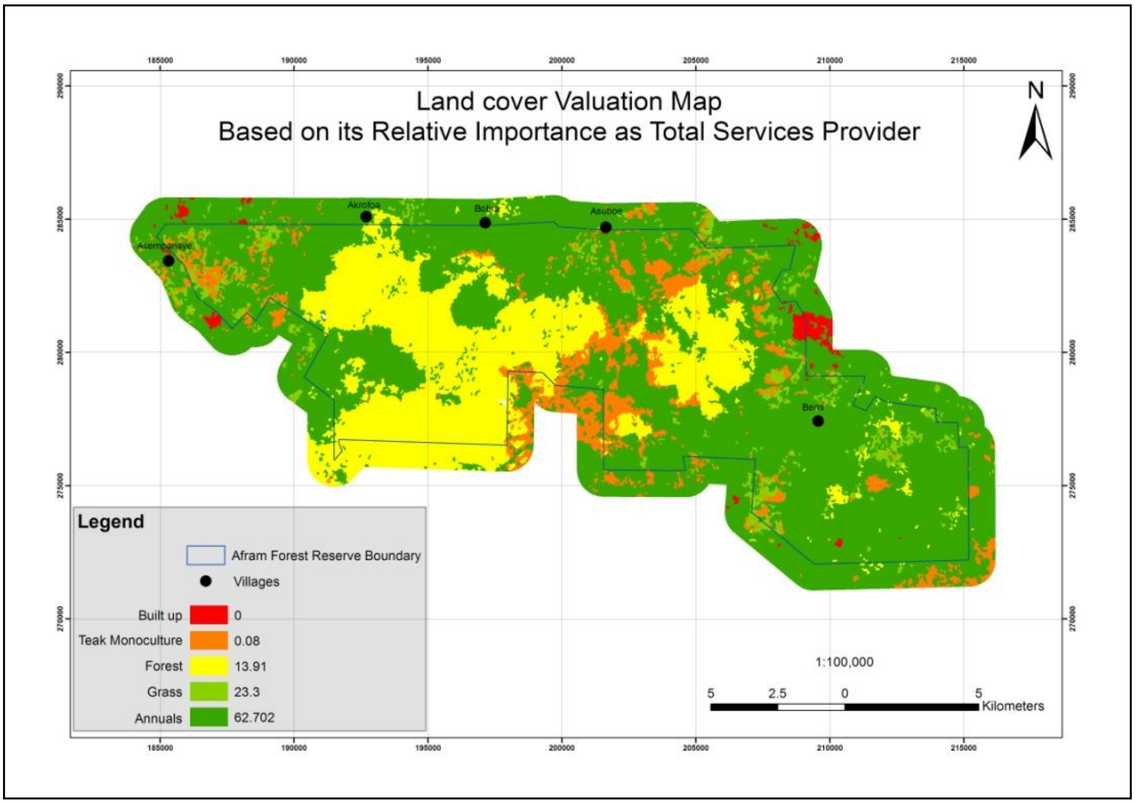

Figure 16 Land cover valuation map based on its relative importance as total services provide

From the valuation, annuals receive the highest value, followed by grass, forest and teak monoculture. Therefore, from the local community perspective, annuals are considered as the land cover that provides all the services which are important in their daily life. On the other hand teak monoculture is considered as the least useful land cover that has no capability in providing all the services that are important for them.

4.2.6.4. Valuation of land cover based on its relative importance as total services provider with walking distance consideration

Walking distance is considered as one of the indicator in valuing the land cover as total services provider. Walking distance map was generated to take a consideration of the local community perception that nearest the location to their settlement the higher the value, and vice versa. Walking distance was generated using the proximity function and villages point as the centre.

Land cover valuation map based on its relative importance as total services provider then combined with the walking distance map to obtain the total value of the land not only as a function of the total services provider but also the availability of the land cover which is represented by the distance of the land cover from the settlement. The equal weight is used based on the consideration that walking distance might influence the value, but the availability of the services is equally important for them. The valuation of land cover based on its relative importance as total services provider with walking distance consideration is mapped in Figure 17.

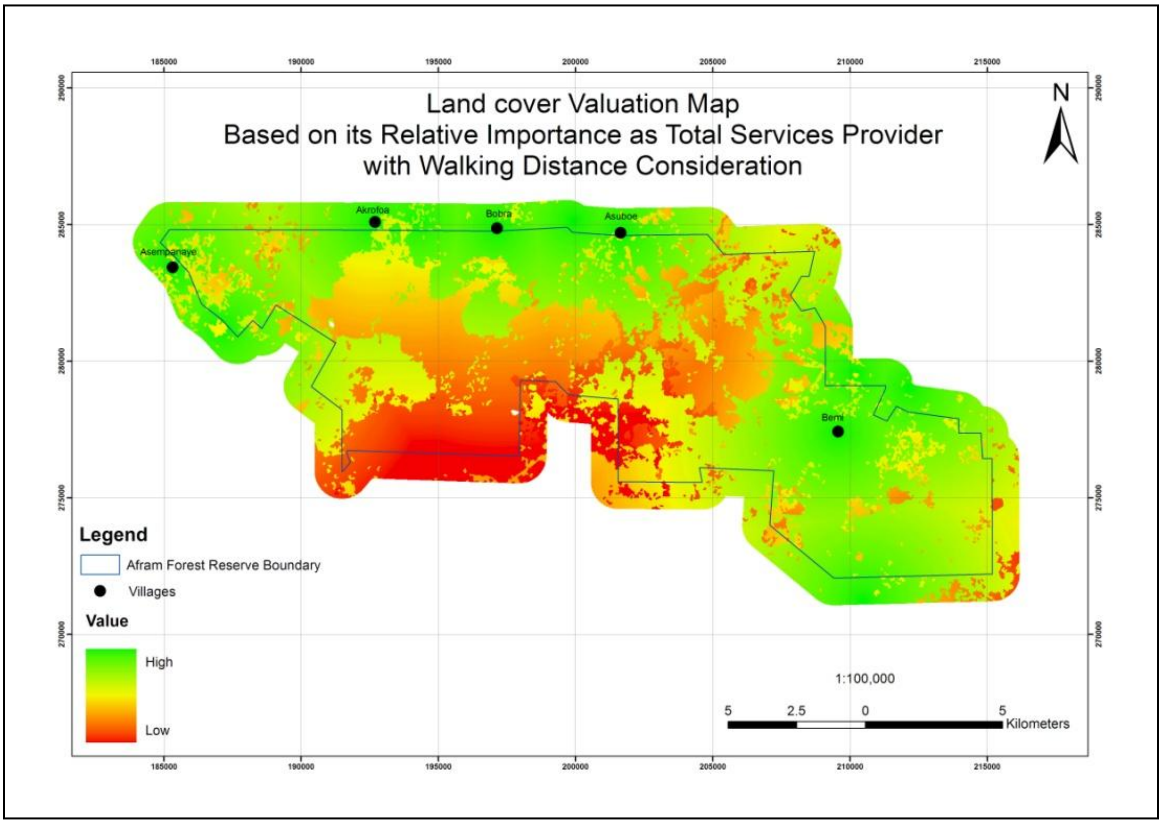

Figure 17 Land cover valuation map based on its relative importance as total services provider with walking distance consideration

The map clearly shows that the value gradually changes as the location of the land cover is further away from the settlement. It shows in the southern part of the study area, the value of the land cover is mostly a low value. And the land cover surrounding the settlement is registered as high value.

4.2.7. Carbon stock in living above-ground woody biomass

Carbon sequestration as one of the services provided by the forest and tree based ecosystems was calculated in this research to show the value and the existence of regulating services that provided by forest and tree based ecosystems, this also answered the fifth research question. Although not appreciated by local people this regulating service could, in future, play a substantial role in people's livelihood through the carbon market. The calculation was derived from the sample plots which were obtained from the field work (Table 21).

