Total Economic Valuation For Nzaui Hills Water Tower

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Kenya Water Towers Agency
NHIF Building, 15th Floor, Ragati Road,
P.O. Box 42903-00100
NAIROBI.
Tel: 020 271 1437
Email: info@kwta.go.ke
www.kwta.go.ke

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Foreword

Natural Ecosystems particularly Water Towers in Kenya are undergoing tremendous degradation through sanctioned excisions, illegal encroachments and illegal resource extraction. For instance, the rate of deforestation in Kenya stood between 0.4% and 1.2% per annum (Mogaka, 2005) while decades of anthropogenic activities in important catchments have resulted 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). 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).

Despite their critical importance in ensuring environmental stability and economic development, Water towers in Kenya are facing unprecedented challenges due to increasing population, encroachment 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 degradation (Allaway and Cox, 1989; Emerton, 1996; Emerton, 2001; Mogaka, 2001). The Agency has taken a lead role in valuation Ecosystem Services in line with its legal manadate of coordinating and overseeing the protection, rehabilitation, conservation and sustainable management of the Water Towers in Kenya.

Total Economic Valuation 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.

The real or true value of the ecosystems benefits and services such as fresh water supply, pollination, medicinal herbs, among others are critical to livelihoods of the local communities. These resources need to be considered as an opportunity cost compared with high economic value such as crop production. It is apparent that the failure of markets to adequately consider the value of ecosystem services is of concern not only to environment, development and climate change ministries but also to finance, economics and business ministries. In fact, the lack of market prices for ecosystem services means that the benefits we derive from these ecosystem Services which are often public in nature are usually neglected or referred as externalities ('beyond our control') in decision-making. This has been reported as the lead in unsustainable exploitation that has resulted to not only loss on critical ecosystem but has impacted negatively on community livelihood.

The exponential scale of current level of resource exploitation coupled with climate change, degradation of Water Tower ecosystem shall continue unabated unless the contribution of ecosystem services are considered in decision making processes. Nonetheless, significant progress has so far been made in valuation of ecosystem services over the last twenty years, and the economic invisibility of ecosystems and biodiversity has no doubt reduced over these years though a lot more needs to be done. For instance, quantifying impacts that occur when ecosystems are damaged or services lost and then estimating their monetary equivalent. Both the ecological understanding of these services and monetary valuation methods are continuously being improved and this report should be a catalyst to propel and elevate negotiations for enhanced conservation of water tower resources from a Total Economic Value point of view.

Dr. Julius Makau Malombe (PhD)
Board Chairman,
Kenya Water Tower Agency

Preface

The Total Economic Valuation (TEV) for Nzaui WT has been built on the scientific information generated from socio-economic, biophysical and market surveys. The information was aimed at understanding the contribution of Nzaui Hills Water Tower Ecosystem Services in Monetary terms. Undoubltly, use of ecosystem Services contribution as an accounting tool cannot be supported better that use of such information as tangible evidence. For instance, the contribution of Ecosystem Services (ES) from Nzaui Hills Water Tower was estimated at KSH 6.1 Billion while majority of the community around the water tower attested that the ecosystem is critically important. This shows how data and information generation can be important in supporting the call for action to conservation.

Kenya Water Towers Agency is mandated to coordinate the sustainable management of water towers in Kenya. A general consensus on the challenges of management and governance of the water tower ecosystems stems from both poor information on their economic contribution to the country's economic growth as well as other institutional and policy issues. There is lack of knowledge about the contribution of water tower ecosystems to human welfare and how human actions lead to environmental degradation impacting on human welfare. In other cases institutions, notably markets provide the wrong incentives while lack of an enabling policy on economic contribution of water towers to the country's growth and socio-economic development lead to poor resource allocation for their conservation. These three types of failures, and the complex dynamics between the ecology-economy interfaces, often lead to large scale and persistent degradation of the water towers accelerating loss of ecosystem services and biodiversity.

