ECONOMIC VALUATION OF FOREST ECOSYSTEM SERVICES AND ITS IMPLICATIONS ON CONSERVATION STRATEGIES IN EAST MAU FOREST, KENYA

DAVID KIPKIRUI LANGAT

A Thesis Submitted to the Graduate School in partial fulfillment of the requirements for the Degree of Doctor of Philosophy in Natural Resources Management of Egerton University

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Declaration and Recommendation

Declaration

I declare that this thesis is my original work and has not been presented in any other institution of higher learning for the award of an academic degree.

Signature …………………………………………Date ……………………………………

David Kipkirui Langat

(ND11/0332/12)

Approval

This work has been submitted with our recommendation as University Supervisors.

Prof. Abdillahi A. Aboud (PhD)

Department of Natural Resources

Egerton University, Njoro

Signature ……………………………………………Date…………………………………..

Dr. Elias K. Maranga (PhD)

Department of Natural Resources

Egerton University, Njoro

Signature ………………………………………Date……………………………………..

Dr.Joshua K. Cheboiwo (PhD)

Kenya Forestry Research Institute, Muguga

Signature ……………………………………………Date…………………………………

Dedication

This thesis is dedicated to my beloved mother; Edna Tabutany Barabii, who though, never went to school, understood the value of education and struggled to support me in my education.

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Abstract

This thesis quantifies the economic values of East Mau forest ecosystem using Market based, Contingent Valuation and Benefit Transfer techniques. Data was collected from households, sawmills and forest product traders within and adjacent to East Mau forest. Additional data were obtained from published and unpublished sources. Descriptive statistics and parametric tests were applied to describe forest ecosystem values. Difference in forest incomes across locations; ethnicity and wealth classes were tested using comparison of means and ANOVA. A multiple regression model was used to identify determinants of forest dependence with relative forest income and socio-economic characteristics as dependent and independent variables respectively. The total economic value (TEV) of East Mau forest ecosystem was KES 24billion (US$266million) per annum and indirect use values formed the bulk of TEV at KES 19.7billion (US$219 million) (82.4%), direct use values was KES 4.2billion (US$ 46million) (17.5%), and non-use values was KES 31million (US$ 347, 000 (0.1%). The bulk (96%) of direct use values were appropriated by local communities. Carbon sequestration and oxygen generation contributed 79% of indirect use values and 65% of the TEV. The local community and government of Kenya are subsidizing conservation of East Mau by KES 650million (US$7.2million) per annum. The bulk of ecosystems values (65%) accrue to global community and only 35% are appropriated by local communities and government of Kenya. Forest income contributed 33% of household income and poor households are more dependent on forests resources. However, in absolute terms, the wealthy derived greater monetary benefits from forest resources. The key determinants of forest dependence are off-farm income and number of cattle. These results provide valuable information on the types and magnitude of values that could be relevant in decision-making concerning conservation and management of East Mau forest ecosystem for enhanced ecosystem services and livelihoods.

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List of Abbreviations and Acronyms

BT	Benefit Transfer
HH	Household
Mil.	Million
ACC	African Conservation Center
ACTS	African Center for Technology Studies
ADB	African Development Bank
ANOVA	Analysis of Variance
AU	African Union
CBD	Convention Biological Diversity
CBO	Community Based Organization
CDM	Clean Development Mechanism
CVM	Contingent Valuation Method
DRSRS	Department of Remote Sensing and Resource Surveys
ECA	Economic Commission for Africa
ETS	Electronic Trading System
EU-BCP	European Union- Biodiversity Conservation Project
GDP	Growth Domestic Product
GIS	Geographic Information System
GNP	Gross National Product
HPM	Hedonic Pricing Method
IPCC	Intergovernmental Panel on Climate Change

ITCZ	Inter-tropical Convergence Zone
KEFRI	Kenya Forestry Research Institute
KFMP	Kenya Forestry Master plan
KFS	Kenya Forestry Service
KFWG	Kenya Forest Working Group
KII	Key Informant Interviews
KNBS	Kenya National Bureau of Statistics
MEA	Millennium Ecosystem Assessment
MENR	Ministry of Environment and Natural Resources
MFC	Mau Forest Complex
NPV	Net Present Value
NTFP	Non-timber Forest Product
NTFPs	Non-Timber Forest Products
PES	Payment for Ecosystem Services
PFM	Participatory Forest Management
PPP	Purchasing Power Parity
PRA	Participatory Rural Appraisal
REDD	Reducing emission from Deforestation and Forest Degradation
SEI	Stockholm Environment Institute
SPSS	Statistical Package for the Social Sciences
TCM	Travel Cost Method
TEEB	The Economics of Ecosystems and Biodiversity
TEV	Total Economic Value
TLU	Tropical Livestock Unit

UNEP	United Nations Environmental Program
WRMA	Water Resources Management Authority
WTA	Willingness to Accept
WTP	Willingness to Pay

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Forests cover about 25% of the world's land mass and are critical in provisioning of various commodities and services such as water, food, medicine, fuel wood, fodder and timber. Forests also provide a wide range of environmental services that support biodiversity conservation, watershed protection, protection of soil and mitigate global climate change (Landell-Mills and Porras, 2002). However, there is unprecedented increase in deforestation globally. According to the Food and Agriculture Organization (FAO) about 13million hectares of world's forests are cut down and converted to other land uses every year (FAO, 2006). For instance, in the period 1990 to 2000, the world lost about 3% of its forest cover to alternative land uses (UNEP, FAO and UNFF, 2009). This raises serious concerns about the sustainability of the various ecosystem services provided by the forest ecosystems.

Africa is endowed with diverse, rich natural and plantation forests which cover 23 percent of the land area of the continent. These forests provide a wide range of goods and services that create opportunities for development, and support the livelihoods of millions of people, living in and around the forest. For example, forest resources contribute about 6 per cent of the Gross Domestic Product (GDP) of the national and local economies in the region but this value exclude fuel wood energy which account for about 90 per cent of domestic energy and subsistence forest uses (Barrow *et al*., 2009). African forest constitute 21 per cent of global total of carbon stock in forest biomass and have the capacity to sequester up to 680kg of carbon per hectare per year, thereby providing critical buffer against global climate change (Katerere *et al*., 2009). Despite the importance of forests in Africa's socio-economic development and sustainable development, the forest estate is declining at a faster rate due to increasing deforestation, land degradation and poor forest management practices. From 2000 to 2010, Africa recorded an annual loss of about 3.4million hectares making it second largest net forest loser in the world (ECA *et al*., 2012).

Forest resources in Kenya are undergoing tremendous degradation through sanctioned excisions, illegal encroachments and illegal extraction.

The rate of deforestation is currently between 0.4% and 1.2% per annum (Mogaka, 2005). Decades of anthropogenic activities have resulted in degraded forests resulting in loss of biodiversity, impaired ecosystem functions and less availability of important wood and non-wood forest products (KEFRI, 2005).The majority of Kenya's 3million forest people depend on forest resources and agricultural activities for their livelihoods (Chao, 2012). The direct forest use and indirect use values contribute 1% and 13% to GDP respectively (World Bank, 2000; UNEP, 2012).

The Forestry sector provides linkages with agriculture and livestock sectors, which are the backbone of Kenya's economy. The sector supports agriculture through soil and water conservation and amelioration of environment and provides economic benefits such as generation of jobs in the rural areas in small and medium-scale forest products processing industries. The regulating services of Kenya's natural ecosystems are important production factors to the agriculture, forest and fishing sectors, the energy and water sectors, tourism , the public administration and security sectors, and sustain a large proportion of the country's population (SEI, 2009; UNEP, 2012). These sectors, together, contributed between 33% and 39% in Gross Domestic Product (GDP) between 2000 and 2010 (UNEP, 2012). In addition, these sectors have a significant multiplier effect on the rest of the economy's GDP. For example, more than 90% of the country's domestic energy requirements are met by fuel wood. One of the highest sources of foreign income is wildlife tourism, which is highly dependent on forest ecosystem (MENR, 1994). Forest ecosystems minimize risks to the economy through the provision of regulatory functions (climate and disease control) and thus provide insurance values to the economy, during times of market volatilities and when security and exports of goods in certain sectors may be a challenge (UNEP, 2012). This insurance value is critical for maintenance of economic resilience in the face of unpredictable variability of environment and economic conditions and also minimizes long-term economic hazards like climate change (UNEP, 2012).

Despite its critical importance in ensuring environmental stability and economic development, forests ecosystems in Kenya are facing unprecedented challenges because of burgeoning population, poverty and accelerated conversion to other land uses (Allaway and Cox, 1989; SEI, 2009). This problem is partly explained by the lack of appreciation of total economic values and the costs of forest degradation (Allaway and Cox, 1989; Emerton, 1996; Emerton, 2001; Mogaka, 2001).

Most policy decisions concerning management and conservation of forest resources do not consider the non-market benefits of the forest ecosystem and therefore a large part of economic costs of forest degradation is ignored in natural resources decisions by policy makers (Emerton, 2001; Mogaka, 2005; Kipkoech *et al*., 2011). This leads to inappropriate allocation of resources and less investment in forest ecosystems. The role played by forests in the provision of ecosystems services such as biodiversity conservation, amenity reservation and aesthetic values are positive externalities which accrue to the public at local, regional, national and global levels. Most ecosystems services unlike conventional goods and services have no developed markets and their prices are not easily determined (Pearce *et al.*, 2002). This has consequently resulted in forest degradation and subsequent negative impacts on hydrological functions such as irregular rainfall, reduction in water levels in rivers and lakes and increased flushness of medium-sized storm flows due to decreased base flows (Mogaka, 2005; Otuoma *et al*., 2011). The impacts of forest clearance has exacerbated flooding and mitigation costs for irrigation, flood control and hydropower generation. For example, by 2011 human activities in upper catchment of Masinga dam had resulted in the loss of water storage capacity of the dam by 215.26m^3 (13.59 %) of its design storage capacity to sedimentation (Bunyasi *et al*., 2013). Forest resource degradation is costing the national economy about KES 175million (US$ 3.5million) per annum due to flush floods, health hazards and crop failures (Mogaka, 2005). Moreover, the country has wood products deficit (fuel wood, timber, pulp and paper and poles).The situation will be exacerbated by further deforestation and environmental degradation that will negatively impact on the livelihoods of the local people (Mogaka, 2005). If natural forests are not restored and the process of deforestation halted, it may reduce land productivity and exacerbate vulnerability to climate change (ACTS and ACC 2011). It is, therefore, important that decisions about forest resources take account of all costs and benefits to ensure their optimal uses.

The Mau complex forms the largest closed-canopy montane forest ecosystem in East Africa covering approximately 400,000ha. It is situated at 0°30’ South, 35°20’ East within the Rift Valley Region and spans seven counties: Baringo, Bomet, Keiyo-Marakwet, Kericho, Nakuru, Nandi, and Narok. The area is thus the largest water tower in the region, being the main catchment area for 12 rivers draining into Lake Baringo, Lake Nakuru, Lake Turkana, Lake Natron and the Trans-boundary Lake Victoria (Kipkoech *et al*., 2011). East Mau forest is one of the critical forest blocks of the Mau Forest Complex (MFC).

It is a source of river Njoro and river Makalia that support Lake Nakuru ecosystems, the largest bird sanctuary in the world and important tourism destination. Additionally, it is the source of Mara River, which is a source of water for the wildlife and livestock in the extensive Mara River Basin and ecosystem–world famous site for spectacular wild beast migration and tourism destination and thriving livestock sector. The forest block was originally about 66,000 ha of contiguous forest and formed one-fifth of the MFC. However, it lost 50% of its size due to excisions for human settlement in late 1990's and early 2000 (UNEP *et al.*, 2006). The encroachment and excisions have led to drastic and rapid land fragmentation, deforestation of watershed and destruction of wetlands in fertile upstream areas (Olang and Kundu, 2011).

The government of Kenya (GoK) recognizes the important role the environment plays in supporting the productive sectors of the economy and this is amplified in the Vision 2030 (GoK, 2007a). To achieve the noble objectives of Vision 2030, the Government of Kenya (GoK) is committed to enhance the protection of critical "water towers" in the country including Mau Forest Complex (MFC). The government of Kenya has initiated a series of reforms in Forestry and Environmental Sectors through policies and legislations (MENR, 1994; GoK, 2005; GoK, 2007b; GoK 2015a). The draft new Forest Policy 2015 proposes to integrate all forest values into the national development processes (GoK, 2015) and recognizes the important role the forest ecosystems play in socioeconomic development of the nation.

The National Forest Policy of Kenya, (GoK, 2015a) and the revised Forest Conservation and Management bill 2015(GoK, 2015b), recognizes and support the active participation of local communities in forest management. The Participatory Forest Management (PFM) approach seeks to develop partnerships between Kenya Forest Service (KFS) and local communities as co-managers for sustainable forest management. However, KFS has not developed a benefit sharing framework suitable for reconciling conservation and livelihoods of the local people (Mariara and Gachoki, 2008). In this context, it is important to know the extent of forest use and level of community's forest dependence and identify factors that influence forest dependence. Many studies in other parts of the world continue to define the crucial role forest resources may play in poverty alleviation and minimizing income inequalities (Mamo *et al*., 2007; Kamanga *et al.,* 2009).

In addition, it has been shown that the forest extractive activities of households are, in fact, quite diverse both within and across communities (Coomes, 1995; Coomes and Barham, 1997, Mariara and Gachoki, 2008; Heubach, 2011). This diversity or heterogeneity means that whereas forest products may represent major sources of income for some households, others in the same community may rely primarily on other sources such as agriculture for their livelihoods. Thus, the factors that influence household participation in forest activities are critical in designing appropriate conservation strategies. Despite the increasing knowledge on forest-livelihood links in developing countries (Cavendish, 2000; Angelsen and Wunder, 2003; Fisher, 2004; Adhikari *et al*., 2004, Vedeld *et al*., 2004; Angelsen *et al.*, 2014), there are few studies on forest –livelihood dependence in Kenya. Although, it is known that forests in Kenya support forest adjacent communities, there is little quantitative data on the extent of forest use and contribution of forest income to household welfare. Most of the information on contribution of forest resources to households is descriptive, and often location specific (MENR, 1994; Emerton 1996; Emerton, 2001; Mogaka, 2001; Langat, *et al*., 2005; Langat and Cheboiwo, 2010 b). The net effect is poor understanding of the role of forests in local livelihoods. Most studies of forest valuation in Kenya have largely relied on direct use values for few selected forests (Mogaka, 2001; Emerton, 1996, 2001; Langat and Cheboiwo, 2010(b) but do not include quantitative information on household-level use or activities that cover a complete range of forest products and the importance of forest resources in local livelihoods and the wider economy. What is important in designing a win-win strategy for forest conservation and household welfare is a clear understanding of all forest values, households' forest dependence on products and services, factors influencing household's forest dependence, distribution of costs and benefits of conservation to different stakeholders and the potential linkages between conservation and livelihoods.

1.2 Statement of the Problem

In the last three decades, the East Mau forest area in Kenya has declined primarily due to anthropogenic activities. Central to the anthropogenic activities is the dependence of the people on forest products and services for livelihoods. These human perturbations threaten biodiversity and future ecosystems functions of this forest and thus livelihoods. The full values of the ecosystem benefits have not been adequately quantified, and their role in socioeconomic development has not been examined.

Moreover, most natural ecosystems services are not traded in the market and therefore often true values of forest ecosystems are obscured. Consequently, the total economic values of forest ecosystems are incomplete and undervalued (Babulo *et al*., 2006; Kipkoech *et al.*, 2011). Such undervaluation has resulted in marginalization of forest ecosystems in budget allocations, land-use change decisions, leading to excisions and degradation.

Despite its importance as a resource for local livelihoods, there is hardly quantitative information on direct use values and the role of the forest to the household and the wider economy. Studies have found that the relationship between socio-economic and external factors on forest resource dependence are contestable and can vary between locations, product types, or specific forest (Adhikari *et al*., 2004; Kamanga *et al.,* 2009; Kalaba *et al.*, 2013). However, there are few studies in Kenya which have analysed the role of socioeconomic and external factors on household dependence on forest resources. To address the information gaps articulated above economic, Economic valuation of forest ecosystems services was undertaken in East Mau forest.

1.3 Research Objectives

1.3.1 Broad Objective

To determine the total economic value of ecosystem services and its implications on conservation strategies in East Mau forest

1.3.2 Specific Objectives

1. To determine the magnitude of provisioning services from East Mau forest ecosystem to the local community and other stakeholders;
2. To determine the soil conservation functions, carbon sequestration, oxygen cycling, watershed functions, (indirect use values) and bequest, option (non-use values) values to local community and other stakeholders;
3. To determine the TEV distribution of benefits and costs of forest resources and implications to community livelihood needs and conservation;
4. To determine the level of forest dependence by forest adjacent households and examine the socioeconomic factors that influence dependence.

1.3.3 Research Questions

Objective 1

i. What are the quantities of forest products collected by households in study locations?
ii. What is the monetary value of forest products obtained by households across the study locations?
iii. What is the economic value of forest product trade among small scale forest product traders and saw millers
iv. What is the total revenue collected from products and services to Kenya Forest Service from East Mau?

Objective 2

i. What are the cultural and spiritual use values of East Mau forest ecosystem by the local community?
ii. What are the potential carbon sequestration and oxygen generation values of vegetation types of East Mau forest ecosystem?
iii. What are the monetary values of water flow and quality regulations functions (watershed) of East Mau forest Ecosystem?
iv. What are the monetary value of soil protection and nutrient cycling functions (soil functions) of East Mau forest Ecosystem?
v. What is the pharmaceutical potential value of East Mau biodiversity?
vi. What is the bequest value of East Mau forest ecosystem?

Objective 3

i. What is the total economic value of the forest ecosystem?
ii. How are the costs and benefits distributed among different stakeholders?

Objective 4

i. What are livelihood activities of households in the study locations?
ii. How much does forest income contribute to household’s income portfolios in the study locations?

iii. How does reliance on forest income vary with different levels of income and ethnicity?

iv. What socioeconomic characteristics affect the magnitude and relative importance of forest income?

1.4 Justification of the Study

East Mau Forest has undergone tremendous degradation and conversion to other land uses. One reason is the lack of appreciation of the varied values from the forest ecosystem. Most of the benefits have received little attention due to lack of knowledge or difficulty in monetary quantification. Primary amongst these benefits are the ecological services provided by the forests, including: the benefits to agricultural production, climate regulation; regulation of water flow; and soil protection, pollution control, biodiversity; aesthetic value; existence value, option and bequest value. To make optimal choices between the conservation and the continuation and expansion of human activities in forest ecosystems there is need to fully recognize the total economic values of the ecosystem goods and services so that they can be compared with the economic values of activities that may compromise them.

1.5 Significance of the Study

A proper understanding of the economic values and contributions of East Mau forest ecosystem to all stakeholders at all levels will provide clear signals to policy makers and resource managers to appreciate the importance of forest resources to household wellbeing and the wider society and therefore make optimal decisions regarding this important forest ecosystem. A comprehensive determination and appreciation of all forest values will provide justification for fair allocation of scarce public resources into its conservation. Furthermore, information on forest total economic values is important in identifying the costs and benefits of conservation and how the benefits accrued from forest conservation are appropriated by different stakeholders. Such information is critical for developing incentives for effective community participation and may contribute to shaping policies for mainstreaming forestry in local livelihoods and poverty alleviation (Campbell and Luckert, 2002; Mariara and Gachoki 2008) and may provide a key step towards sustainable use and management of this forest ecosystem.

Moreover, a clear understanding of the factors influencing household forest dependence can enable the resources managers to identify and focus conservation programs on the categories of local populations that are most dependent on forest resources (Gavin and Anderson, 2007). The information generated from this study may assist the government and other stakeholders in developing conservation strategies for optimizing forest resources to achieve economic and social objectives in tandem with national aspirations contained in Vision 2030.

1.5 Scope and Limitations of the Study

The study focus was on the East Mau forest blocks of Kiptunga, Mariashoni, Teret, Nessuit and Baraget. It was undertaken in four administrative locations of Mariashioni, Teret, Nessuit, Kapsimbeiywo and Silibwet, covering households in the location inside the forest (Mariashioni) and households within 5km from the forest reserve Teret, Nessuit, Kapsimbeiywo and Silibwet. The study also covered small scale, medium and large sized wood industries, small scale forest users, traders adjacent to East Mau forest and traders in major urban centres of Nakuru, Molo, Elburgon, Njoro, Keringet and Olenguorone. Data collection concentrated on the use of East Mau for extractive and non-extractive uses within the one year using cross-sectional design. The study focused on use (local) and non-use values (national and global) of East Mau forest, contribution of forest resources to local people and other stakeholders, household's socioeconomic factors and contextual factors such as distance to the forest, ethnicity, and distance to markets and access to credit), costs and benefits of conservation.

The data collected for the study had some limitations. The data collected relied on recall of the respondents and because some forest use /products are continuously collected throughout the year, or harvested seasonally, it was a challenge for respondents to recall with ease. Another problem experienced during data collection was because some products were collected by local communities illegally and most likely the respondents might have concealed the actual quantities of products extracted.

The main objective of this thesis was to estimate the total economic value of East Mau forest ecosystem. It is however, important to note that the economic values derived from this study are not exhaustive. For example, the carbon sequestration value did not take into account the below ground biomass.

In addition, the estimates of non-use values only considered local bequest values and did not account for bequest values by the international community. Furthermore, the study did not take into account existence and recreation values for the local and international communities. The economic values derived from this study are largely conservative and need to be treated as indicative values in the complex arena of forest ecosystems valuation. However, the estimated values are based on the best available primary and secondary sources.

1.6 Definition of Terms

The following terms are defined in the context of this study.

Forest adjacent households - These are households bordering the forest reserve and are located within 5km from the forest boundary (Wass, 1995).

Household head - Household head refers to the member of a household who is the primary sole decision maker of the household (KNBS, 2010).

Livelihood - A livelihood refers to income-generating activities determined by natural, social, human, financial and physical assets and their access such as farming, livestock keeping and business (Ellis, 2000).

Forest income - Monetary value of all products obtained from forest activities for home consumption and sale (Wollenberg, 2000).

Forest dependence - This is a level of forest reliance for subsistence and cash income (Wollenberg, 2000).

Direct use - This is use of forest ecosystem through extractive use or enjoyment of services from the forest (Pearce *et al*., 2002), for example the collection of firewood for home consumption and sale.

Indirect use - This is the positive influence of the forest on productive sectors which have a direct bearing on human welfare; such as improving quality and quantity of water for domestic use and for industry, soil protection, flood control, climate amelioration and carbon sequestration (Pearce *et al*., 2002).

Ecosystem services - This is defined as the benefits people obtain from ecosystems (Pearce *et al*. 2002; MEA, 2005), for instance, provisioning services including timber, firewood etc.

Economic value - This is the expression of value of forest products or services in monetary terms (Pearce *et al*., 2002).

Consumer surplus-An economic measure of consumer satisfaction, which is calculated by analyzing the difference between what consumers are willing to pay for a good or service relative to its market price. A consumer surplus occurs when the consumer is willing to pay more for a given product than the current market price. (http://en.wikipedia.org/wiki/Economic_surplus).

Total Economic Value - This is the sum total of all economic values and includes direct use, indirect use (use) and non-use values (Pearce *et al*., 2002).

Non use value is the value that people assign to economic goods (including public goods) even if they never have and never will use it. Non-use value as a category may include: option value, bequest value and existence value (Pearce *et al*., 2002).

Option value –The value placed on individual willingness to pay for maintaining an asset or resource even if there is little or no likelihood of the individual actually ever using it (Pearce *et al*., 2002).

Bequest value- This is the value placed on individual willingness to pay for maintaining or preserving an asset or resource that has no use now, so that it is available for future generations (Pearce *et al*., 2002).

Existence value- This the value people derive from knowing that a unique environment or species exists (Pearce *et al*., 2002).

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

This chapter discusses the definition and classification of ecosystems services and the linkages with livelihoods and the theoretical concepts of that underpin the study. This is followed by a short review of valuation studies and review of valuation techniques. The chapter ends with a review of determinants of forest dependence.

2.2 Definition and Classification of Ecosystem Services

The concept of ecosystem services has become pivotal in articulation of conservation practice and policy at international level (Ferarro *et al*., 2011). However there is diversity of opinions between authors on the definition of ecosystem services, more so in relation to processes and functions (Hawkins, 2003). Daily (1997) defines ecosystem services as:“the conditions and processes through which natural ecosystems and the species that make them up, sustain and fulfil human life” (pp. 3). According to Daily (1997), the services functions and services are interlinked. Costanza *et al*., (1997) define functions as “the habitat, biological or system properties or processes of ecosystems” (pp. 4). Services in this context are the benefits humans obtain from these functions and the functions encompass processes, which provide the services and this definition is echoed in the Millennium Ecosystem Assessment Report (MEA, 2005). Similar exposition of this concept of ecosystem services is articulated by De Groot *et al*., (2002). However, the only difference is that what Costanza *et al., (*1997) call services, De Groot *et al.,* referred to as functions. De Groot *et al*., (2002) defined functions as the capacity of natural ecosystem to provide goods and services for the human welfare. Accordingly, processes lead to functions, which lead to services. Boyd and Banzhaf (2007) defined ecosystem services as ecological components directly consumed or enjoyed to produce human well-being. The element in these definitions is the need to identify linkage(s) either in product or intermediaries which form an important component in meeting the human needs directly or indirectly.

Hawkins (2003) argued the need to distinguish between functions and services and expounded that functions are inherent biological and chemical processes that occur in ecosystems regardless of human presence and services are dictated by human needs, uses and preferences. This distinction is very critical for conceptualizing, organizing and classifying diverse ecosystem services (Hawkins, 2003; MEA, 2005 and TEEB, 2010). De Groot *et al.*, (2002) provide a useful classification system. They delineated four types of functions: regulation, habitat, production, and information. Regulation functions are those that maintain the ecosystems and life support systems. This category consists of bio-geochemical cycles and abiotic-biotic interactions that are important to all living organisms, and directly or indirectly benefit humans. Habitat functions provide habitat for various life cycles of plants and animals, which maintains biological and genetic diversity and the evolutionary processes. Production functions consist of the processes that combine and change organic and inorganic substances, through primary or secondary production, into goods that can be directly used by humans. Information functions are aspects of ecosystems that contribute to human mental and spiritual well-being. Because most of human evolution took place in natural systems, our information gathering and sense of well-being are strongly tied to natural landscapes and species (Hawkins, 2003).

The Millennium Ecosystem Assessment approach took the step further but emphasized the value of ecosystem processes to human welfare (MEA, 2005). The millennium ecosystem assessment (MEA, 2005) framework recognizes four main ecosystem values namely: Provisioning services (direct use values), regulating services, supporting services and cultural and information services. These values have been categorized in different ways by different authors, however for the purpose of economic valuation; it is essentially narrowed to four namely: direct use, indirect, option and existence values (Fig.2.1).

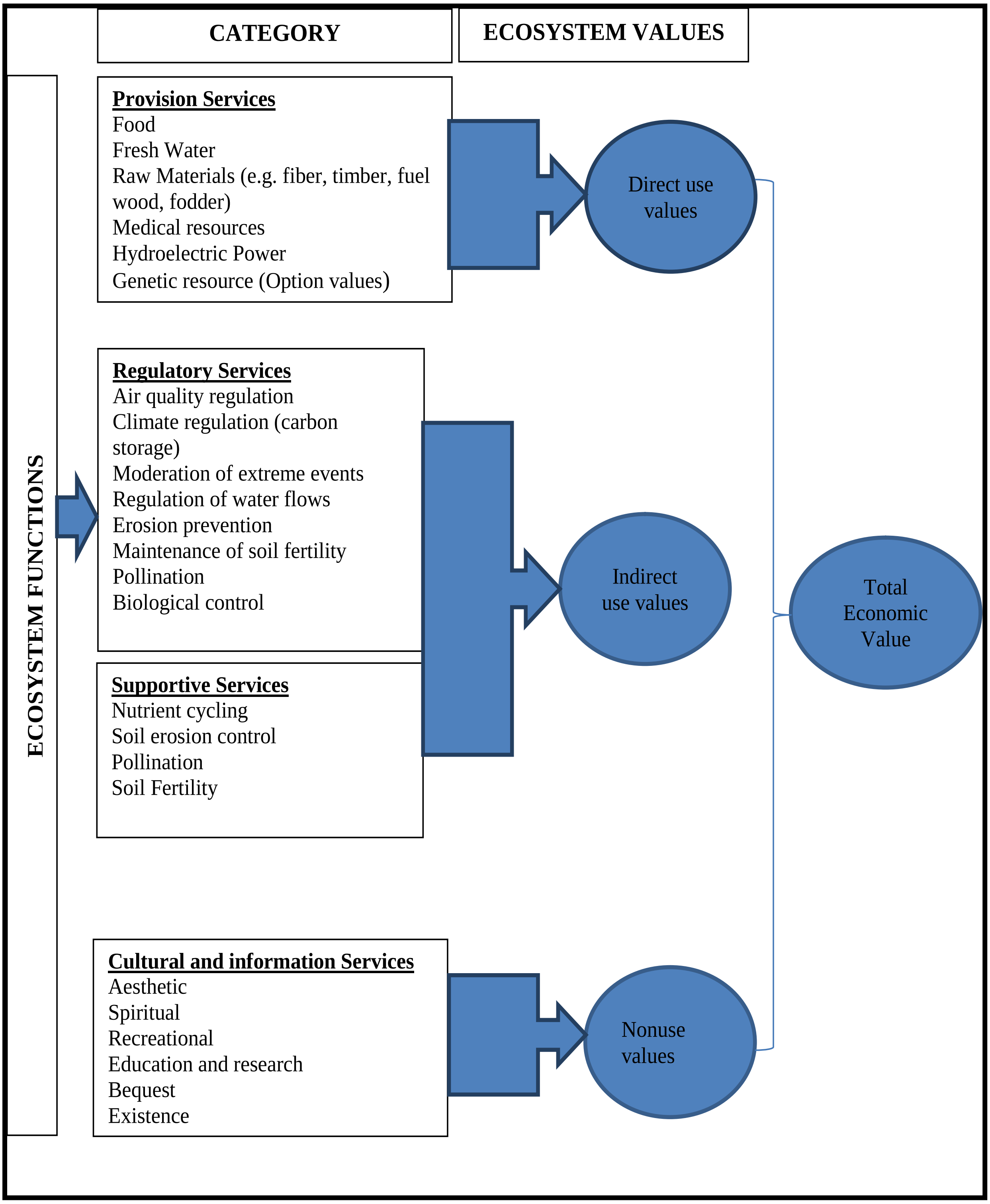

Fig.2.1: Relation between ecosystem functions, ecosystem services, and economic values

(Adapted and modified from Nahuelhual *et al*., 2007)

2.3 Economic Valuation of the Environment and Tropical Forest Ecosystems

The concept of value is ambiguous and difficult to measure. Many disciplines, have attempted to address it, however, there are many areas of controversy and among disciplines. In conventional economics, the worth of something is based on human preferences, and money is used as a unit to measure its value. Preferences are determined by a number of factors and vary between different interest groups. This makes the issue of value to be both subjective and dynamic.