Table 21 Sample plots in each land cover type

Land cover type	Number of plots	Average number of trees (/plot)	Average dbh (/plot)
Annuals	40	9	48.4
Forest	31	31	22.2
Grass	4	5	45.7
Teak monoculture	17	30	21.2

4.2.7.1. Aboveground woody biomass distribution in different land cover type

The average aboveground woody biomass (AGB) in the study area ranged between 79.41– 381.72 M g/ha. Forest with 381.72 M g/ha registered the highest average aboveground woody biomass, followed by annuals, teak monoculture and grass land. However, due to the large extent of the area, the total biomass quantity was found the highest in the annuals. Distribution of estimated total biomass is listed in Table 22.

Table 22 Distribution of estimated total biomass

No	Land cover type	Average aboveground woody biomass (Mg/ha)	Total Area (ha)	Total biomass		
				(Mg)	(Gg)	%
1.	Annuals	177.45	18,721	3,322,041	3,322.04	52.05
2.	Grass	79.41	1,091	86,636.31	86.63	1.36
3.	Forest	381.72	6,712	2,562,105	2,562.05	40.14
4.	Teak monoculture	177.17	2,327	412,274.6	412.27	6.46

The spatial distribution of biomass in the study area is shown by the map in Figure 18.

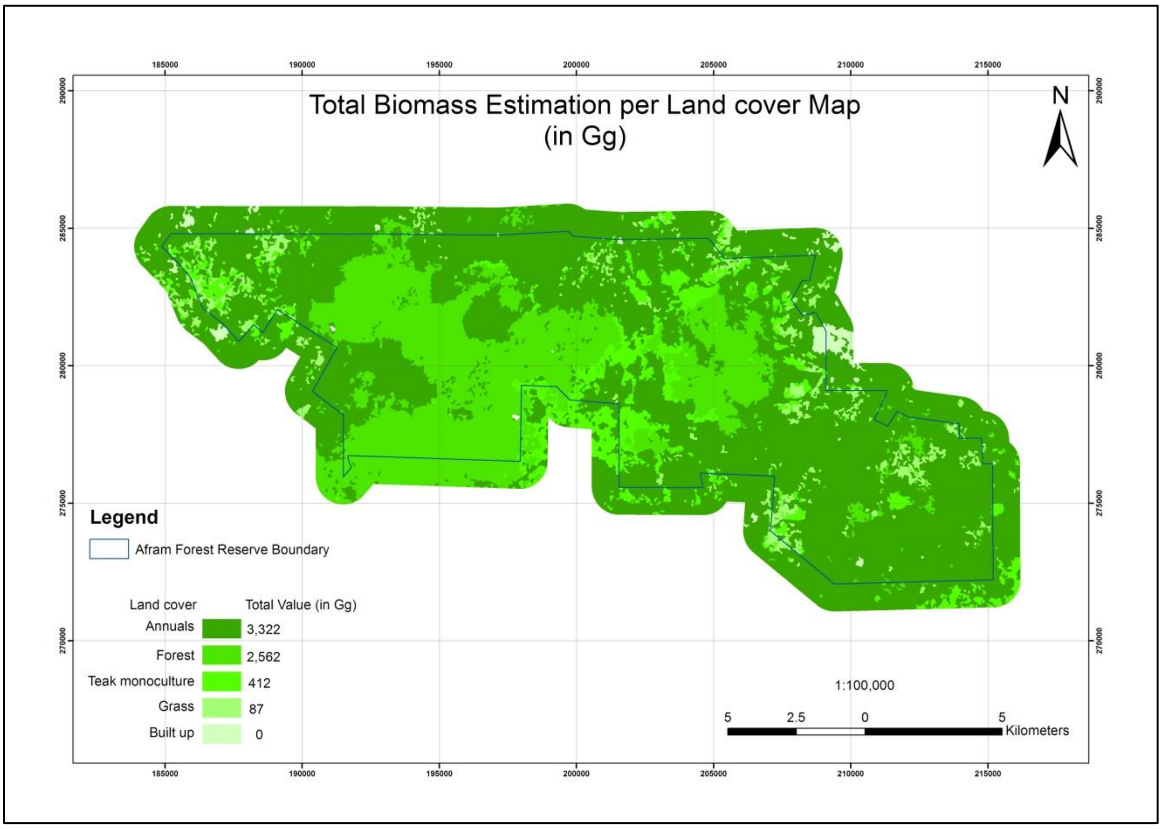

Figure 18 Total biomass estimation map

4.2.7.2. Carbon stock in aboveground woody biomass

Carbon stocks of the cover types followed the pattern of aboveground biomass levels. Annuals in total comprise the highest C stock which is 1,661 G g, followed by forest, teak monoculture and grass land. Distribution of the estimated S stock is listed in Table 23.

Table 23 Distribution of estimated C stock

No	Land cover type	Total C Stock		
		(M g)	(G g)	%
1.	Annuals	1,661,021	1,661	52.05
2.	Grass land	43,318.16	43.32	1.36
3.	Forest	1,281,052	1,281	40.14
4.	Teak monoculture	206,137.3	206.14	6.46

The spatial distribution of estimated C stock is mapped in Figure 19.

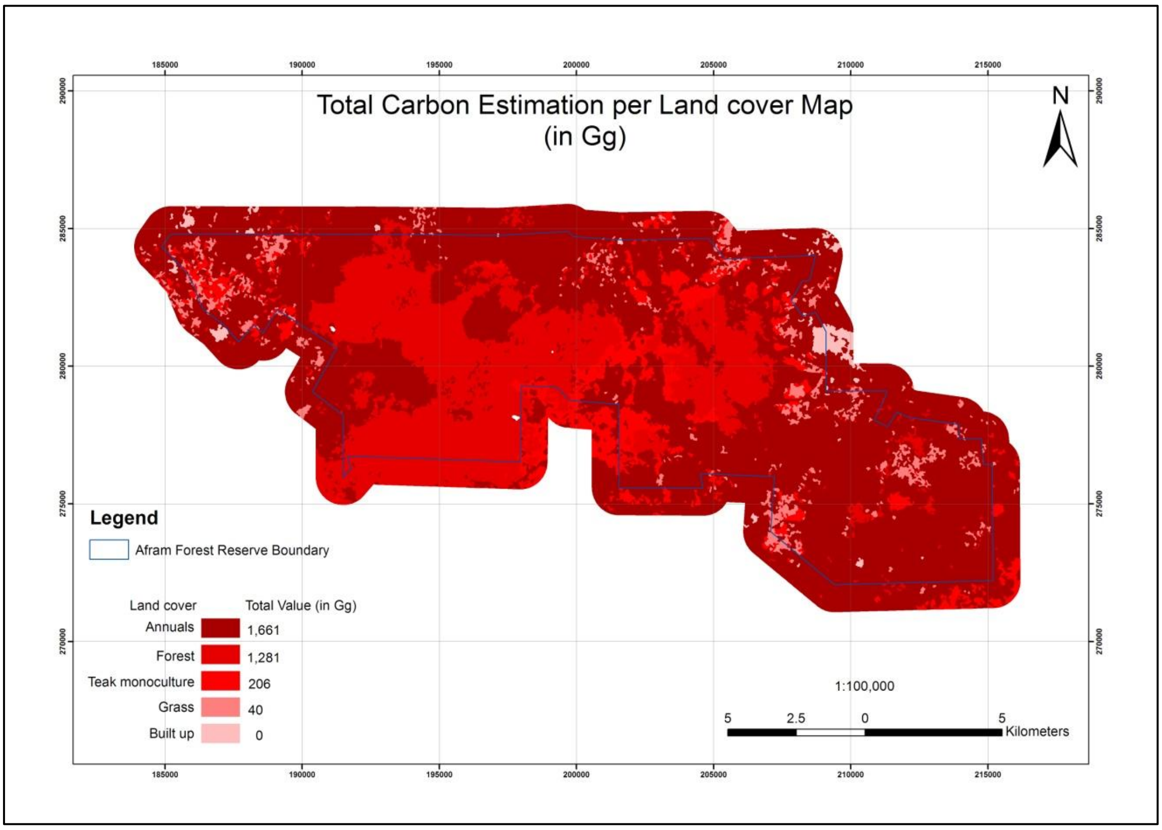

Figure 19 C stock estimation map

4.2.7.3. Carbon sequestration modelling

As mentioned in section 4.1 annuals appear as farm land and agro-forestry. For predicting the future carbon stock carbon sequestration potential, this research is only concentrated on the agro-forest area, which means the area is inside the forest reserve. The reason is that, in agro-forest there are trees that should be planted by the local community as part of the reforestation program. Besides, trees outside the reserve (in the farm land) are too dynamic, as farmers are allowed to fell down the trees and prediction of their future carbon yield does not make sense. This future carbon stock modelling incorporates the research question on the prediction of the carbon stock if trees are left undisturbed in five years time.