Given the large scale of human activities on water tower ecosystem in Kenya, a point has been reached where the cumulative losses in ecosystem services should ignite a discussion for decision makers rethink how to incorporate the value of these services into budgetary processes, policy and decision-making for fair and equitable share of financial resources. Valuation of these goods and services provided by water towers is an important function of the Agency in light of the accelerated deterioration of these resources. Thus, the Agency adopts Total Economic Valuation for Water Towers to understand the economic contribution of ecosystem goods and services, support policy and enhanced resource allocation for sustainable management of water towers.

Prof. Julius Tanui (PhD)
Ag. Director General
Kenya Water Towers Agency

Partners

Kenya Water Towers Agency

University of Nairobi

Kenya Forest Service

KEFRI

Wildlife Works Kenya

County Government of Makueni

Acknowledgement

Total Economic Valuation (TEV) for Nzaui Water Tower involved considerable effort particularly from the planning and audit section. TEV is a process that involved desktop reviews, field surveys, data processing and analysis, drafting of the report, editing and approval of the final report. These were made possible by support and contribution from the various actors including KWTA technical team led by Ass. Director Vincent Mainga, Jutus Eregae, Dennis Wafula and Joyce Wangari and other State and Non-State Actors. In this regard, we would sincerely thank all the key players (University of Nairobi, KEFRI, WildlifeWorks-Kenya, KFS and County Government of Makueni) who participated in compilation of the report. We also want to thank the local community for supportingdata collection. Our gratitude also goes Titus Masinde (KEFRI) soil sampling and analysis; Dr. Thuita Thenya (UoN) Socio-economic survey; Dr. Nadir (KEFRI) soil and water assessment; Mwololo Muasa (Wildlife Works Kenya) Carbon assessment; Christopher Chesire and Kennedy Matheka (both from National Musuem of Kenya (NMK) Kenya Forest Service staff (Makueni County) and County Government of Makueni.

While it may not be possible to thank all who contributed to development of this document, we recognize all efforts that led to the development of the report.

Executive Summary

Total Economic Valuation is the sum total of all economic values and includes direct use, indirect use (use) and non-use values (MA, 2005). Underestimation of the value of the many goods and services provided by natural ecosystems including Water Towers is one of the major causes of the failure to protect and manage them in a sustainable way. There is an overall consensus that Valuation of Ecosystem goods and services should take account of the easily quantifiable Ecosystem products as well as those that are not easily quantifiable. The intangible costs and benefits. Thus, the need for proper valuation of Ecosystem goods and services to quantify multiple benefits and costs of natural ecosystems including Water Towers.

Valuation of the intangible goods and services provided by forests and natural ecosystems like water towers is increasingly important at local, national and international levels when the deterioration of critical ecosystems, wetlands and other biodiversity-rich areas is at stake. International policy discussions are progressing towards a better understanding of these “hidden values”, and they are calling for the development of simple tools with which to arrive at a better understandingof the Escosystem Services involved.

This report has shown the need for economic valuation of Water Towers to supportdecision-making and touches on the causes and effects of undervaluation of such natural ecosystems. The report also highlights the significance of relatively small but exteremely important ASAL ecosystems in the Country. The study has also shown the need for investmenting in Water Tower conservation Vis-a-Vis other competing land uses such as agriculture.

Ecosystem goods and services are commonly categorized as use and non-use values. Use values are either direct or indirect use. All the above categories have been clustered into four groups of services (provisioning, regulatory, Cultural and support) by the Millenium Ecosystem Assessment (MEA). Direct use values for instance are goods and services that are exploited and utilized either as raw or processed materials. These goods are mainly provisioning services e.g. water, firbre and fuel, food etc.; indirect use value on the other hand are mainly regulatory and cultural services e.g. flood control, water regulation, spiritual among others. The non-use values values or refered as ‘passive values’ and are mainly bequest, existence or stewardship values. However, due to high data demand and time constraints, only some of use ecosystem goods and services were assessed and valued in Nzaui Water Tower.