2.3.1 Theoretical Basis of Tropical Forest Economic Valuation

There are quite a number of theories and models that have been espoused by researchers and scholars in the understanding of natural resources use, conservation and management in socio-economic perspectives. These are behavioural approach, indigenous knowledge and individual economic models approaches. The behavioural model stipulates that people interact with the environment through their behaviours to maximize their socio-economic benefits (Byers, 1996). In the model, the local stakeholders (local people, small-scale forest products processors, saw millers) will seek to maximize their utility from forest resources through their strategies while the government tries to interact with them through policies, legislations and regulations. Each actor will develop strategies to maximize from the resources. This model is good for analysing competing interests and how the claims can be structured for equitable and sustainable resources use. The indigenous model approach tries to explain the natural resource use, management and conservation through the prism of indigenous or traditional knowledge, skills and attitudes of the local people. The individual economic model tries to explain the behaviour of an individual in the context of competing human needs and scarcity of resources to maximize utility. Forests provide benefits and services but the forest land has competing land use such as agriculture, human settlement etc. In this case, the efforts to conserve forest resources and other natural resources are challenged by a number of competing socio-economic activities, and therefore, there is need to compare competing options to determine the best approach to ensure maximum benefit to society and the environment.

In the context of this thesis, individual economic model approach, which draws heavily on principles of welfare economics in an idealized market economy, was adapted. Economic theory of individual preferences and the demand for goods and services assume that consumers are aware of what gives them maximum utility (Bateman and Turner, 1993; Gravelle and Rees, 2004; Hanley *et al*., 2007). Conventional neoclassical analysis of a market involves an examination of the demand for and supply of a good or service.

In the case of environmental goods and services, such a framework implies that prices are determined by the forces of supply and demand for goods and services. Any monetary value placed on the environment should represent the value placed on it by society. Given the usual assumption of optimising the value of the natural resources that we have, the value will be at a minimum where the marginal costs of using it are equal to the marginal benefits derived from it. With increasing marginal benefits, net value will increase. In the case of environmental goods or services, the costs and benefits are usually referred to as social cost and social benefit. This contrasts with more conventional models, which commonly use *private* costs and benefits associated with neoclassical market models (Bateman and Turner, 1993; Grafton *et al*., 2004).

In perfect markets, individuals choose goods that maximize their utility subject to a budget constraint. When the consumers are faced with fixed prices and a budget constraint they choose types and quantities of different goods to maximize on their utility. A higher price of a good results in less demand and consumption or enjoyment of that good and consequently a welfare loss to the individual (Dolan and Lindsey, 1988). On the opposite, a lower price results in higher quantity consumed and an increase in welfare of the individual. Welfare is based on market and non-market priced goods and services, for today and values in the future (Ezebilo, 2010). Many environmental goods and services provided by tropical forests are non-market priced and their economic values are not revealed in market prices. Therefore a link must be established between environmental good or services and a related market commodity. When the linkage is established, we can value ecosystems services using economic demand theory, even if these ecosystem services are indirect, subtle, or latent (Pattanayak, 2004). In this context, the concepts of consumer surplus and total economic value formed the basis for forest ecosystem services valuation in this thesis.

2.3.2 Value as a Consumer Surplus

The value or utility of a good or service is reflected in the willingness to pay (WTP) for it. Willingness to pay measures preference over other goods or services and this is normally measured in monetary terms (Pearse, 1990; Grafton *et al*., 2004). The value of a good or service can be derived from its demand curve. The demand for environmental goods and services can be depicted graphically and is shown in Figure 2.2. The Figure represents the demand curve for environmental goods, such as non timber forest products (NTFPs) (Grafton *et al*., 2004). From figure 2.2 it can be seen that at a price (P_1), quantity (Q_1) is consumed. At such a price, the total costs represent the area C, while the producer surplus, area B, represents the net rent for the use of factor inputs, and area (A) represents consumer surplus. From this model, the two areas, A and B, represent the total net benefit from the production and consumption of any goods or service. The value of service or goods provided without cost is determined by estimating the consumer surplus. This is the theoretical basis for valuing un-priced forest or environmental values such as option values and existence values. The methods for valuing up-priced environmental values are based on estimating consumer surplus through direct methods such as Contingent Valuation Method (CVM) or indirect methods such as Travel Cost Method (TCM).

The concept of willingness to pay is depicted here as the total area represented by A, B and C, or the area under the demand curve. It is important to remember that in addition to the consumer surplus and net rent depicted by A and B, this amount also includes area C, representing costs.

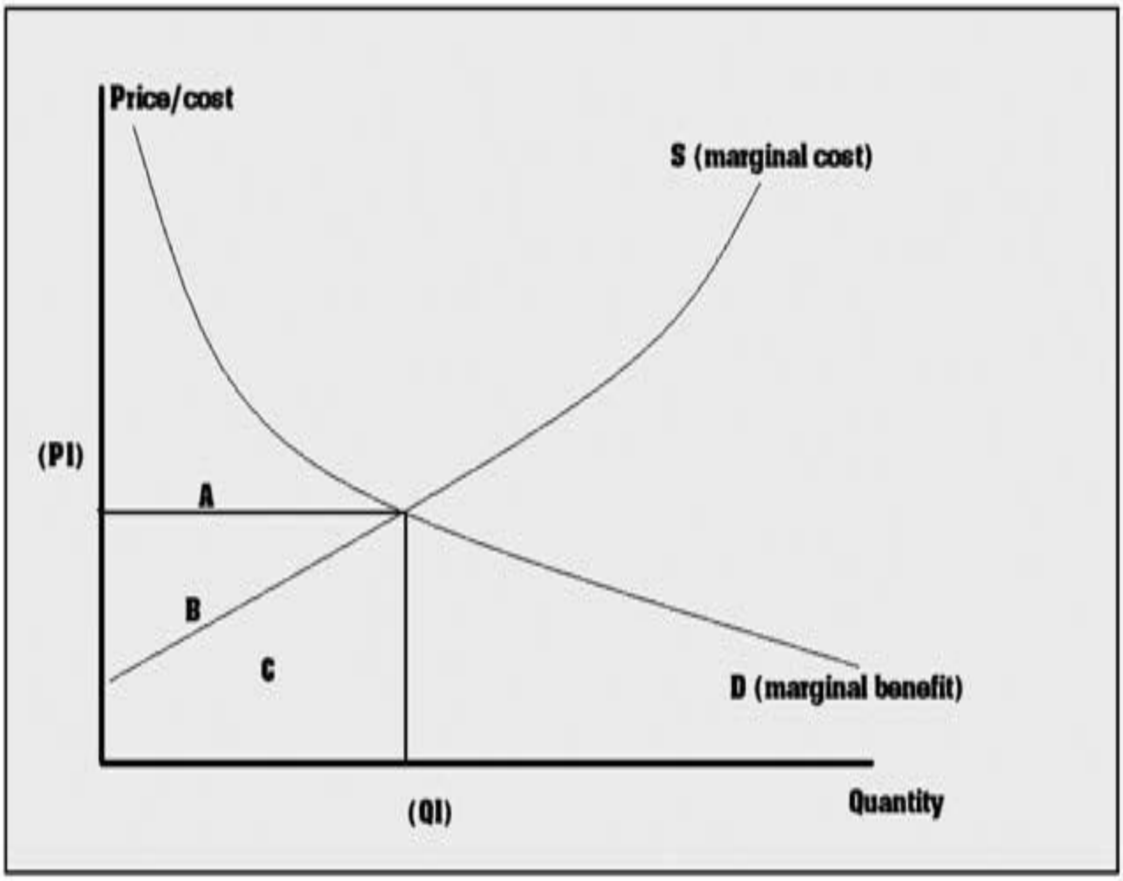

Fig.2.2: **Demand for environmental goods and services**

Source: Grafton *et al*., 2004

The valuation of a natural resource or environmental service is usually based on the monetary value individuals place on it. The maximum amount of money an individual is willing to pay for obtaining a benefit or avoiding a loss in most situations reflects the preferences for such a benefit or loss. Preferences are based on the values he or she attaches to the goods or services in question. The maximum willingness to pay (WTP) can be considered therefore an expression of the individual’s values. Analogously, the minimum Willingness to Accept (WTA) an amount of money as compensation for giving up a benefit or for receiving a loss reflects the value of such a benefit or loss. As an example, it might be of interest in estimating the aggregate WTP of people to maintain the environmental quality and amenity benefits of Mau Forest Complex. Alternatively we could estimate the WTA compensation where a development project might compromise these values, by changing the water flow upstream or damaging the forest.

When an individual buys an asset at the market price, the price paid directly reveals a lower bound of his maximum willingness to pay. Our willingness to pay for such an asset is "at least" equal to the price paid. For example, if an individual pays 10 Kenya Shillings for a kilo of sugar, this means that he or she is willing to pay at least that much, otherwise they would not buy at that price. When someone sells an asset at the market price, the amount of money received directly reveals an upper bound for his or her minimum willingness to accept for giving up such an asset. The direct use values are easily derived, tangible and easy to measure, however, non-use values, are more difficult to grasp and measure.

2.4 Ecosystem Values and Linkage to Human well-being

Forest ecosystems provide (direct use values) such as timber, firewood, construction materials and other non-timber forest products for subsistence and cash incomes and also provide ecosystem services (indirect use values) such soil protection, hydrological services , biodiversity conservations and amelioration of local and global climate and the non-use values. The sum of all these values gives the total economic value of an ecosystem (Nahuelhual *et al*., 2007, Aboud *et al*., 2012; Emerton, 2014) (Fig. 2.1). In theory, valuation should strive for total economic value, however in practice; economists have to settle for a partial measure. The challenge lies in devising methods to determine these values in a meaningful way (Pearse, 1990). By designing methods to capture all components of TEV, it is possible to ensure that all aspects of production costs (including social costs) will be covered by market prices. If this does not occur, then there is market failure.

2.4.1 Direct Use Values

In most regions of the world, forests provide employment, energy, food, construction materials and a wide range of goods and ecosystem services. Well managed forests have tremendous potential to contribute to sustainable development and to a greener economy (FAO, 2014).

Globally, it is estimated that between 1.095billion and 1.745billion people depend to varying degrees on forests for their livelihoods and about 200million indigenous communities are almost fully dependent on forests (Chao, 2012).

Moreover, 350million people who live adjacent to dense forests depend on them for subsistence and income (World Bank, 2006; Chao, 2012). Forty-five million artisans or employees are engaged in formal or informal forest-based enterprises (Chao, 2012). Latest data indicate that the formal forest sector employs about 13.2 million people across the world and at least 41million people are employed in the formal sector (FAO, 2014). In addition, 20% to 25% of rural peoples' income is obtained from environmental resources in developing countries (Vedeld *et al*., 2007). Over two-thirds of Africa's population obtain a big proportion of their subsistence and cash income from forest products and forest-related activities (Arnold and Townson, 1998; Kaimowitz, 2003). It is estimated that 40% of people in less developed countries and 27% of Africa's population depend primarily on fuel wood cooking and heating. Furthermore, forest products provide shelter to about 18% of the world's population (FAO, 2014).

In Kenya, about 3million people are dependent on forest resources (Chao, 2012). Forests provide timber, non-timber forest products, agricultural land and provision of environmental services. These products are important for cash income, shelter (construction building poles, timber), food security (e.g. honey, mushrooms, fruits, vegetables) and health (herbal medicine) (Wass, 1995; Emerton, 1996; Mogaka 2001; Langat and Cheboiwo, 2010 (b). In addition, the forests are important for socio-cultural values and provision of ecosystems services for agriculture and other production sectors. Recent studies in Kenya have shown that forest contribute significantly to household livelihoods (Lubanga, 1991; Langat and Cheboiwo 2010b). However, most of these studies have relied on secondary data and may not reflect the true value of most forest ecosystem values. Moreover, there are few studies on the how forests contribute to wellbeing of local households and this is particularly important to inform policy on integration of forestry in poverty alleviation and the development of equitable framework for sharing costs and benefits in the context of participatory forest management (Mariara and Gachuki 2008). Few forest valuation studies (Emerton, 1996; Mogaka, 2001; Langat and Cheboiwo, 2010(b) give aggregate values for few selected forests. A recent study (Kipkoech *et al*., 2011) estimated the economic values of the three forest blocks of East Mau, Maasai Mau and Transmara but mostly relied on secondary data. Estimation of total economic value of forest ecosystems would help to capture of the true value of forests and depreciation of natural capital and highlight the critical role of forests in the national economy. This research would fill some of the gaps in knowledge regarding economic valuation of forest resources.

2.4.2 Indirect Use Values

Indirect use values refer to the functional or ecological service benefits generated by the forest ecosystem but are not directly consumed such as soil conservation, nutrient cycling, climate regulation and recreation, etc. (Turner *et al*., 1994; Pearce , 2001; Kulindwa, 2006; Nahuelhual *et al*., 2007; Emerton, 2014). Some indirect use values are discussed below:

2.4.2.1 Maintenance of Soil Fertility and Erosion Control

Soil fertility is influenced by maintenance of soil mantle which is a function of geography, climate conditions, and vegetation cover and its root architecture (De Groot *et al*., 2002). Deforestation exposes forest soils and exacerbates soil erosion resulting on site and off site effects such as sedimentation of rivers and lakes, increased runoff and localized flooding, and reduced hydrological cycling and recharge of ground water, streams, and rivers (Adger *et al*., 1995).

2.4.2.2 Carbon Storage

Forests play an important function of regulating both global and local climates by storing huge quantities of carbon and regulating localized precipitation and temperature patterns (Pearce, 2001; Krieger, 2001; Ramirez *et al*., 2002; Ferraro *et al*., 2011). It has been established that carbon released from harvesting and burning of forests contribute about 12% of the global greenhouse gas emissions (Van der Werf *et al*. 2009 cited in Ferarro *et al*., 2011).

Valuation of carbon sequestration services of forests may trigger action to protect and encourage sustainable management of forest ecosystems (Pearce, 2001) and this has led to the development of reduced emission from deforestation and forest degradation (REDD) programs to pay for forests carbon storage, through voluntary carbon markets and public funding of afforestation programmes (Ferarro *et al*., 2011). Estimates of the value of forests' carbon storage range from US$ 378 ha^{-1} in Paraguay's Atlantic forests (Naidoo and Ricketts, 2006) to US$ 1,500 ha^{-1}on Borneo (Naidoo *et al*., 2009). There is wide variation in carbon storage values based on topography, climate and wide variation in carbon market (Ferarro *et al*., 2011).

In most valuation of carbon sequestration- carbon market price or an estimate of the social damages from emissions is applied. Ferarro *et al*., (2011) have argued that using the carbon market prices do not reflect the true social value of damage avoidance by forests. Pearce (2001) recommends the use of climate change damage functions for valuation, though it may overestimate the values of carbon storage. However, the climate damage functions are difficult to estimate and therefore most studies on carbon valuation adapt carbon market prices.

Locally in Kenya there have been studies to quantify the carbon stocks in different forest ecosystems (Glenday, 2006; Omoro *et al*., 2013; Kinyanjui *et al*., 2014; and Otuoma, 2015). However, the economic valuations of carbon sequestration potentials of Kenya's forest are scantily available.

2.4.2.3 Hydrological Services

Forests provide watershed services, such as soil conservation, regulation of water flows, and water purification. There are few studies which have estimated the values of hydrological services because of the complexity of these services and the demand for interdisciplinary approaches (Ferarro *et al*., 2011). Because of these challenges most researchers have only focused on the impact of changes in forest cover on hydrological outcomes (e.g. Ataroff and Rada, 2000) or the value of hypothetical hydrological outcomes on local populations (e.g.Wang *et al.*, 2007). The few studies that have attempted hydrological valuation have tended to focus on individual hydrological services, rather than the full range. Nu´n˜ez *et al*., 2006), Nahuelhual *et al*., (2007) and Bush (2009) have estimated the value of the contribution of forests to the production of drinking water.
Elias *et al*., (2014) gives an estimate of water quality regulation of forests to public water supply. Table 2.1 below presents a summary of some values of hydrological services cited in literature.

Table 2.1: Selected hydrological services functions of forest ecosystems from literature

Source	Country	Service	Valuation method	Value (US$)
Bush (2009)	Uganda	Provision of drinking water	Replacement cost	3.05/hh/yr
Elias *et al*., (2014)	USA	Water protection value(quality regulation)	Avoided cost	92-95 /km^2/day
Guo *et al*.,(2007)	China	Avoided sedimentation of power plant	Change in productivity	
			NPV of water regulation benefits:	21.9million
			NPV of reduced sedimentation	15.1 million
Klemick (2011)	Brazil	Water flow regulation from forest fallow	Production function	3.6-24.3/hh/yr
Nahuelhual *et al*., (2007)	Chile	Production of drinkable water	Production function	235/ha/yr
Nu´n˜ez *et al*., .(2006)	Chile	Production of drinkable water	Change in productivity	5.8-15.8/hh/yr or
				61.2-162.4/ha

hh- household

Most of the studies above have focused on the role of the forest ecosystem on the provision of drinkable water or quality regulation (Bush, 2009; Klemic, 2011; Nahuelhual *et al*., 2007; Nu´n˜ez *et al*., 2006) and the values ranges from US$ 3.6 to 24.3 $HH^{-1}yr^{-1}$ or US$ 61.2 to 235 $ha^{-1}yr^{-1}$ (Table 2.1). One study by Guo *et al*., (2007) on the benefits of forest cover to the operation of hydroelectric dams showed that protection of existing forest cover in the watershed around the Three Gorge Hydroelectric Plant in China would generate net present benefits of US$ 22 million from water regulation and US$ 15 million from reduced sedimentation. The hydrological benefits are highly location specific because of the variation in the local geophysical and climatic conditions that influence the magnitude of water scarcity and sedimentation. Secondly, the economic benefits from these hydrological changes depend on their spatial relationships to human activities, such as the presence of adjacent farming activity, downstream residential populations demanding clean drinking water, or downstream hydropower plants (Ferarro *et al*., 2011).Valuation of hydrological services in Kenya is still at infancy and is beset with data constraints and inadequate capacity.

2.4.3 Non Use Values

Non use values are important to human welfare though the resource is not directly or indirectly used. One component of non-use value is the bequest value, which is preserving the resources and the environment for future generations. People may value the desire to pass on certain natural resources or environmental function to their children. Another component is existence value where people value just knowing that a natural resource or environmental function exists, even though they may never see or use it. This value was first discussed by Krutilla, in his seminal paper “Conservation Reconsidered", in which he argued for the inclusion of existence value in benefit estimates. Krutilla (1967) explained that where the existence of a grand scenic wonder or a unique and fragile ecosystem is involved, ‘its preservation and continued availability are a significant part of the real income of many individuals".The last component, option value, cuts across both use and non-use values. This is the value of keeping options open to generate use and non-use values in the future. This value measures what people are willing to pay to protect the resource for potential use in future and is essentially an expression of the consumers’ preferences for the preservation of a natural resource in the case where a change arises in terms of its use (Kengen, 1997).

For example, forest protects biological diversity and ensures future wealth of genetic resources that could in future be used to improve yields of commercials crops in breeding programs (Pimentel *et al*., 1997). In addition, genetic diversity contributes to the development of pharmaceutical products and thus improves the quality of live for human beings and may also find applications in biotechnology for improving crop yields and control pests and diseases (Krieger, 2001).

There are few studies in Kenya, which have valued option value but one study in Tindiret forest using benefit transfer method found that the pharmaceutical potential to be in excess of KES5mill/yr (Langat and Cheboiwo 2010(b).

2.5 Techniques of Forest Ecosystem Valuation

Three basic approaches to forest ecosystem valuation are used frequently. They all attempt to assign monetary values to forest attributes, and can be identified as:
(i) Revealed preference (Market based) from both direct and indirect market statistics, such as the travel cost method and hedonic pricing) (ii) Stated preference methods where, in the absence of actual markets, preferences of consumers are assessed through surveys, e.g. Contingent Valuation) and (iii) Benefit Transfer approach (BT).

2.5.1 Market Based Methods

These methods are used to estimate the value of forest products through various market price approaches: a) by using the market price of the product; b) by the prices people are willing to pay or sell in market place; c) by looking at the prices of alternative or substitutes for forest products; d) by expenditure on goods and services that are directly linked to forest benefits and e) by the way the forest benefits affect the value of other goods. Examples of techniques are market valuation of goods with developed markets or use surrogates/proxies, travel cost method (TCM), defensive expenditure or replacement cost and hedonic pricing method (HPM) (Turner *et al*., 1994; Pagiola *et al*., 2004; Kulindwa, 2006).

2.5.1.1 Market Prices of Forest Products

This happens in situation where the commodity is tradable and the human preference can be estimated using the market prices. For forest benefits, this can be assessed by looking at the prices people are willing to pay and sell forest products in the local markets net of transport and other costs. The total value of product can be estimated using the own reported values and use of the market price of the good should reflect the net of transaction costs.

2.5.1.2 Market Price of Substitute or Surrogate/Proxies

In a situation where the price of environmental good has no developed market its value can be imputed from a related product or service with market price for instance, forest browse /grazing can be computed using the hay equivalent (Mogaka, 2001; Langat and Cheboiwo 2010(b).

2.5.1.3 Dose-Response Functions

These are statistical methods for valuation that rely on the existence of a relationship between environmental attribute (e.g. soil erosion) and a change in agricultural productivity. Once this dose-response relationship is established, it is then assessed in terms of the economic value of its effect. An example of this would be the loss in agricultural yields caused by soil erosion after deforestation. This method of valuation is especially useful in situations where adequate price and expenditure data are not available. It is effective in situations where there are clear relationships between pollution/forest degradation and material damage e.g. between soil erosion and declining agricultural yields, and between pollution and aquatic ecosystems (Grafton *et al*., 2004). For greatest reliability, these dose-response linkages need to be analysed with a behavioural model of the demand for the goods and services that are affected. Once the dose-response relationship is established, a monetary damage function is constructed (physical damage multiplied by the value per unit of damage) and analysed using multiple regression techniques. Similarly, benefits can be calculated on the basis of damage avoided.

2.4.1.4 Defensive Expenditure or Replacement Cost and Substitute Methods

The damage cost avoided, replacement cost, and substitute cost methods are related methods that estimate values of ecosystem services based on either the costs of avoiding damages due to loss of services, the cost of replacing ecosystem services, or the cost of providing substitute services. These methods do not provide strict measures of economic values, which are based on peoples' willingness to pay for a product or service. Instead, they assume that the costs of avoiding damages or replacing ecosystems or their services provide useful estimates of the value of these ecosystems or services. This is based on the assumption that, if people incur costs to avoid damages caused by lost ecosystem services, or to replace the services of ecosystems, then those services must be worth at least what people paid to replace them. Thus, the methods are most appropriately applied in cases where damage avoidance or replacement expenditures have actually been, or will actually be made, for example valuation of erosion protection services of a forest by measuring the cost of removing eroded sediment from downstream areas.

2.5.2 Stated Preference Methods

2.5.2.1 Contingent Valuation Method

Contingent valuation methods are based on artificial markets and preferences, which are described hypothetically by respondents in a survey. An example of this is a survey asking local people how much they would be willing to pay to have access to forest resources. This type of hypothetical valuation is known as the Contingent Valuation Method (CVM), and has become popular in estimation of option, bequest and existence values in recent years. Though, the method is gaining prominence in environmental valuation studies, it is beset with a number of constraints in practice (Mitchell and Carson 1989; Navrud and Brouwer, 2007; Whittington, 2002; Riera and Signorello, 2013).

There is much controversy on the use of CVM when most of the values of the goods are derived from passive uses and this has been the subject of immense debate in literature and contestation in jurisprudence (Portnoy, 1994)**.** Most critics of CV allege that the method is limited in generating quality data and inferior to observed preferences methods.

However, the response of individuals to hypothetical questions has been found to be consistent with actual economic behaviour of individuals (Turner *et al.,* 1994). Despite criticisms of the method, CV has been used as basis for policy making in the United States and is increasingly being applied in developing countries for valuing non-timber forest products and other intangible forest services (Cropper and Alberini, 1998; Whittington, 2002; Ezebilo, 2010; Riera and Signorello, 2013).

One of the best known of these studies is that by Wollenberg *et al*., (2001), who investigated the income of forest dwellers from NTFPs in Kalimantan, and also Caldecott (1988), who estimated the total value of hunting in Sarawak. Several other valuation studies have been undertaken using this approach, including those of Angelsen and Wunder (2003). The increased interest in this method in recent years is due to its versatility and suitability for use in valuing use and non-use values. In addition, it is a method that can be applied in many different situations that require forest product values.

2.5.2.2 Theoretical Basis of Contingent Valuation

The main aim of contingent valuation is to measure the compensating or equivalent variation for the good/service in question. Compensating variation is the appropriate measure when the person must purchase the good, such as an improvement in environmental quality and equivalent variation is suitable when the person is likely to experience a potential loss of the good/service, as she/he would if a proposed policy results in the deterioration of environmental quality (Grafton *et al.*, 2004). Both compensating and equivalent variation can be elicited by asking a person to report a willingness to pay amount. For instance, the person may be asked to state his/her willingness to pay (WTP) for obtain the good/service, or to avoid the loss of the good/service. Formally, WTP is defined as the amount that must be taken away from the person's income while keeping his utility constant:

$$V(\text{y-WTP}, \text{p}, q_1; \text{Z}) = V(\text{y}, \text{p}, q_0; \text{Z}) \quad \ldots\ldots 2.1$$

Where: *V* denotes the indirect utility function, *y* is income, *p* is a vector of prices faced by the individual, and q_0 and $q_1$are the alternative levels of the good or quality indexes (with $q_1>q_0$, indicating that q_1 refers to improved environmental quality).

Willingness to accept for a good is defined as the amount of compensation a person facing a loss in environmental quality must be given to maintain his utility constant.

$$V(y+WTA, p, q_0; Z) = V(y, p, q_1; Z) \quad \ldots \ldots 2.2$$

In equations (2.1) and (2.2), utility is allowed to depend on a vector of individual characteristics influencing the trade-off that the individual is prepared to make between income and environmental quality.

An important implication of equations (2.1) and (2.2) is that WTP or WTA should, therefore, depend on (i) the initial and final level of the good in question (q_0 and q_1); (ii) respondent income; (iii) all prices faced by the respondent, including those of substitute goods or activities; and (iv) other respondent characteristics. Internal validity of the WTP responses can be checked by regressing WTP on above variables (i) to (iv), and showing that WTP correlates in predictable ways with socio-economic variables.

In theory, there is an absence income effect and when WTP is a small fraction of income, WTP and WTA for a given commodity should be approximately equal. However, a number of CV studies have found that WTA is often much larger than WTP for the same commodity (Hanemann, 1991). This has been explained by the fact that the difference between WTP and WTA depends on the elasticity of substitution between the commodity to be valued (a public good) and private substitutes. When the elasticity is low and there are fewer substitutes there is greater difference between WTP and WTA (Hanemann, 1991). Another explanation is the theory of prospects – where individual have been found to value losses more than gains.

Property rights perception on who has rights over resource has an influence on the WTA values. If the proposed policy contradicts the perception of the existing property rights, individuals might express their disaffection and rejection of the scenario through high WTA values. This might happen, if for example, individuals believe that they are entitled access to forest resources and are outraged at the possibility of losing it through a proposed policy. Carson (1991) suggests that WTP should be used whenever the individual might incur benefits from the proposed policy, and Mitchell and Carson (1989) offer ways to frame the payment question to elicit WTP.

However, even when the individual might incur benefits from the proposed policy, there are some scenarios under which the respondent may not overstate WTA values (Cooper and Osborn, 1998).

2.5.2.3 Performing a Contingent Valuation Study

There are several steps for performing the CVM. Hanley *et al.,* (2007) suggested 4 stages for any CVM exercise: setting up the hypothetical market, obtaining bids, estimating mean WTP/WTA and aggregating of data. The process of developing a CV scenario consists of a number of steps. The first step is to set up a hypothetical market for the environmental good that is the subject of the study. The central basis of the CVM is to elicit a hypothetical bid that mimics actual market situations (Turner *et al*., 1994). In this way, it is possible to value an environment, in a non-market situation. For this purpose different types of bid vehicles can be used. Some of the bid vehicles are: levy, property taxes, income tax, utility bills trust fund payments, and entry fees (Hanley *et al.*, 2007). Once the survey instrument is ready, the survey is undertaken. Numerous types of survey instruments are available such as: face-to-face interviewing, telephone interviewing, or mail interviews. Each of them has its own benefits and costs. Mitchell and Carson (1989) reported that phone surveys have higher response rates than mail surveys. However, they are costly to undertake and preclude the use of visual material, such as photographs to show likely changed scenarios. Mail surveys are the cheapest but have proved to have low response rate and do not provide opportunities to elaborate questions that respondents may find confusing. Face to face interviews are the most reliable survey method but also the most costly. In the CVM individuals are asked to state their maximum willingness to pay/willingness to accept for the increase or decrease in environmental quality, which is the subject of the survey. A variety of questioning formats has been used in Contingent Valuation studies to obtain WTP/WTA, such as: bidding game, payment card, open-ended question, and close-ended referendum. (a) bidding game*:* In this technique, respondents are suggested higher and higher amounts until their maximum WTP is reached (Hanley *et al*., 2007). The interviewer suggests the first bid and the respondent agrees or disagrees that she/he would be willing to pay it. Then, the starting point price is adjusted upwards to see if the respondent would still be willing to pay it, and so on until the respondent declares he/she is not willing to pay the extra increment in the bid (Turner *et al*., 1994). The last accepted bid, then, is the maximum willingness to pay.

(b). Payment Card: A range of values is presented on a card which may also indicate the typical expenditure by respondent in a given income group. This helps respondents' to calibrate their replies.

(c) Open-ended choice: Individuals are asked for their maximum WTP without any value being suggested to them.

(d) The dichotomous choice: A single payment is suggested, to which respondents either agree or disagree (yes/no reply). The dichotomous choice (DC), close-ended, and open-ended formats are the commonly used response formats to estimate the willingness to pay.

Open-ended questions ask people to specify their willingness to pay, and close-ended questions first specify a sum and then ask people to choose whether or not pay the sum (Kealy and Turner, 1993; Riera and Signorello, 2013). Most CV studies that have compared estimates of WTP obtained using the dichotomous choice and open-ended formats have found that dichotomous choice yields higher estimates. The open-ended direct question may provide a lower more conservative estimate of value than would the interactive bidding technique (Riera and Signorello, 2013). The iterative procedure has been preferred because it is specifically designed to assist respondents as they approach the point of indifference between having the amount of income stated or the environmental amenity. However, open-ended questions in mail surveys may have several advantages of their own. The questions can be answered at home and at a time convenient to the respondents (Riera and Signorello, 2013). Several studies have assessed the reliability of these different formats. However, there is no consensus on the underlying causes for the difference in the results of the formats or which format will yield the most accurate estimate of actual WTP (Boyle and Bishop, 1988). Both the open-ended and iterative approaches are used to estimate the same underlying construction, i.e. mean willingness to pay, but it is not known whether the two methods yield the same contingent values in practice (Boyle and Bishop, 1988; Haneman, 1994).