From the carbon prediction, it gives an overview that agro-forest will contribute more in stocking the carbon if the trees are not felled deliberately. From this point of view, the prediction was done using the current average stock of the carbon in the agro-forest as the initial carbon value.

Teak is chosen as the cohort because teak is one of the determined trees that should be planted in the agro-forestry. The yield table of teak was used as the main input for the modelling. Teak was used as the only cohort for the modelling, due to the lack of the yield table data for many other trees species that also exist in the agro-forestry.

For the calculation in carbon stock, the density of carbon (in Mg/ha) in agro-forest was obtained from the total carbon stock in agro-forest divided by the total extent of the area. Then, the value was used as the input for the initial carbon in agro-forest. From the prediction result, the C density (in Mg/ha) in living woody biomass in the agro-forest in 5 years time without cutting the trees will be 151.27 Mg/Ha.

To obtain the total stock prediction in agro-forest area, then the predicted density was multiplied by the total extent area of the agro-forest. The total C stock in living woody biomass in the agro-forest area in 5 years time without cutting the trees is 1,796,028.71Mg (1,796 G g).

As the current C stock of the in agro-forest is 1,053,431 Mg (1,053 G g), and the predicted C stock is 1,796,028.71Mg (1,796 G g), so the C stock in agro-forest area in 5 years time without cutting the trees will stock 743 G g carbon more. This, if it is well managed, such as in e.g REDD context, could attract a substantial amount of money.

In addition, based on the information obtained from the local community, teak usually has the first thinning at age 7. With an assumption that in the thinning management, the action taken is only cutting the branches. And the fraction removed is considered only 0.2 (20%) of the tress. Another assumption was made, as from the local community information that mostly the current teak that they had planted is in the age of 5. Which means, the thinning management will be done in two years from now, thus the simulation will be predicted for the C stock in the 2 years time from now. The initial carbon density value was the same as the simulation for the 5 years time.

The prediction of the C stock with simulation years at 7 with thinning management and without is listed in Table 24.

Table 24 C Stock prediction at years 7 with and without thinning management

<table>
<tr><th></th><th>Fraction removed</th><th>C (M g/Ha)</th><th>Total area of agro-forestry (ha)</th><th>Total C stock prediction (M g)</th><th>Total C stock prediction (G g)</th></tr>
<tr><td>Thinning Management</td><td>0.2</td><td>113.76</td><td rowspan="2">11,873</td><td>1,350,672.5</td><td>1,351</td></tr>
<tr><td>Without Thinning Management</td><td>0</td><td>142.20</td><td>1,688,340.6</td><td>1,688</td></tr>
</table>

5. Discussions

5.1. Assessment of ecosystem services that recognized by local people

All respondents, from different genders, education levels and villages confirmed that they recognized provisioning services as the main services provided by the ecosystems. The five main services are the products that they can easily get from forest and tree based ecosystems. They are namely, bush meat, grass, fuel wood, medicinal plants and lumber. The provisioning services that recognized by local people are mostly the direct services that constitute their livelihood. This fact shared by the opinion (Hein et al., 2006) in his paper that all the production services produce in the ecosystems are well recognized by local people. However, the cultural, supporting and regulating services are less well recognised by communities and people do not place any value in them.

One supporting services that is recognized by local communities, are maintaining soil fertility. And the few of regulating services are water and fresh air provision. Research done by (Blay et al., 2007) in three different districts (Dormaa, Begoro and Offinso) in Ghana, indicates that fertility of land for farming is one of the top three issues that prioritized by the respondents. Study done by (Daniel, 2008), have similar result, that the local people recognized maintaining soil fertility as the non-provisioning services. In his study, local people even ranked soil fertility in number two as the second important services after the food collection.

Carbon sequestration is one of the regulating services with great potential. Carbon sequestration is not only consider as natural brake for climate change, but also now day's carbon market is growing (Gibbs et al., 2007). The United Nations Framework Convention on Climate Change, recently agreed to study and consider a new initiative, led by forest-rich developing countries that entitled economic incentives to help facilitate reduction in emissions from degradation and deforestation in developing countries (REDD). Under this framework, reward to individuals, communities, projects and countries in reducing the emission from forest will be given. It can be more easily said, that by keeping the trees grow, the local people will able to benefit the incentives from the carbon market (Gibbs et al., 2007, Angelsen, 2008).

However, as carbon sequestration knowledge was being explored, from the interview and questionnaire, resulted that none of the respondents recognized carbon sequestration as one of the services provided by the ecosystem. Similar study in ranking the ecosystem services was done by (Daniel, 2008) in Ghana, and the result was that from the local people perspective, provisioning services is always ranked as the most important services and carbon and other regulating services are the least important.

5.2. Provisioning service collection

Fuel wood is the most sought service by local people, followed by grass, medicinal plants, lumber and bush meat. Bush meat considered as the least sought service. Local people said that bush meat now days are hardly found anywhere. The bush meat that they can quite easily find is only rat and grass cutter. However study done by (Apiah et al., 2007) in Ghana, resulted in different perception of bush meat. From their study, local people are considered bush meat as one of the forest products that can generate their income.

The interesting result comes from different education level. People with the secondary background admitted collect all the provisioning services. This can be because that people from the secondary education have more knowledge in knowing how to collect the services better than people from other education level. Or, their educational background makes them easier to understand the question, and then they can understand better the question during the discussion and interview. But however this was not clearly explored during the discussion and interview.

5.3. The importance of provisioning services

When it comes to the importance of the services, fuel wood is always ranks as number one and grass in the second place, followed by bush meat, medicinal plants and lumber.

Fuel wood is ranked as the most important service. This corresponds with the fact that fuel wood is collected by all respondents. Some of the fuel wood that they collect is partly sell to generate their income. Similar result comes from the study done by (Apiah et al., 2007) in Ghana. They indicate that petty trading of fire wood is one of their incomes that form an integral part of the way of life of the local people. But mostly, they used the fuel wood for daily needs in cooking. As confirmed by (Prasad, 2008) that studied the energy in West African households, and Ghana is one of the countries that under this study , found out that households in West Africa have traditionally used biomass fuel for cooking. Moreover, also found that in Ghana, the two most common cooking fuels are charcoal and wood.

From the valuation, it shows that fuel wood receives higher value from female rather than male. The reason behind this different valuation is the existence of traditional rule in the area, that female is responsible for collecting fuel wood. However, this traditional rule is not strict anymore but still applied by the majority of the people. Nevertheless male also considers that fuel wood is the most important service for their life. And surprisingly all male respondents admitted to collect it as well. Unfortunately during the discussion and the interview the reason behind this male valuation in fuel wood was not clearly explored. However there are some hints that probably become the reasoning. One of which is, as most male is the head of family that usually responsible for the economic of the family, thus make fuel wood is interesting because it could generate income.