Specific methods for estimating particular ecosystem services according to the nature of goods or services and proxy function availability has listed market pricing, contingent valuation method (CVM), hedonic prices, direct estimation of opportunity costs, replacement costs, cost savings, threshold values etc. However, almost all methods have varied degrees of uncertainties and not all may be applicable in each case. The choice of appropriate methodology usually depends on the selection of ecosystem service to be valued. In this research, market pricing, avertive cost, replacement, value and unit transfer methods were applied.

The survey included five major components; socio-economic, market survey, plant assessment,

carbon and soil mineral assessment. The socio-economic involved identification and ranking of ecosystem services (goods and services) as well as profiling beneficiaries. This included information on types and quantities of goods and services extracted and utilized as well as the number of beneficiaries within and far away from the Water Tower. Market survey assessed the resource demand and supply and prices variablity. Plant assessment generated information on Important Value index, species composition and association, ground and tree cover and level of disturbance. Plant carbon and below ground mineral assessment generated information on Water Tower CO_2 sequestration and nutrient content that was later correlated within plant assessment data. The data on ecosystem goods and services, number of beneficiaries and commodity average price was used to compute values on provisioning and cultural services while information on CO_2 and global carbon prices were used to estimate the value on air quality regulation. Soil mineral data was used to estimate soil and nutrient retention and erosion control. Quantities on Crop production multiplied with commodity average prices were used to estimate pollination value based on FAO insect pollinated dependency factor/ ratio. Other services however, applied unit transfer based on the criteria provided for diverse ecosystems. Overall, all the sub-total for provisioning, regulatory, support and cultural were summed up to estimate the Total Economic Value for Nzaui WT.

The valuation results shows a potential value of **KES 6.15 billion** (US$ 61 Million) was provided annually by Nzaui Hills Water Tower ecosystem translating to over KES 336,172 (US$ 3,328.43) per ha per year. Regulatory Services contributed the largest portion of benefits estimated at KES 4.17billion (US$ 41.3million/year) accounting for 68%, followed by provisioning services at KES 1.12billion (US$11.1million/year) accounting for 18%, while Cultural services was valued at KES 561.58million (US$5.56million/year) accounting for 9% and Support services at KES 295.95million (US$2,93million/year) accounting for 5%. The Net Present Value is estimated at KES 48.86 Billion (US$483.7 million)

However, because of time and data constrain some of the ecosystem services such as disease and pest control, primary production, natural disaster regulation, genetic resources, seed dispersal and other socio-economic benefits (e.g. poverty reduction, employment) were not valued. Similarly, because of constraints on data availability and accessibility, most of the coefficients and values were retrieved from existing research findings, consultations and secondary literature within and outside the continent.

In future, further research could focus on improving valuation framework wherever data is available and appropriate models can be applied.

The above values suggest that Nzaui Water Tower has subsidized cost that the local community, County and the National Government would have otherwise incurred were it that the ecosystem is converted to other land uses. For instance if every year we loose 1Ha of forest in Nzaui it translates to a loss of KES 336,172 (US$ 3,328.43) $Ha^{-}yr^{-}$. This Value therefore, provides a practical guide in response to the growing evidence on the economic impacts of ecosystem degradation, land use change and biodiversity loss. It is imperative to utilize this information for the conservation of Nzaui Hills Water Tower.