2.5.2.4 Estimating Mean Willingness to Pay and Willingness to Accept and Bid Curves

If open-ended, bidding game, or payment card approaches have been used, then the calculation of mean and/or median WTP or WTA is straightforward. A bid curve can be estimated for open-ended CVM formats using WTP/WTA amounts as the dependent variables and a range of independent variables (Ndebele, 2009; Riera and Signorello, 2013). For example, in an open-ended CVM survey, WTP bids might be regressed against income (Y), education (E), and age (A), as well as some variable measuring the “quantity” of environmental quality being bid for (Q), if this is variable across respondents:

WTP = f (Y, E, A, Q) …………………………………………………………………2.3

Dependent variables should clearly be chosen with regard to those variables, which from a theoretical perspective might be expected to explain WTP. Bid curves also are useful to predict the valuation of changes in Q other than those suggested in the survey, and to test the sensitivity of WTP amounts to variations in Q (Hanley *et al.,* 2007; Riera and Signorello, 2013).

2.5.2.5 Aggregating Data

Aggregating refers to the process whereby the mean bid or bids are converted to a total value figure for the population (Hanley *et al*., 2007). According to the Hanley *et al.,* (2007) and Riera and Signorello, (2013), three issues should be considered for the aggregation process. The first issue is the choice of relevant population. This should be decided when constructing the sampling frame from which the sample was drawn. The boundary of the population should be well drawn. This population can be the local population, regional population, population of the country, or the whole continent. The second step is moving from the sample mean to a mean for the total population (Loomis, 1987). The number of households in the population, N, could multiply the sample mean to obtain the population benefits. The third issue is the choice of the time period over which the benefit should be aggregated.

This will depend on the setting within which the CVM exercise is being undertaken. If the present value of environmental benefit flows over time is of interest, then benefits normally are discounted.

2.5.2.6 Respondent's Biases in CVM Studies

A very large part of the literature on the CVM deals with discussion about biases of the CVM. "Bias" implies systematic over- or under-statement of true WTP/WTA. A classification of the nature of the biases is described in Turner *et al*., (1994), Hanley *et al*., 2007; Riera and Signorello, (2013) (a) Strategic bias**:** Hanley *et al*., (2007) state that if respondents believe that bids will be collected, they may understate their WTP for a welfare improving change because environmental goods are typically non-excludable in consumption (free rider problem). When an individual thinks he/she may influence an investment or policy decision by not answering the interviewer's question truthfully, this problem arises. For example, if individuals are told that a service will be provided if a) the total aggregated sum they are willing to pay exceeds the cost of provision, and b) that each will be charged a price according to their maximum WTP, the presumption is that each individual will understate his/her true demand. However, CVM studies have found that strategic bias is not a significant problem (Pearce and Turner, 1990).

(b) Starting point bias**:** This problem occurs in the bidding game question format. The first bid suggested may influence the respondent in some way. CVM studies have attempted to test for this source of bias, usually by offering different starting bids, and sometimes by letting the respondent make the first bid. Then the effect of starting bid on mean WTP can be tested. As Turner *et al.*, (1994) emphasized, the studies on the effect of the starting bid do not end up with the same results. Some studies found that no correlation exists between starting bid and mean bids, whereas other studies found that mean bids were affected by the stating bids.

(c) Vehicle bias**:** This problem results from choice of payment instrument, i.e. vehicle. If a respondent is sensitive to the vehicle, she/he may think it costly to pay 1US$ through taxes, but it will be suitable for him/her to pay 1US$ through an entrance fee. If the value of environment is different for the different payment vehicles, it means that vehicle bias exists.

(d) Information bias**:** Information style supplied by the interviewer is the reason for this problem. The sequence in which information is supplied also may influence respondents. The general amount and the quality of information also are very important.

(e) Hypothetical Bias: Since the situation takes place in non-market conditions, the valuation is carried out by setting a hypothetical market. The basic difference between an actual and a hypothetical market is that in actual markets purchasers will suffer a cost if they get it wrong (Blumenschein *et al*., 2001; Ndebele, 2009). If the respondent does not understand the hypothetical market, he/she may state WTP for a completely different market. This is mainly caused by lack of or inadequate relevant information provided to the respondents before eliciting their willingness to pay (List and Gallet, 2001) and when close-ended WTP survey questions are not administered properly and do not encourage the respondents to seriously think about and respond to the questions (Arrow *et al*.,1993; Whittington *et al*., 2002).

2.5.3 Benefit Transfer Methods

Benefits transfer method refers to the use of valuation estimates in one context to estimate values in a different context. Thus, this method is used to estimate economic values for ecosystem services by transferring available information from studies already completed in another location and/or context (Navrud and Brouwer, 2007; Riera and Signorello, 2013). For example, an estimate of the benefits obtained by tourists viewing wildlife in one park may be used to estimate the benefits obtained from viewing wildlife in another park. The simplest type of benefit transfer is the unit value approach, where existing values for product of service at the study site is used to value the same service at the policy site. These estimates are based on expert judgment in combining and averaging benefit estimates from a number of existing studies. These “unit values” may be adjusted for characteristics of the study site when they are applied e.g. income adjustment (Navrud and Brouwer, 2007; Riera and Signorello, 2013).

A more rigorous approach involves transferring a benefit function from another study. The benefit function statistically relates peoples’ willingness to pay to characteristics of the ecosystem and the people whose values were elicited. When a benefit function is transferred, adjustments can be made for differences in these characteristics, thus allowing for more precision in transferring benefit estimates between contexts.

According to Navrud and Brouwer (2007) and Riera and Signorello (2013), the following conditions and steps should be applied when using BT approach: (a) the commodity or service being valued should be very similar at the site where the original estimates were made and the new site where they are to be applied and (b) the populations affected should have very similar characteristics at the two sites.

In applying benefits transfer method, the following steps are necessary:

1. The first step is to identify existing studies or values that can be used for the transfer.
2. The second step is to decide whether the existing values are transferable. The existing values or studies would be evaluated based on several criteria, e.g., service attributes, site comparability, qualities of sites, population characteristics, etc.
3. The next step is to evaluate the quality of studies to be transferred.
4. The final step is to adjust the existing values to better reflect the values for the site under consideration, using whatever relevant information available.

Benefit transfer is typically less costly than conducting an original valuation study. The method can be used as a screening technique to determine if a more detailed, original valuation study should be conducted. The method can easily and quickly be applied for making gross estimates of forest ecosystem values. However, benefit transfer may not be accurate, except for making gross estimates of ecosystem values, unless the sites location, and user specific characteristics. Though, benefit transfer approach is treated with some skepticism, it is still a method of choice for analyzing economic value of a policy in situations where collection of data is not feasible due to limitation of time or financial resources (Rosenberger and Loomis, 2001; Plummer, 2009; Riera and Signorello, 2013).

2.6 A Critique of Forest Valuation Methodologies

Welfare depends on a variety of variables such as income, access to basic infrastructure, availability of public facilities, and environmental quality. As a result, attempts to access welfare benefits will inevitably be met with difficulty. While some of these welfare influencing variables may be easily measured in the conventional econometric sense, some of them, especially those relating to environmental quality, are not. These factors may possibly be measured both quantitatively and qualitatively.

The ability to integrate the two types of data into the problem solving process will possibly result in more efficient techniques of forest ecosystem valuation. Some of the limitations of the conventional valuation methods are discussed below.

2.6.1 Limitations of Valuation Methods

There are limitations associated with the various methods of forest function valuation. These include methodological constraints, such as sampling procedures, survey models, and avoidance of various forms of bias, such as cultural or socio-economic factors influencing the results.

In addition to design constraints, there are also serious conceptual problems in product valuation. Under a neoclassical framework, the problem of market failure is tackled with an attempt to estimate the costs and benefits of forest change on the basis of preferences and utility. The use of consumer choices as a means of identifying product values is the traditional approach, but the concept of existence values makes this inappropriate. This was pointed out by Hanley *et al.,* 2007, and it has been suggested that when measuring existence values, using conventional valuation methods contribute little to our understanding of the trade-offs people would be willing to make, where non-use values are important. Hanley *et al*., (2007) also suggested that the degree of trade-off will depend on depth of knowledge about forest resources, which implies that as the knowledge of the environment increases its valuation is likely to rise as well. A further problem with indirect methods in particular is the dynamic adaptation of the individual to the changing environment, so the *ceteris paribus* assumption used in neoclassic economic analysis cannot hold. It means that the assumption of input-output ratio remaining constant over time is incorrect, most likely resulting in an underestimation of the benefits of those changes using such methods.

Although the conventional analysis of Total Economic Value (TEV) may seem straightforward, it is complicated by the fact that adequate information does not exist about both the supply and demand for many goods and services provided by forests (Turner *et al*., 1994). The slopes of these demand and supply curves represent the marginal propensities to consume or produce and, as a result of this lack of information, the shape of the curves themselves is often unknown, meaning that the size of the TEV will be difficult to determine.

The slopes of these demand and supply curves are influenced by their elasticity (Turner *et al*., 1994), which itself is influenced by such factors as ease of substitution and degree of necessity. Given the finite nature of any ecosystem's carrying capacity, it seems likely that the supply of the goods and services it provides will ultimately be inelastic.

At the same time, the demand for life support services provided by forests will also be inelastic; increasingly so, as populations rise, and carrying capacity is reached.

A problem faced by many studies is the choice of money as the numeric value in valuation. This has been examined by Brekke (1997), who pointed out that using money as a numeric value has the effect of putting a greater weight on judgments if compared to those who do not use money as numeric. This has a distributional implication, as higher income groups tend to value money less than lower income groups. As a consequence, the inputs into valuation figures by lower income groups will have more effect (Brekke, 1997). It is common for the use of money and its time preferences to be a major problem in the valuation of forest resources. This problem is related to the units of money used in the calculation – whether the local currency is used or converted into a well-known currency such as the US dollar. If money is our operational unit, then any additional US dollar corresponds to the same amount of cardinal utility as any other US dollar, irrespective of income or other characteristics of the person receiving that dollar. It is obviously not realistic, as the value of a Kenya Shilling in terms of purchasing power, or utility, varies greatly from place to place, time to time and from person to person. The consequence of this is that if other values are used as a numeric unit in valuation of forest resources, different results may be produced. For example, if the selected numeric unit is kilograms of NTFP production, instead of money, a completely different conclusion from the study could result.

In practice, this means that the choice of numeric units favours different interest groups in society, but it may be possible to use a system of welfare weighting in calculations in order to overcome this problem. It is worth noting at this point, however, that by estimating the monetary value of environment resources, it becomes possible for policymakers to assimilate this information into their existing accounting procedures, thus possibly promoting more sustainable management strategies. The reviewed literature points to the need for internalizing externalities and that the concept of valuation is critical in attempts to solving the problem of free riding.

2.7 Factors influencing Dependence on Forest Resources

Most quantitative studies on the contribution of forest income to rural livelihoods have showed the importance of various socio-economic and contextual factors in influencing the participation of households in forest activities. Based on the reviews of these studies, it is evident some relationships are contestable, for example, it is expected young people because of energy may earn more from forest activities or may despise forest activities due to lack of essential forest skills. In old age, individuals may lack energy and time to carry out and therefore less dependent on income from forest activities. This however, was found contrary in a study in Malawi; young and old age (<35 years and >45 years) got more income from low-value forest products and less from high-value forest products whereas the reverse is true for middle age groups (35 - 44 years old) (Fisher, 2004).

Education level and family labour can be positively or negatively related to forest dependence depending on community attributes (Illukpitiyaand Yanagida, 2008). Vedeld *et al*., (2004) further argued that the impact of education, like age, may be compounded by cultural or local factors where engagement in forest extractive activities are considered backward and not for the elderly or the well-educated. In eastern Honduras, McSweeney (2002) found that households that are most reliant on earnings from forest products also get the highest earnings from forest products. In addition, households earning from forest products appeared to have more diversified income strategies (McSweeney, 2002). In Sri Lanka, diversification increases the income of households and thus, decreases dependence on forest resources (Illukpitiya and Yanagida, 2008).

Access to the market may affect extraction of resources in different ways; it may unlock better employment opportunities thereby making people less dependent on forest resources. Conversely, it may facilitate commercialization of forest resources and so encourage forest extractive activities. Therefore, it is difficult to predict the impact of market accessibility on dependence on forest resources. Gunatilake (1998) found that access to markets for agricultural goods reduces forest resource dependence. Godoy and Bawa (1993) found that indigenous people isolated from markets can deplete forest resources. For example, a remote area with no market access may show greater dependence on forest income mainly because of the abundance of the forest resources.

Also remoteness may mean reduced alternative livelihood activities and thus more dependence on forest resources. Access to markets may have no effect particularly if the forest products are chiefly used for subsistence rather than cash income (Vedeld *et al.*, 2004).

The effect of distance to the forest on household participation in the collection of forest products is variable. Households that live closer to the forest have a more secure and accessible supply of forest produce (Gunatilake, 1998). However, households living further from the forest find it more costly to collect forest products due to travel time requirements (Hedge and Enters, 2000). But in some special cases, it is contrary, in Tanzania's Nanguruwe village, women regularly walk 8 to 16 km to gather a wild yam that form an important component of their diet (Missano, 1994). In general, the effect of distance on forest dependence is variable and may depend on the importance of specific product for either subsistence or cash income.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Introduction

This chapter describes the methods of data collection and analysis in the economic valuation of forest products and services of East Mau forest. The chapter begins with a detailed description of the study area in terms of geographical location, climatic, environmental characteristics and socioeconomic characteristics of the surrounding population. This is followed by the research framework, the fieldwork procedures and the description of the methods used in data collection and data analysis.

3.2 Study Area

3.2.1 Description of the Study Environment

This study was undertaken in East Mau Forest ecosystem in Nakuru County. The forest ecosystems is located between 30 to 50 Km south of Nakuru Town at 35° 58’ 00” E and 00° 32’ 00” S at an altitude range of 1200 and 2600 m. It covers eight forest stations of Sururu, Likia, Teret, Nessuit, Elburgon, Mariashoni, Kiptunga and Bararget. It borders Naivasha district to the east, Narok North District to the south, Njoro and Molo to the north and Kuresoi East district to the west. The forest is found within administrative divisions of Mauche, Mau-Narok, Njoro, Elburgon, and Keringet. It has an area of approximately 280 km^2 and has the highest number of forest dwellers – the Ogiek community, in Mariashoni and Nessuit locations. East Mau forest forms an important watershed within the Mau Forest Complex, feeding major rivers and streams that make up the hydrological systems of Lake Victoria and inland Lakes of Nakuru, Baringo and Natron. The total forest area was originally about 66,000 ha but 35,302 ha was excised in 2001 (UNEP *et al*., 2006). The remaining 30,699 ha consists of high forest, grassland and planted forest mainly of Cypress and Pines (KFS, 2012).This area was chosen for this study because it represents the changing social and environmental conditions now common in Kenya.

The forest is facing immense anthropogenic pressure due to livelihood needs and the increasing social and ethnic heterogeneity, influence of globalization and the commoditization of natural resources. The forest is also important for provision for ecosystems services and risks further degradation if remedial measures are not implemented.

3.2.2 Land Use and Settlement History

The watershed of East Mau has been progressively settled and deforested in phases and the initial process of land use change occurred during British Colonial period in 20th Century (Trupnik and Jenkins, 2006). The area was originally settled by the Ogiek- the honey gatherer community (Sang, 2001). The process of conversion of forest to human settlement started with the Taungya system of plantation establishments and the forest workers were allowed to farm and stay inside the forest. However, with the rapid population growth, demands for land by squatters became apparent and the government in early 1980's discontinued the Taungya system and encouraged non-resident cultivation. The workers in the forest camps were mainly immigrants from central Kenya. The most recent phase of land use change occurred in 1990's sanctioned by the government of Kenya for human settlement. About half of East Mau was excised for settlement (UNEP *et al*., 2006). The excised areas were used to settle the Ogiek and other Kalenjin groups like Kipsigis and Tugen. The latter group are agro-pastoralists. With political and tribal clashes of 1990's, some immigrants from central have sold most their farms to new settlers from other counties in Rift Valley.

3.2.3 Physiography, Geology and Soils

The East Mau shares the same physiographical and geological features of the Mau complex. The area comprise of the escarpments, hills, rolling land and plains. The topography is predominantly rolling land with slopes ranging from 2% in the plains to more than 30% in the foothills. Geological studies have shown that the area is mainly composed of quaternary and tertiary volcanic deposits (Sombroek *et al*., 1980). In the lowlands, the top soils are of mainly clay loam (CL) to loam (L) in texture and the subsoil texture ranges from silty clay loam (SCL) to clay loam (CL) and clay (C), with pH values ranging from 5.6 to 6.4 (China, 1993).

In the lowland, Luvisol, Vertisol, Planosol, Cambisol and Solonetz soils from the Holocene sedimentary deposits are primarily prevalent and occur in saline and sodic phases. In the upland areas however, the soils have a high content of silt and clay predominantly of Ferrasols, Nitisols, Cambisols and Acricsols (China, 1993). The adjoining settlements have gentle slopes with deep-fertile-volcanic soils which are suitable for maize, wheat, potatoes, horticultural crops and livestock keeping (Jaetzold and Schmidt, 1982).

3.2.4 Climate

The climate of the study area is mainly influenced by the North – South movement of the Inter-tropical Convergence Zone (ITCZ) modified by local orographic effects (Olang and Kundu, 2011). The climate is characterized by a trimodal precipitation pattern with the long and intense rains from April to June ; short rains in August; and shorter, less intense rains from November to December with total annual precipitation of 956mm (Baldyga, 2005) and mean monthly rainfall between 30 mm to over 120 mm are common (Kundu, 2007). Mean annual temperatures are in the range of 12°C to 16°C, with greatest diurnal variation during the dry season. Due to diverse topography of the entire Mau Forest Complex it is difficult to predict the rate of evapo-transpiration and in many cases; the average evapo-transpiration is estimated in relation to the existing land use types. In the entire complex, annual average estimates between 1.3mm/day to 4.2 mm/day, with an average of about 3.85 mm/day, have been recorded (Olang and Kundu, 2011).

3.2.5 Vegetation Composition and Biodiversity

The rainfall amount and distribution, climate and fertile soils of East Mau forest has made it conducive habitat for diversity of plants and animals. The original vegetation pattern is dictated by altitudinal gradient and topographical features. At the lower altitudes closed canopy moist forest are interspersed with bamboo above 2200masl (Jackson and McCarter, 1994). Between 2,300 and 2,500m indigenous bamboo (*Arundinaria alpina*)(K.Schum)) is the dominant vegetation while above the 2500m above sea level (asl), there is mixture of bamboo/tree stands associated with human disturbances (Jackson and McCarter, 1994).

Ninety percent of the vegetation is composed of thick impenetrable bamboo forest at high altitude interspersed with indigenous trees like Cedar (*Juniperus procera*) (J.Lewis), African olive (*Olea africana*) (J.Durand), *Dombeya torida* (J.F. Gmel) and shrubs and in areas with anthropogenic influences (Baldyga, 2005). Wherever indigenous species have been harvested, colonizing species such as *Neuboutonia macrocalyx* (H. Kaisa) and *Macaranga capensis (*D. Prain*)* are found (personal observations). Large areas mainly in the north eastern parts of the reserve have been planted with plantations of exotic trees such as cypress (*Cupressus lusitanica*), pine (*Pinus patula* (L.Balchin) and *Pinus radiate* (R.Patel), *Grevillea robusta* (A. Dermatol) and *Eucalyptus* (KFS Perscom).

The forest is also home to endangered mammals like the Yellow-backed duiker *(Cephalophus sylvicultor* and the African golden cat (*Felis aurata*) (J.Keulemans). There are numerous animals, like the Giant Forest Hog (*Hylochoerus meinertzhageni*) (Thomas), Gazelle(Gazella thomnosii) (N.Dilmen), Buffalo(*Bubalus bubalis*)(Linnaeus), Leopard (*Pandera pardus* (K.T. Holzer), Hyena(Hyaenidae lars (Werdelin and N. Solounias), Antelope (*Alcelaphinae* spp (Walther), Monkey (*Cercophicidae* spp (G.Davies) and small animals like the Giant African Genet (*Genetta genetta* (Linaeus), Tree Hyrax (*Dendrohyrax arboreus* (Bothma), and Honey badger(*Mellivora capensis*-(V. Schreiber) (Sang, 2001). This makes the forest an important asset resource to the local, national and international community.

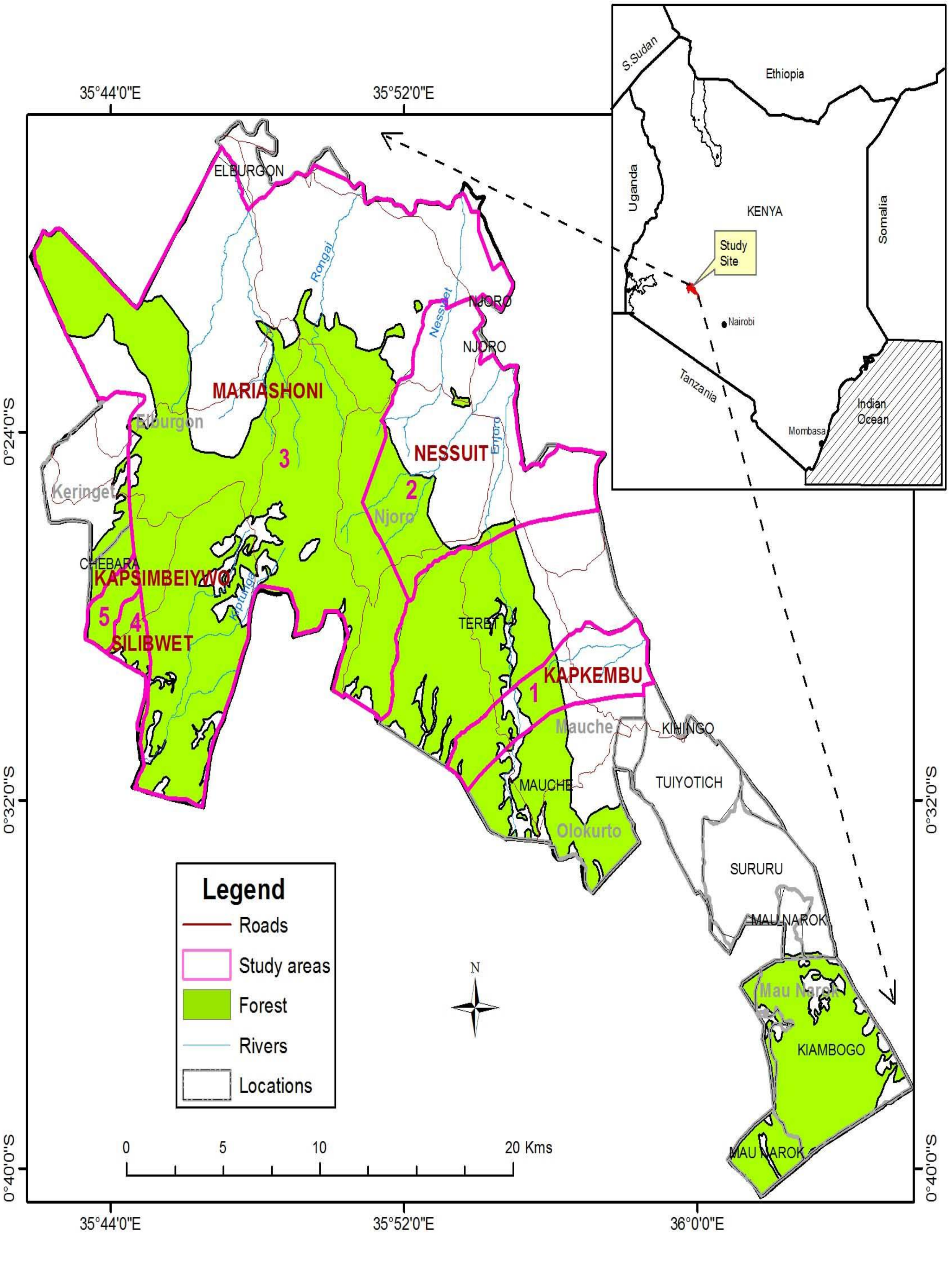

Fig. 3.1: Map showing East Mau Forest and Study Locations

Source: Own GIS Production

3.3 Research Design and Surveys

The use of surveys in economic research was first suggested by (Ciriacy-Wantrup, 1947). Household surveys can provide detailed information at the household level which can be used for espousing particular economic/development policy or intervention (Deaton, 1997).In this study, cross-sectional survey design was used to collect data from sampled households, wood processors (large and medium), small scale forest products processors and traders. The method involves collection of in depth data from research population in a given period. This type of design was found to be versatile and practical for collecting detailed data. The survey instruments (questionnaires, checklists) were designed to include probing questions to the respondents and this was triangulated with information from Focus Group Discussions and Key Informants Survey (Kothari, 2004). The data was collected from respondents from the month of January to May 2013 and September to December 2013 using a set of questionnaires (Appendix 1 to 4).

3.3.1 Research Population and Sampling Frame

All households within and adjacent to East Mau forest totalling 43, 257 households from 17 locations (KNBS, 2010) formed the research population for the purpose of this study. All sawmills and small-scale wood and non-wood forest products traders in major urban centres formed the research population for the saw mills and traders surveys. For the household surveys, the sampling frame constituted all households in selected locations within and adjacent to East Mau forest. The selection was on the basis of ethnic composition and age of the settlement. Through consultations with the local administration and forest officers, five administrative locations were selected. Mariashoni representing an old settlement predominantly occupied by Ogiek indigenous community; Kapkembu – representing a recent settlement with a homogenous community of the Kipsigis; Nessuit –representing a recent settlement with a heterogeneous population of indigenous and immigrant ethnic groups; and Kapsimbeiywo and Silibwet - representing a relatively old settlement with a homogenous community of the Kipsigis community. These locations represented the forces of change and forest use in East Mau. According to KNBS (2010), Silibwet, Kapsimbeiywo, Kapkembu, Mariashoni and Nessuit had 650, 978, 1, 177, 2,630 and 2,744 households respectively and therefore the research sampling frame had a total of 8,179 households (KNBS, 2010).

Study villages in all the five locations were randomly selected from the list of villages provided by local chiefs and village elders. The household lists from sampled villages were compiled with their names. In polygamous unions, households were listed according to the wife's name and each considered a separate household. The list of households in each location was taken as the sampling frame. A list of registered sawmills, small scale processors and non-wood and wood traders within and adjacent to East Mau were obtained from saw millers' register at the Kenya Forest Service (KFS) Zonal manager's office while a list of small scale wood processors in Molo, Elburgon, Njoro and Nakuru, Keringet and Olenguorone were obtained based on discussions with key informants.

3.3.2 Sample Size for Household Surveys

The 2009 Kenya National Bureau of Statistics Household Census data from the selected locations were used in determining sample size. The five study locations had 8,179 households (KNBS, 2010). Sample size for the households was determined using the formula in equation 3.1 (Mugenda and Mugenda 1999).

$$n = \frac{Z^2pq}{d^2} \qquad \text{.......... 3.1}$$

Where: n = the desired sample size if the target population is greater than 10, 000, Z= the standard normal deviate at 95% confidence interval, P= the proportion in the 8,179 households; q= 1-p; d = the level of statistical significance.

According Mugenda and Mugenda (1999), the value of P should be determined based on a pilot survey and when it is not available, a 50% (maximum variability) is assumed.

Therefore, $n = \frac{(1.96)^2(0.5)(0.5)}{(0.05)^2} = 384$

Therefore, 384 is the desired sample size for population greater than 10,000. In this study the target population was 8,179 (less than 10,000), and the desired sample size is calculated using the second formula in equation 3.2 (Mugenda and Mugenda, 1999).

$$n_f = \frac{n}{1+n/N} \qquad \text{.......... 3.2}$$

Where n_f = desired sample size (when population is less than 10,000, and n= desired sample size when population is more than 10,000, N= the estimated population of the 5 locations (8,179).

According to the formula 3.2, the total sample size for the five locations was 367, i.e.

$n_f = \frac{384}{1+{}^{384}/_{8179}}$=367, and therefore the sample size for each location are shown in Table 3.1.

Table 3.1: Sample size of households by location in East Mau

Location	Total household number[1]	Sample size (n_f)
Silibwet	650	29
Kapsimbeiywo	978	44
Kapkembu	1,177	53
Mariashoni	2,630	118
Nessuit	2,744	123
Total	8,179	367

3.3.3 Sampling Procedures

3.3.3.1 Households

The names of resident households from the sampling frame were written on pieces of paper and put in a box. One paper at a time was randomly drawn and recorded without replacement until the desired number of respondents in each village was achieved. All drawn pieces of paper with corresponding names of households formed the study sample in each village and location.

[1] Data based on 2009 National Census (KNBS 2010)

3.3.3.2 Sawmills, Small-scale Wood Processors and Informal Traders

Registered sawmills in and within the vicinity of East Mau forest were obtained from Nakuru County Ecosystem Coordinator's office, Nakuru County where official records are held and maintained. The list of saw mills in the register was used as the study sample. The small-scale wood processors were sampled from a list generated from discussion with key informants primarily from Kenya Forest Service staff and local chief. The number of informal wood and non-wood products traders was difficult to determine beforehand and therefore a rapid survey of wood and non-wood traders was undertaken in major trading routes and centres and the contacts made were used to connect with other traders. In essence, snowballing sampling strategy was adapted.

3.3.3.3 Key Informants

Purposive sampling was used to select key informants. Twenty-two key informants (one key informant from each sampled village) were selected based on the following criteria: familiarity with the area and the local people, and having a broad and in-depth knowledge about his/her village, its households and the forest issues in general and specific aspects of this study.

3.4 A framework for Assessing Forest Values from East Mau Forest Ecosystem

Recent ecosystem valuation have emphasized the need to focus on the end products (benefits) to avoid the prospect of double accounting of ecosystem functions, intermediate services and final services (Boyd and Banzhaf, 2007; Fisher *et al*., 2009). In the light of this development and the need to capture a wide range of ecosystem services a framework based on the concept of total economic value, identification of all forest benefits and the appropriate valuation method was adapted for this study (Fig.3.2). In the framework, the forest ecosystem provides use and non-use values. The forest provides direct use benefits through the flow of forest products and ecosystems services to the local people and other stakeholders. More specifically, forest ecosystems are vital for provision of timber and non-timber products and environmental services.

The local people collect timber and non-timber forest products for domestic uses and for cash income and land for agricultural and forest fodder and browse for livestock production. Forests also provide indirect use benefits through flows of services such as watershed protection, storm and soil protection, climate regulation, biodiversity conservation, aesthetic values and hydropower generation, which in turn generate socio-economic value to the local and downstream populations (Godoy, 1992; Godoy *et al*., 1993; Aboud *et al*., 2012). Loss and damage to forest would affect those on-site and off-site in terms of livelihoods and economic options foregone from services provided by this forest. Forests are also important for non-use values (bequest, existence) (Fig.3.2).