Grass is ranked number two for its important for local community’s livelihood. Grass is used for roofing their house and animal storage. Apart from that grass is used as well to feed their animal. Grass is fully collected for their consumption. They don’t sell grass to generate income.

Bush meat is ranked in the third place. However, bush meat is still necessary for supporting the livelihood of local community. They need bush meat for their consumption, from the discussions some of the respondents said that if they have more than enough of bush meat, then they can sell it to others that also need it. This selling part is only a very small trading. The income that they get from selling the bush meat was not clearly known during the discussion and interview. But, from their statement that bush meat are now hardly found in forest or in any other land cover, thus it could be a based of argument that bush meat not significant in generate the income of local community.

However, they rank medicinal plants number four for its importance for local community live livelihood. Medicinal plants are needed mostly for their personal use. They need it to heal sick people. Nonetheless this need is not based on daily needs. Apart from that, some respondents who didn’t collect medicinal plants stated that they can easily get the medicinal plants from others who collect it.

Lumber is ranked as the least important service that is essential for their live. Lumber is used for building their house, animal storage and crops storage. The reason why they put lumber as the least important provisioning service is because these utilizations are not required to be fulfilled daily. The utilization will be based on their needs. Apart from that, they aware that lumbering is not allowed in the forest reserve. During the discussion and interview, one of the interpreters is the Forestry Commission employee, that quite well known by the local people in the study area as one of the forest guard person. And as they aware that lumbering is not allowed in the forest reserve, and even if they want to do lumbering in their taungya system, they should have permission from the Forestry Commission. Those reasons make them did not dare to express the real fact of the way they value and collect the lumber.

5.4. The influence of different gender, education level and village in collecting and valuing the provisioning services

As for the valuation, the statistical result shows that there is no significant difference on the valuation of the provisioning services based on different gender, education level and villages. Although they give different value for each service, but the pattern of the valuation is the same, which means that they give the same higher value for a specific service and lower value for other specific service.

5.5. Land cover map as the basic spatial information in defining the boundary of ecosystem to be valued

From the image classification result, there are five main types of land cover exist in the study area, namely: annuals, built up, forest, grass and teak monoculture.

Annuals constitutes the highest area which covered 53.3% (18,722 ha) of the study area, followed by forest that covered 19.1% (6,712 ha), built up which covered 17.87% (6,276 ha), teak monoculture covered 6.62% (2,327 ha) and grass as the smallest extent covered only 3.1% (1,091 ha) of the study area.

In this study land cover map was used as the basic spatial information for the valuation. Once we know on what type of the land cover in the study area, thus we can determine the boundary of the ecosystem to be valued in the study. Apart from that, the information of the land cover leads us to the better understanding of ecosystem services and the land cover type that provide them.

Study done by (Chen et al., 2009) in Tiantai County, China, give similar point of view in the importance of the land cover as basic spatial information in valuation. They stated that valuation requires that the object of the valuation is should be clearly defined. Thus they underline that a specification of the boundaries of the ecosystem and moreover, the type of the services to be valued should be the first step in doing the valuation.

Similar study done by (Troy and Wilson, 2006) in Massachusetts and California. Even, they don’t put land cover establishment is the first step in the valuation, but they highlight that the establishment of land cover type in the study area will give a significant prediction of the difference value from the ecosystem.

5.6. The importance of local community valuation, their criteria and indicators

While many studies often valued the ecosystem services from economic and biophysical point of view (Raymond et al., 2009), in this study local people valuation was assess and mapped. Local people are considered as one of the stakeholders that are attached to the forest and tree based ecosystem. This is inline with the definition from (Hein et al., 2006) in relation with ecosystem services valuation, that stakeholders are “any group or individuals who can affect or is affected by the ecosystem’s services”.

Local people can affect the management in the area. This clearly seen from the study area, those local people are willing to be part of the taungya system. As under this taungya system, there are benefits that people obtain more, rather than they encroach the forest. One of the benefits is they can legally do cropping in the forest reserve (degraded), which has higher soil fertility rather than their privately owned farm that out side the forest. The sharing benefit is also one of the interesting parts of this taungya system. However those who participated in the taungya system should plant trees in their taungya. Thus, this fact can be seen as the affect of the local people perspective in manage the ecosystem. Similar opinion shared by (Blay et al., 2007) that the role of people in forest rehabilitation in Ghana is have a significant influence the successfulness of the rehabilitation.

Large numbers of local people posses’ knowledge of their environment. Therefore it is important to take the advantage from their knowledge to give a valuation on their environment. This can be used as information in better understanding the relationship between local people and their environment. As the forest and tree based ecosystem are part of their environment, and those ecosystems give numerous benefit that is ranging from being a source of agricultural land to non-timber forest product, that have significant value for local people livelihood. And in consequence their needs are affecting the way they treat the ecosystem. One of the most their main activities that are affecting to the ecosystem is that they can easily convert the forest into their agricultural land and cutting trees. Another example is that the local people will not cut a certain tree if the tree has culture value; or they will not disturb the area which they considered as heritage site. Thus it makes the future of the ecosystem is linked with the lives and livelihood of local people (Norris et al.)

However it is difficult to map such valuation without knowing the people’s criteria and indicators, used to value the ecosystem. Local people may put different reason from forest managers, or timber sellers, in valuing the ecosystem services. As (Hein et al., 2006) confirmed in his paper that each stakeholders that attach to ecosystem will give different value for the ecosystem.

Therefore, the identification of the criteria and indicator for the valuation was explored. From the discussion, interview and questionnaire conducted with local people, resulted to identification of two criteria as the basic for valuation from their perspective. The first criterion is the capability of land cover in providing a specific service. The second criterion is the capability of the land cover in providing all the services that constitute their livelihood. The third criterion is walking distance that they do to travel from their settlement into the specific land cover.

5.7. Land covers valuation based on the criteria and indicators from local people perspective

Before discussing the land cover valuation, note that as mention in section 4.1, for the land cover valuation, annuals were considered as land cover with mixed system between privately on farmland and agro-forest.

From the land cover valuation based on its relative importance as a collection place for a specific service, annuals (taungya) receive the highest value as collection place for bush meat, fuel wood, medicinal plants and lumber. As for grass collection place, grass land receives the highest value from local people.

Regarding the importance of land each land cover as total services provider used as the criteria, annuals, again received the highest value, followed by grass, forest and teak monoculture,

From those two criteria, it shows that the dependency of the local people is high in annuals. In fact this highest value in annuals is actually the value of the mixed system. However, if we look back to the history of the annuals, we see that in fact that part of the annuals is degraded forest that is given as parcels to the local people, and managed under the taungya system. This degraded forest that partially given to local people as part of reforestation effort done by Forestry Commission (See Section 4.1). Thus, this dependency is relevant according to the opinion shared by (Shackleton et al., 2007), that the majority forests, by their very nature, are located within rural and frequently remote areas. (Shackleton et al., 2007) shared opinion that mostly local people livelihood is depend on the environment in their surrounding areas.

The opinion from (Shackleton et al., 2007), was proofed from the result from this study. In the study area, annuals are the dominant land cover. This implies that, not surprisingly that local people have high dependency on this land cover. And moreover this imply to the fact that taungya is an important system, not only because of the reforestation function, but also it provides many services, which could be an incentive for people to apply the system.

From the discussion and interview, in the taungya they should responsible as well to the rule put by the Forestry Commission in the taungya, such as not cutting the trees deliberately, except for land clearing; and planting the determined trees. This is a very strict rule, and if they don’t follow the rule certain action will take by the Forestry Commission. Thus it makes local people more preserve this area; since it is not only providing most of their needs, generate their income from the cropping, but also guarantee their rights in the taungya.