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Acronyms

ACC	African Conservation Centre
ACTS	African Centre for Technology Studies
ADB	African Development Bank
AGB	Aboveground Biomass
ANOVA	Analysis of Variance
BT	Benefit Transfer
CBD	Convention Biological Diversity
CBO	Community Based Organization
CDM	Clean Development Mechanism
CVM	Contingent Valuation Method
DBH	Diameter at Breast Height
ECA	Economic Commission for Africa
ETS	Electronic Trading System
EU-BCP	European Union- Biodiversity Conservation Project
FAO	Food and Agriculture Organization of the United Nations
FGD	Focus Group Discussion
FLES	Forest Livelihood and Economic Survey
GDP	Growth Domestic Product
GEF	Global Environment Facility
GIS	Geographic Information System
GNP	Gross National Product
HH	Household
HPM	Hedonic Pricing Method
IBA	Important Bird Area
ILUA	Integrated Land Use Assessment
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter-tropical Convergence Zone
IUCN	International Union for Conservation of Nature
KEFRI	Kenya Forestry Research Institute
KES	Kenya Shillings
KFMP	Kenya Forestry Master plan
KFS	Kenya Forest Service
KFWG	Kenya Forest Working Group
KIFCON	Kenya Indigenous Forest Conservation
KII	Key Informant Interviews
KNBS	Kenya National Bureau of Statistics
KWS	Kenya Wildlife Service
KWTA	Kenya Water Tower Agency
LUV	Land Use/Vegetation type

LVBC	Lake Victoria Basin Commission
MEA	Millennium Ecosystem Assessment
MFC	Mau Forest Complex
MGR	Mara Game Reserve
Mil.	Million
MoE&F	Ministry of Environment and Forestry
MRB	Mara River Basin
MTF	Mau Forest Task force
NEMA	National Environment Management Authority
NPV	Net Present Value
NTFP	Non-timber Forest Product
PA	Protected Area
PES	Payment for Ecosystem Services
PFM	Participatory Forest Management
PPP	Purchasing Power Parity
PRA	Participatory Rural Appraisal
PSU	Primary Sampling Unit
REDD	Reducing emission from Deforestation and Forest Degradation
REDD+ (Plus)	REDD plus afforestation, reforestation and livelihood improvement
SEA	Standard Enumeration Area
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 xix
UNEP	United Nations Environmental Program
UNFCCC	United Nations Framework Convention on Climate Change
UoN	University of Nairobi
US$	United States Dollar
USAID	United States Agency for International Development
VT	Value Transfer
WRA	Water Resources Authority
WTA	Willingness to Accept
WTP	Willingness to pay
WWF	World Wildlife Fund

Definition of Terms

Adult: Refers to persons who are 18 years or older.

Avoided Damage Costs: The value is based on the costs of actions taken from either avoiding damages from lost ecosystem services (e.g. cost to protect property from flooding);

Benefit Transfer: Transferring a value from studies already completed in another location and/or context (e.g. estimating the value of forest using the calculated economic value of a different forest of a similar size and type). This is usually applied where primary data collection is prohibitive may due to resource and time constrain. Benefit transfer in this case can be used to value ecosystem service such as erosion control, nutrient cycling, pollination services which may demand a lot time and resources

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)

Biodiversity hot spot: means a unique habitat with rare and diverse animals, organisms and endangered species, which is under threat of extinction;

Biodiversity: Means the variability among living organisms from all sources including ecosystems and the ecological complexes of which they are a part, compassing ecosystem, species and genetic diversity;

Biological resources: includes genetic resources, organisms or parts thereof, populations, or any other biotic component of ecosystems with actual or potential use or value for humanity;

Black carbon: formed through incomplete combustion of fuels and may be significantly reduced if clean burning technologies are employed

Blue carbon: carbon bound in the world's oceans. An estimated 55% of all carbon in living organisms is stored in mangroves, marshes, sea grasses, coral reefs and macro-algae.

Brown carbon: industrial emissions of greenhouse gases that affect the climate.

Choice Experiment/ Modelling: Ask respondents to rank/rate/choose alternative choice sets which have different combination of price attribute and ecosystem attributes i.e. People chose from a "menu" of options with differing level of ecosystem services and differing costs

Community: means a group of persons who have a customary relationship in which they depend on a Water Tower, wetland and biodiversity hot spots for subsistence, culture or religion;

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.