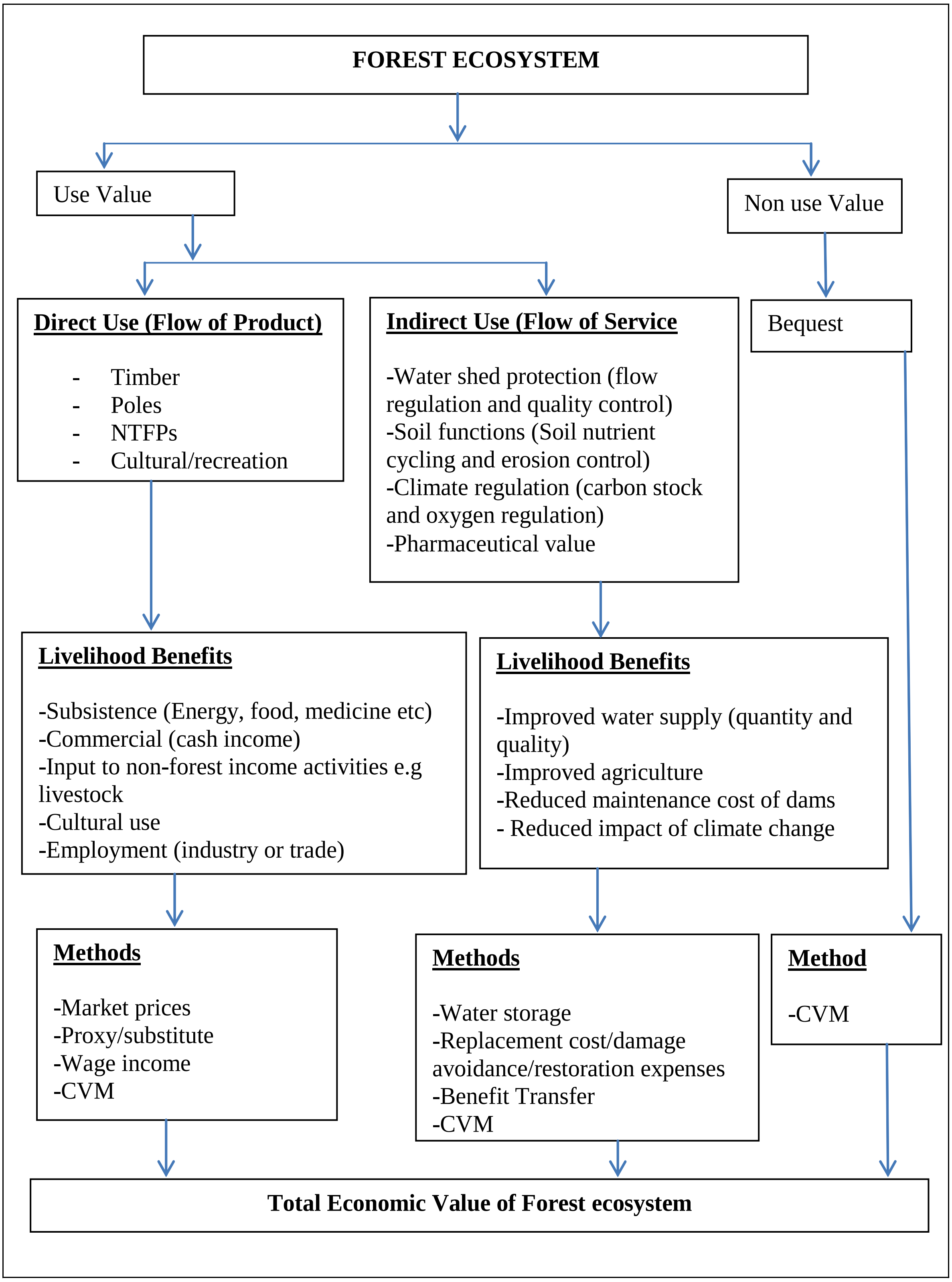

Fig. 3.2: Framework for assessing forest values from East Mau forest ecosystem

Source: Adapted and modified from Pearce and Moran 1994; MEA, 2005

3.5 Questionnaire Design and Pretesting

Some forest products are collected continuously throughout the year, while others are harvested seasonally and this presents a challenge to respondents to recall with ease. In this study, forest use data were obtained by asking the respondents to give forest product information collected in a shorter recall period (one week) so as to minimize on recall errors. This approach was augmented by use of a prepared exhaustive checklist of forest products or services from the forest to prompt respondents. Another likely source of inaccuracy is inconsistent measurement units. Quantities of products harvested from forests are often collected in local units such as head-loads, pieces, tins, buckets, and sacks which are imprecise and not standardized. To resolve this issue, random assessments of local units were undertaken and converted into standardized measurements e.g. weighing the mass of product (charcoal) in local units (tin or sack) to estimate in kilograms.

To ensure clarity of questions, a pilot survey was undertaken in a village outside the study locations and sections/parts of the questionnaire that were sensitive, ambiguous or prone to misinterpretations, by respondents were restructured. To minimize on the problem of respondent strategic bias (conceal information e.g. cautiousness about revealing illegal activities, or to misinform in the expectation of a reward or anticipation of projects (Wollenberg, 2000), the objectives and purpose of the research were explained to residents in community meetings by enlisting the support of the local administration. To enhance the local community's confidence in the study, the support of the local leaders and elites was build during field visits and consultations.

Experienced research assistants were identified, recruited and trained rigorously on the objectives, content of the questionnaire and techniques of conducting social surveys. The trainings involved role-plays and conducting supervised test interviews. The research assistants were closely supervised during the research period. During the actual surveys, the research assistants were accompanied by village elders appointed by the relevant chiefs.

3.6 Data Collection

3.6.1 Household Surveys

Structured closed questions and semi-structured questions were used to obtain quantitative data and qualitative data respectively on forest use, costs and benefits of conservation. The household survey was used to obtain socioeconomic and demographic data (income sources, total household income, value of assets, land size, livestock size, education years of members of household, years of residence, membership in associations or groups, household size) household contextual factors (distance to the forest, ethnicity, and distance to markets and forest use (frequency of forest use, quantities collected per visit, time spent, number of household members involved, costs of forest activities (Appendix 1).

3.6.2 Contingent Valuation Surveys

The CV method was used to determine willingness to pay (WTP) for maintenance of the forest for medicinal, cultural and bequest values. CVM surveys were conducted according to guidelines suggested in Mitchell and Carson, (1989), Whittington, (2002); Hanley *et al*., (2007), Ojeda *et al*., (2007), Ezebilo, (2010), and Riera and Signorello, (2013) namely, setting up the hypothetical market. This involved describing hypothetical scenarios on conservation measures and description of a payment vehicle (levy) (questions 19 to 21, Appendix 1); obtaining bids by asking respondents to state the maximum amount they would be willing to pay to achieve the conservation objectives; estimating mean WTP and aggregating data.

3.6.3 Wood Industry Survey

The number of saw millers/processors active in East Mau, Nakuru County was obtained from the saw millers' register at the KFS Zonal office, Elburgon. The following information was obtained from licensed saw millers: volume of saw logs (M^3), proportion of raw materials sourced from East Mau forest, number of people employed in logging, processing and sales and the prices of various wood products (Appendix 4).

3.6.4 Small-scale Forest Products Processors and Traders Survey

Small-scale wood processors, saw-bench operators, power-saw operators and informal forest traders/users surveys were undertaken in rural areas adjacent to East Mau and urban centres (Molo, Elburgon, Njoro and Nakuru, Keringet and Olenguorone). The surveys covered full-time and part-time operators/traders. Data collected included: nature and volume of products (saw logs (m^3), poles (units/year), charcoal (Kg/yr), firewood (Kg/yr), bamboo etc.), number of people employed in the processing and business (Appendix 5). Additional information on the prices of the wood and non-wood products was obtained from a rapid market survey in the nearby urban centres of Nakuru, Molo, Elburgon, Keringet and Olenguorone.

3.6.5 Focus Group Discussions

This method was used to provide detailed information on two topical issues (i) The nexus between people and the forest resources and (ii) the importance of forest values to local stakeholders. The two focal issues were used to explore trends of forest cover, village history, income and livelihoods of the local people, forest products and importance in livelihoods, threats facing conservation of the forests, options for sustainable use of East Mau forest resources (Appendix 2).

3.6.6 Key Informant Interviews

Key informant such as local chief, government officers (KFS, Department of Agriculture and livestock) were interviewed to obtain relevant information e.g. livelihoods of the local people, agricultural productivity, licensed forest product traders etc (Appendix 3).

3.6.7 Secondary Data Collection

Secondary data on importance of East Mau to the local community, livelihoods and socioeconomic characteristics of forest and forest adjacent communities were collected from reports, bulletins and documents from provincial, district and local forest extension and agriculture offices, community based organizations (CBO) and research organizations, journal articles and internet sources. Data were also collected from agricultural offices on productivity of common crops in the study area, livestock data (types and number within the study area and their average weights, average fodder consumption), cost of production (crops and livestock), market prices of crops and livestock, prices of alternative fodder resources such as hay. Data on productivity of crops (maize and potatoes and livestock were used in estimating the opportunity cost of conservation. Livestock data and alternative fodder resources were used to estimate the value of forest browse/grazing. The data from Kenya Forest Service (KFS) included budgetary allocation for the watershed management, costs of protection activities. The costs of obtaining water through alternative means (borehole drilling) other than improved watershed protection were obtained from local experts (Hydrogeologist WRMA office in Nakuru).

3.7. Valuation Techniques for Forest Products and Services

Participatory Rural Appraisal (PRA), Key informant interviews (KII) and literature reviews were used to determine the types and forest services from East Mau. The PRA and KII helped identify key products and services for the development of research tools for valuation of the resources. There are quite a number of methods that have been developed by economist to capture the total economic value of forests. There is no one approach that can capture all the forest values and thus combinations of these methods have been used for this study. The valuation techniques used in this study is shown in Table 3.2.

Table 3.2: Valuation methods for estimating economic values

Product or service	Valuation method(s)
Firewood	Own reported values (Household surveys) and market prices
Timber	Own reported values and market approach
Game meat	Own reported values use of proxy (meat from butcheries)
Fruit/vegetable	Own reported values and use of proxy and market price
Thatching materials(Grass)	Own reported values, market prices
Grazing	HH Survey, Secondary data and substitute approach
Fencing /constructions poles	Own reported values (HH surveys), market approach
Forest honey	Own reported values and use of market approach
Medicinal herbs	Contingent valuation survey (CVM)
Soil nutrient cycling	Secondary data and replacement cost approach
Soil protection (erosion control)	Secondary data and avoided cost approach
Water provision	Own reported values and replacement cost approach
Water flow regulation	Secondary data and rainfall storage method
Water quality regulation	Secondary data and avoided cost approach
Carbon sequestration	Secondary data and benefit transfer approach
Oxygen cycling	Secondary data and benefit transfer
Cultural and spiritual values	Contingent valuation survey (CVM)
Bequest value	Contingent valuation survey (CVM)
Option value (pharmaceutical value)	Secondary data and benefit transfer(adjusted PPP)

3.7.1 Forest Household Consumption Values: Use of own Reported Values

To measure direct use values, household's own-reported values for forest products /goods collected were used as a basis for valuation. Households/respondents were asked the weekly amount of each product harvested/gathered by the household for domestic consumption and for sale and the cash amount received from sales of these products. This was then extrapolated for the whole year. In the study locations/villages some products such as firewood, construction woods (timber, poles, posts etc.) for houses and farm structures, farm implements, household furniture, bamboo for basket making and fencing and construction are widely traded in local markets and hence have local markets. For such forest goods/products the household's own reported quantities and local market prices were used in the valuation exercise (Godoy *et al*., 1993; Campbell and Luckert, 2002; Langat and Cheboiwo, 2010(b). This was done by multiplying the quantities extracted per annum by the average local market price (P_m) less the transaction costs (Godoy *et al*., 1993). To ensure that the prices used in calculations reflect true value of in the market, average market prices were used. This was achieved by discussing with key informants on the seasonal price movements in three market situations (scarce, moderate scarce and plentiful). The total net value (T_n) of the product is the cumulative (aggregate) for the total number of households in the areas surveyed i.e. the value of product is given by expression:

$$T_n = (P * Q) - C \quad \text{......3.3}$$

Where, Q is the quantity of good extracted; P is the price of good which may be equal to market price in the absence of externalities), C is the transaction costs (cost of collection, transport, and sale).

3.7.2 The Market Prices of Substitutes or Proxies for Forest Products

Forest products such as wild food items, (e.g. wild fruits and vegetables), fodder and game have no developed markets and their values were imputed from substitutes or proxies (Hufschmidt *et al.*, 1983; Emerton, 2001, Gunilake, 1998; Mogaka, 2001; Langat and Cheboiwo, 2010(b).

3.7.2.1 Estimating the Value of Forest Grazing/Browse

The value of the forest as a source of browses and fodder was determined using secondary data and proxy value of alternative fodder resource (Hay).From literature, the dry fodder requirements for livestock is about 2% to 3% of the body weight per day (Ganesan, 1993) and the cattle in the forest adjacent areas weighs between 200 and 400kg, with 250kg taken as an average (Livestock office Njoro). The quantity of fodder required for maintenance is therefore is between five and seven kilograms per day. The daily dry fodder requirements was estimated based on average weight per livestock unit and extrapolated for the whole year for all livestock units grazing inside forest. The total livestock units were estimated based on Tropical Livestock Unit conversion factors (0.7 for cattle and 0.1 for goats and sheep, 0.4 for donkey (Jahnke, 1982).

$TDM = (TLU * P * V)$……………………………………………………………….3.4

Where: TDM is the total dry matter requirements for the livestock; TLU is the Tropical Livestock Units, P is the proportion of forest graze in livestock diet; and V is the minimum fodder requirement for one tropical livestock unit.

The total dry matter requirement was converted to hay equivalent. The average weight of one bale of hay was obtained from Agricultural and Veterinary inputs stores within Njoro town. The TDM above was converted to dry-hay unit equivalent (bales).One bale of hay weighs about 30kg and currently sells at Ksh 150.00. The total value was obtained by multiplying hay equivalent by the market price of 30kg bale hay (Appendix 6 for detailed calculations).

3.7.2.2 Determining the Value of Game Meat

The value of the game meat was estimated based on ‘own reported’ consumption quantities and the local meat equivalent in the local butcheries.

3.7.3 Value of Water for Domestic Consumption and Livestock Production

Water is one of the main services obtained from the forest by households within and outside East Mau for domestic use, livestock, for irrigation, and in hospitality industry and to maintain wildlife. Forest ecosystems influence the quantity and quality of water. The valuation of water for domestic use has been approached in numerous different ways in the literature. Estimates of the contribution of East Mau towards the provision of quality and quantity water were obtained by estimating the cost of alternative source of water if the forest was not in existence (Sjaasted *et al*., 2003; Bush, 2009). The next alternative source of water is from boreholes. The cost of sinking borehole and maintenance was used as proxy value of the forest ecosystems for water provision. Whilst a borehole may not be appropriate for all cases (Bush, 2009), but boreholes are one of the most common sources of provision of clean water supply in many rural households in Kenya. Data on domestic water consumption were obtained from household surveys and the livestock consumption data obtained from literature (Penden *et al*., undated). The cost of sinking borehole, lifespan and maintenance was obtained from Water Resources Management Authority (WRMA –Rift Valley, Nakuru office) and review of local literature. The water yields from boreholes in areas near East Mau (Nakuru County) were obtained from a study by Bosuben, 2014 (Appendix 8). The livestock water demand was estimated based on total number of livestock units dependent on waters from East Mau and average TLU consumption of water /year (Penden *et al*., undated) (Table 3.3). The total water demand was estimated and converted to number of boreholes yield equivalents and the costs of provision.

Table 3.3: Indicative water requirements to sustain animal production

Species	Tropical livestock unit (TLU/head)	Voluntary daily water intake by season and average temperature (Litres/TLU)			
		Wet	Dry	Dry hot	Average
Cattle	0.7	14.3	21.9	31.3	22.5
Sheep	0.1	20.0	40.0	50.0	36.7
Goats	0.1	20.0	40.0	50.0	36.7
Donkeys	0.4	5.0	27.4	40.0	24.1

Source: Penden *et al*., undated

3.7.4 Determining Indirect Use Values

Forest ecosystems regulate soil nutrients and soil water relations (hydrology) both on-site and off-site, regulate climate (carbon sequestration), oxygen generation etc. Estimating these values is often difficult because of paucity of relevant data. However, there are a number of indirect techniques which can be applied to estimate these values such as: replacement cost approach, productivity change approach, and damage cost avoided approach). In this study, the replacement and avoided cost approach were applied using secondary data from different sources as described below.

3.7.4.1 Estimating Nutrient Cycling Value

The ecosystem function of conservation is manifested in a reduction of in soil erosion. Soil conservation results in a reduced silt in rivers, lakes and reservoirs and less soil loss due to due reduced soil erosion. The soil nutrient values were thus estimated using replacement cost approach. The principle behind this approach is to calculate the cost of a particular damage under consideration and to put the value on it using the equivalent cost of replacing the product or service (Turner *et al*., 1994; Nahulheal *et al*., 2007; Riera and Signorello, 2013).

The soil nutrient cycling value of East Mau were estimated by determining the likely on-site effect of soil erosion due to deforestation by using secondary data of soil loss for indigenous forest converted to agricultural use (without natural forest scenario) (Xue and Tisdell, 2001) and estimating the soil nutrients loss and placing the value of the equivalent cost of commercial (artificial) fertilizer using the following steps: (a) using the mean soil loss per hectare (erosion rate) on different land use types (Okelo, 2008); (b) using nutrient loss data estimated from stream input loads to Lake Nakuru from River Njoro (Kulecho and Muhandiki, 2005); (c) valuing the nutrient loss per hectare (loss of major nutrients i.e. nitrogen, phosphorus, and potassium) by taking the cost of each nutrient in commercial fertilizer replacement based on nutrient-fertilizer conversion ratios. These ratios were computed using the concentrations reported for commercial fertilizers and real prices of fertilizers for 2015 and (d) scaling up (extrapolating) to the entire area of East Mau forest.

3.7.4.2 Estimating the Value of Soil Erosion Prevention

Forests help to prevent soil erosion and minimize sedimentation in reservoirs and rivers, thus extending reservoir life. The ability of forest in rainwater retention and reduction of rainfall volume and velocity reaching the ground serves to regulate runoff quantity and speed and minimize soil loss (Junhua, 1999; Xue and Tisdell, 2001). The soil conservation value was estimated based on avoided cost of sediment removals from rivers or dredging of reservoir using the method by Xi, (2009) applying the formula below:

$V_k = K \cdot G . \Sigma Si * (d_i - d_o)$ ………………………………………………………………......3.5

Where: V_k is the economic value of soil conservation; K is the cost of 1 ton sediment removal- (Ikobe, 2014); S_i is the area of forest vegetation types (ha); G is the ratio of amount of sediments entering rivers or reservoirs to total soil lost; d_i is the erosivity of all vegetation types of forest (t/ha); d_o is the erosivity of non-forest land (t/ha) (Agricultural land). In this study, the average cost of sediment removal in Kenya is about KES 178.09[2]/= per ton. The ratio of sediments entering rivers or reservoirs to total soil loss was assumed at 50% or G=0.5. The soil erosivity values were based on a local study in East Mau (Okelo, 2008)) and the area covered by each vegetation types of East Mau forest (Table 3.4).

Table 3.4: Soil loss under different land use/vegetation types in East Mau

Land use / Vegetation type	Soil loss(t/ha)
Agricultural land	8.57
Deforested forest area	3.16
Grazing/pastures	1.48
Plantation forest	0.06
Indigenous forest	0.00

Source: Okelo, 2008.

[2] This is the cost sediment removal (Ikobe, 2014)

3.7.4.3 Estimating Value of Carbon Sequestration

To determine the economic value of carbon sequestration of East Mau, the above ground carbon stock in forest vegetation was determined based on published biomass data from Mau forest and Kakamega forest in Kenya (Kinyanjui *et al*., 2014; Otuoma, 2015). It was assumed that since, the East Mau study site is part of the larger Mau Complex, the biomass data for indigenous vegetation was applied and the data for exotic tree species from Kakamega site with fairly similar climatic and soil conditions was adapted (Table 3.5).

The carbon sequestration potential was calculated in 4 main stages: (i) Determination of area covered by different vegetation types by delineating vegetation types using Landsat and GIS techniques and producing vegetation area map (Appendix 9) (ii) Assigning ecosystem-based carbon content values to these vegetation types by equating to a range of carbon content per unit area. Carbon stock was assumed to be 50% of the biomass density (IPCC, 2003).

Table 3.5: Carbon stock values applied in estimating carbon sequestration value

Vegetation/type	Mean AGB, Mg/ha	Carbon stock Mg/ha	Source(s)
Open forest	37.78	18.89	Kinyanjui *et al*., (2014)
Moderately dense forest	71.56	35.78	
Very dense forest	265.90	132.95	
Bamboo forest/grassland	137.99	69.00	
Cypress plantation	267.20	133.60	Otuoma, (2015)
Pine plantation	242.80	121.40	

(iii) Estimating the carbon content for each vegetation type and aggregating for the whole of East Mau.

(iv) Estimating CO_2 equivalent by multiplying per ha carbon stock by a factor of 3.7[3]. The gross economic value of carbon sequestration of East Mau was computed using the net production of forests each year using the formula by (Xi, 2009; Patton *et al*., 2011).

$$V=Q*P*S \quad \ldots\ldots 3.6$$

Where: V is the release or absorption service value; Q is the carbon sequestration ($CO_{2});$ P is the international carbon sequestration price; S is the area of each forest type (ha). The price per unit of carbon dioxide in carbon market was based extensive review of carbon trade. The cost of carbon sequestration varies from region to region, and also from country to country.

The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (IPCC, 2007) suggests that real prices at US$ 20 to US$ 50 per ton of CO_2, however, the average price in the Clean Development Mechanism (CDM) was US$ 10.5 per ton of CO_2. The current CDP (2013) report and World Bank 2014) indicated that the average price of carbon based on carbon tax is about US$ 11.38 and the average price in the Emission Trading Schemes (ETS) cluster around US$ 12/tCO_2 (World Bank, 2014). An average of carbon tax and ETS of US$ 11.40/tCO_2 was adapted.

Table 3.6: Price of carbon/unit ton of CO_2 (Carbon tax) US$ from selected countries

Country	Price of carbon/unit ton of Co_2(Carbon tax)USUS$
Australia	21.11
Canada, British Columbia	29.12
European Union	5.93
India	0.85
Japan	2.89
South Africa	12.22
United Kingdom	7.55
Average	11.40

Sources: World Bank 2014, CDP 2013, (EESI) 2012

[3] This is because carbon sequestration converts atmospheric carbon dioxide to biomass carbon. The conversion factor is derived from the ratio of atomic weights of CO_2 and C i.e. Atomic weight of CO_2 = 44 / atomic weight of C = 12) (Cox, 2012).

3.7.4.4 Estimation of the Value of Oxygen Generation Potential

Oxygen generation capacity was estimated based on carbon sequestration capacity, using the photosynthesis reaction equation (Xue and Tisdalle, 2001; Xi, 2009).

$6CO_2$（264g）+$12H_2O$（180g） $C_6H_{12}O_6$（180g）+$6O_2$（192g）

⬇

Polysaccharide（162g cellulose or starch）

According to the equation above, 1 ton of CO_2 absorbed will release 0.73 ton O_2. The Economic value O_2 generation for all vegetation types were calculated using the total potential quantity of O_2 generated multiplied by the average cost of industrial oxygen production in Kenya.

3.7.4.5 Estimating the Value of Water flow Regulation

The rainfall storage method was applied to estimate water flow regulation functions (Li Jinchang, (1997), Xue and Tisdalle, (2001) and Xi, (2009).

$V = Q * C_{yt}$……………………………………………………………………………..3.7

$Q = S * J * R$……………………………………………………………………………3.8

$J = J_o * K$………………………………………………………………………………3.9

$R = R_o - R_g$……………………………………………………………………………3.10

Where:

Q- Increase in water preserved in forest ecosystems, compared to bare land (m^3);

S- Area under forest in ha (indigenous vegetation only) =31,719.23[4]

J- Annual precipitation runoff of the study area =615[5]

J_o- Annual precipitation of the study area =1,500[6]

K- Ratio of precipitation runoff yield to total precipitation of the study area; = 0.41

R- Beneficial coefficient of reduced runoff of forest to non-forest area

R_o- Precipitation runoff rate under precipitation runoff condition in grazing (%) =80[7]

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[4]Area under indigenous forest based on GIS map

[5]Average runoff data from the Upper River Njoro watershed (Okelo *et al*., 2005)

[6]Kundu *et al*., 2007

R_g- Precipitation runoff rate under precipitation runoff condition in forests (%) =1.33

C_{yt}- Investment cost of reservoir construction per m^3=254.34[8]

3.7.4.6 Estimation of Value of Water Quality Regulation

The value of water quality service provision by the forest was estimated using a method by Xue and Tisdalle, (2001) and Xi, (2009).

V=Q*P……………………………………………………………………………3.11

Where:

V is the value of water purification by forest; Q is the amount of water preserved in ecosystems (the households' consumption of the water supply); P is the unit cost of water treatment. The unit cost of treatment was obtained from local data in a World Health Organization (WHO) report (WHO, 2008)[9].

3.7.5 Estimation of Medicinal, Bequest, Cultural and Spiritual Values

Contingent Valuation Method (CVM) was applied to estimate Willingness to Pay (WTP) by local communities to support the conservation of East Mau forest for medicine, non-use (bequest value) and cultural and spiritual values. CVM surveys were conducted according to guidelines suggested in Whittington, (2002); Hanley *et al*., (2007), Ojeda *et al*., (2007) and Riera and Signorello, (2013). A hypothetical conservation scenario was described and respondents asked to state the maximum contribution to a local fund to ensure a continued provisions or existence of the forest using personal interview method (see part C: Household questionnaire (questions 29 to 33 in the Appendix 1). The payment vehicle was an annual contribution to a community development fund. This payment vehicle was adapted because; the local people in East Mau often contribute to local community infrastructure projects (e.g. school classrooms through the 'pool together' approach popularly known as Harambee.

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[7]Average runoff data in grazing area in Upper River Njoro watershed (Okelo *et al*., 2005)

[8]This is the average unit cost of constructing a water reservoir in Kenya (Ikobe, 2014).

[9] The average treatment cost based on simple technologies- Water Guard™ (PSI brand of sodium hypochlorite)

Open – ended value elicitation technique was adapted using a payment card and asking the respondent the maximum amount one would be willing to pay for each of the services. To minimize on the problem of free riding, the respondents were provided with a range of monetary values from KES 100 to KES 15,000. These values were derived from Focus Group Discussions on the minimum and maximum amount local people could pay for voluntary contributions in local fund raisings (Harambees).

3.7.6 Estimating Biodiversity Value

The biodiversity value of East Mau forest ecosystem resources was estimated based on the likely discovery of forests plants with economic medicinal and pharmaceutical extracts (Pearce and Pearce, 2001; UNEP, 2011).There are few data from Kenya, which could assist in estimating these values, and therefore have used values from studies from similar forests in tropics with adjustments for purchasing power parity (Navrud and Brouwer, 2007; UNEP, 2011) using the benefit transfer formula below:

$$V_{EM} = BV_{Cx} * \left[\frac{PPP_{GNPKenya}}{PPP_{GNPCountry\ x}}\right]^{E} \quad \ldots\ldots 3.12$$

Where:

V_{EM} is the biodiversity value of East Mau

B is the biodiversity correction factor for the two sites

V_{cx} is the biodiversity value of study site in country x

PPP GNP is the purchasing power parity GNP per capita[10]

E is the elasticity of values with respect to real income, assumed E=1.00)

A study in a biodiversity rich country Costa Rica indicated that the potential pharmaceutical value would be of the order of US$ 10 to US$ 16 per hectare (Mendelsohn and Ballick, 1995). With the assumption that East Mau ecosystem is three times lower in biodiversity richness to the Amazonian rainforest, a value of US$ 5.50 was adapted for the benefit transfer. The value obtained in equation 3.12 was multiplied by the total hectares of indigenous forest of East Mau (Appendix 14).

[10]The PPP GNP values were obtained from World Bank report (World Bank, 2014).

3.8 Data Analysis

Data collected were cleaned and stored in MS Excel Spread sheet and analysed using the Statistical Package for the Social Science (SPSS) Program.

3.8.1 Computation of Household Income

The household incomes[11] were computed using Microsoft Excel (MS Office 2010) spreadsheet using formulae described below:

Household Annual Income = (Forest Income +Agriculture Income +Return to Wealth + Wage Income)

$$Y_{tinc} = \sum_{i=1}^{n}[s_i] \ldots\ldots\ldots 3.13$$

Where:

Y_{tinc} is the total household income; S_i is the income source *I,*

Forest Income = (Fuel wood annual income +Timber income + wild fruits income+ poles income + Thatching grass income etc.)

$$Y_f = \sum_{i=1}^{n}[F_iP_i - (K_i)] \ldots\ldots\ldots 3.14$$

Where:

Y_f is the total forest income, F_i is the quantity of product collected *I,* P_i is market price of forest product *I,* K_i is production costs of forest product *i*

Crop incomes; this was summation of value of yield from various crops grown by a household less all costs of production. Total crop income was calculated as:

$$Y_c = \sum_{i=1}^{n}[C_iP_i - (K_i)] \ldots\ldots\ldots 3.15$$

Where: Y_c is the total crop income, C_i is the yield of crop *I*,P_i is the market price of crop *I*, K_i is the production costs of crop *i*

[11]In all income calculations, cost of own labour was not taken into account because of substantial existing variations in labour prices depending on tasks and the possibility that multiple work at the same time can lead to under or over estimations of own labour costs (Campbell and Luckert, 2002). All total incomes reported are the sum of cash and subsistence annual household incomes.

Livestock income = (Cattle sale income + Goats income + Sheep income + Donkeys income + Chicken income) +income from livestock products i.e.

$Y_l = \sum_{i=1}^{n}[N_i P_i - (K_i)] + \sum_{i=1}^{n}[Q_i P_i - (K_i)]$...3.16

Where:

Y_l is the total livestock income, N_i is the number of livestock in category I, Q_i is the quantity of product from livestock I, P_i is the market price of livestock I, K_i is the cash costs of keeping livestock i, like pay for herder, costs of medicines, feeds.

Household Value of physical Asset = (Radio price + TV price + Bicycle price + Tractor price + Donkey cart price + Car price + Cell phone price + Fridge price +furniture price) i.e.

$$Y_{Va} = \sum_{i=1}^{n}[A_i] \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots 3.17$$

Where:

Y_{va} is the total household value of physical assets A_i is the current value of asset *I*,

Income from off-farm income /employment*:* this was the total value of earnings through hiring out of labour on other households' lands for agricultural or any other economic activity.

3.8.2 Computation of Total Economic Value of Forests

The total economic value of forests was computed using the model below:

$TEV = D_{uv} + I_{uv} + B_v + O_v$...3.18

Where: TEV = Total Economic Value; D_{uv} - Direct-Use Value; I_{uv} - Indirect-Use Value; B_v - Bequest/Existence Value and O_v - Option Value

Direct Use = Σ (Fuel wood income, timber income, charcoal income, wild fruits income, poles income, water, thatching grass income, fodder etc.). The total value of commodities/products was estimated using the 'own reported quantities' and the market price –the price of the good in question net of transaction costs i.e.

$T_v = Q_m(P_m - C_m) \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots$..............3.19

Where, T_v = total value of product, Q_m = quantity of goods extracted, P_m = the forest gate price of goods, C_m = transaction costs

Indirect Use Values = Σ (Soil nutrient conservation, soil erosion (protection), watershed protection (flow regulation, quality regulation), carbon sequestration, oxygen cycling, storage, cultural and spiritual values etc.).