Forest considered as not having the highest capability in providing the services, the restriction that is put on it, becomes one of the reasons why the value given is not as high as annuals. From the valuation, it resulted that they put low value for forest and even higher for grass, as the land cover for collecting fuel wood and lumber. This is quite surprisingly, since from many case studies, and literature review mentioned that fuel wood and lumber are one of the services that provided by the forest and tree based ecosystem (MA, 2003b, Prasad, 2008, Blay et al., 2007, Apiah et al., 2007, de Groot et al., 2002). One of the reasons is that, during the interviewed, one of the interpreters is from Forestry Commission; and local people are aware that they not allowed collecting fuel wood (except the falling branches) and lumber in the forest, so they are not likely to confess that they still do.

Apart from that, as the fact that fuel wood is rank as the most important service for their life, and from the valuation, annuals receive the highest value as the land cover that important as collection place for fuel wood. In fact, the fuel wood is collected from their taungya. From the discussion they stated that during the land clearing they will get a lot of fuel wood. However, during the field work, it wasn’t seen much small trees or trees that are easy to use as fuel wood in taungya. Most of the trees in taungya is old and huge trees which are seems do not have branches that can be used as the fuel wood unless they cut down the trees. However, if seeing the forest conditions, it seems that it is more sense that people will collect the fuel wood and lumber from the forest. Thus makes the valuation for land cover as fuel wood and lumber collection is suspicious.

The lowest value always registered for teak monoculture. Teak monoculture is privately owned by the company and or by Forestry Commission. The restriction that is put in this ecosystem by the owner is clear. The only service that provide by teak monoculture is the falling branches that sometimes found by local people on their way. In fact teak monoculture will have a lot of lumber. Local people usually use teak as poles for construction, fencing, rafters, fuel wood, stakes and wind breaks. It has also become an important source of income for small scale farmers (Nunifu and Murchison, 1999). But people are not allowed to use it at will. Often teak is owned by someone else, who gets the revenues. Sometimes it is a village woodlot but still people will not be allowed to use it for themselves only. It will belong to the entire village and the poles will be sold to e.g. Electricity Company. Apart from that, the allelopathic of teak that inhibits the growth of other plants (Healey and Gara, 2003). That reasoning make teak monoculture is having the least capability in providing the services needed by the local people.

GIS is widely available as a powerful and easy-to-use tool in evaluating and mapping the ecosystem services valuation. Using GIS function, the land cover valuation map as total services provider (second criterion) is then combined with the third criterion, the walking distance. From the result, it can be seen that the further need to walk to reach the collection place to collect the services, then the lower the value that they put. However, from the discussion and interview, there was no quantitative value given by local people on the importance of their waking distance in influencing their valuation. Even, road and foot path can be considered make their walking distance shorter, however the roads are not included in the walking distance assessment because there is no foot path information and only including main roads might give erratic results, or it can be said that there is not enough accessibility information.

5.8. Valuing carbon sequestration as hidden service

From this research, it can be revealed that in the study area, clearly carbon sequestration is having no value from the local people’s perspective. They don’t recognize it as one of the services of the ecosystem. The capability of forest and tree based ecosystems to sequester carbon and support climate stabilization is not taken into account by the local people.

Long rotation systems , such as agro-forests can sequester large quantities of C in plant biomass (Albrecht and Kandji, 2003). However, due to the several activities such as land clearing, agro-forest also emitted the carbon. Due to the time constraint, the carbon emission in the agro-forest is not quantified in the study. The study only focuses on the ability of agro-forest in sequestering the carbon.

From the carbon estimation, the estimated C stock calculation in the study area resulted in the fact that annuals have the highest C stock (1,661 G g) among other land cover types followed by forest which has 1,281 G g C stock, teak monoculture has 206.4 G g and the smallest stock is registered in grass land which has only 43.32 G g stock of carbon. However, annuals appear in two different land uses, they are farm land and agro-forest, which managed under the taungya system. From the C stock estimation, it can be calculated as well, the stock in agro-forest, simply by considering only the C stock from annuals inside in the forest reserve. The C stock estimation in agro-forest alone is 1,053 G g.

Annuals, in the study area, which mostly are appeared as agro-forest (see section 4.1), are not only valuable as the land cover that provides food in addition to all the provisioning services needed by local people, but it is also valuable as the highest land cover in stocking the carbon.

For carbon prediction modelling, agro-forest has more attention in this study, because in fact this agro-forestry which is managed under the taungya system, is part of the reforestation done by the Forestry Commission in Ghana. Thus makes the agro-forestry system shows the potential benefit from the reforestation management that put in it, the capability in sequestering the carbon and providing ecosystem services needed by the local people.

From the carbon prediction, agro-forest will sequestered 1,796 G g carbon in 5 years time, if the trees in agro-forest are left undisturbed. It means that agro-forest sequestered 743 G g carbon more from the current carbon stock. However, in agro-forest area there are trees that are purposively plant. Teak is one of the trees that determined to be planted in the agro-forest area. Thus, from the point of view from the local people, teak has economic value. Apart from the sharing benefit that managed under the taungya system, the local people also have more benefit from the incentive given to them for their labour activity during the harvesting. But, the actual amount of money (in Ghana cedis) that they could potentially receive from the sharing benefit and the labour activity can not be calculated at this stage.

During the discussion with the local people, the information on the age of the teak that they had planted, and the harvesting management was explored. They mentioned that most of the teak now, is at age 5. The thinning management, usually do at the age of 7. During the thinning management, the local people also have benefit from the falling branches that can be used as their fuel wood. The carbon modelling prediction allows taking into account the thinning management. In this case, it assumed that during the thinning management, the fraction removed from the Teak is only 0.2. Which means that only 20% of the branches from the Teak that removed. However, the thinning management is also taking part into the number of the C stock in agro-forest. From the carbon prediction, if thinning management is done in the agro-forest, and the simulation year is two years more from the current age, so the carbon stock in the agro-forest will be 1,351 G g. And if there is no thinning management, and the trees are left to growth at age 7, the stocked will be 1,688 G g. It shows that the management of Teak in the agro-forest influence the capability of agro-forest in sequestering the carbon.

However this valuable service from agro-forest is not recognized by local people. They don’t considered carbon stock as one of the services, since this service is not having direct value in their livelihood. They don’t have income, or direct benefit from carbon. Similar opinion is shared by (Apiah et al., 2007), from their research in Ghana. They conclude that local people give less attention to the environmental issues, because their priority is to fulfil their household needs.

On the other hand, as the concern on the carbon sequestration is increased, the United Nations Framework Convention on Climate Change (UNFCCC) introduced the new policy which is entitled as Reduced Emission from Deforestation in Developing Countries (REDD). This can be adopted for abating the carbon by reducing the forest degradation and deforestation, through forest enhancement. The REDD concept is a proposal to provide financial incentives to help developing countries voluntarily reduce national deforestation rates and associated carbon emissions below a baseline (based either on a historical reference case or future projection). Countries that demonstrate emissions reductions may be able to sell those carbon credits on the international carbon market or elsewhere. These emissions reductions could simultaneously combat climate change, conserve biodiversity and protect other ecosystem goods and services (Angelsen, 2008, Gibbs et al., 2007). Thus makes REDD has the potential to achieve significant co-benefits, including alleviating poverty, improving governance, and conserving biodiversity and providing other environmental services.

This opens the possibilities for people that are engaged in forest management to participate in the global carbon market. Several studies have pointed to options (such as multi-species people-based reforestation or agro-forestry (Karky and Skutsch, 2010)) that have potential to deliver benefits to those marginal populations, these are true to the goals of the UNFCCC, and can also be attractive to emerging socially and environmentally responsible markets (Karky and Skutsch, 2010, Boyd et al., 2007).

In practice, carbon markets are very complex because they assume the existence and integration of many conditions at multiple levels. The requirements include the technical capacity to enhance carbon storage in production systems, the capacity for farmers and other resource users to collectively adopt and maintain land resource practices that sequester carbon, the ability to monitor carbon stocks at a landscape level, the institutional capacity to aggregate carbon credits at levels large enough for dealers to consider worthwhile, the financial mechanisms for incentive payments to reach farmers, and transparent and accountable governance structures that can ensure equitable distribution of benefits. (Perez et al., 2007).