Contingent Valuation (CVM): This involves asking people how much they would be willing to pay to prevent loss of, or enhance an ecosystem service (e.g. willingness to pay to keep the keep the Water Tower intact). The condition of the method application is explanation of ecosystem goods and services and the likely improvement envisaged at enhanced benefits. The method can be used at valuing non-traded goods and services especially religious/spiritual ecosystem services.

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.

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

Ecosystem services – Direct and indirect benefits acquired from an interaction with the natural ecosystem and are either provisioning (including timber, firewood etc.), supporting, regulatory and cultural services(MA, 2005; Pearce***, et al.***, 2002)

Ecosystem: A dynamic complex of plant, animal, micro-organism communities and their non-living environment interacting as a functional unit;

Endangered ecosystem: means an ecosystem of exceptional biodiversity value or a habitat of endangered or endemic species which has undergone severe degradation;

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

Forest adjacent households - These are households bordering the forest reserve and are located within 5km from the forest boundary(KWTA, 2017).

Forest income - Monetary value of all products obtained from forest activities for home consumption and sale (KWTA, 2017).

Forest product: For the purpose of this survey and all its questionnaires refers to forest products in and out of forests

Green carbon': carbon stored in terrestrial ecosystems e.g. plant biomass, soils, wetlands and pasture and increasingly recognized as a key item for negotiation in the UNFCCC (in relation to forest carbon and mechanisms such as REDD, REDD-Plus, or LULUCF).

Hedonic pricing: This is referred as value of environmental amenities (air quality, scenic beauty, cultural benefits, etc.) that affect prices of market goods (e.g. the higher market value of waterfront property, or houses next to green spaces);

Household head - Household head refers to the member of a household who is the primary sole decision maker of the household (KNBS, 2008).

Household: Consists of all members of one family who are related by blood, marriage, or adoption, including other persons, such as house-help or farm labourers, if any, who normally live together in one house or closely related premises and take their meals from the same kitchen. It may also consist of one member. A household considers one person as the head of the household

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).

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(KWTA, 2018)

Market Prices: Money paid for ecosystem goods and services that are traded in commercial markets (e.g. financial values of changes in supply of forest products and non-forest products). This method will be used to value mostly provisioning services such as water, timber, thatch, fodder, fuel wood, honey, biochemical/pharmaceutical products etc.

Mitigation or averting Expenditure: The cost of dealing with the effects of the loss of an ecosystem service, in terms of what has to be spent to remediate any negative impact (e.g. cost of buying bottled water to avoid using polluted water, costs of food relief and resettlement of affected populations, cost of de-silting a reservoir)

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).

Non-wood forest product: Goods derived from forests that are tangible and physical objects of biological origin other than wood. non-wood forest products include the following: fruits (nuts, seeds, roots, berries, etc.), mushrooms**,** fodder**,** rattan**,** plant medicines**,** herbs and spices**,** dying / tanning**,** seeds (for regeneration purposes)**,** fibres (for rope etc.), wildlife (including bush meat), apiary & honey collection and caterpillar;

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).

Participatory Economic Valuation: Based on stakeholders' own participation, perceptions, preferences and categories of value. There is no fixed approach or method for participatory economic valuation, but participatory rural appraisal (PRA) techniques are often applied

Productivity Change/Approach: Estimates economic values of ecosystem services that contribute to the production of commercially marketed goods (e.g. different in yields with or without soil erosion, as measured by soil moisture and nitrogen fixation) and also valuation of water quality improvements resulting in reduced costs of water purification, increased agricultural productivity due to better pollination and increasing soil carbon stocks.

Productivity factor/Effect of Production: The value is inferred by considering the changes in quality and/ or quantity of a marketed good that results from an ecosystem change (e.g. improved water quality from enhanced forest health);

Qualified respondent: A qualified respondent is an adult member of the household who is knowledgeable about livelihood and other activities of the household. A child is not a suitable respondent. It is not necessary that all the information be given by one person. A respondent may consult any other member of the household on different items in the questionnaire. Knowledgeable female members are encouraged to participate as respondents.