Non Use Values = ∑ (Bequest value and Option value)

3.8.3 Analysis of Contingent Valuation Data

Frequency distributions for maximum WTP for each value or service were determined. The mean and the median of the sample were computed using the descriptive functions in SPSS (IBM version 20). The sample was assumed to be representative of the population and the distribution of the WTP values in the sample were assumed to be similar to that of the total population of residents adjacent to East Mau so that the expected sample mean and median are good estimates of the population mean and median. To obtain aggregate population WTP, the sample mean was multiplied by the population size (Hanley *et al*., 2007; Riera and Signorello, 2013). This is equivalent to horizontal summation of individual willingness to pay across individuals who constitute the total population adjacent to East Mau forest.

3.8.4 Statistical Tests

Socioeconomic data presents a challenge in a heterogeneous community where extreme income values from individual households are expected. The data was subjected to normality tests (Box-plot, histogram, Kolmogorov-Smirnov tests). All the identified outliers in the data set were deselected for the relevant variable to conform to normal distribution.

It was then that parametric tests (ANOVA) were applied (Chan, 2003). In most statistical tests $P \leq 0.05$ level of significance was used. Several tests on socioeconomic characteristics, χ^2test for association of location and sources of forest products, wealth and education level, ethnicity and education level, ethnicity and use value of forest for cultural purposes.

Comparison of means and ONE WAY ANOVA were used to test the difference on forest incomes, relative forest incomes across locations, ethnicity and wealth class and means separation undertaken using Tukey B tests.

3.8.5 Estimating the Opportunity Costs to Local Households

Opportunity cost of the conservation area is very important for management in identifying potential competitive threats. Land occupied by East Mau forest could be put under human settlement and agricultural and livestock production. Therefore, the net benefits foregone from the potential agricultural production was used to estimate opportunity cost of maintaining East Mau forest. In this thesis, potato farming was used to estimate the opportunity cost of conserving the forest. Primary data (production costs, yields and revenues) from household surveys were used to calculate net income from the potato farm enterprises. It was assumed that 50%of the total area is suitable for agricultural use and this was equivalent to 18,457.23 ha. The mean net total household income from agricultural sources (value of own produced agricultural goods consumed and sold) was applied in estimating the opportunity cost of forest conservation.

3.8.6 Operational Cost of Management of East Mau

The cost of management of East Mau forest blocks were obtained from records from Kenya Forest Service for staff costs, equipment cost, coordination costs, surveillance and field operations etc.

3.8.7 Net Benefit of Conservation

This is the total economic value of the forest less the cost of maintaining it. This includes the costs of managing the forest in a year and the opportunity cost (OC) of the forest in its present state as a conservation area. The net benefit of conservation was estimated using the expression below (Norton-Griffiths and Southey, 1995):

$$N_b = [(D_{uv} + ID_{uv} + N_{nov}) - (M_c + O_c)] \ldots\ldots 4.20$$

Where:

N_b- Net benefit of conservation; D_{uv}- direct use values; ID_{uv}-Net indirect use value; N_{nov}-Net non-use value; M_c- Total operational costs incurred by managing agency (KFS) in conservation of East Mau- Recurrent and operational costs per annum; O_c-Opportunity costs

3.8.8 Measuring Forest Dependence by Households

The forest dependence was measured using the relative forest income. Relative forest income (RFI) was computed as a share of Net forest income to total household income accounts derived from consumption and sale of forest environmental resources. This was derived as:

$$RFI = \frac{TFI}{TI} \quad \text{...} \quad 3.21$$

Where: *TI* is the total household income and *TFI* is total net forest environmental income.

To test the level of forest dependence of income groups, sampled households were categorized into 3 income groups based on their level of total households income in Kenya Shillings (Very poor < 156,000) (Moderate poor 156,001 ≤ 270,000) and (less poor, > 271,000). The categories were based on local conditions and do not reflect the general poverty levels in the study area and Kenya.

3.8.9 Estimating Determinants of Forest Dependency

Most recent studies on forest dependency have analysed forest dependency using regression models with total forest income of households as dependent variable (Fisher, 2004; Illukpitiyaand Yanagida,2008) or relative forest income like as proposed by (Vedeld *et al.,* 2004; Angelsen *et al*., 2014), and as relative cash income (Fisher, 2004). While total forest income shows the magnitude of forest utilization compared across households, forest dependency as an income ratio highlight the individual economic contribution of forest products/resources to overall household income and, thus, determine its relative importance among other income sources (Heubach, 2011). Relative forest income was thus adapted in this study to measure forest dependency as the share of income from forest products and services to total household income (relative forest income). Multiple regression analysis using ordinary least square (OLS) regression procedure in SPSS (IBM 20) was used to analyse relationship between relative forest income (dependent) and the independent variables and to test their statistical significance at 5%.

The multiple regression model of the form shown in equation 3.22 was used.

$Y=\beta_0 + \beta_1 X_1 + \beta_2^{X2} + \ldots\ldots\ldots\ldots\ldots \beta_n X_n + \ldots + \varepsilon$……………………………………………3.22

Y is the dependent variable (relative forest income); β_0 is a constant or y intercept; $\beta_{1 \ldots\ldots} \beta_n$ are the regression coefficients or change induced in Y by each X; $X_{1 \ldots\ldots} X_n$ are the independent variables, ε is the error term.

The following independent variables were tested in the model: Ethnicity, Age of household head, formal education of household head, off-farm income, farmland size, number of livestock units per household, distance to the forest (in minutes). The selection of these variables was based on the assumptions below:

Resident Status/Ethnicity is one of the key variables focused on in this analysis because some communities in the study area have had a long association with the forest (Ogiek) and it was hypothesized that there was difference in resource use patterns between indigenous people (Ogiek) and other ethnic groups due to primary traditional source of livelihood (the emigrant group are mainly farmers and the indigenous group is honey gatherer/pastoralists group), It was expected that ethnicity would have an influence also on forest dependency.

Age of Household Head: Higher age household head is assumed to be more knowledgeable about the forest and plants and have the necessary skills to extract a diversity of forest products; conversely age can be a negative aspect to forest use because old people may not have the energy to engage in high value extractive activities like timber. Thus, it is expected that greater age would have a mixed effect on forest income (Vedeld *et al*., 2007).

Education Level of Household Head: Education is a can help create access to a greater diversity of income opportunities (Adhikari *et al.,* 2004; Fisher 2004). It is hypothesized, that the higher formal education, the lower forest dependency.

Off-farm Income: When occupied with profitable off-farm income activities, forest extraction activities will be expectedly low (Adhikari *et al*., 2004; Fisher, 2004).

Farmland Size: Farmland size is determining the extent of crop production. If land size and, thus, crop production is rising, forest extraction activities are likely to decrease (Fisher, 2004; Vedeld *et al*., 2007).

Number of Cattle: Since fodder forms a major part of forest income, the latter should be positively related to the number of livestock units.

The gender and resident status of the household head were taken as dummy variables in the model. The variables are defined in Table 3.7 below:

Table 3.7: Definition of terms used in the forest dependence regression model

Variable	Definition
1.% For -income	% Forest income to total household income
2.AgeHH	Age of household head (years)
3.Edl	Educational level of household head(Primary=1,Secondary=2, Post-secondary=3)
4.Sizeland	Size of land owned by household (acres)
5.No.cat	Number of cattle owned by household(N)
6.Farminc	Income from farming(agricultural) KES)
7.TLivinc	Income from livestock(KES)
8.off-farminc	Off-farm income(KES)
9.Distfore	Distance from forest (Walking minutes)
10.Gender	Gender of head of Household(Female=0, Male=1)
11.Residentstatus	Ethnicity of household head(Indigenous=0, Non-indigenous=1)

3.8.10 Multiple Regression Model of Forest Dependency

Multiple regression analysis was done to test the relationship between the dependent variable (% forest income) and the socioeconomic variables. Before the regression analysis was carried out, it was necessary to ascertain that the four principles assumptions namely: absence of outliers, linearity, independence of errors, homoscedasticity and normality of error of distribution) are satisfied to ensure that the model is parsimonious. Severe multi-collinearity compromises both the statistical solutions obtained and the scientific soundness of the results (Denis, 2011). Checking for outliers was done by estimating Cook's distance. The Cook's distance that is greater than one signals an outlier problem (Denis, 2011). The results showed that all cases were acceptable.

A sound model should not have a multi-collinearity problem i.e. the model should not have inter-correlation of independent variables. This is because when there is a high multi-collinearity, then the B and beta coefficient (β) will not be stable. The tolerance and VIF were used to test multi-collinearity. The tolerance and VIF should be less than one and ten respectively (Cohen *et al*., 2003). The variables with multi-collinearity problems were removed from the model. The normal Q-Q plot of the standardized residual for the full regression were produced for the model and indicated that the residual errors are normally distributed in the population for each independent variable. For sound regression model, the residual errors should be randomly dispersed throughout the range of estimated dependent variable (Cohen *et al*., 2003). The Multiple regression analysis was undertaken using linear model of SPSS with the 'Enter procedure.

CHAPTER FOUR

4.0 RESULTS

4.1 Introduction

This chapter describes the results based on the objectives and research questions posed in chapter one. The results presented are the socioeconomic characterization of the sampled population, direct forest use values by the local community and other stakeholders, indirect use and non-use values and the estimation costs of conservation and the Total Economic Value (TEV), forest dependence and determinants.

4.2 Socioeconomic and Demographic Characteristics of Households

The overall average household was composed of nine members (8.8±3.2) with an adult equivalent of (4.8±1.9). The gender distribution of household heads showed that 62.6% (n= 243) were males while 37.4% (n=145) were females. The mean age of household head was significantly different ($P<0.001$) for female (53.35±1.9) and male-headed households (47.56±1.2). The majority of the respondents in the Kapsimbeiywo and Silibwet location are immigrants (100%) while in Nessuit there was an equal presence of indigenous (Ogiek-50%) and non-indigenous people (Kipsigis, Kikuyus, Kisiis etc (50%). In Mariashoni, the majority of households were of Ogiek tribe (65%) while the rest (35%) were non-indigenous. In Kapkembu, the area is inhabited mostly by non-indigenous group of Kipsigis (92.5%) and a small proportion of Ogiek at 7.5% (Table 4.1).

Overall, the majority of households were not born in the current place of residence (64.8%) and only about one third (35.2%) were born in the current locations. Mariashoni had the highest number of indigenous residents (65.8%) followed by Nessuit (50%). The rest of the locations were dominated by households whose heads were not born in the current location (Table 4.1.). Results on the highest educational level attained by heads of households revealed that, 73.4% have at least primary level of education, while 20% have attained secondary level of education and only 6.9% have completed post- secondary education with the lowest with 2.4 % and 4.9% in Nessuit and Mariashoni respectively (Table 4.1).

Table 4.1: Socioeconomic and demographic characteristics of sampled households (N=367)

Variable	Location					Sig(LSD)
	Kapsimbeywo	Silibwet	Kapkembu	Nessuit	Mariashoni	
Gender(HH)%						
Male	73.3	85.4	67.2	72.0	60.5	NS
Female	27.7	14.6	32.8	28.0	37.4	NS
Ethnicity (%)						
Indigenous	0.0	0.0	7.5	50.0	65.0	0.05*
Non-indigenous	100.0	100.0	92.5	50.0	35.0	0.05*
Education level (%)						
Primary	66.7	60.4	62.7	87.9	89.3	0.05*
Secondary	33.3	27.1	22.4	9.7	5.8	NS
Post-secondary	0.0	12.5	14.9	2.4	4.9	NS
Household size						
Number	9.0 ±2.4	10.1 ±3.1	9.8 ±2.6	8.9 ±3.0	7.3 ±3.6	0.472NS
Adult equivalent	4.9 ±1.4	6.0 ±1.8	5.7 ±1.5	5.1 ±1.9	3.3 ±1.6	NS
Land size and use						
Land size(Ha)	2.5 ±1.2	2.1 ±0.8	2.1 ±0.9	1.7 ±1.4	1.9 ±1.5	0.472NS
Natural forest	0.4 ±0.3	0.4 ±0.2	0.4 ±0.2	0.3 ±0.2	0.4 ±0.3	0.00*
Planted forest	0.4 ±0.2	0.3 ±0.1	0.3 ±0.1	0.3 ±0.3	0.4 ±0.2	0.406NS
Food crops	0.8 ±0.4	0.7 ±0.3	0.7 ±0.3	0.8 ±0.7	0.8 ±0.5	0.204NS
Cash crop	0.5 ±0.2	0.4 ±0.3	0.4 ±0.2	0.3 ±0.2	0.6 ±0.7	0.017*
Pasture land	0.6 ±0.6	0.3 ±0.1	0.3 ±0.2	0.6 ±0.6	0.8 ±0.7	0.00*
Wastelands	0.4 ±0.3	0.3 ±0.1	0.3 ±0.2	0.3 ±0.2	0.4 ±0.2	0.129NS
Resident years	24.8 ±2.0	23.0 ±1.8	13.6 ±5.4	14.8 ±2.7	16.2 ±4.5	NS
Food months	3.6 ±0.4	4.7 ±0.3	4.4±0.3	4.3 ±0.2	4.0±0.2	NS
Age of HH(yrs)	44.8 ±2.0	48.5 ±1.9	40.3 ±1.6	42.3 ±1.4	42.4±0.7	0.05*

* Means were significantly different at $p \leq 0.05$; NS-Not significantly different at $p \leq 0.05$

4.2.1 Land Ownership among households

All households interviewed owned land and the total land size, land under crops and pastures were significantly different. However, the land size under forests (planted and natural), food crops and wastelands were not significantly different (Table 4.1). Most households in the study area allocate their land use to crops (both cash and food). Between 52% and 74% of the land holding is allocated to agricultural crops and less than 21% (14.2% to 21%) were devoted to planted and natural forests (Table 4.1). The ownership of another piece of land differ from location to location with highest number of households indicating alternative ownership of land being highest in Kapsimbeiywo (73.3%) and least in Nessuit (4.0%).

4.2.2 Livestock Ownership among Households

The survey found out that livestock keeping is one the main activity undertaken by households. The most common livestock kept by households in East Mau are: cattle, goats, donkeys, hens. The average number of cattle, sheep, goats, donkeys, hens is 5.0, 4.0, 2.0, 1.0 and 7 per household respectively. The mean TLU per household is 4.65 units (Table 4.2).

Table 4.2: Livestock owned by households in East Mau

	Statistic			N
Animal type	Mean	SE	SD	367.00
Cattle	5.32	0.18	3.58	367.00
Sheep	4.44	0.24	4.70	367.00
Goats	1.98	0.14	2.66	367.00
Donkeys	0.86	0.05	0.91	367.00
Hens	7.12	0.33	6.47	345.00
TLUs	4.65	0.13	2.54	367.00

(SE- Standard error of mean, SD- Standard deviation and N- Number of cases)

The total livestock units was significantly different among income group ($F_{(2,367)} = 8.06$; $p<0.05$).

Separation of means by Tukey B test indicated that very poor households (Mean =3.85, SD = 2.78) were significantly different from moderately poor households (Mean = 5.23, SD = 2.41) and less poor households (Mean = 4.76, SD = 2.54) in livestock holdings. Tropical livestock units per household differed significantly across locations ($F_{(4,367)}$ =11.86; p<0.05). Separation of means by Tukey-B test showed that TLU for households in Nessuit (Mean =3.49, SD = 2.81) and Kapsimbeiywo (Mean = 6.33, SD=2.60) were significantly different. The households were significantly different from the other locations in livestock holdings (TLU). However, households in 3 locations of Sililbwet (Mean=4.99 SD=1.84, Kapkembu (Mean=5.02. SD=1.71) and Marioshion (Mean=5.10, SD=2.46) were not significantly different in livestock units. In addition, livestock holding (TLU) was not significantly different between indigenous and non-indigenous groups ($F_{(1,367)}$ =0.410, P> 0.05).

4.3 Livelihood Activities of Households

Most of the households (90.5%) interviewed are farmers (n=344) relying mostly on rain-fed agriculture and livestock keeping. Farming and livestock keeping was the primary occupation of the local people while business, formal employment and sale of forest products and other activities were secondary activities. Total household income was significantly different across locations ($F_{(4,367)}$ = 5.10; $p<$ 0.001) and between indigenous and non-indigenous groups ($F_{(1,367)}$ = 7.82; $p<$ 0.05). Total household income in 3 locations of Kapsimbeiywo, Nessuit and Kapkembu were not significantly different. However, total household income was significantly between from Silibwet, Mariashoni and Kapkembu (Table 4.3). Household's agricultural income was significantly different across locations ($F_{(4,382)}$ = 2.55; $p<$ 0.05). The Tukey B test separation of means showed that Kapsimbeiywo households' agricultural income was significantly different the households in other locations. Agricultural household income in Silibwet, Kapkembu, Nessuit and Mariashoni were not significantly different. In addition, income from forest product sales were not significantly different across locations ($F_{(4, 72)}$ =1.23; p>0.05) and between indigenous and non-indigenous groups ($F_{(1, 75)}$ = 1.62; $p>$ 0.05) (Table 4.3).

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Table 4.3: Household cash incomes by location in East Mau

Site	Household income	Agriculture	Livestock	Forest products	Off farm income
1	170075.85±19237.75(26)[a]	48965.52±7841.79(29)[a]	60644.82±7599.54(29)[ab]	18666.67±15666.67(3)[a]	127789.65±15021.36(29)[a]
2	259363.80±21404.55(44)[bc]	56545.45±7899.30(44)[ab]	86521.67±8955.22(48)[c]	7937.50±2161.15(16)[a]	141563.11±12708.57(45)[a]
3	203385.34±9506.64(67)[ab]	65530.30±5140.098(66)[ab]	62231.34±4571.41(67)[ab]	5100.00±1805.55(5)[a]	130873.13±6702.83(67)[a]
4	212286.69±10677.74(123)[ab]	73305.08±4626.89(118)[ab]	37007.90±3642.59(124)[a]	25982.14±8182.06(28)[a]	119698.18±7509.90(121)[a]
5	247952.86±9448.39(117)[bc]	58817.39±4161.96(115)[ab]	51899.66±4710.23(118)[ab]	19720.00±3335.93(25)[a]	114714.56±6988.97(114)[a]
Total	224356.88±5741.35(377)	63567.20±2446.98(372)	53871.45±2490.55(386)	18558.44±3313.08(77)	123419.36±3931.34(376)
	$F_{(4,372)} = 6.02$; $p < 0.001$	$F_{(4,382)} = 2.55$; $p < 0.05$;	$F_{(4,381)} = 10.67$; $p < 0.001$;	$F_{(4,72)} = 1.23$; $p > 0.05$	$F_{(4,371)} = 1.27$; $p > 0.05$

Notes: Kapsimbeiywo -1, Silibwet- 2, Kapkembu- 3, Nessuit- 4, Marioshoni- 5)

Means (column) with a different superscript imply the means are significantly different at $P \leq 0.05$ level

4.4 Direct Use Values to Local Community and Other Stakeholders

4.4.1 Sources of Forest Products

All interviewed households collect and use different provisioning forest ecosystem services to meet various household needs. Overall, 45.5% households obtained various foods from the East Mau forest ecosystem. Most households collect firewood and charcoal from the public forest compared to the other sources (own farm, neighbors, markets) (72.9% and 67.3% respectively) and this was observed similarly for all products (Table 4.4). The products collected by most households were: firewood, herbal medicine, poles and honey respectively in the study locations (Fig.4.1). About fifty percent of the households use the public forest as a source of medicine. In the study area, 57.0%, 35.7% and 54.8% of households used forest as a source of construction materials (timber, poles and fibers respectively).Households collect foods products such as indigenous fruits (34.0%), mushrooms (49.3%), game meat (47.1%) and honey (51.6%) and low number of households reportedly obtain them from other sources (own farms, neighbors and markets) (Table 4.4).

Table 4.4: Reported sources of products by of households (N=367)

Products	Sources (% of households)			
	Public forest	Own farm	Neighbours	Market
Firewood	72.9	21.6	3.4	2.1
Timber	57.0	16.6	6.2	19.2
Charcoal	67.3	8.2	7.6	16.9
Honey	51.6	13.9	9.7	24.9
Medicine	49.9	18.7	5.0	26.4
Poles	35.7	21.7	14.0	28.6
Thatch Grass	30.6	35.0	6.2	28.2
Fruits	34.0	22.3	9.8	34.0
Animal Fodder	66.8	31.3	1.8	0.3
Agricultural Tools	42.8	18.9	1.3	37.0
Forest soils	45.1	21.8	7.3	25.7
Building Stones	41.2	20.0	9.2	29.2
Mushrooms	49.3	14.4	8.1	28.1
Fibres	54.8	19.3	10.6	15.3
Meat	47.1	3.7	2.3	26.8

Most households in the study area collect firewood (90.3%); herbal medicine (83.3%), poles (34.8%), honey (27.4%) with the least collected product was building stones (5.7%) (Fig.4.1).

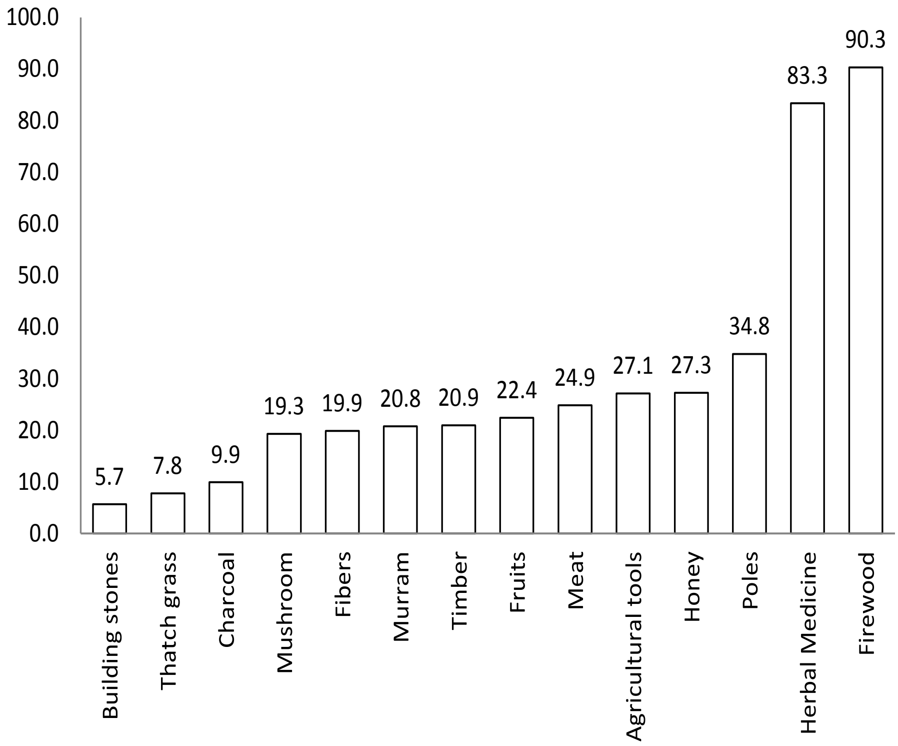

Fig.4.1: Households (%) collecting forest products from East Mau forest, Kenya

4.4.2 Quantities and Value of Provisioning Products

The extent of use and monetary value of various products is depicted in Table 4.5. Firewood is the most collected product by households and each collect an average of 122 back-loads (4,100 kg) of firewood per year worth about KES 25,000 (US$ 280) accounting for 5.7% of forest income (Table 4.6). Another popular product collected by households was herbal medicine (83.3%) with an average of about 50kg per year. However, in terms of monetary value per household charcoal, honey and poles scored high. The values of these products were KES 144,156, 69,424 and 32,959 respectively (Table 4.5). Households that graze their livestock in public forest ranged from 57.1% (Kapsimbeiywo) to the highest of 77.9% of households in Mariashoni. Overall, 66.8% of the households reported using the forest as a source of fodder for their livestock. The monetary value of this use ranged from KES 11,983 (US$ 133.10) to 17,974(US$ 199.70) per household /year (Appendix 6).

Wood fuel (firewood and charcoal) is the dominant source of forest income with a mean of 49.1% of forest income per household and this was followed by food products (26.5%) and structural and fibre products (17.4%) (Table 4.6). Charcoal is not the most collected product (9.9%) by households yet its contribution is significant contributing to 43.4% to household forest income due its high monetary value. Other forest products which are significant to forest income are poles and honey each contributing 13.0% and 12.4% respectively. The absolute and forest relative incomes ranged from KES 47,662 (US$ 530) to 71,642 (US$ 740) and 28.8 % to 36.5% respectively. The mean absolute and relative forest income was KES 62,906 (US$ 699) and 32.5% respectively (Table 4.6).

Table 4.5: Quantities and monetary values of forest products per households per year

Product	Unit	Quantities	Value $HH^{-1}Yr^{-1}$(KES)
Firewood	Kg	4,070.45±167.67	25,447.47±1,104.60
Herbal Medicine	Kg	48.78±2.69	7,677.09±1,781.22
Poles	Number.	343.22±17.62	32,959.22±1,855.49
Honey	Kg	102.39±16.95	69,424.33±5,301.33
Agricultural tools	Number	104.73±17.50	1,053.82±174.60
Meat	Kg	125.24±12.84	12,919.20±1,502.18
Fruits	Kg	256.68±23.44	9,573.34±552.13
Timber	Running feet	171.38±18.46	18,292.06±1,963.06
Murram	Tons	120.22±38.21	102.18±32.48
Fibers	Kg	251.77±38.98	4,227.20±383.12
Mushroom	Kg	257.92±45.98	3,021.28±467.80
Charcoal	Bag	128.73±31.52	144,156.77±22,375.53
Thatch grass	Kg	179.08±27.80	4,530.72±142.99
Building stones	Running feet	34.50±4.20	1,000.00±56.05

Values are arranged as means, followed by SEM (Standard Error of Means))

Table 4.6: Main products providing forest income (Percent of income category)

Product	Location					
	Kapsimbeiywo	Silibwet	Kapkembu	Nessuit	Mariashoni	Mean
Fuel	**17.2**	**59.8**	**50.3**	**51.4**	**66.9**	**49.1**
Firewood	10.8	3.9	5.1	4.4	4.1	5.7
Charcoal	6.4	55.9	45.1	47	62.9	43.4
Food	**26.6**	**28.3**	**28.7**	**29**	**19.7**	**26.5**
Fruits	1	3.1	2.8	1.9	1.9	2.1
Honey	9.4	15.5	13.4	13.9	10	12.4
Mushroom	14.1	7.6	10	8.4	5.5	9.1
Meat	2	2	2.6	4.8	2.3	2.7
Structural and fibre	**46**	**7.1**	**14.4**	**11.8**	**7.4**	**17.4**
Timber	6.4	2.7	5.4	4	2.1	4.1
Poles	39.4	4.3	8.5	7.6	5	13
Agricultural tools	0.2	0.1	0.6	0.3	0.2	0.3
Grass	**7.6**	**3.8**	**4.6**	**5.1**	**4.6**	**5.1**
Thatch grass	1.1	1.1	0.8	2	2.8	1.6
Fodder	6.5	2.7	3.7	3.1	1.8	3.6
Herbal Medicine	2.6	0.9	2	2.6	1.2	1.9
Others	**0**	**0.1**	**0**	**0**	**0.2**	**0.1**
Total	**100**	**100**	**100**	**100**	**100**	**100**
% of household income	28.8	30.7	32.9	36.5	33.4	32.5
Absolute value (KES)	47,662	63,427	65,218	66,580	71,642	62,906
Absolute value (US$)	530	705	725	740	796	699

4.4.3 Medicinal and Cultural Values

Eighty three percent of households in East Mau are involved in collection of herbal medicine for own consumption. The results from the Contingent Valuation surveys revealed that most respondents were willing to pay between KES 100 and 1,000 per annum to secure the continued availability of herbal medicine from East Mau. The frequency distribution, mean and median of the WTP values are shown in tables 4.7 and 4.8. The majority (95.1%) of respondents were willing pay between KES 100 and 1000. Less than 5% of respondents were willing to pay more than KES 1,000 (Table 4.7). The overall mean willingness to pay for medicinal use was 586±22.71 and median WTP KES 500 (Table 4.8).

WTP for medicinal use was significantly different across locations. Separation of mean using Tukey B test showed that WTP of Mariashoni households were significantly different from the other locations ($F_{(4,356)} = 4.49$; $p < 0.05$; 0.01). However, the mean willingness to pay in the other four locations was significantly different (Table 4.7).

The local communities in East Mau value the forest for cultural purposes; overall, 71.2% of the sampled households use the forest for cultural purpose and more of this usage is pronounced in Nessuit, Kapkembu , Nessuit and Marioshion with 90% using East Mau forest at least once a year. Contingent valuation surveys revealed that most respondents were willing to pay between KES 100 and 1,000 per annum to secure the continued use of East Mau for cultural purposes. The frequency distribution, mean and median of the WTP values are shown in Tables (4.7 and 4.8). The majority (88%) of respondents was willing pay between KES 100 and 1,000 and less than 12% were willing to pay more than KES 1,000 (Table 4.7). The overall mean willingness to pay for cultural use was 549.44±23.84.71 and median WTP was KES 500 (Table 4.8). Similarly WTP for cultural use WTP was significantly different across locations ($F_{(4,353)} = 7.49$; $p < 0.01$). Separation of mean using Tukey B test showed that WTP of Mariashoni households were significantly different from other locations ($F_{(4,353)} = 7.49$; $p < 0.05$). However, the mean WTP in the other four locations were not significantly different (Table 4.8). WTP across income group were not significantly different (Very poor –mean =583.00, SD=383.24, moderate poor- mean =518.37, SD= 383.24 and less poor –mean=628.83, SD=481.09) ($F_{(2,358)} = 2.02$; $p > 0.05$). Similarly, WTP between ethnic groups were not significantly different (indigenous (mean=631.15, SD= 536.30 and non-indigenous (mean=, 561.34, SD=365.52) ($F_{(1,358)} = 2.12$; $p > 0.05$) (Table 4.9).

Table 4.7: Frequency distribution of WTP for medicinal use and cultural values

WTP medicinal use			WTP cultural use		
Bid Amount	Number of bids	Frequency %	Bid Amount	Number of bids	Frequency %
100	106	29.3	100	127	33.2
500	134	37	500	125	32.6
1,000	104	28.7	1,000	85	22.2
1,500	11	3	1,500	14	3.7
2,000	7	1.9	2,000	8	2.1
	362	100	3,000	5	1.3
			4,000	2	0.5
			5,000	14	3.7
			6,000	1	0.3
			10,000	1	0.3
				362	100

Table 4.8: WTP for conservation for medicinal and cultural use (KES $HH^{-1}year^{-1}$)

	Medicinal use		**Cultural use**	
Location	**Mean**	**Median**	**Mean**	**Median**
Kapkembu	514.90±51.70 [a]	500	535.80±53.15 [a]	500.00
Kapsimbeiywo	590.00±77.20 [a]	500	533.30±79.43 [a]	500.00
Marioshoni	740.90±43.90 [ab]	500	745.20±45.12 [b]	500.00
Nessuit	543.50±38.00 [a]	500	418.20±39.55 [a]	500.00
Silibwet	491.70±61.00 [a]	500	529.20±62.80 [a]	500.00
Overall	586.15±22.71	500	549.44±23.84	500.00
$F_{(4,356)} = 4.49$; $p< 0.01$;			$F_{(4,353)} = 7.49$; P< 0.01;	

Means test (in column) with a common superscript means that the averages are not significantly different at P ≤ 0.01

The WTP for cultural use were not significantly different among income groups (Very poor –mean =480.39; SD=383.58), moderate poor- mean =577.78, SD= 454.80) and less poor –mean=576.43, SD=486.24) ($F_{(2,355)} = 1.67$; $p > 0.05$). However, WTP for indigenous households (mean=638.02, SD = 580.69) was significantly different from non-indigenous groups (mean= 500.00, SD =356.10) ($F_{(1,355)} = 7.70$; $p<0.01$) (Table 4.9).