In the study area, carbon aspect was not popular. The economic value from the Teak and the sharing benefit under the Taungya system are much more attractive for the local people than the carbon value. It can be a suggestion for the management to start, at least to disseminate the knowledge on the carbon sequestration and its value. The carbon management that can be applied in the study area and how that can give the benefit to local people should be explored as well. Learning from the study done by (Karky and Skutsch, 2010), in Himalaya Nepal, the carbon trading will only be attractive for the local people if the benefit from carbon management exceeds benefit from existing management.

5.9. Limitations of the research

During the interview and discussion, language is a significant constraint in this study. The role of the interpreter became significant during the interview and discussion session. Thus, when the interpreter could not explain properly of the questions and the answers, it led to the misunderstanding of the information needed.

Another limitation in this study is related to the carbon stock prediction modelling. Due to the difficulty in obtaining the yield table data for teak (as single cohort for the modelling) in the study area, the yield table derived from the model built by (Nunifu and Murchison, 1999) was used as the input data in the carbon stock modelling. However, yield table was modelled in the plantation area in northern Ghana. The carbon stock prediction in this study was done in agro-forestry, where other plants and crops exist in the same area with the teak. Unlike in the plantation where there are no other plants except the teak itself. Thus it makes the competition in the agro-forest and plantation different. The competition in the agro-forest is likely to be higher than in the plantation, due to the existence of other plants.

Apart from that, the yield table was modelled based on the sample plots of the plantation in northern Ghana, where the climate and the soil condition are different from the study are which was in southern Ghana. Northern Ghana is characterized by distinct dry and wet seasons, and southern Ghana is characterized by humid and semi-equatorial climate.

The differences between the location where the yield table was modelled and the study area are likely to introduce uncertainty in the result from the modelling.

6. Conclusions

What are the land cover type/ecosystems in the study area?

There are five main land cover types in the study area, namely annuals, built up, forest, grass land and teak monoculture. Annuals constitutes the highest area which covered 53.3% (18,722 ha) of the study area, followed by forest that covered 19.1% (6,712 ha), built up which covered 17.87% (6,276 ha), teak monoculture covered 6.62% (2,327 ha) and grass as the smallest extent covered only 3.1% (1,091 ha) of the study area.

What are the services provided by these ecosystems in study area?

Provisioning services are the most recognized by local people as the service provided by the ecosystems. Apart from that, there are other services from the ecosystem that recognized by partly of the local people, namely maintaining the soil fertility, water and fresh air provision. Carbon sequestration knowledge was explored as well; however none of the respondents recognized it as one of the services provided by the ecosystem.

What can be indicators to measure the value of these services?

From the discussion, interview and questionnaire, can be concluded that there are three criteria that they put for the valuation, and each criteria has its own indicators. The criteria and indicators are:

1. The capability of each ecosystem in providing a specific service. The indicators for this criterion are, number of animal (for bush meat), number of bundle (for grass and fuel wood), number of medicinal plant species (for medicinal plants) and the type of the allowable cutting trees species (for lumber).
2. The capability of each land cover in providing numerous of services that important in constituting the livelihood of local people. The indicators for this criterion are number of services and the importance of the services for local people.
3. The availability of land cover. The indicator for this criterion is walking distance.

How it can be mapped?

Identification the criteria and indicator for the valuation is important to understand the value that put in the ecosystem. Land cover map was used as the basic spatial information. Then GIS function was applied to transfer the value given to each land cover. Spatial multi criteria analysis then applied to overlay the criterion map and consequently mapped the total valuation.

What is the value of the regulating service aboveground carbon stored in woody biomass of the forest and tree based ecosystems in the study area?

The total carbon stored in woody biomass in study area is 3,191.46 G g. The highest carbon stored in woody biomass is registered in annuals (1,661 G g), followed by forest (1,281 G g), teak monoculture (206 G g) and grass (43 G g).

How the prediction of the (carbon) profit is could be in 5 years time if trees are left undisturbed?

The prediction of the carbon profit is could be in 5 years time if trees are left undisturbed was done only in the annuals that appears as agro-forest area. The prediction was used teak as the single cohort due to the lacking of other species data. In 5 years time, the carbon stock prediction is 1,796 G g.

How does this relate to the other services as valued by the people?

From the local people perspective, carbon sequestration receives no value, carbon sequestration is not recognized as one of the services provided by forest and tree based ecosystem. Thus from the local people perspective, carbon is not having value compared to the provisioning services that valuable for them.

7. Recommendations

Grid based analysis is one of the methods that is recommended to be used to spatially assess the ecosystem services. The area can be divided in a grid, and the assessment is done per grid cell, based on several criteria and indicators. In this approach the value of the services is not directly linked to the vegetation, as was the case in current study. The roughness of the road and the foot path and the difficulty to access the location should be included as indicators to be valued. The roughness of the road and the foot path are likely to influence the value given, since the travel time to location could be longer in the rough road compared to the smooth one. The local people will give lower value difficult accessible areas and high value to the easily accessible ones. However, not only the difficulty to access the location also influences the valuation. The steep slope should be considered as the constraint for the local people to travel to the location. The steeper the slope level then it might the lower the value given.

Then, the combination of the access conditions will give different valuation. This makes the influence of accessibility and its indicators in the ecosystem services valuation interesting to assess.

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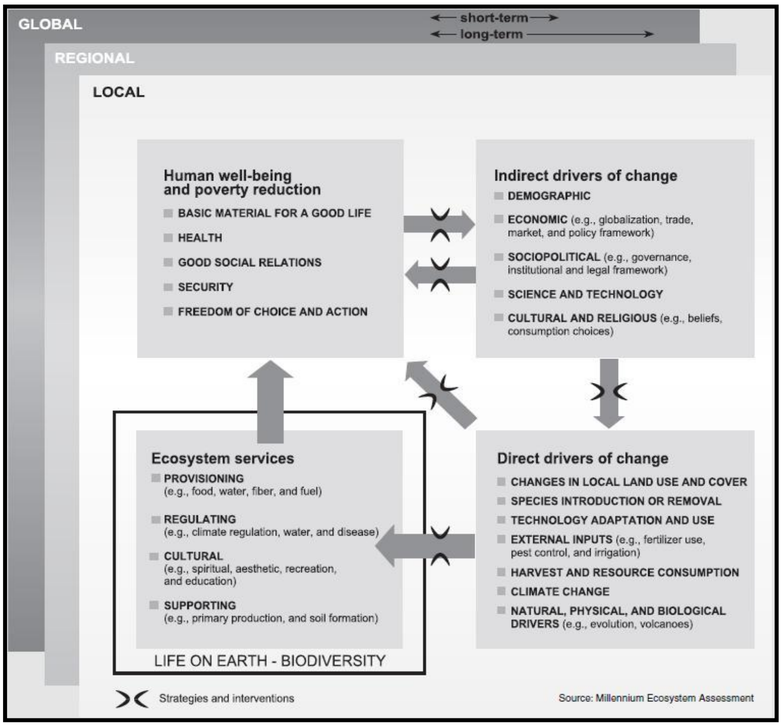
Appendices

Appendix 1. MA Conceptual Framework



Appendix 2. Leigon Projection

Projection: Transverse_Mercator

False_Easting: 274319.510000

False_Northing: 0.000000

Central_Meridian: -1.000000

Scale_Factor: 0.999750

Latitude_Of_Origin: 4.666667

Linear Unit: Meter (1.000000)

Geographic Coordinate System: GCS_Leigon

Angular Unit: Degree (0.0174532925199433299)

Prime Meridian: Greenwich (0.000000000000000000)