Replacement costs: The Value is based on the cost of replacing the ecosystem (function) or providing substitutes (e.g. previously clean water that now has to be purified in a treatment plant);

Silviculture: It consists of the technical interventions undertaken in the forest to improve the productivity of the trees and ensure the sustainability of the forest, in other words, the management of forests;

Standard Enumeration Area: The Standard Enumeration Areas are geographical units with well-known borders. They are the basic units for statistical data collection and primary sampling. They cover the entire country;

Surrogate/ Proxies/ Substitute Prices: The market prices of a close substitute for naturally-occurring products (e.g. Kerosene for fuel wood, roof tiles for thatching grass, purchased feeds for pasture);

Sustainable management: Present use of the environment or natural resources which does not compromise the ability to use the same future generations or degrade the carrying capacity of supporting ecosystem;

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

Total Economic Value - This is the sum total of all economic values and includes direct use, indirect use (use) and non-use values(MA, 2005).

Traditional knowledge: information that may be acquired, preserved and passed on through cultural and social processes unique to certain communities;

Travel Cost: The technique assumes that the value of a site is reflected in how much people are willing to pay to travel to the site. The cost considered are travel expenditure, entrance fees and the value of time.

User group: User groups are defined as people who relate to and use the forest and tree resources on a frequent basis. Different forest products can have different user groups. User groups can originate in the area or come from outside, and they can be subsistence-oriented or commercial.

Water body: means any significant accumulation of water that forms on the land such as ponds, puddles, swamps, lakes and streams or rivers;

Water Tower: means an area gazetted as such and includes upland areas; hills, plateaus and mountains whose climate, geology, tectonics, substrate, land cover or use and hill-slope morphological characteristics support reception, infiltration, percolation and storage of rainfall, or any form of precipitation, on the surface, in the soil, rock and aquifers that, apart from surface runoff, is a gradual source of water through springs, rivers and swamps in a drainage basin;

Watershed: means the land trough that receives precipitation which flows on its way to a water body;

Wetlands: means areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water to the depth of which at low tide does not exceed six meters;

Wood product: wood products include the following forest products: industrial wood, fuel wood, charcoal, wood for wood carvings and wood for poles

Technical Team

Name	Designation	Technical Expertize	Department
Dr. Winfred Musila (PhD)	Director Ecosystem Assessment & Planning – Team Leader	Forest Ecology and Biodiversity	KWTA
Edith Bikeri	Deputy Director- DEAPA	Environmental Planning	KWTA
Vincent Mainga	Head Ecosystem & Audit Planning Section- Survey Team Leader	Forest Ecology and Policy	KWTA
Justus Eregae	Senior Ecosystem Planning & Audit- Lead on Economic Valuation	NRS- Carbon Mapping & Ecological Economics	KWTA
Dennis Wafula	Senior Ecosystem Planning & Audit Officer- Socio-Economic Surveys	Environmental Planning & Management	KWTA
Joyce Wangari	Ecosystem Planning & Audit Officer- Socio-Economic Survey	Environmental Planning & Management	KWTA
Dr. Thuita Thenya (PhD)	Senior Lecturer- Lead in Socio-economic Survey and Digital Data	Socio-economist	UON
Christopher Chesire	Lead-Plant and Vegetation assessment	Forest Ecology	NMK
Kennedy Matheka	Plant Assessment	Taxonomist	NMK
Dr. Stanley Nadir (PhD)	Lead In Soil Mineral Mapping	Water and Ground Mineral Assessment	KEFRI
Mwololo Muasya	Carbon Mapping	Carbon mapping	Wildlife Works Kenya

CHAPTER ONE

1.1 Background Information

For decades, Kenya has seen its forests and critical Water Towers severely degraded by a myriad of factors ranging from changing global climatic conditions to the direct actions of human beings such as conversion of forest to other land use and encroachment. A significant percentage of Kenya's forests have been under constant threat of degradation over the years with the country loosing approximately 5,000 hectares of forests per annum (MoE&F, 2018). At this rate of destruction, it is extremely challenging to attain the globally recommended minimum forest cover of 10% of the total land area against Kenya's estimated forest cover of 7.4%.