The total cultural and spiritual value of East Mau forest based on this method is KES 17, 014,182.00 (US$ 189,046.50) (549[12]*0.712[13]*43,527[14]). This was equivalent to KES 539.10 (US$ 6.0) $ha^{-1}yr^{-1}$.

Table 4.9: WTP for conservation for medicinal and cultural use by income group and ethnicity (KES $HH^{-1}year^{-1}$)

Socioeconomic factor		Medicinal use	Cultural use
		Mean WTP	Mean WTP
Income group	Very poor	583.00 [a]	480.39 [a]
	Moderate poor	518.37 [a]	577.78 [a]
	Less poor	628.83 [a]	576.43 [a]
($F_{(2,358)}$ = 2.02; p >0.05)		($F_{(2,355)}$ = 1.67; p > 0.05)	
Ethnicity	Indigenous	631.15[a]	638.02[b]
	Non-indigenous	561.34 [a]	500.00[c]
($F_{(1,358)}$ = 2.12; p >0.05)		($F_{(1,355)}$ = 7.70; p >0.01)	

Means test (in column) with a common superscript means the averages are not significantly different at P≤ 0.05

4.4.4 Water Provision for Domestic and Livestock Consumption

All respondents (100%) obtained water on daily basis for their domestic use from river /streams emanating from East Mau forest. Most of the water in the household was fetched by women and children (99.2%), house help (0.3%) and least by husbands (0.3%). The mean water usage for domestic uses was 87.80 litres per household day^{-1}. Each water collector takes on average of 40 minutes per return trip walking to a water source. Most respondents (82.9%) rate the water from the forest as drinkable without treatment and only 18.1% consider the water to be fair or of poor quality and therefore requires minimal treatment for human use.

[12]Mean WTP
[13] Proportion of households using forest for cultural and spiritual purposes
[14]Total number of forest adjacent households (KNBS, 2010)

Therefore 43,527[15] households all put together utilize 3,821,670.60 litres (~3,822m^3) of water per day. Total annual consumption was 951,328,462.46 litres (~951,329m^3) with an estimated value of KES (64, 045,325.76 yr^{-1}) - equivalent to US$ 711,614.73) yr^{-1}(Table 4.10). The mean value of water provision is KES 1,471.39 $HH^{-1}year^{-1}$-(US$ 16.3 $HH^{-1}year^{-1}$).

Table 4.10: Water demand for human use and livestock and its monetary value (KES)

A. Water for human use	
Mean yield of local boreholes m^3hr^{-1}	11.51[16]
Maximum allowable borehole licensed hours	10.00[17]
Expected total extraction per day (litres/day)	115,100.00
Daily water demand (litresHH^{-1})	87.80[18]
Number of household neighboring Mau	43,527.00
Proportion of households sourcing from forest	0.68
Potential extractable volumeyr^{-1} from boreholes	42,011,500.00
Total households water demand liters/day	3,821,670.60
Annual total households demand of water	1,394,909,769.00
Annual demand of water from forest	951,328,462.46
Number of borehole equivalent	22.64
B. Water for domestic animals	
Daily water intake for TLU equivalent	22.50[19]
Average TLU/HH in East Mau	4.90
Total Tropical Livestock Units in East Mau	213,282.30
Daily Water demand for domestic animals $HH^{-1}day^{-1}$	4,798,851.75
Annual demand[20]	1,226,106,622.13
Borehole equivalents	29.19
Total borehole Equivalent (Human and Livestock)	51.83
Cost/unit borehole	1,235,692.50[21]
Total replacement cost/year	64,045,325.76
Value$HH^{-1}yr^{-1}$	1,471.39

[15]The total number of households adjacent to East Mau forest (KNBS, 2010)
[16] Borehole water yield from boreholes adjacent and within Nakuru county (Bosuben, 2014 Appendix 8)
[17]Allowable extraction by regulatory authority -WRMA(Pers.com-Munywoki-Hydro-geologist WRMA, Nakuru)
[18]Average household consumption based on household survey
[19]Mean daily water need of one TLU (Penden *et al.*, n.d)
[20] Assumption: 70% water for livestock is from forest
[21] Average cost of drilling, commissioning and maintenance of borehole (Pers.com-Munywoki-Hydro-geologist WRMA, Nakuru)

4.5 Economic Value Derived by Other Stakeholders

4.5.1 Small scale Forest Based Businesses in East Mau

Most of the small scale traders are engaged in charcoal business (38%), poles (26%), firewood (22%), and bamboo (7%) (Fig.4.2). All of small scale except charcoal traders reported sourcing their merchandize from public forest (East Mau). About sixty five per cent of charcoal traders source their merchandize from East Mau forest, twenty seven per cent from private farms and less than 10% (7.7%) obtain charcoal from intermediaries.

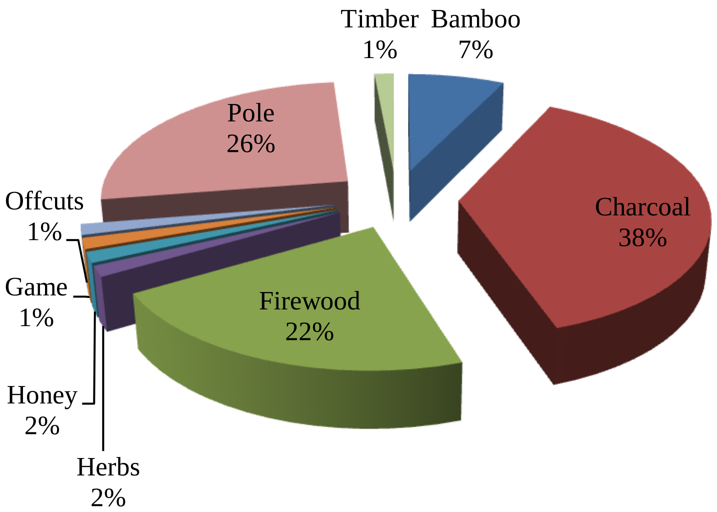

Fig. 4.2: Small scale forest product traders in East Mau forest environs (N=69)

The overall mean net income per annum is about KES 170,000 per trader. It is estimated that there are about 300 small scale forest traders scattered around East Mau (KFS pers. com.). Based on this estimation, the aggregate value of this trade was about 51million per annum. If we assume a value added of 20% in the forest sector, the economic value of this trade was about 11.2million per annum.

4.5.2 Economic Value Derived by Small scale Sawmills from East Mau

From the analysis, small scale saw-millers make a net income of about KES 1, 189,907 per annum.

There are about 30 active small-scale sawmills depending directly on East Mau and this gives aggregate net value of KES 35,697,210. If it is assumed value added of 20% in the forestry sector, the economic value of this primary processing subsector is about 7.1million per annum.

4.5.3 Economic Value Derived by Large scale Sawmills from East Mau

It was difficult to get their operational data for the large scale saw millers, and therefore relied on the total royalty values from KFS records to estimate the economic value derived by these players. The average royalties collected by KFS from sale of logs from East Mau stations for the three years (2011 to 2014) were obtained from KFS offices –Elburgon. The average royalties was KES 127, 578,124.45 per annum. Assuming that value added is 20% in the forestry sector, the economic value of this primary processing subsector is about 25million per annum.

4.5.4 Direct Benefits by Kenya Forest Service from East Mau

Kenya Forest Service, the primary agency involved in management of East Mau forest collects revenues through levies and royalties. The total value of this collection was about 130million per annum (Table 4.11).

Table 4.11: Revenue from KFS operations in East Mau

Item	Value per annum(KES)
Monthly fuel wood license	771,530.00
Fuel wood	240,090.50
Grazing license	33,620.00
Poles	76, 900.00
Royalties	127,578,124.45
Grass	2,040.00
Withies	5,450.00
Total Revenue	128,707,754.95

4.6 Total Direct Use Values by Households and Other Stakeholders

4.6.1 Direct Use Values Derived by Forest Adjacent Households

The total direct use value derived by local communities is about KES 4billion/year (Table 4.12).

Table 4.12: Total direct use values derived by forest adjacent households (KES)

Product / service	Mean value HH^{-1}/yr^{-1}	% Households	Total value (KES)
Murram/soils	102.18	20.80	925,098.48
Building stones	1,000.00	5.70	2,481,039.00
Agricultural tools	1,053.82	27.10	12,430,667.87
Cultural value	549.44	72.1	17,014,182.00
Herbal medicine	586.15	83.30	21,252,621.42
Mushroom	3,021.28	19.30	25,380,900.13
Fibers	4,227.20	19.90	36,615,469.55
Water	1,471.39	100.00	64,045,192.53
Thatch grass	20,267.69	7.80	68,810,955.93
Fruits	9,573.34	22.40	93,340,524.52
Meat	12,919.20	24.90	140,021,170.58
Timber	18,292.06	20.90	166,405,485.58
Grazing	14,978.50	66.70	434,863,436.06
Poles	32,959.22	34.80	499,246,357.19
Charcoal	144,156.77	9.90	621,196,461.05
Honey	69,424.33	27.30	824,960,357.65
Firewood	25,447.47	90.30	1,000,209,780.10
Total			**4,029,199,700.00**

The largest proportion of the aggregate value is due to fuel (50%), food (27%), construction material (18%) and grass products (fodder and thatch) (Fig.4.3). These translate to (US$) 509.0, 274.9, 186.2 and 53.4 per household per year respectively.

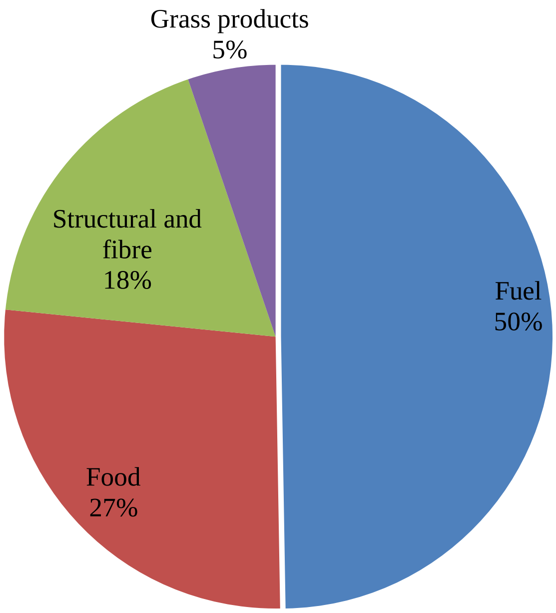

Fig.4.3: Proportion (%) of use values by category

4.6.2 Economic Value of Forest Product Processing and Trade

The economic value derived by small scale forest product trader, small and large sawmills through added value is about KES 43.3million (US$ 477,000) per annum.

4.7 Indirect Use Values of East Mau Forest

4.7.1 Soil Conservation Functions

East Mau contributes to soil nutrient cycling and soil protection (soil erosion prevention). These values were estimated using replacement and avoided cost approach for nutrient cycling and soil protection respectively (Appendices 12, 13). The average value of East Mau for soil nutrient cycling was about KES 1,378.15 (US$ 13.30 $ha^{-1}yr^{-1}$). The total value for East Mau was KES 44,100,832.44 (US$ 490,009.20). The soil protection value was about KES 14,996,853.96 (US$ 166, 631.70) based on cost avoided in de-silting of dams equivalent to about KES 405 (US$ 4.5) $ha^{-1}yr^{-1}$.

4.7.2 Contribution of East Mau to Climate Regulation

The potential value of East Mau for carbon sequestration is KES 11billion (US$ 122,119,854.40) (Table 4.13).

4.7.3 Value of Oxygen Generation from East Mau forest

Oxygen generation value was estimated based on carbon sequestration capacity of the forest through photosynthetic process (Xue and Tisdalle, 2001; Xi, 2009). The value of oxygen generation from East Mau was about KES 4.5billion (US$ 50,395,269.35) per annum (Table 4.14).

Table 4.13: Carbon sequestration value in East Mau

Vegetation type	Area(ha)	Above Ground Biomass (tons/ha)	Carbon stock tons/ha[22]	CO_2 sequestration tons/ha	Value	
					(KES)	(US$)
Indigenous Intact forest	13,586.48	265.90	132.95	491.92	6,857,161,535.24	76,190,683.72
Disturbed indigenous forest	18,132.75	71.56	35.78	132.39	2,462,935,819.78	27,365,953.55
Bamboo/grassland	3,886.48	137.99	69.00	255.28	1,017,942,251.67	11,310,469.46
Cypress plantation	1,056.00	267.20	133.60	494.32	535,573,969.92	5,950,821.89
Pine plantation	254.25	242.80	121.40	449.18	117,173,319.39	1,301,925.77
Total					**10,990,786,896.00**	**122,119,854.40**

[22] The carbon stock is 50% the value of Above ground biomass (IPCC , 2003)

Table 4.14: Oxygen generation values in East Mau

Vegetation type	Area (ha)	Carbon stock tons/ha	CO_2 sequestration tons/ha	O_2 generated tons/ha[23]	Value[24]	
					(KES)	(US$)
Indigenous Intact forest	13,586.48	132.95	491.92	359.10	2,829,748,727.12	31,441,652.52
Disturbed indigenous forest	18,132.75	35.78	132.39	96.64	1,016,381,117.05	11,293,123.52
Bamboo/grassland	3,886.48	69.00	255.28	186.36	420,074,804.44	4,667,497.83
Cypress plantation	1,056.00	133.60	494.32	360.85	221,015,612.93	2,455,729.03
Pine plantation	254.25	121.40	449.18	327.90	48,353,979.95	537,266.44
Total					**4,535,574,241.49**	**50,395,269.35**

[23]This is based on photosynthetic equation where 1 ton of CO_2 absorbed will release 0.73 ton O_2.
[24]Estimate based on the price of one ton of industrial oxygen (KES 580)

4.7.4 Water Flow and Quality Regulation Functions

The water flow regulation function of East Mau was estimated based on water storage method (Xue and Tisdalle, 2001; Xi, 2009). The total value of this service was found to be about KES 405, 667,002.27 (US$ 45,074,122.25) or equivalent to KES 127, 893.11 (US$ 1,421.03) $ha^{-1}yr^{-1}$. The value of the forest for water purification is about KES 43million (for all household and translates to about KES 1,000 (US$ 11.0) per household per year or US$ 12.83ha^{-1} (Table 4.15).

Table4.15: Potential water purification value of East Mau forest ecosystem

Daily water demand (litres/household)	87.80
Number of households neighboring Mau	43,527.00
Proportion of households sourcing from forest	0.68
Total water demand liters/day	3,821,670.60
Potential yearly water demand (L) (100%HHs)	1,394,909,769.00
Actual yearly demand of water from forest (L)	951,328,462.46
Unit cost of water impurity removal using local water treatment system (KES)/L	0.045[25]
Value of water quality purification (KES)	42,640,385.81
Value of water quality purification (US$)	473,782.06[26]
Value of water quality purification(US$/HH/yr)	10.88
Value $ha^{-1}yr^{-1}$ (US$)	12.83

4.8 Non Use Values of East Mau

4.8.1 Biodiversity Values of East Mau

The biodiversity value (option) of East Mau was estimated using Benefit transfer approach by using data from Costa Rica and making adjustment to account for the difference in price levels in the two countries using PPP GNP of each country (Work Bank, 2014).

[25]The unit cost of water treatment by use of Water Guard (WHO , 2008)
[26]Conversion rate of 1US$=KES 90.00

The biodiversity value of East Mau is about KES 5million (4,711,274.76) (US$ 52,347) or ~US$ 1.42$ha^{-1}yr^{-1}$. This estimate is the conservative estimate for biodiversity value of East Mau forest ecosystem.

4.8.2 Bequest Value of East Mau

Contingent Valuation Method (CVM) wasused to estimate the bequest value of East Mau by asking respondents their maximum willingness to pay for conservation of East Mau for the welfare of future generations.Ninety eight (98%) of the respondents indicate that the forest is important for their welfare and were willing to contribute to its conservation. This CV was successful because there were no protest responses. Most (93.2%) of response bids ranged from KES 100 to 1,000 and few respondents were willing to pay more than one thousand shillings –less than seven per cent (6.8%). WTP significantly different across the five locations $F_{(4,365)} = 10.55$; $p < 0.001$). Separation of mean using Tukey B test showed that WTP from households in Silibwet, Kapkembu and Nessuit were not significantly different (P=0.491). WTP from households in Mariashoni and Kapsimbeiywo were not significantly different (P=0.133) but significantly different from the households in other locations (Table 4.16). Mean WTP among groups income were significantly different among income groups (Very poor–mean =515.53, SD =411.81), moderate poor (mean =583.67, SD = 441.81) and less poor – (mean=681.66, SD =511.14) ($F_{(2,367)} = 4.25$; $p<0.05$). The WTP for indigenous households (mean=743.61, SD= 598.91) and non-indigenous (mean=, 534.18, SD=361.52) were significantly different ($F_{(1,367)} = 17.59$; $p>0.01$). Overall the mean willingness to pay for conservation of East Mau for bequest value was KES 609.00 ±2 4.50 (US$ 6.75) per household yr^{-1} (Table 4.17). The total bequest value for forest adjacent households was KES 26,527,965 (43,527*609.46) – US$ 294,755.17 or US$ 8.0ha^{-1}.

Table 4.16: Maximum WTP for conservation for bequest values (KES HH^{-1} $year^{-1}$)

Location	Mean WTP	Median
Kapkembu	541.80±54.80 [a]	500.00
Kapsimbeiywo	603.30±81.90 [ab]	500.00
Marioshoni	847.10±44.40 [ab]	500.00
Nessuit	508.10±40.30 [a]	500.00
Silibwet	454.20±64.80 [a]	500.00
	$F_{(4,365)} = 10.55; p < 0.01$	

Table 4.17: WTP for bequest values by income group and ethnicity (KES $HH^{-1}year^{-1}$)

Socioeconomic factor		Mean WTP
Income group	Very poor	515.53 [a]
	Moderate poor	583.67 [b]
	Less poor	681.66 [c]
($F_{(2,367)} = 4.25$; p<0.05)		
Ethnicity	Indigenous	743.61[a]
	Non-indigenous	534.15 [b]
($F_{(1,367} = 17.59$; $p>0.05$)		

Means values with different superscript means averages are significantly different at P≤ 0.05

4.9 Total Economic Value of East Mau

4.9.1 Total Direct Use Values of East Mau forest ecosystem

The total direct value of ecosystem services provided by East Mau forest was about KES 4.2billion/year (~US$ 46mill.) (Table 4.18) and the bulk (96%) of this value is contributed by direct use values by local communities through subsistence and cash income.

Table 4.18: Direct use values of East Mau forest ecosystem

Stakeholder	Value (KES)	Value (US$)	% contribution
Local communities	4,014,309,445.04	44,603,438.28	95.90
Small scale traders/small and large sawmills	43,300,000.00	477,000.00	1.03
Revenue collected by KFS	128,707,755.00	1,430,086.17	3.07
Total	**4,186,317,200.04**	**46,514,635.56**	**100.00**

4.9.2 Indirect use Values of East Mau forest

The total indirect value of ecosystem services provided by East Mau forest was about KES19.7billion/year (US$ 219million) (Table 4.19). The bulk (79%) of this value was composed of carbon sequestration and oxygen generation followed by water flow regulation functions (20.6%).

Table 4.19: Indirect use values of East Mau forest ecosystem

Ecosystem service	Value		% contribution
	(KES)	(US$)	
Soil nutrient cycling	44,100,832.44	490,009.20	0.2
Soil protection	14,996,853.96	166,631.70	0.1
Carbon sequestration	10,990,786,896.00	122,119,854.40	55.8
Oxygen generation	4,535,574,242.49	50,395,269.35	23.0
Water flow regulation	4,056,671,002.00	45,074,122.25	20.6
Water quality regulation	42,460,385.81	471,782.06	0.2
Total	**19,684,590,213.00**	**218,717,669.00**	**100.0**

4.9.3 Non Use Values of East Mau forest

The non use values of East Mau estimated were as bequest and option values. The bequest value was estimated using CVM method. The maximum willingness to pay for bequest value was KES 609.46 per household yr^{-1} and this value was extrapolated for all forest adjacent of East Mau and totaled KES 26,527,965.42. The option use value estimated based on the potential of East Mau to generate in future pharmaceutical products is KES 4,711,274.76.

4.9.4 Summary of Total Economic Value

The total economic value of East Mau based on this study was about KES 24billion (US$ 265million) per annum. Indirect and direct use values contributed 82.4% and 17.5% of the total economic value of East Mau forest ecosystem (Table 4.20).

Table 4.20: Summary of Total Economic values of East Mau

A. Direct use values	Value		% contribution to TEV
Product/service	KES	US$	
Timber and non-timber forest products	4,014,309,445.04	44,603,438.28	16.8
Economic value of trade and processing industries	43,300,000.00	477,000.00	0.2
Revenue collected by KFS	128,707,755.00	1,430,086.17	0.5
Subtotal	**4,186,317,200.04**	**46,514,635.56**	**17.5**
B. Indirect use values			
Soil nutrient cycling	4,410,0832.44	490,009.20	0.2
Soil protection	14,996,853.96	166,631.70	0.1
Carbon sequestration	10,990,786,896.00	122,119,854.40	46.0
Maintenance of Oxygen cycle	4,535,574,242.49	50,395,269.35	19.0
Water flow regulation	4,056,671,002.00	45,074,122.25	17.0
Water quality regulation	42,460,385.81	471,782.06	0.2
Subtotal	**19,684,590,213.00**	**218,717,669.00**	**82.4**
C. Non-use values			
Bequest	26,527,965.42	294,755.17	0.1
Option (biodiversity value)	4,711,274.76	52,347.50	0.0
Subtotal	31,239,240.18	347,102.67	0.1
D. Total Economic Value (TEV)	**23,902,146,653.22**	**265,579.407.23**	**100**

4.10 Costs of Conservation of East Mau

4.10.1 Opportunity Cost of Conservation in East Mau

The opportunity cost of conserving the East Mau forest is the net revenue obtained when the forest is put under potato production. The total areas of East Mau forest is about 36,914.45ha and is comprised of the high forest and grasslands and plantations. The mean net total household income from agricultural sources (value of own produced agricultural goods consumed and sold) was 115,000.00 $acre^{-1}$ $year^{-1}$ from potato farming. The opportunity cost of conservation using the net income from potato farming was about KES 4,779,899,223 and 5,695,297,062 (114,886.42±10,039.60*18,457.23*2.47[27]). Using the lowest value as the conservative estimate, the opportunity cost of conservation was KES 4,779,899,223 (US$ 53,109,991.37) per annum.

4.10.2 Operational Costs of Conservation of East Mau forest

This was the operational costs incurred by Kenya Forest Service in conservation activities through protection and other operational activities. Data was obtained from Kenya Forest Service. The total operational cost is about 50,918,000 (US$ 565,755) per annum. The total cost of conservation (management costs and opportunity cost) was KES 4,830,817,223 (US$ 53,675,746.92) per annum.

4.10.3 Net Benefit of Conservation of East Mau

The total cost of conservation (management costs and opportunity cost) was KES 4,830,817,223 per annum and the total direct use value was KES 4,186,317,200.04. This means that the local stakeholders are subsidizing the cost of conservation of East Mau to the tune of about KES 0.65billion per annum (i.e. 4,186,317,200.04- 4,830,817,223) =-KES 644,500,022.96(-US$ 7,161,111.34).

[27]1 ha is equivalent to 2.47 acres

4.10.4 Distribution of Benefits in Conserving the East Mau forest

Determining the distribution of benefits between different stakeholders in society, allow the quantitative analysis of externalities. Table 4.21 shows the benefits valued in this study and where they accrued in the value chain (local to global). The results showed that more half (65%) accrue to global community and only 35% is shared between local communities (17%) and the national government (18%) (Table 4.21 and Fig. 4.4).

Table 4.21: Economic Benefits of East Mau to local, national and global stakeholders

	Value		% of TEV
Type of Value	KES	US$	
Local			
Timber and non timber forest products	4,014,309,445.04	44,603,438.28	16.8
Economic value of trade and processing industries	43,300,000.00	477,000.00	0.2
Total	**4,057,609,445.04**	**45,080,438.28**	**16.9**
National			
Bequest	26,527,965.42	294,755.17	0.1
Soil nutrient cycling	44,100,832.44	490,009.20	0.2
Soil protection	14,996,853.96	166,631.70	0.1
Water flow regulation	4,056,671,002.00	45,074,122.25	17.0
Water quality regulation	42,460,385.81	471,782.06	0.2
Revenue collected by KFS	128,707,755.00	1,430,086.17	0.5
Total	**4,313,464,794.63**	**46,497,300.38**	**18.0**
Global			
Option (biodiversity value)	4,711,274.76	52,347.50	0.0
Carbon sequestration	10,990,786,896.00	122,119,854.40	46.0
Maintenance of Oxygen cycle	4,535,574,242.49	50,395,269.35	19.0
Total	**15,531,072,413.25**	**172,515,123.75**	**65.0**

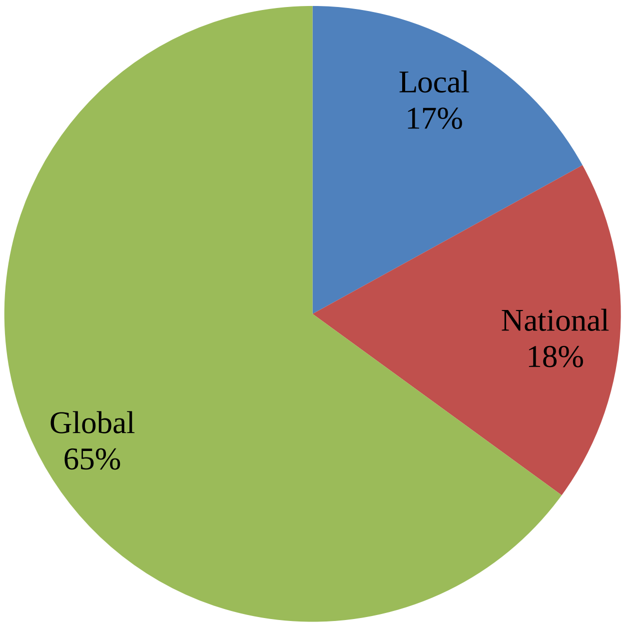

Fig.4.4: Distribution of benefits of conservation of East Mau ecosystem

4.11 Forest Dependence by Household in East Mau

The forest dependence was calculated as the ratio of total forest environmental income to the total household income and expressed as a percentage. The level of dependence was greater than 25% in all locations –ranging from 28.8% to 36.5% with an overall mean of 33.7% (Table 4.22). Relative forest income was not significantly different among households in five locations ($F_{(4,294)} = 1.18$, $p > 0.05$).

Table 4.22: Absolute forest income, relative forest income (%) by study location, wealth status and ethnicity

Variable		Absolute Forest income (KES)	Relative Forest Income (%)
Location	Kapsimbeiywo	47,662.10±6,236.81[a]	28.85±3.70[a]
	Silibwet	63,427.11±6,470.64[a]	30.71±3.34[a]
	Kapkembu	65,217.56±4,801.03[a]	32.89±2.18[a]
	Nessuit	66,579.73±3,762.37[a]	36.46±1.84[a]
	Mariashoni	71,641.51±4,711.57[a]	33.42±2.40[a]
Overall mean		65,836.28±2,232.06	33.73±1.10
		$F_{(4,309)}$=1.76, $p > 0.05$	($F_{(4,294)} = 1.18$, $p > 0.05$)
Wealth status	Poor	46,275.90±2,822.40[a]	41.40±2.13[a]
	Moderate	67,277.30±3,932.40[b]	35.60±2.03[b]
	Rich	81,463.80±3,797.70[c]	26.30±1.30[c]
		$F_{(2,309)} = 23.87$, $p < 0.01$	$F_{(2,296)} = 18.35$, $p < 0.01$)
Ethnicity	Indigenous	63,536.12±3,961.22[a]	31.93±1.75 [a]
	Non-indigenous	62,658.47±2,196.54[a]	33.15±1.25 [a]
		($F_{(1, 241)} = 0.74$, $p > 0.05$)	($F_{(1, 245)} = 0.307$, $p > 0.05$)

Means with a common superscript means that the averages are not significantly different at $P \leq 0.05$

Absolute forest income and relative forest income were significantly different among income groups ($P < 0.01$), meaning there was substantial difference in absolute forest income (Very poor = 46,275.90±2,822.40), (moderate poor household = 67,277.30±3,932.40) and (less poor household=81,463.80±3,797.70) and relative forest income (%) (Very poor =41.40±2.13, moderate poor household=35.60±2.03 and less poor household=26.30±1.30). The very poor households benefit less in absolute terms from the forest than the moderate poor and the less poor (Table 4.22) (Very poor < Moderate poor < Less poor).

However, in relative terms (%forest income), the very poor are more dependent than the two income categories (Very poor > moderate poor > Less poor) (Table 4.22). The absolute net forest income ($F_{(1, 241)}$ = 0.74; P≤ 0.05) and relative forest income ($F_{(1, 245)}$ = 0.307; P≤ 0.05) between indigenous and non-indigenous ethnic groups were not significantly different (Table 4.22).

4.12 Determinants of Forest Dependency

The relationship between relative forest incomes, dependent variable was tested against socioeconomic variables in a multiple regression model. The prediction model was statistically significant, $F_{(10, 244)}$ = 15.76, $P \leq 0.01$), - meaning that the model can explain the relative forest income. The independent variables explained 36.5% of the variation in percentage forest income (R^2=40.0%), R^2 adjusted =36.5%) i.e. the independent variables accounted for 36.5% of the proportion of forest income (R^2=40.0%), R^2 adjusted =36.5%). This may indicate that there are other important factors which influence forest dependence and were not considered in the model. Forest income (%) was primarily predicted by the constant (B = 62.93) the total off-farm income and number of cattle owned by household. The raw and standardized regression coefficients of the predictors together with their correlations with percent (%) forest income, their squared semi-partial correlations and their structure coefficients, are shown in Table 4.23.

The off-farm income received the strongest weight in the model followed by the number of cattle owned and age of the household head. With the sizeable correlations between the predictors, the unique variance explained by each of the variables indexed by the squared semi-partial correlations was quite low. Based on this model, the critical factors (both in magnitude and significance) which are likely to reduce forest dependency among households are (i) total off-farm income (this is evidenced by a significant correlation between total off-farm and percentage (%) forest income, r =-0.602, p < 0.01) and ii) number of cattle meaning higher income from sale of livestock and livestock products (Table 4.23). The total livestock income was significantly negatively correlated with the relative forest income (r = -0.217, p < 0.01). The importance of these factors is displayed by comparatively high regression coefficients (Table 4.23).

In contrast, gender of household head, age of the household head, education level, agricultural income, livestock income, ethnicity, and distance to the forest (minutes) showed no significant effects on forest dependency, indicating that these factors were not important determinants of forest dependence in the study area.