Datum: D_Leigon

Spheroid: Clarke_1880_RGS

Semimajor Axis: 6378249.144999999600000000

Semiminor Axis: 6356514.869549775500000000

Inverse Flattening: 293.464999999999970000

Appendix 3. Sample Sheet

SAMPLING PLOTS

Date:			
Recorder:			
Plot ID:		X:	Y:
Land cover: (F= Forest, OF= Open forest, G=Grass land, A=annual crop, FL=Fallow land, P= Perennial crop,T= Teak plantation)			
Rectangular: 900m2 (30mx30m) or Circular (R=12.6m)			
ID	Species	DBH (>10 cm)	R

R is the nearest distance to the closest tree
NOTES:
Tree height (only measure 10% of the total trees in the plot)
% cover (5 position - 4 in the corners and 1 at center)
Crown Diameter (only measure 10% of the total trees in the plot)

Appendix 4. Questionnaire

Questionnaire							
Date:							
1	**General Information**						
1a	Field enumerator:	Village name:					
2	**Respondent Information**						
2a	Name:	Gender:	F [ ]	M [ ]			
2b	Age:						
2c	Education level:	Illeterate [ ]	Litterate [ ]	Primary [ ]	Secondary [ ]	Tertiary [ ]	
2d	Occupation:						
2e	No of children:						
2f	No of dependents:						
2g	Income level:	Annuall [ ]	Monthly [ ]	Daily [ ]	Others, specify:		
3	**Harvestable Services**						
3a	Which of the following items do you usually collect:						
	Bush meat [ ]	Grass [ ]	Food [ ]	Fuel wood [ ]	Medicinal plants [ ]	lumber [ ]	
3b	Where do you usually collect these items:						
	Services	Value	Uses	Collection Place	Value	Indicator	Remark
	Bush meat						
	Grass						
	Food						
	Fuel wood						
	Medicinal plants						
	Lumber						
3c	How far do you walk/travel to collect these						

	items:					
	Miles/km	1-5 [ ]	6-10 [ ]	11-15 [ ]	16-20 [ ]	> 20 [ ]
3d	How many minutes do you walk/travel to collect these items:					
	minutes	5-10 [ ]	15-20 [ ]	25-30 [ ]	>30 [ ]	
3e	Do you collect these items for your family or u sell it:	Y [ ]	N [ ]			
	If Y, how many people make use of these items?					
	And how much do you earn from selling these items?					
	Is it depen on the seasoning?	Y [ ]	N [ ]			
	If Y, what kind of items are?					
	Dry		Rainy			
	Items	Value	Items	Value		
3f	Do you have a special valuable/merchantable trees that you prefer/use most:					
	Y [ ]	N [ ]				
	If Y, specify:					
	For what kind of uses?					
	Non-harvestable Services					
4a	Do you know this land cover provides other services:	Y [ ]	N [ ]			
	If Y, specify below:					
	1	5				
	2	6				

	3	7
	4	8

4b	**Pair-wise comparison for non harvestable services**								
		1	2	3	4	5	6	7	8
	1	1							
	2		1						
	3			1					
	4				1				
	5					1			
	6						1		
	7							1	
	8								1

4c	Do you have a place set as a Scared groove/heritage site:	Y [ ]	N [ ]
	If Y, what is the specific reason behind the establishment of the site:		

5	**Carbon Sequestration**		
5a	Do you know what carbon sequestration is:	Y [ ]	N [ ]
	If Y, specify:		
5b	Do you know the importance of carbon in nature:	Y [ ]	N [ ]
	If Y, specify:		
5g	Do you know about the carbon market:	Y [ ]	N [ ]
	If Y, specify:		

Appendix 5. Discussion and interview for valuation

Appendix 6. Teak's provisional yield table

Provisional yield tables for teak plantations in northern Ghana

Age	dbh (cm)	Height (m)		BA (m^2/ha)	Volume (m^3)		
	Mean	Top	Mean		Gross	CAI	MAI
Site class I							
4	5.81	6.72	4.55	4.48	12.62	8.78	3.15
8	11.88	11.54	8.55	17.24	64.39	15.84	8.05
12	16.30	14.66	11.31	31.32	132.56	17.75	11.05
16	19.69	16.90	13.36	44.70	203.87	17.73	12.74
20	22.39	18.63	14.97	56.99	273.49	17.02	13.67
24	24.63	20.02	16.28	68.17	339.71	16.08	14.15
28	26.52	21.17	17.38	78.36	402.07	15.10	14.36
32	28.14	22.15	18.32	87.68	460.57	14.16	14.39
36	29.57	22.99	19.13	96.22	515.43	13.28	14.32
40	30.83	23.73	19.85	104.1	566.91	12.47	14.17
Site class II							
4	3.29	4.98	3.03	1.44	5.50	4.24	1.38
8	7.36	8.55	6.28	6.93	33.47	9.12	4.18
12	10.51	10.86	8.68	13.91	74.49	11.05	6.21
16	13.00	12.52	10.52	21.06	120.00	11.56	7.50
20	15.03	13.80	12.00	27.96	166.16	11.45	8.31
24	16.73	14.83	13.23	34.46	211.27	11.08	8.80
28	18.19	15.68	14.26	40.54	254.64	10.60	9.09
32	19.45	16.41	15.16	46.21	296.00	10.08	9.25
36	20.56	17.03	15.94	51.50	335.29	9.57	9.31
40	21.55	17.58	16.64	56.45	372.58	9.08	9.31
Site class III							
4	1.62	3.69	1.72	0.40	1.15	1.02	0.29
8	4.01	6.33	3.71	2.22	9.10	2.84	1.14
12	5.99	8.04	5.21	4.75	22.74	3.86	1.89
16	7.61	9.28	6.38	7.48	39.25	4.33	2.45
20	8.97	10.23	7.32	10.20	56.98	4.50	2.85
24	10.12	10.99	8.10	12.83	75.02	4.50	3.13
28	11.12	11.62	8.77	15.32	92.90	4.43	3.32
32	11.99	12.15	9.35	17.69	110.38	4.30	3.45
36	12.76	12.62	9.86	19.92	127.32	4.16	3.54
40	13.46	13.02	10.31	22.02	143.66	4.01	3.59

dbh – diameter at breast height; BA – basal area; CAI – current annual increment; MAI – mean annual volume increment.

Appendix 7. Picture of each land cover


Annuals

Grass

Forest

Teak monoculture

Built up

Appendix 8. Picture of provisioning services

Bush meat

Spear grass

Fuel wood

Lumber

Medicinal plants

Appendix 9. Statistical test for the importance of the services based on different gender

FEMALE

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Bush meat	22	31	1.409091	2.634199
Grass	22	65	2.954545	2.235931
Fuel wood	22	164	7.454545	3.116883
Medicinal plants	22	58	2.636364	6.4329
Lumber	22	50	2.272727	4.112554

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	493.6909091	4	123.4227	33.29905	6.39E-18	2.45821
Within Groups	389.1818182	105	3.706494			
Total	882.8727273	109				

	F calculated
Bush meat-grass	7.100737
Bush meat- fuel wood	**108.6548**
Bush meat- medicinal plants	4.477887
Bush meat- grass	2.217445
Grass- fuel wood	**60.2027**
Grass- medicinal plants	0.300983
Grass- lumber	1.382064
Fuel wood- medicinal plants	**69.0172**
Fuel wood- lumber	**79.82801**
Medicinal plants- lumber	0.39312

MALE

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Bush meat	48	142	2.958333	3.785461
Grass	48	149	3.104167	2.350621
Fuel wood	48	282	5.875	3.728723
Medicinal plants	48	98	2.041667	2.296099
Lumber	48	105	2.1875	1.857713

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	460.0583333	4	115.0146	41.02209	4.65E-26	2.410058
Within Groups	658.875	235	2.803723			
Total	1118.933333	239				