There are numerous state and non-state actors in the country that play critical roles in conservation and management of the country's forests. The protection, rehabilitation and conservation of these crucial ecosystems require a coordinated approach to ensure the realization of itsservices. It's under this background that the Kenya Water Towers Agency was established through an Executive Legal Notice in 2012 and mandated to coordinate and oversee the protection, rehabilitation, conservation and sustainable management of all critical water towers in Kenya. The Agency playss a pivotal role in long- Presently, there are 18 gazetted Water Towers namely, Aberdares Range, Cherangani Hills, Chulyu Hills, Huri Hills, Kirisia Hills, Loita Hills, Marmanet Forest, Mathews Range, Mau Forest Complex, Mount Elgon, Mount Kenya, Mount Kipipiri, Mount Kulal, Mount Marsabit, Mount Njiru, Ndotos, Nyambene Hills, and Shimba Hills..

1.2 Area Description

Nzaui Hill Water Tower is located in Nzaui Sub-county, Makueni County. The Water Tower covers a total of 18,302ha (967ha (9.7km^2, 17,335ha for gazetted and bufferzone respectively). The highest point is 1691m above sea level and within latitude 1.51'28S and 1.55''32S and longitude 37.31''55E and 37.33''16E (Figure 1). The ecosystem has both the natural forest and plantation forest. The Nzaui Hill is also referred to as 'White Goat' Hill by the locals derived from the famous local folk tale of a white goat that used to appear on top of the hills very early in the morning just after sunrise. The Water Tower is traversed by three locations: Kilili to the west, Kalamba to the east, and Kawala to the north.