Table 4.23: Results of forest dependence model (N=255)

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
	B	Std. Error	Beta			Zero-order	Partial	Part
(Constant)	62.926	5.779		10.889***	.000			
Gender	2.323	1.886	.063	1.232	.219	.067	.079	.061
Age head of household	-.105	.068	-.078	-1.544	.124	-.096	-.098	-.077
Education level household	-1.008	1.692	-.032	-.596	.552	-.132	-.038	-.030
Size of the farm in acres	.058	.292	.011	.198	.843	-.136	.013	.010
No. of cattle	-.559	.258	-.112	-2.166*	.031	-.217	-.137	-.108
Agricultural income	-5.353E-005	.000	-.136	-1.300	.195	-.482	-.083	-.065
Total Livestock income	-2.238E-005	.000	-.054	-.532	.595	-.416	-.034	-.027
Total off-farm income	.000	.000	-.439	-3.044**	.003	-.602	-.191	-.152
Residence status	-1.327	2.254	-.033	-.589	.556	-.021	-.038	-.029
Forest distance (minutes)	-.012	.030	-.022	-.416	.678	-.027	-.027	-.021

N = 255; R=0.692; R^2 = 0.392; R^2 adj = 0.368; F = 15.76; sig=0.000*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$

Dependent Variable: % forest income to total income; **Independent variables**: Distance from the forest(walking minutes), size of land (acres), gender, age of the head of household, Farm income(ksh), number of cattle owned by household, education level of head of household, Total Livestock income, Residence status(indigenous, non-indigenous), Total off-farm income

CHAPTER FIVE

5.0 DISCUSSION

5.1 Introduction

The chapter discusses results in chapter four in the light of existing knowledge in economic valuation of forest resources and forest valuation and the nexus between the people and forest resources. It explains the results in the local socioeconomic context. The chapter provides detailed discussions on socioeconomic and demographic characterization of the sampled population, direct forest use values by the local community and other stakeholders, indirect use, non-use values and finally TEV and forest dependence and its determinants.

5.2 Socio-economic and Demographic Characteristics

The average family size in the study areas of (8.8±3.2) is higher than national average of 5.3 persons per households (KNBS, 2010). However, households in Mariashoni showed lower family size. This may be explained by the fact that the Ogiek community are more dependent on honey and hunting and may require less labour requirements. Male headed households are dominant in the study locations and this is consistent with customs of the local people -where males are expected to be the heads of households and only females attain this role through bereavement. The results showed difference in resource endowment such as land and livestock ownership. Households in the study areas owned small pieces of land ranging from 1.7 to 2.5 ha (Table 4.1). Most of the study areas, Mariashoni, Nessuit and Kapkembu were once part of East Mau forest. However, it was excised in 1990's and early 2000 for human settlement (UNEP *et al.*, 2006). Each household in the settlement scheme was allocated 2.5ha. The results showed that households in Nessuit and Mariashoni currently have less than originally allocated. This is most likely due to land transactions which may have occurred in the two locations. This finding was corroborated during Focus Group Discussions which indicated that the area has attracted new settlers due to high land productivity for food and cash crops. There have been a growing number of immigrants into the new settlement areas (Table 4.1).

This is evident from the growing heterogeneity in ethnic composition and this is affirmed by household data analysis which showed that most of the household heads (64.8%) were not borne in the current place of residence. This phenomenon of emigration from other areas in search of land and livelihood opportunities supports what has been reported in other African societies where migration is influenced by demographic trends and the search for livelihood opportunities (Heubach, 2011). It is important to note that the ethnic heterogeneity and immigration into new forest ecosystem represents one of the major challenges of environmental conservation in Kenya. Most of the inhabitants have migrated into the areas near East Mau in last 10 to 20 years, and if this trend continues, there will likely be an increase in competition and conflicts over land and forest resources.

Households in the study area have adapted a diverse portfolio of livelihood activities such as farming, livestock keeping, forest resources, small trade and remittance. The most common livelihood activity is farming and livestock keeping. The local indigenous communities, the Ogiek have largely depended on livestock and forest resources. This is however changing due to the growing influence of immigrants from other counties. There is evidence of increasing diversification of income opportunities by the indigenous community. This is consistent with what has been observed by other studies on rural communities where livelihood diversification in livelihood strategies is predominant (Ellis, 2000; Belcher *et al*., 2005; Mamo *et al*., 2007; Kamanga *et al*., 2009) because single livelihood strategy is insufficient for the needs of most rural households (Sunderlin *et al*., 2005).

Based on the results of this study, it was established that there was significant variation in asset endowment (land, physical assets, and livestock). Because crop farming and livestock are main livelihood activities in the study area ownership and access to land is one of key determinants of livelihood options for the local people. On average, each household has access to 2.8 hectares, but with significant variation between locations (Table 4.1). On average, households in Nessuit location have less land compared to households in Mariashoni, Silibwet, Kapkembu. According to local key informants, the area has experienced high land transactions due to movement of settlers from other counties leading to land subdivision.

Households in Kapsimbeiywo have the highest access to land and this is reflected in the fact that about 78% of households have alternative access to land. Furthermore, male-headed households are better off than female-headed households in terms of land ownership, livestock and physical assets.

This could be attributed to the patriarchal systems where males are given preferential allocation of natural capital among the local communities.

The household heads of non-indigenous had more post -secondary education compared to indigenous community. It was observed that there were more schools in other locations compared than in locations (Mariashoni and Nessuit) dominated by indigenous groups. Livestock sizes (TLU) across households in locations were significantly different and the herd size was positively associated with access to alternative land. The households which had alternative land also showed large herd and lowest forest grazing incidence.

5.3 Direct Use Values

Most households collect firewood and charcoal from the public forest compared to the other sources namely own farms, neighbours, markets -(72.9% and 67.3% respectively) and this was observed similarly for all products such as construction materials (poles, timber, rafters and thatch grass) and collection of medicinal plants and most households collect forest products from East Mau (Table 4.4). Most households in the study area collect firewood (90.3%); herbal medicine (83.3%), poles (34.8%), honey (27.4%), food plants (22.4%), mushrooms (19.3%) and the least collected product is building stones (5.7%) (Fig.4.1). These survey findings are consistent with the results from a study in Western Mau (Langat *et al*., 2005) and Uganda that found local people are increasingly dependent on forest resources for subsistence and cash income (Shackleton and Shackleton 2004; Masozera and Alvalapati, 2004). Biomass energy from public forests is dominant with overall average of 50% of the total forest income per household (Table 4.6). This finding is consistent with local findings which have shown that most rural households depend on wood fuel for cooking energy and heating because of lack of affordable alternative energy sources (Langat *et al*., 2005; Mugo and Gathui, 2010). Furthermore results have shown that households have not invested in tree growing as reflected in the land small proportion of land under woodlots or natural forests.
This may due to land size and availability of alternative sources of forest products. This may be explained by the greater reliance dependence on public forest for most of these products.

The value of medicinal herbs to the local community was estimated using CVM. The results from the CVM surveys showed that households were willing to pay about KES 600 (US$ 6.5) (Table 4.8) per year. According to Focus Group Discussions, use of medicinal herbs is a common practice among the local people especially the Ogiek community.

Households in Mariashoni were more willing to pay to conserve the forest for medicinal use and this was found to be consistent with high number of households which indicated preference for medicinal herbs and collect them from the forests. In terms wealth status and ethnicity, there were no significant association (Table 4.9) meaning that the value of East Mau for medicine is important to households irrespective of wealth status and ethnicity. The cultural and spiritual value of East Mau was estimated using CV M and the results showed that households were willing to pay KES 550 (US$ 6.1) slightly less amount than for medicinal values (Table 4.9). Similarly, households in Mariashoni were more willing to contribute more as reflected in the mean WTP amounts. This could be attributed to the dominance (100%) of the Ogiek community- an ethnic group that still conduct traditional rites and ceremonies in the forest (Sang, 2001). This may explain their higher preference for conservation of forest for cultural and spiritual use compared to other heterogeneous groups in other study locations where traditional rites among households is declining and therefore less preference by households in these sites.

Studies of valuation of forest ecosystem for cultural and spiritual values in Kenya are scanty. However one notable contribution in this area is the study by Aboud *et al*., (2012) which estimated cultural and spiritual value of dry lands ecosystem to pastoralist using Benefit Transfer (BT) method to the magnitude of US$ 152.38ha^{-1}. The cultural value from this study is only US$ 6.1 per household per year or 6.0ha^{-1}yr^{-1}, which is comparatively, extremely low. The large difference in estimated values could be explained by different perception of value by individuals and communities in the two study sites. Another probable reason could be that the study by Aboud *et al*., (2012) might not have accounted for the purchasing power parity between the two countries in the estimation of this value which may have led to overestimation.

The gross value of subsistence use of forest is about KES 100,000 (98,298.4 ±3,941.10) HH^{-1}yr^{-1}. The total direct use value by local households was KES 4billion through consumptive and cash income.

This estimate is presumed conservative because, some extracted products such as handcraft, veterinary medicine and oral care products and others were not considered. Similar studies in Kenya have shown substantial contribution of forest resources to livelihoods and any restrictions on access would negatively impact them (Emerton, 1995; Wass, 1995; Emerton, 2001; Mogaka, 2001; Langat and Cheboiwo, 2010 (b).

According to Focus Group Discussions, the collection of food (fruits, mushrooms etc.) is only collected when there is scarcity of food and this is an indication of the safety net functions of the forest to the local people. Similar studies in Africa have indicated the importance of forest resources in supporting livelihoods of the local people (Shackleton and Shackleton, 2004; Shackleton and Shackleton, 2006; Cocks *et al*., 2008; Heubach, 2011). Furthermore, East Mau forest plays an important role in supporting the local wood processing industries and small scale traders. Most sawmills obtain sixty percent (60%) of material requirements from East Mau forest. Sixty five percent of small scale forest product traders obtain their products from the forest. From the study, the contribution of small scale sector is about KES11.2million per annum. Apart from income to individual enterprises, the small scale sector employs more than three thousand people (KFS per com). Because of the labour intensive nature of forest operations, the multiplier impact on the local economy is expected to be high. It is estimated that the large and medium sawmills currently directly employ about 5,000 people. Based on this study, this segment contributes about KES 25million per annum through value added services. If the multiplier effect is taken into account, its economic value is estimated to be more than KES 100million per annum. The government of Kenya through, the Kenya Forest Service collects revenue through the sale of forest produce and regulatory fees and this was found to be about KES 130million per annum.

5.4 Indirect Use Values

The indirect use value of East Mau ecosystem services was estimated using different methods. The total indirect use value was about KES 20billion/year (US$ 219million) (Table 4.19) with carbon sequestration and oxygen cycling contributing (79%) of this total value. This was followed by water flow regulation functions (20.6%). The values obtained from this study can be considered conservative estimates because not all ecosystem services were considered.

5.4.1 Soil Nutrient Cycling and Conservation

East Mau forest contributes to soil nutrient cycling and soil protection (soil erosion prevention). These values were estimated at KES 44,100,832.44) (US$ 490,009.20) and KES 14,996,853.96 (US$ 166,631.70) respectively and totalled KES 59,097,686.40 (US$ 656,641.00). This is equivalent to US$ 15.31, US$ 101.1 $ha^{-1}yr^{-1}$ respectively. A review by Pearce (2001) showed that the soil protection value of temperate forest to be US$ 46 $ha^{-1}yr^{-1}$. The value from this study is about two times this value which could be due to difference in forest cover, soil factors and climatic factors. A meta-analysis by De Groot *et al*., (2012) of ecosystems values of global biomes showed that nutrient cycling and soil erosion prevention to be US$ 3 and 15$ha^{-1}yr^{-1}$(2007 prices) respectively. The values from this study may seem high; however, if these values are considered in the context of prevailing forest degradation and soil degradation in the study area, then the values are plausible. Moreover, the data for soil erosion and nutrient cycling were obtained from local studies and thus reflect the prevailing local conditions. It is also important to note that quantifying economic effects from forest loss on agricultural crops through soil erosion and loss of fertility are complex due to variation in soil types, anthropogenic pressure, land use practices etc. Estimating the economic impacts of nutrient loss and erosion are complicated by the fact that the impacts are time and spatial dependent. None the less the impacts of declining soil fertility are real and should be factored into an estimation of the total economic value or otherwise the forest ecosystem may be undervalued (Bush, 2009).

5.4.2 Climate Regulation

Forests play a major role in climate regulation by balancing the level of carbon dioxide and oxygen cycle in the atmosphere. Discussions at global level have focused on the reduction of emissions from deforestation a priority intervention in addressing climate change through natural forests and forest plantations and deter land use change.

The role of East Mau in climate change and Oxygen generation was estimated based on market price of CO_2 in the international carbon market and local unit cost of production of industrial oxygen. The value of carbon sequestration was about KES 11billion (US$ 122million) and Oxygen cycling was about KES 4.5billion (US$ 50million).

These two values account for about 80% of the indirect use value and 65% of the TEV of East Mau forest ecosystems (Table 4.20). These values translate to US$ 3,308.05 $ha^{-1}yr^{-1}$ and 1,365.13 $ha^{-1}yr^{-1}$ respectively. A recent study (Kipkoech *et al.*, 2011) found that CO_2 sequestration was of the order of US$ 12 $ha^{-1}yr^{-1}$ for East Mau, Maasai Mau and Transmara forest blocks. It is, however, important to note that the study relied mostly on benefit transfer and generalized data for tropical forests and may have underestimated this value. The present study has estimated these values based on local studies in Kenya.

5.4.3 Watershed Functions

East Mau is an important watershed for Lake Nakuru, Lake Baringo and major rivers originate from it. It is the source of river Njoro, river Makalia, river Rongai and Mara river and therefore important in maintenance of water flows, water equilibrium and purification.

The mechanism of watershed protection of forest is manifested in the retention of water by the crown, trunk, undergrowth vegetation, forest litter and soil through which water is relocated to regulate availability of surface water and runoff. The forest is often referred to as a “sponge” and “green reservoir” for its immense osmosis effect and watershed protection capacity (Xi, 2009). By regulating runoffs, forests can contribute to delay in flood peak and reducing flood volumes; in dry seasons, forests gradually release absorbed water to increase river flow and relieve droughts (Nahuelhuel *et al*., 2007; Ferraro *et al*., 2011).

The water flow regulation and purification functions estimated using water storage method (Xue and Tisdall, 2001; Xi, 2009) and avoided cost approach is about KES 4billion per year (US$ 45,074,122.25 (US$ 1,421ha^{-1}) and KES 42million (US$ 471,782.06) (US$ 12.83ha^{-1}). One study in Chile estimated that native forest is worth over US$ 200$ha^{-1}yr^{-1}$ on drinking water supply (Nu´n˜ez *et al*., 2006; Guo *et al*., 2000). The annual net benefit of these watershed functions has been estimated at US$ 85 per hectare of forest (Ruitenbeck, 1992; Myers, 1996). Result from this study is higher than what has been reported in literature but is apparent that watersheds services are important. However, the functionality and value of forest hydrological services are likely to be highly variable, and site specific.

5.5 Non Use Values of East Mau

5.5.1 Bequest Value

The non use values for this forest were challenging because of the local people's understanding and perceptions of the concept and monetization of hypothetical value. However, the WTP for bequest values was estimated using CVM.

There was also a difficulty in determining the scope of target population or deciding on the relevant population (whether local or national or global) since, East Mau is a small and not extremely unique in its characters; the bequest value would be relevant to the local community and therefore, for the purpose of aggregation, the local population was used. The total bequest value for forest adjacent households was about KES 26million (US$ 294,755.17 or US$ 8.0ha^{-1}).

5.5.2 Biodiversity Values

The biodiversity value of East Mau was estimated on the likelihood of discoveries of plants of pharmaceutical potentials using benefit transfer method. The biodiversity value of East Mau is about KES 5million (4,711,274.76)-equivalent to US$ 52,347) - or ~US$ 1.42$ha^{-1}yr^{-1}$. This is the conservative estimate of biodiversity value (pharmaceutical potentials) of East Mau forest ecosystem. Other studies for different forests and ecosystems have given different values depending on assumptions made. Ruitenbeek (1989) reported values US$ 0.1$ha^{-1}yr^{-1}$ for the Korup National Park in Cameroon for the potential value of plant-based undiscovered drugs. Pearce and Moran (1994) estimated the pharmaceutical value of tropical forests to range between US$ 0.101$ha^{-1}yr^{-1}$ to US$ 211$ha^{-1}yr^{-1}$.Similarly, studies by Mendlesohn and Balik (1997) produced a value for undiscovered plant-based drugs in tropical forest with average plant endemism of US$ 3.0ha^{-1}.The value from this study at US$ 1.42$ha^{-1}yr^{-1}$ is reasonable considering that East Mau forest is low in plant diversity compared to other tropical forest ecosystems.

5.6 Total Economic Value

This study has revealed that the total economic value of East Mau forest ecosystem is about KES 24billion (US$ 265million) per annum with the 82.4% and 17.5% of the value contributed by indirect and direct use values respectively (Table 4.20). The value from this study is higher than the results of Kipkoech *et al*., (2011) for the three forest blocks of East Mau, Maasai Mau and Transmara which estimated the TEV of the three forest blocks to be KES 17billion with direct use values accounting for 12.4%. This could be attributed to the fact that this study attempted as much as possible to use primary data and expanded the scope of values which were not captured by the previous study. However, the two studies have brought out the importance of indirect use values which were hitherto not valued. Though the values from this study may seem exhaustive, it did not encompass all aspects of total economic values of East Mau. This is especially because the existence values were not estimated at the global level and the bequest value focused on local community.

Estimating the existence value is challenging though there are attempts at estimating this values for different ecosystems at global scale (Contanza *et al*., 1997; Pagiola *et al*., 2004). However, it was not certain how these global values could be applied in the case of East Mau and therefore existence values were left out of the TEV. Therefore the TEV for East Mau can be considered a conservative estimate.

5.7 Net Benefits of Conservation

The net benefit of East Mau forest conservation is largely negative indicating the benefits derived by local communities is not commensurate with the opportunity cost. The local community and national government are largely subsidizing conservation to the tune of about 650million (US$ 7.2million) annually. This clearly indicated that conversion of East Mau to agricultural production would be much more preferable than forest conservation. However, there is a caveat to the estimates of opportunity costs because the assumptions relied upon which may be partially valid. It was assumed that forest land has uniform development potential and that the land is a limiting factor in the local and national economy and that its conversion to agricultural production would be at the same level of production like other local areas.

Another assumption made in the analysis is that the farmers in the area have the capacity to produce efficiently and cost effectively. The current level of agricultural production is lower than could otherwise be achieved using improved techniques (Krupnik and Jenkins, 2006). In addition, it was assumed that conversion to alternative land uses could happen without any other associated costs or benefits being incurred. There are potential negative impacts from changing the ecosystem functions on soils and water relations in downstream areas and these costs were not accounted in the opportunity cost estimations.

5.8 Distribution of Benefits of East Mau

Most of the benefits from East Mau are appropriated by global stakeholders (65%) with only 35% accrue to the local and national government yet the costs of conservation are incurred locally (opportunity and management costs). Though, the local community appropriated about KES 4billion per annum through direct use values; it is still way below the global value (KES 20billion). This study reinforces the findings by Norton and Southey (1995) and Langat and Cheboiwo (2010(b) that Kenya is heavily subsidizing conservation, because most of the benefits accrue to global community and Kenyans have no way of appropriating these values. The values like carbon sequestration are global values whereas the local communities and the government of Kenya bear the costs of maintaining these forests. Local communities may not value these ecosystem services when benefits accrue at the regional, national and global scales (Myers, 1996) and the costs of protection are locally incurred. This may encourage communities to pursue short term livelihood unsustainable extractive activities leading to forest degradation (Balmford *et al.*, 2002). Results from this study could be used to articulate for the sharing of burden of conservation in national and international fora.

5.9 Forest Dependence and Determinants

5.9.1 Forest Dependence

The level of forest reliance by local communities ranged from 28.8% to 36.5% with an overall mean of 33.7%.

The result from the study has shown that local people depend primarily on forest resources for subsistence needs and at times for sale with the highest contribution to household forest income being fuel wood (50%) and food products (27%). The high value from fuel wood use category is because of significantly high level of firewood collection by majority of households (90.3%) in the study area and the relatively high value of charcoal. The result of this study on forest reliance corroborated what others have concluded in other parts of Africa. For instance, Cavendish (1999) found out that 35% of rural household income is derived from environmental products in Zimbabwe. Fisher (2004) showed that 30% of household income in rural Malawi is contributed by forest income.

Mamo *et al.,* (2007) found out that 39% of the household income in Ethiopia highlands is contributed by forest income. Another study by Kalaba *et al.,* (2013) in Miombo woodlands of Zambia showed that forest income contributed 43.9% to the average household income. In a compressive comparative analysis of environmental income, Angelsen *et al*., (2014) found that environmental income accounted for 28% of household income in 24 developing countries. Therefore it can be argued that the findings of this study are not exaggerated nor over estimated the importance of forest resources to households. It is rather consistent with results elsewhere in Africa and globally.

In terms of who benefits more from forest resources, this study has demonstrated that higher income households derive higher absolute forest income than the very poor households. This is probably because the high income households are engaged in high value products such as timber, poles which require more resources such as equipment which may not be accessed by very poor households. Poor households in most cases are engaged in less lucrative and often labour intensive forest extractive activities (Arnold and Townsend, 1998). This fact is supported by the fact that poor households had the lowest aggregate physical value of assets. Limited access to financial and social capital has been advanced by various authors (Angelsen and Wunder, 2003; Dewi *et al*., 2005) to explain the inability of the very poor households to benefit substantially from environmental resources. In some cases, difference in political power has been suggested to explain why the resource use is skewed in favour of the rich (CBD, 2010). However, in terms of relative forest income, lower income households showed higher level of forest dependency.

These findings are consistent with findings of Godoy and Bawa (1993), Cavendish (2000), Neumann and Hirsch (2000); Babulo, 2007; Mamo *et al*., (2007); Kamanga *et al*., (2009); Babulo, *et al.*, 2009; Illukpitiya and Yanagida (2010); Heubach (2011) and Angelsen *et al*., 2014.

5.9.2 Determinants of Forest Dependence

The socioeconomic factors (education, household size, household income, wealth status, distance to forest etc.) can be used to predict the household dependence on forest resources (Gavin and Anderson, 2007). Results from forest dependency model highlighted the critical factors both in magnitude and significance which are likely to influence forest dependency among households. They are: (i) total off-farm income (this was evidenced by a significant correlation between total off-farm and relative forest income, $r = -0.602$, $p < 0.01$) and ii) number of cattle meaning higher income from sale of livestock and livestock products (Table 4.23). The total livestock income is significantly negatively correlated with the relative forest income($r = -0.217$, $p < 0.01$). The importance of these factors is displayed by comparatively high regression coefficients (Table 4.23). This means that households with alternative income sources are less likely dependent of forest resources for their livelihoods in the study areas. Equally important is the number of livestock and attendant benefits. Households with higher number of cattle are mostly depends on livestock income and therefore less dependent on forest resources. This outcome is not consistent with results from other countries, where ownership of cattle increases the level fodder requirements and hence higher dependence (Adhikari *et al*., 2004).

Household dependence on forest resources is also influenced by land size owned as supported by a significant correlation between land size and % forest income ($p < 0.01$).
Though the size of land is not significant in the model, there is a negative correlation with relative forest income. Households with greater land holdings are more likely to obtain their basic forest product needs on their farms while households with insufficient farmland are likely to be dependent on public forest resources. In the study area, very poor households have smaller acreage under natural forest or planted forest than the moderate and higher income households. In contrast, gender of household head, age of the household head, education level, agricultural income, livestock income, ethnicity, and distance to the forest (minutes) showed no significant effects on forest dependency.

This indicates that these factors are not important determinants of forest dependence in the study areas(Table 4.23). The analysis revealed that few households head had secondary or tertiary education (< 30%), indicative of the rather low number of persons that can be employed into the formal sector. Generally, education widens the scope for employment opportunities, which usually diverts people from subsistence agriculture and forest resources extractive activities (Adhikari *et al*., 2004; Fisher, 2004). Low income brings dependency on the forest resource and overreliance on natural resources. From the foregoing, it can be argued that, in the absence of any other rural employment opportunities besides farming activities, inhabitants of the East forest area have no other choice but to channel their labour into the gathering of forest resources. Limited sources of livelihood are therefore a cursor that drives more dependency on the forest resources and one way of easing the dependence is to diversify income /employment opportunities for the local population.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter synthesizes the results and draw some conclusions on some policy and management issues regarding socially optimal strategies to conserve East Mau and other similar forest ecosystems in the country.

6.2 Summary of Key Findings

The following are key findings based on the study objectives and research questions as set out in chapter one:

- The total direct use value of ecosystem services provided by East Mau forest was about KES 4.2billion/year (~US$ 46million) and the bulk (96%) of this value was appropriated by local communities through subsistence and cash income. The largest proportion of direct use value was contributed by fuel wood (50%), food (27%), construction material (18%) and fodder and thatch grass. The economic value derived by small scale forest product traders and wood processing sector through valued added activities was about KES 43.3million (US$ 477,000) per annum.
- The total indirect use value (soil functions, hydrological functions, carbon sequestration and oxygen generation) was about KES 20billion (US$ 219million. The bulk (79%) of this value was from carbon sequestration and oxygen generation followed by water flow regulation functions (20.6%).
- The total economic value of East Mau forest ecosystem was KES 24billion (US$ 265million) per annum. Indirect use values (soil functions, climate regulation and hydrological functions values) form the bulk of TEV (82.4%), direct use values (17.5%) and non-use values (0.1%).
- The opportunity cost of conservation and management costs far outweighs, the benefits to the local stakeholders and the government of Kenya and thus the local community and the government of Kenya are subsidizing conservation of East Mau to the tune of KES 0.65billion(US$ 7.2million) per annum.

- The distribution of overall benefits of East Mau is skewed towards global community which appropriates 65% and the local community and government get only 35% of the TEV.
- Forest income is important to households in East Mau and contributed about 33% of total household income with fuel wood (firewood and charcoal) contributing 50% to the household forest income. The absolute forest income ranged from KES 47,662 (US$ 530) to 71,642 (US$ 740).
- Forest income is crucial to poor households. However, in absolute terms, the wealthy households benefit more from forest resources.
- The most important determinants of forest dependence are off-farm income and number of cattle owned.

6.3 Conclusions and the Implications for Policy and Management

The ecosystem values presented in this thesis illustrate the importance of conservation and sustainable management of East Mau forests to the local communities, national government and global community. It is evident that East Mau forest ecosystem play an important role in provision of direct (provisioning) and indirect use values (soil functions, climate regulation, hydrological functions).

This study has shown that indirect use values (carbon sequestration, oxygen generation, soil conservation and hydrological functions form the bulk of total economic values of East Mau forest ecosystem. The bulk of these ecosystem services are appropriated largely by international community. The regulation functions (carbon sequestration and Oxygen generation) are global values yet the costs of conservation are borne locally. Thus there is strong argument to seek for conservation funds from the international community.

Furthermore, this study has shown that forest resources make an important contribution to households' income. The consumption and sale of forest products contributed 33% of annual household income and poor households were more dependent on forest resources than the wealthier households. This means that community conservation approaches need to focus on addressing equity issues amongst those households that are likely to be impacted negatively.

Higher income households expropriated more (in terms of financial value). This clearly, means that improving the living standards of the forest adjacent households (*ceteris paribus*) will increase the pressure and threaten East Mau forest. With the increasing population in East Mau and surrounding areas, the demand on forest resources are likely to rise and this will exert pressure on the state of forest resources in East Mau. However, reflecting on the findings of this study, it would not prudent to restrict access to forest resources by the local community because; it may worsen their welfare.

The household dependence analysis in the present showed that off farm income and numbers of cattle owned are negatively correlated to forest dependence. Hence providing alternate source of income for the livelihood through employment opportunities or improving the dairy enterprises might assist the community especially the poor to be less dependent on forest resources.

6.4 Recommendations

The Kenya Forest Service through the Ministry of Environment and the National Treasury should pursue support for conservation funds (REDD Plus programs, GEF and Carbon fund) and articulate for more support from international community through international conventions and multilateral treaties. The carbon market offers increasing opportunities for payments for restoration and retention of forest carbon. The Kenya Forest Service should aggressively seek partnerships with companies from industrialised countries seeking to reduce carbon emissions. Considering that most of the ecosystem values are public goods and suffer the nuances of non-exclusivity, the Kenya Forest Service should articulate for the local (county) and the national government to increase budgetary allocations to cover for the non-market benefits of conservation. There is urgent need to develop Payment for Ecosystem Service (PES) scheme so that the costs of conservation are shared by beneficiaries (stakeholders). For example, conservation of East Mau support provision of water in the region but water companies are not directly funding conservation.

Another strategy to minimize anthropogenic impacts in East Mau is to lower the opportunity cost of engaging in forest resources by creating a robust income opportunities independent of forest product extraction or improving the technical efficiency of agricultural and production systems in order to minimize illegal and lessen forest exploitation.

These measures may improve rural livelihoods and conserve forest resources and biodiversity. Programs that encourage tree planting outside natural forests may reduce dependency on forest resources and thus support forest conservation. Promotion and intensification of tree growing on farms through support for agroforestry or farm forestry should be pursued by the Kenya Forest Service and other stakeholders. The current policy on 10% cover on farms is an important entry point for this kind of intervention. Another possibility is the creation of buffer zones along the forest boundary with an agreed benefit sharing framework involving local community through Community Forest Associations (CFA's) and the Kenya Forest Service.

Management of expansive forest area like Mau requires a lot of resources both in human, financial and equipment. However, going by past experiences of poor financial resource flow from central government for managing critical water catchments, it would be desirable to design carefully a robust institutional framework engaging all stakeholders (users) and resource managers and taking into consideration market and non-market benefits of forest ecosystem. Designing of property rights regime is one way of managing externalities. Community participation as envisaged in the Forest Policy and Forest Act 2005 should be pursued so that resource users and managers account for non-market benefits in their own interests. This can in turn reduce the need for costly supervision by Kenya Forest Service, whilst achieving a more efficient mix of market and non-market benefits. Community Forest Associations (CFA) can play an important role and assist in managing the forest resources but a robust procedure of costs and benefits sharing should to be institutionalized

6.5 Further Research

Based on the results of this study, there are knowledge gaps which need further research so as to estimate full values for East Mau forest ecosystem namely:

1. The East Mau forest exerts a great influence on climatic factors such as temperature, precipitation, wind and so on of the surrounding areas and therefore influence agricultural productivity. However, it was not possible to capture these values in the current study. Further studies could address the role of East Mau forest on surrounding agricultural productivity through micro-climatic influences.

Moreover, the role of forest ecosystem in provision of habitat for natural pollinators and the economic value of pollination service should be investigated.

2. East Mau forest ecosystem is important for the maintenance of genetic diversity and has potential to provide economic products in future. This study only captured the potential of East Mau for pharmaceutical products. It is important to undertake detailed inventory of biodiversity and assess the potential economic value through provision of new bio products.
3. There is need to assess the below ground carbon fluxes and use it in estimation of carbon sequestration potential of East Mau forest ecosystem.
4. East Mau forest provides critical ecological services to Lake Nakuru ecosystem. However, the magnitude and value of this ecological service has not been determined.