	F calculated
Bush meat-grass	0.182292
Bush meat- fuel wood	**72.91667**
Bush meat- medicinal plants	7.202381
Bush meat- grass	5.093006
Grass- fuel wood	**65.80729**
Grass- medicinal plants	9.676339
Grass- lumber	7.202381
Fuel wood- medicinal plants	**125.9524**
Fuel wood- lumber	**116.5513**
Medicinal plants- lumber	0.182292

Appendix 10. Statistical test for the importance of the services based on different education level

Illiterate

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Bush meat	31	64	2.064516	3.529032
Grass	31	90	2.903226	2.356989
Fuel wood	31	211	6.806452	4.227957
Medicinal plants	31	40	1.290323	1.47957
Lumber	31	54	1.741935	1.197849

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	616.0258	4	154.0065	60.19923	3.05E-30	2.431965
Within Groups	383.7419	150	2.55828			
Total	999.7677	154				

	F calculated
Bush meat-grass	4.36129
Bush meat- fuel wood	**139.4129**
Bush meat- medicinal plants	3.716129
Bush meat- grass	0.645161
Grass- fuel wood	**94.45806**
Grass- medicinal plants	16.12903
Grass- lumber	8.36129
Fuel wood- medicinal plants	**188.6516**
Fuel wood- lumber	**159.0258**
Medicinal plants- lumber	1.264516

Literate

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Bush meat	10	25	2.5	5.166667
Grass	10	32	3.2	1.066667
Fuel wood	10	61	6.1	0.988889
Medicinal plants	10	29	2.9	4.544444
Lumber	10	26	2.6	1.822222

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	90.12	4	22.53	8.289861	4.25E-05	2.578739
Within Groups	122.3	45	2.717778			
Total	212.42	49				

	F calculated
Bush meat-grass	0.907407
Bush meat- fuel wood	**24**
Bush meat- medicinal plants	0.296296
Bush meat- grass	0.018519
Grass- fuel wood	**15.57407**
Grass- medicinal plants	0.166667
Grass- lumber	0.666667
Fuel wood- medicinal plants	**18.96296**
Fuel wood- lumber	**22.68519**
Medicinal plants- lumber	0.166667

Primary

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Bush meat	18	50	2.777778	5.124183
Grass	18	59	3.277778	3.74183
Fuel wood	18	111	6.166667	3.911765
Medicinal plants	18	55	3.055556	5.114379
Lumber	18	47	2.611111	5.075163

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	155.5111	4	38.87778	8.463717	8.5E-06	2.479015
Within Groups	390.4444	85	4.593464			
Total	545.9556	89				

	F calculated
Bush meat-grass	0.5
Bush meat- fuel wood	**22.96914**
Bush meat- medicinal plants	0.154321
Bush meat- grass	0.055556
Grass- fuel wood	**16.69136**
Grass- medicinal plants	0.098765
Grass- lumber	0.888889
Fuel wood- medicinal plants	**19.35802**
Fuel wood- lumber	**25.28395**
Medicinal plants- lumber	0.395062

Secondary

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Bush meat	9	31	3.444444	1.527778
Grass	9	28	3.111111	1.361111
Fuel wood	9	52	5.777778	6.444444
Medicinal plants	9	29	3.222222	2.694444
Lumber	9	25	2.777778	1.944444

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	52.22222	4	13.05556	4.671968	0.003448	2.605975
Within Groups	111.7778	40	2.794444			
Total	164	44				

	F calculated
Bush meat-grass	0.185185
Bush meat- fuel wood	**9.074074**
Bush meat- medicinal plants	0.082305
Bush meat- grass	0.740741
Grass- fuel wood	**11.85185**
Grass- medicinal plants	0.020576
Grass- lumber	0.185185
Fuel wood- medicinal plants	**10.88477**
Fuel wood- lumber	**15**
Medicinal plants- lumber	0.329218

Appendix 11. Statistical test for the importance of the services based on different village

Akrofoa

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Bush meat	11	33	3	6.8
Grass	11	41	3.727273	2.018182
Fuel wood	11	71	6.454545	1.472727
Medicinal plants	11	26	2.363636	1.854545
Lumber	11	19	1.727273	0.418182

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	148	4	37	14.72504	5.14E-08	2.557179
Within Groups	125.6364	50	2.512727			
Total	273.6364	54				

	F calculated
Bush meat-grass	1.163636
Bush meat- fuel wood	**26.25455**
Bush meat- medicinal plants	0.890909
Bush meat- grass	3.563636
Grass- fuel wood	**16.36364**
Grass- medicinal plants	4.090909
Grass- lumber	8.8
Fuel wood- medicinal plants	**36.81818**
Fuel wood- lumber	**49.16364**
Medicinal plants- lumber	0.890909

Asempanaye

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Bush meat	10	17	1.7	6.677778
Grass	10	25	2.5	6.277778
Fuel wood	10	66	6.6	5.155556
Medicinal plants	10	15	1.5	8.055556
Lumber	10	5	0.5	1.166667

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	224.32	4	56.08	10.25854	5.45E-06	2.578739
Within Groups	246	45	5.466667			
Total	470.32	49				

	F calculated
Bush meat-grass	0.592593
Bush meat- fuel wood	**22.23148**
Bush meat- medicinal plants	0.037037
Bush meat- grass	1.333333
Grass- fuel wood	**15.56481**
Grass- medicinal plants	0.925926
Grass- lumber	3.703704
Fuel wood- medicinal plants	**24.08333**
Fuel wood- lumber	**34.4537**
Medicinal plants- lumber	0.925926

Asuboe

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Bush meat	15	45	3	2.714286
Grass	15	53	3.533333	1.12381
Fuel wood	15	96	6.4	6.685714
Medicinal plants	15	36	2.4	1.4
Lumber	15	35	2.333333	2.666667

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	168.4	4	42.1	14.42722	1.22E-08	2.502656
Within Groups	204.2667	70	2.918095			
Total	372.6667	74				

	F calculated
Bush meat-grass	0.735632
Bush meat- fuel wood	**29.89655**
Bush meat- medicinal plants	0.931034
Bush meat- grass	1.149425
Grass- fuel wood	**21.25287**
Grass- medicinal plants	3.321839
Grass- lumber	3.724138
Fuel wood- medicinal plants	**41.37931**
Fuel wood- lumber	**42.77011**
Medicinal plants- lumber	0.011494

Bemi

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Bush meat	19	60	3.157895	2.473684
Grass	19	42	2.210526	1.064327
Fuel wood	19	104	5.473684	3.48538
Medicinal plants	19	64	3.368421	4.578947
Lumber	19	69	3.631579	2.467836

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	108.0421	4	27.01053	9.598504	1.65E-06	2.472927
Within Groups	253.2632	90	2.814035			
Total	361.3053	94				

	F calculated
Bush meat-grass	3.045113
Bush meat- fuel wood	**18.19549**
Bush meat- medicinal plants	0.150376
Bush meat- grass	0.761278
Grass- fuel wood	**36.12782**
Grass- medicinal plants	4.548872
Grass- lumber	6.851504
Fuel wood- medicinal plants	**15.03759**
Fuel wood- lumber	**11.51316**
Medicinal plants- lumber	0.234962

Bobra

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Bush meat	15	18	1.2	0.885714
Grass	15	53	3.533333	1.266667
Fuel wood	15	109	7.266667	2.352381
Medicinal plants	15	15	1	0.142857
Lumber	15	27	1.8	0.314286

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	407.4133	4	101.8533	102.6353	1.61E-28	2.502656
Within Groups	69.46667	70	0.992381			
Total	476.88	74				

	F calculated
Bush meat-grass	45.37037
Bush meat- fuel wood	**306.7037**
Bush meat- medicinal plants	0.333333
Bush meat- grass	3
Grass- fuel wood	**116.1481**
Grass- medicinal plants	53.48148
Grass- lumber	25.03704
Fuel wood- medicinal plants	**327.2593**
Fuel wood- lumber	**249.037**
Medicinal plants- lumber	5.333333