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APPENDICES

Appendix 1. Household Survey Questionnaire

Introduction

Kenya Forestry Research Institute is conducting research on forest use and value of forest resources to the local communities. We are interviewing people to know their opinion concerning East Mau forest. You are one of the selected people in the village for the interview. The interview is for research and academic purposes and we would appreciate if you would participate in the survey. We assure your responses will be held strictly in confidence. If you have any queries about this study feel free to contact the under mentioned.

CONTACTS: MR. DAVID LANGAT –KEFRI – P.O BOX 5199 KISUMU, TEL: 0722842100

Prof. Abdillahi Aboud Tel: 0734052935; Dr. Elias Maranga-Tel: 0722694378

Interview number	________________	Research assistant's name:	____________________
Division	________________	Location	____________________
Sub-location:	________________	Village:	____________________
Gender	M/F-____		

A. Forest use and Economic Dependence

1. How long do you take to walk to nearest forest? _________________(Minutes)

2. What is shortest distance from your homestead to the forest? _________________Km

3. Where do you get the following forest products/commodities for home use?

Product	Sources (Tick if applicable)				
	1=Public forest	2= Own farm	3= Neighbours	4=Market	5= Others
Firewood					
Timber					
Charcoal					
Honey					
Medicine					

Poles (fencing, building etc.)					
Thatch grass					
Fruits					
Animal fodder/browse					
Agricultural tools (yoke, tool handles etc.)					
Murram					
Building stones					
Mushrooms					
Fibers					
Meat					

Of the products you collect from the public forest (in Q3):

4. How many working hours do you spend per trip, including time of travel to and from the forest? __________________________

5. How many trips do you make per week? ________________________

6. What amount of items do you collect per trip? __________________

7. How many people from your household collect the products/items from the forest?

8**.** For the products you get from the forest how much do you extract for **home consumption** and for **sale**?

Forest products and services obtained from the forest

Products	Local unit 1=Kg 2=Head load 3=Backload 4=Bag 5=pieces 6=other	4.Time/trip(hrs)	5.Trips/week	6.Amount/trip	7.Number involved	8.Amount /month	
						Home	Sale
Firewood							
Timber							
Charcoal							
Honey							
Herbal medicine							
Poles (fencing, building etc.)							
Thatch grass							
Fruits							
Animal fodder/browse							
Agricultural tools							
Murram							
Building stones							
Mushrooms							
Fibers							
Meat							

9. Do you use the forest for cultural and spiritual purposes? Yes/No (1, 0)……………

10. If yes, how often do you use the forest for cultural and spiritual purposes?___________

(1= More than once a week, 2= once a week, 2 or 3 times a month 3= once a month 4=few times a year 5= once a year)

11. Do you graze your domestic animals inside the public forest? Yes/No (1, 0)………

12. If yes, indicate the type and number and period in months grazed inside the forest

Animal	Number owned (in 2011)	Number of months in a year
1.Cattle		
2.Sheep		
3.Goats		
4. Donkeys		

13. Which month do you use the forest most and why?

Month	Reason

14. Are you and members of your household employed in forest product industry or Kenya Forest Service? (Yes=1/No=0) ………………………………………………………….

15. If yes, how many people in your household are employed? ----------------------

16. How much do members of your household earn from employment in forest product industry mentioned in Q 15? KES...

17. Where do you get your water?

(a) Stream/river (b) Borehole/Well (c) Spring (d) pond/dam (e) Piped water

18. Does your water come from the forest? (Yes=1/No=0) ……………….

19. How far is the water source (one way) from your house? In minutes………………

20 Who collects water in the household and how many?..

21. How many 20litres Jerry cans do you use each day?..

22. What type of purification do you undertake for your drinking water?

(a) Nothing (b) Boiling (c) Boiling and filtering (d) Use of chemicals

23. What is the quality of water you collect from the forest?

(a) Excellent (b) Good (c) Fair (d) Poor

24. Do you have any problems with crop raiding animals from the forest? (1) Yes (0) No

25. If yes, please indicate the type and cost of the damage (KES) in the recent past.

……………………………………………………………………………………………………
……………………………………………………………………………………………………
…………

B. Attitude

26. In your opinion what was the main purpose of the establishment of the East Mau Forest reserve? (a) Environmental and biodiversity conservation (b) creating more employment opportunities (c) tourism (d) provide raw materials for industry (e) I don't know (f) other

27. According to you, how important is the forest to you and members for your household for the following reasons? In the table below, fill in 1 for least important, 2 for somewhat important, 3 for important, 4 for more important and 5 for most important

Services/values	Level of importance
Economic (income)	
Subsistence(Domestic uses)	
Cultural/spiritual/worship	
Future use values	

C. Contingent Valuation

East Mau forest is important for cultural and spiritual values, medicine and is rich in plants and animals. These values are important now and for future generations and are also a potential source of potential products in future e.g. drugs for incurable diseases. In order to protect this important resource, for now and future generations, a levy is proposed to improve the conservation of East Mau. This proposed levy would be managed by individuals chosen by the members of your community.

Successful implementation of the project would ensure that East Mau forest will be conserved for sustainable use by community members and for future generations.

28. Would you support the project? (Yes=1 / No=0) If 'no' go to question 33)

29. If 'yes' what is the **HIGHEST** amount (KES) you would contribute every year to the project to ensure that the forest remains in good state for **cultural and spiritual values**?

(**100, 500, 1000, 1500, 2000, 3000, 4000, 5000, 6000, 8000, 10,000**) (**Mention the values one by one)**

30. If yes, what is the **HIGHEST** amount you would contribute every year to the project to ensure that the forest is conserved so that **future generation** enjoys the services from the forest? (**100, 500, 1000, 1500, 2000, 3000, 4000, 5000, 6000, 8000, 10,000**) - (**Mention the values one by one)**

31. If yes, what is the **HIGHEST** amount you would contribute every year to the project to ensure that the forest is conserved so that you continue **harvesting medicinal plants** for own use and family members from the forest? (**100, 500, 1000, 1500, 2000, 3000, 4000, 5000, 6000, 8000, 10,000**) **Mention the values one by one)**

32. If you would not contribute to the project described in questions 28 to 30. Please state your reasons. (**Long text**)

……………………………………………………………………………………………………
……

D. Socioeconomic Characteristics

33. Year born by the head of household 19______________

34. Head of household educational level: (a) Primary (b) High school (c) Post-high school

(Education years) ______________

35. Were you born in this village? Yes/No (1, 0), *If 'yes', go to 38* ______________

36. If 'no': how long have lived in the village?______________years

37. Which ethnic group do you belong to?_______________

(Codes: 1=Ogiek; 2=Kipsigis; 3=Tugen; Nandi=4; Kikuyu=5; Maasai=6; 7=others)

38. How many people are living in your household?

Gender	Number
Men	
Women	
Children <16	

39. What is the size of your land? ______________(Acres)

40. How do you use your land?

Land use	**Size (acres)**	**What proportion of total land?**(To be computed)
Natural forest/woodland		
Planted forest(woodlot)		
Food crops (Maize, potatoes etc)		
Cash crop(Pyrethrum, wheat, tea)		
Pasture land		
Wetlands/marshy /rocky areas		

41. Do you have another parcel of land elsewhere? (Yes/No (1, 0),) ______________

42. If yes, what is the size of the other parcel(s)? ______________acres

43. What is your permanent occupation? Rank them according to time spent on them.

a) ______________b) ______________ c) ______________

44. Do you own any of the following livestock and poultry assets?

Livestock type	Tick as appropriate	Number
Cattle		

Sheep		
Goats		
Donkeys		
Chicken/Ducks/geese		
Pigs		
Others (name)		

45. What is your average annual income from following activities?

Income source(s)	**Gross income in 2011(KES)**
Farming (annual crops)	
Livestock sales	
Livestock products(milk, wool, hides, skins etc)	
Remittances	
Pension	
Payment for renting out land	
Income from residential/commercial buildings	
Income from business	
Income from sale of forest products	
Other, specify	

46. What are the quantities and values of inputs used in agricultural and livestock production duringin the past 12 months (cash expenditures)?

(a) Agriculture ______________(b) Livestock ______________

E Financial and Social assets

47. Have you had an account with financial/credit institutions in the last 5 years?

Yes/No (1, 0), ___

48. How much savings do you have in your account? KES______________

49. Have you received any formal credit in the last 5 years? Yes/No (1, 0), ______________

50. Are you a member of an environmental conservation group? (Yes/No) (1, 0), _____________

F. Crisis and Unexpected Expenditures

51. Are you self-sufficient in food throughout the year? Yes/No (1, 0) ____________

52. Which months is food scarce or expensive?

Month	Reason

53. If no, what is the duration of self-sufficiency?____________months

54. Has your household faced any major crisis in the past 5 years? Yes/No (1, 0) _____

55. How did you cope with the crisis? ____________

(a)Harvest more forest products (b) Spend cash savings (c) Sell assets (land, livestock, etc.), (d) Do extra casual labour work, (e) Assistance from friends and relatives

(f)Assistance from NGO, community organization and government

(g)Get loan from money lender, welfare association, bank etc.

(h) Did nothing in particular

(Multiples answers may apply)

I. Ownership of movable assets

56. Do you own the following assets /equipment?

Asset	Tick if owned	1.Units owned	2.Year purchased	3.Respondent valuation (Resale value of all units)	4.Computed value
Car/truck					
Tractor					
Motorcycle					
Bicycle					
Cell phone/phone					
TV					
Radio					
Cassette/CD/ VHS/VCD/DVD/ player					
Stove for cooking (gas or electric only)					
Chainsaw					
Plough					
Wooden cart or wheelbarrow					
Furniture					
Water pump/Money					

maker					
Solar panel					
Others					

Any comments by the respondents

………
………
………
………
…………………………………………………

Appendix 2. Check list for Focus Group Discussions

- Brief history of the village, important changes over the years, different land uses and who uses them and record of any conflicts over forest resources or land
- Overview of income generating activities, what is produced, how, where it is sold etc.
- Seasonal calendar of the main activities (Focus group discussion)
- Importance of forest for various commodities and forest products
- Alternative income generating activities
- Alternative sources of forest products and services
- Threats facing conservation of the forests
- What are options for sustainable use of East Mau forest resources?
- Which products and services can be promoted without compromising ecological integrity of the forest
- Conservation outcome (biodiversity, ecological services etc.)
- What conservation regime can give a positive livelihoods and resource outcomes

Appendix 3. Check List for Key Informant Interviews

A. Administrative Official(chiefs)

- Ethnic composition of your location
- Number of households
- Demographic characteristics of the study villages,
- Livelihoods of the local people
- Wood and non-wood products and services obtained by the local people from the forest
- Level of reliance on forest resources
- Threats to forest conservation

B. Kenya Forest Service Officers

- Licensed wood and non-wood products extractions
- Quantities of licensed extraction per year
- Estimated illegal extraction per year
- Licensed and unlicensed grazing
- Stumpage prices of logs and current prices of forest produce,
- Cost of operations and revenues

C. Agriculture and Livestock Officers

- Type of crops grown
- Productivity of crops
- Markets structures of farm produce,
- Seasonal price of food and cash crops
- Cost of production of common crops,
- Processing and sales
- Type of livestock and their number per household
- Fodder resources requirement per animal,
- Alternative fodder sources and their cost of production cost of herd maintenance, prices of livestock and livestock products (milk, hide and skins and wool).

Appendix 4. Questionnaire for Sawmills and Small scale Forest Product Processors

Interview number	________________	Enumerator's name:	________________
Name of sawmill/mobile bench	________________	Location	_______________
Sex	M/F________________		

1. Where do you get your materials for your operation? Public forest/Private farms

2. What proportion of your materials is from the public and private farms?

Source	Proportion (Percent)
Public forest	
Private farms	

3. If public forest, what proportion is from forests of East Mau?

4. What is the capacity of your mill/processing unit per year?-------M^3/yr

5. What is the estimate volume of wood you access from East Mau in a normal year? ------M^3

6. How much money did you realize last year (2011) from your forest product processing unit? KES

7. How many people have you engaged in your operations (logging, processing and sales?......

Socioeconomic Characteristics

8 Year born by the head of household 19______________

9 Respondent's educational level: (a) Primary (b) High school (c) Post-high school. (Education years) ______________

10. How many people are living in your household?

Gender	Number
Men	
Women	
Children <16yrs	

11. What is the size of your land? ______________(Acres)

12. Do you have another parcel of land elsewhere? (Yes/No)

13. If yes, what is the size of the other parcel(s)? ______________

14. What is your permanent and temporary occupation? Rank them according to time spent on them. a) ______________b) ______________ c) ______________

Appendix 5. Questionnaire for Small scale Forest Product Traders

A. General information

Interview number ________________	Enumerator's name:___________________
Name of business owner_______________	Location _________________________
Sex M/F-____	

B. Forest Use

1. Do you engage in any forest product income generating activity? (Yes / No)

2. If 'yes' to question (1) which type of activity do you engage in?

(a) Timber vendor (b) Charcoal vendor (c) Firewood vendor (d) Poles vendor (e) Other--------

3. For how long have you been in the business? -----------------Years

4. Where do you get your products?

Source	Proportion (Percent)
Direct from government forest	
Private farms	
Sawmills	
Timber yards	

5. If public forest, what is the estimate volume of wood you access from East Mau in a normal year? ------M^3

6. How much do you sell per year? -------M^3/yr

7. How much money did you realize last year from your sales in the 2011? --------------KES.

8. How many people have you employed in your business apart from self? ----------------

C. Socioeconomic Characteristics

9. Year born by the head of household 19_____________

10. Respondent's educational level: (a) Primary (b) High school (c) Post-high school.

(Education years) _____________

11. How many people are living in your household?

Gender	Number
Men	
Women	
Children <16yrs	

12. What is the size of your land? ______________(Acres)

13. Do you have another parcel of land elsewhere? (Yes/No) ______________

14. If yes, what is the size of the other parcel(s)? ______________

15. What is your permanent and temporary occupation? Rank them according to time spent on them. a) ______________b) ______________

Appendix 6. Estimation of the Value Forest Grazing

According to the household data livestock data the mean livestock numbers 4.9 livestock units and 67% of households graze their animals inside the forest and forest fodder/browse make up to 40% of the fodder requirements. From literature, the dry fodder requirement for livestock is taken to be about 2−3% of the body weight per day (Ganesan, 1993) and a livestock unit (250Kg) requires a minimum quantity of fodder for maintenance of between 5.0-7.5 kg per day.

Step 1: Calculate the number of households who graze their animals = (43,527*67)/100=29,163

Step 2: Calculate the total number of livestock units grazing inside the forest =29,163*4.9=142,898

Step 3: Calculate the Total Dry matter requirements for the total livestock units for the whole year from the forest

1 TLU requires between 5.0 and 7.5Kg per day; therefore 365 days =142,898*(5.0 -7.5)*365

The total dry matter requirements per year is between 260,788,850 and 391,183,275kg

40% of the total fodder requirements are obtained from the forest and therefore forest contribute between 104,315,540 and 156,473,310 kg.

Step 4: Convert the estimate quantities of dry matter into Hay equivalent

1 bale of hay weighs 30kgs; the number of equivalent hay is between 3,477,185 and 5,215,777 bales.

Step5: Calculate the monetary value of hay using the current market price. The current market price of 1 bale is KES 150.

The total value of forest grazing is KES 52,577,750 and 782,366,550/yr

The value /HH/Yr is between 11,983 and 17,974

Appendix 7. Net Annual Value by Product by Location (KES)

	Location					
Product	Kapsimbeiywo	Silibwet	Kapkembu	Nessuit	Marishoni	Total
Firewood	30624.7±22959.83(27)	26420.1±14020.2(43)	25851.4±17609.5(62)	26975.9±17672.52(107)	41152.7±34356.69(113)	31540.9±25149.84(352)
Timber	23040±0(1)	23328±22280.32(20)	33920±28567.44(15)	30350.8±27104.09(26)	24106.7±20636.9(9)	28232.1±25040.88(71)
Charcoal	20232±0(2)	410709.6±415963.23(5)	242784±228003.06(3)	277628±269506.98(9)	545859.4±1174249.61(25)	431079.5±908066.62(44)
Honey	26792±17090.7(6)	96788.9±73984.56(14)	62055±48363.5(24)	74637.2±61424.46(29)	90341.2±54130.02(39)	77615.2±58234.58(112)
Herbal Medicine	7800±6245(25)	6615.4±4252.65(39)	10450±10207.05(60)	16800±13909.4(108)	12561.3±14586.51(93)	12500.3±12692.74(325)
Poles	92748±299753.29(14)	30257.7±18673.61(19)	42866.2±17858.73(22)	46230.5±22289.74(37)	51971±29670.12(37)	49999.1±99428.29(129)
Thatch grass	3600±0(1)	8700±4666.9(2)	4800±0(1)	13600±1385.64(3)	33206.3±42938.35(32)	28953.8±39905.45(39)
Fruits	3000±0(1)	21300±21251.96(8)	13800±6825.25(11)	11254.5±10761.42(33)	18127.7±20454.76(47)	15486±16804.26(100)
Agricultural tools	855±420.62(20)	654.5±388.34(11)	3438±3472.18(10)	1930.9±1682.96(11)	2280±1572.64(3)	1577.5±1943.28(55)
Murram	25.2±14.37(10)	232±404.95(12)	28.8±13.68(5)	156.7±343.15(18)	54.7±57.9(9)	120.2±280.82(54)
Building stones	nd	572±90.07(3)	nd	nd	1352±2397.87(6)	1092±1935.91(9)
Mushroom	40800±74376.77(6)	52400±48582.47(6)	49920±58033.37(5)	50800±93546.92(24)	56258.8±80848.28(34)	52544±79806.59(75)
Fibers	1782±2164.08(10)	3129.2±4355.19(13)	2970±4504.6(10)	1755±1317.61(4)	6558.8±4417.39(16)	3776.6±4256.72(53)
Meat	5760±1920(3)	13632±11027.7(10)	12617.1±9183.77(14)	28549.6±27197.94(23)	22848±23601.83(60)	21434.2±22474.57(110)

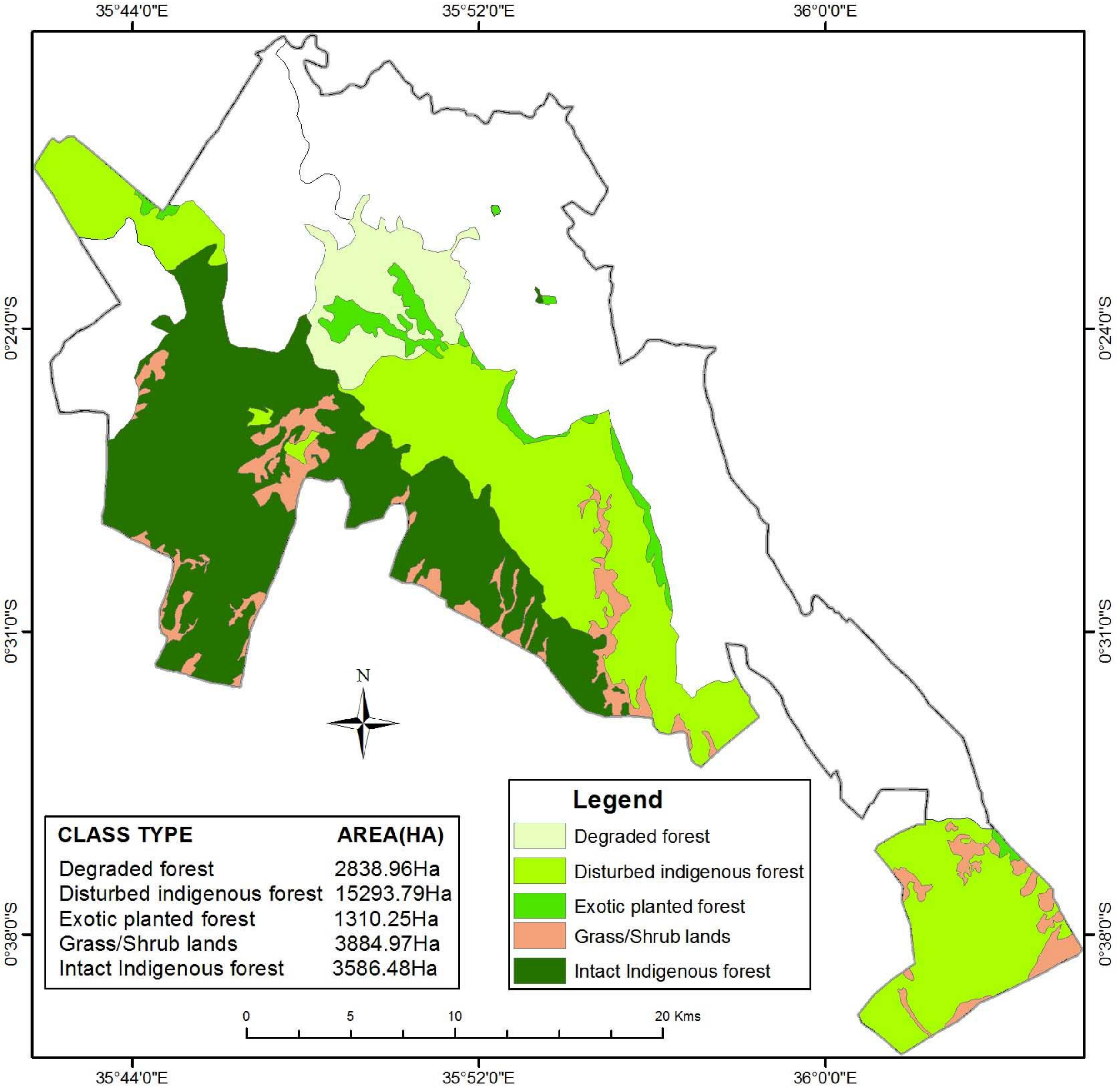
Appendix 8. Boreholes Characteristics Within Nakuru County

S/NO	BH No	OWNER	LOCALITY	TOTAL DEPTH	WATER REST LEVEL	**WATER STRUCK LEVEL**	**TESTED YIELD M3/HR**	**WATER QUALITY**	**YEAR**
1	C 4979	Elliots Bakeries	Nakuru	150.0	97.0	120.5	27.7		1981
2	C 7376	Nakuru Chrome Tanneries	Nakuru	67.0	64.0	65.5	8.1		1987
3	C 882	Kiamunyi Farm	Nakuru	180.75	160.32	171.14	5.45	Good	1949
4	C 805	Soil Conservation	Nakuru	166.42	112.38	70.79	8.18	Good	1948
5	C 287	RVIST	Technology	137.16	109.18	12.8	6.14	Good	1943
7	C 855	Kirobon Farm	Nakuru	183.0	54.86	136.55	6.08	Unknown	1949
8	C 1362	Kirobon Farm	Njoro	203.7	175.3	80.3	4.55	Good	1951
9	C 1491	Piave Ltd	Njoro	162.2	85.37	129.3	10.34	Good	1951
10	C 485	Kerma Ltd	Njoro	120.09	64.62	83.82,13.64	3.64	Good	1946
11	C 1125	Nakuru Municipal Council	Njoro	124.97	80.16	108.2, 118.87	12.8	Good	1950
13	C 1844	CMS Africa Education	YACA	121.95	30.49	30.49	0.45	Unknown	1952
14	C 4506	Rumwe Farmers	Njoro	149.0	121.6	130-146	5.91		
15	C 5403	Njoro High School	Njoro	260	113.52	9.8			
16	C 211	Military Authority	Njoro	135.53	89.42	92.96	1.82	Good	1943
17	C 2745	P. D. Townsend	Njoro	178.35	92.38	109.76, 170.73	9.77	Good	1957
18	C 1586	J. G. Adams Esq.	Njoro	155.49	86.89	92.99	1.36	Good	1951
19	C 205	OL TO Njoro	Njoro	140.2	103.63	115.8	0.68	Good	1942
20	C 202	Ngongongeri Farm	Njoro	137.16	37.8	60.96, 132.59	0.5	Good	1942
21	C 8163	Egerton College (No.11)	Njoro	136	54	60-65, 112-130	33.0		1989
24	C 1749	Mwigito Farm	Njoro	175.3	85.37	68.64,134.15	13.64	Good	1952
25	C 916	Ngondu Farm	Njoro	233.6	57.0	21.4	3.64	Good	1949
28	C 1190	C. W. Dagget Esq.	Kalenjin Estate	172.26	79.27	30.49,170.73	9.09	Good	1950
29	C 306	Mwariki Farm	Nakuru	73.15	18.32	72.54,73.15	13.64	Good	1944
30	C 307	Ronda Estate	Nakuru	70.1	13.1	13.72	10.45	Saline	1944

								Potable	
31	C 1022	Kalenjin Estate	Barut Farm	126.8	80.77	82.3, 100.58, 112.78	8.54	Good	1950
32	C 4979	Elliots Bakeries	NAKURU	150.0	97.0	107,124	27.27		1981
33	C 1934	Plant Breeding - Njoro	Njoro	198.17	96.95		12.59	Good	1953
34	C 1935	Plant Breeding - Njoro	Njoro	184.15	121.95	128.05	6.82	Good	1953
35	C 4206	MOWD	Njoro Project Nucleus	250.0	100.87	130, 157/160, 240/242	20.4	Good	1976
36	C 4214	Norconsult	Njoro Market	248.6	103.0	62,110,146	8.89	Good	1976
37	C 1489	Mr. Williams	Near Lake	53.66	29.88	36.59	15.15	Potable	1951
38	C 4517	Egerton College	Njoro	188.0	96.8	10.42, 180-180.5	13.5		1978
39	C 4669	Egerton College	Njoro	214.0	22.6	14, 118-128	15.67		1970
40	C 5029	Njoro Canning Factory	Njoro	210.0	84.0	30, 138-198	3.0		
41	C 8161	Egerton College (No.9)	Njoro	202.0	93.02	13.4, 176	11.16		1988
42	C 8162	Egerton College (No.10)	Njoro	136.0	50.72	61, 103	8.04		1988
43	C 8164	Egerton College (No. 12)	Njoro	142.0	100.0	72, 124-135	27.0		1989

Source: Bosuben 2014 unpublished data

Appendix 9. Map of East Mau showing Vegetation Types and Area Coverage



Appendix 10. Cost of De-silting and Construction of Dams

Water Service Board	Estimated cost of dam de-silting (KES m^{-3})	Estimated cost of new dam construction (KES m^{-3})
Coast		230.05
Lake Victoria North	129.82	376.35
Lake Victoria South	177.07	200.75
Northern	110.17	242.17
Tanathi	334.03	277.39
Rift valley	433.26	-
Grand mean	**236.87**	**265.34**

Source: Ikobe, 2014

Appendix 11. Sources of Fertilizer, their Conversion Factor and Unit Cost

Fertilizer source	Nutrient content	Kg (CF) fertilizer required for 1kg of nutrient	Price of fertilizer per kg	Unit cost of nutrient (KES)	Mean cost
SOA	20.6% N	4.85	66.00	320.10	247.98
Urea	46.0%N	2.17	52.00	112.84	
CAN	25.0%N	4.00	48.00	192.00	
DAP	18.0N	5.56	66.00	366.00	
MRP	20% P_2O_5	5.0	48.00	240.00	270.00
SSP	16% P_2O_5	6.25	48.00	300.00	
MOP	60K_2O	1.67	45.00	75.15	75.15

Appendix 12. Estimated Soil Nutrient Value of East Mau

Nutrient	Loss Kg/ha/yr	4% available as nutrients to plants	Unit cost/kg	Total value(KES)/yr
A. Cost of fertiliser replacement				
Nitrogen	1 724 097.18	68 963.89	247.98	17 101 664.75
Phosphorous	204 540.62	8181.62	270.00	2 209 038.70
Potassium	115 200.00	4 608.00	75.15	346 291.20
Total value of chemical fertilizers	2 043837.80			19 656 994.64
B. Transport and application costs				
Transport cost of 50kg equivalent fertilizer bags	40 876.76		50.00	2 043 837.80
Labour cost (fertilizer application)	32 000.00		700.00	22 400 000.00
Total replacement cost				44 100 832.44
Soil conservation value/ha/yr (KES)				1 378.15
Conservation value/ha/yr (US$)				15.31

Appendix 13. Estimated Soil Erosion Protection Value of East Mau

The formular for estimating the soil erosion protection value is:Vk=K·G.ΣSi*(di-do)

where: Vk_ Economic value of soil conservation; K —Cost of 1 ton sediment removal-(Ikobe, 2014); Si— Area of forest of all types (ha) (Vegetation cover map on Appendix (9)

Parameter	**Units**
K	118.44
Area of vegetation type in East Mau (Appendix 9)(S_i)	**Area(ha)**
Indigenous Intact forest	13,586.48
Disturbed indigenous forest	18,132.75
Bamboo/grassland	3,886.48
Plantations	1,310.25
G— Ratio of amount of sediments entering rivers or reservoirs to total soil lost;	0.5
d_i— Erosivity of all types of forest(t/ha)	
d_o— Erosivity of non-forest land (t/ha) (Agricultural land)	8.57
Erosivity of different vegetation types (Okelo, 2008)(d_i-d_o)	
Land use / Vegetation type	**Soil loss(t/ha)**
Agricultural land	8.57
Deforested forest area	3.16
Bamboo/grazing/pastures	1.48
Plantation forest	0.06
Indigenous forest	0
V_k	**14,996,853.96**

Appendix 14. Estimating the Biodiversity Value of East Mau Using Benefit Transfer (BT)

The value was estimated using the formula:

$$v_{EM} = Bf \quad * V_{cx} * \left[\frac{PPP_{GNPKenya}}{PPP_{GNP\ Country\ x}}\right]^{E}$$

Where:

V_{EM-} Biodiversity value of East Mau

$V_{cx/ha-}$ Biodiversity value of study site in country X

B_f biodiversity correction factor

E- Elasticity of values with respect to real income (UNEP/GPA (2003) assumed E=1.00)

PPP GNP- Purchasing Power Parity Gross National Product

$V_{EM/ha-}$ Biodiversity value per hectare

Estimation parameter	Value
$V_{cx/ha}$ (Costa Rica) (US$)	10.00[28]
Biodiversity correction factor (B)	0.3
PPP Kenya (million US$)	123,968.00
PPP Costa Rica (million US$)	67,605.00[29]
Exchange rate 1US$	90.00
$V_{EM/ha}$	5.50
Total area of indigenous area (ha)	31,719.23
Total Value(US$)	52,347.50
Total value(KES)	**4,711,274.76**

[28]Mendesoln *et al*., 1997
[29]Data from World Bank report 2014

Appendix 15. Operational Costs of Conservation of East Mau by Kenya Forest Service

Item	Number	Estimated cost/year
Staff category		
Ecosystem conservator	1	1,920,000
Assistant conservator	1	1,440,000
Foresters	6	4,320,000
Accountant	1	720,000
Clerical officers	4	1,728,000
SS	60	18,720,000
Drivers	1	320,000
Plant operator	1	240,000
Artisans	2	480,000
Forest rangers	30	17,280,000
Sub-total		**47,168,000**
Plant/vehicle/equipment		
Lorry	1	800,000
Pick ups	2	1,600,000
Tractor	1	300,000
Generator	1	100,000
Motorbikes	4	100,000
Water pumps	2	50,000
Sub-total		**2,950,000**
Office consumables		400,000
Electricity/utility bills		400,000
Sub-total		800,000
Total		**50,918,000**