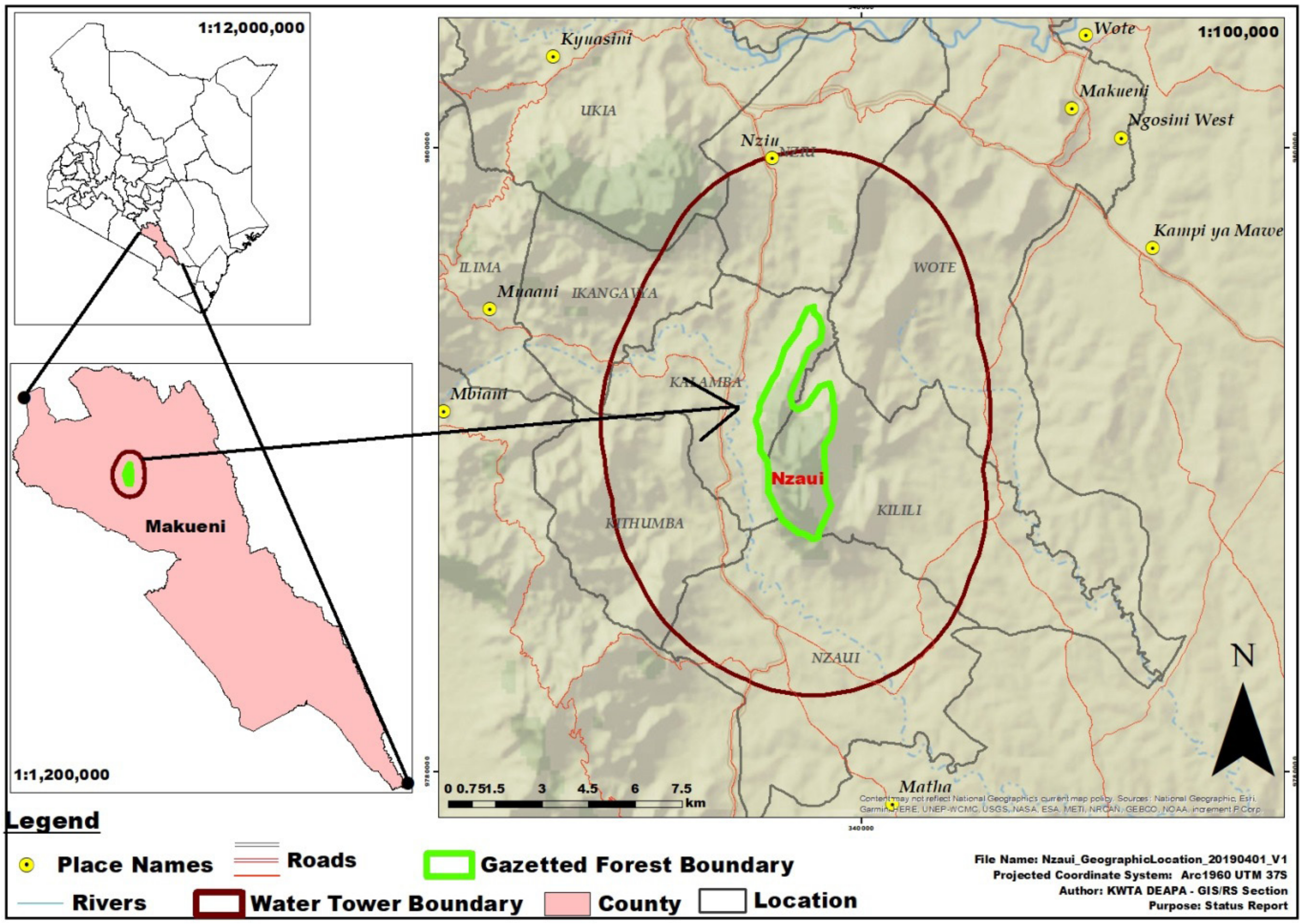


Figure 1.1 : Map of the Study Area

1.3 Population and Demographic Characteristics

Makueni County is one of the forty-seven counties in Kenya situated in the South Eastern part of the Country. It borders Machakos County to the North, Kitui County to the East, Kajiado County to the West and Taita Taveta County to the South. The County lies between Latitude 1º 35´ and 30 00 South and Longitude 37º10´ and 38º 30´East and covers an area of 8,008.7km^2. Makueni County lies in the arid and semi-arid zones of the Eastern region of Kenya. Major physical features in the County include the volcanic Chyullu hills which lie along the South West border of the County in Kibwezi West Sub County, Mbooni hills in Mbooni Sub County, Nzaui hill in Nzaui Sub County and Kilungu and Iuani hills in Kaiti Sub County. The terrain is generally low-lying from 600M above sea level in Tsavo at the southern end of the County. The main river in the County is Athi River. This river is perennial and is fed by tributaries such as Thwake, Kaiti, Kikuu, Muooni, Kiboko, Kambu and Mtito Andei which drain from various parts of the County. A few other streams flow from the Mbooni, Iuani and Kilungu hills but their flow becomes irregular as they move to the low-lying areas. These rivers are ideal for both large and small-scale irrigation.

The Akamba community form 98.1% of the population in the county. The population within within the Water Tower was 126,195; (64,990 women and 61,205 men) Unoa sub location in Wote location has the highest population with 10,542 and Mulenyu with the lowest at 1,140 (Figure 2)(KNBS, 2013). Study carried out by KWTA in 2019 revealed that, Nzaui sub-county has 43 % of the household between 6-8 members and 36% had between 3-5 members. Only two percent of the household had more than 12 persons and 9 % had family size of two members or less. The Makueni County Integrated Development Plan(Makueni County, 2013) identified, the county's population being dominated by young people.

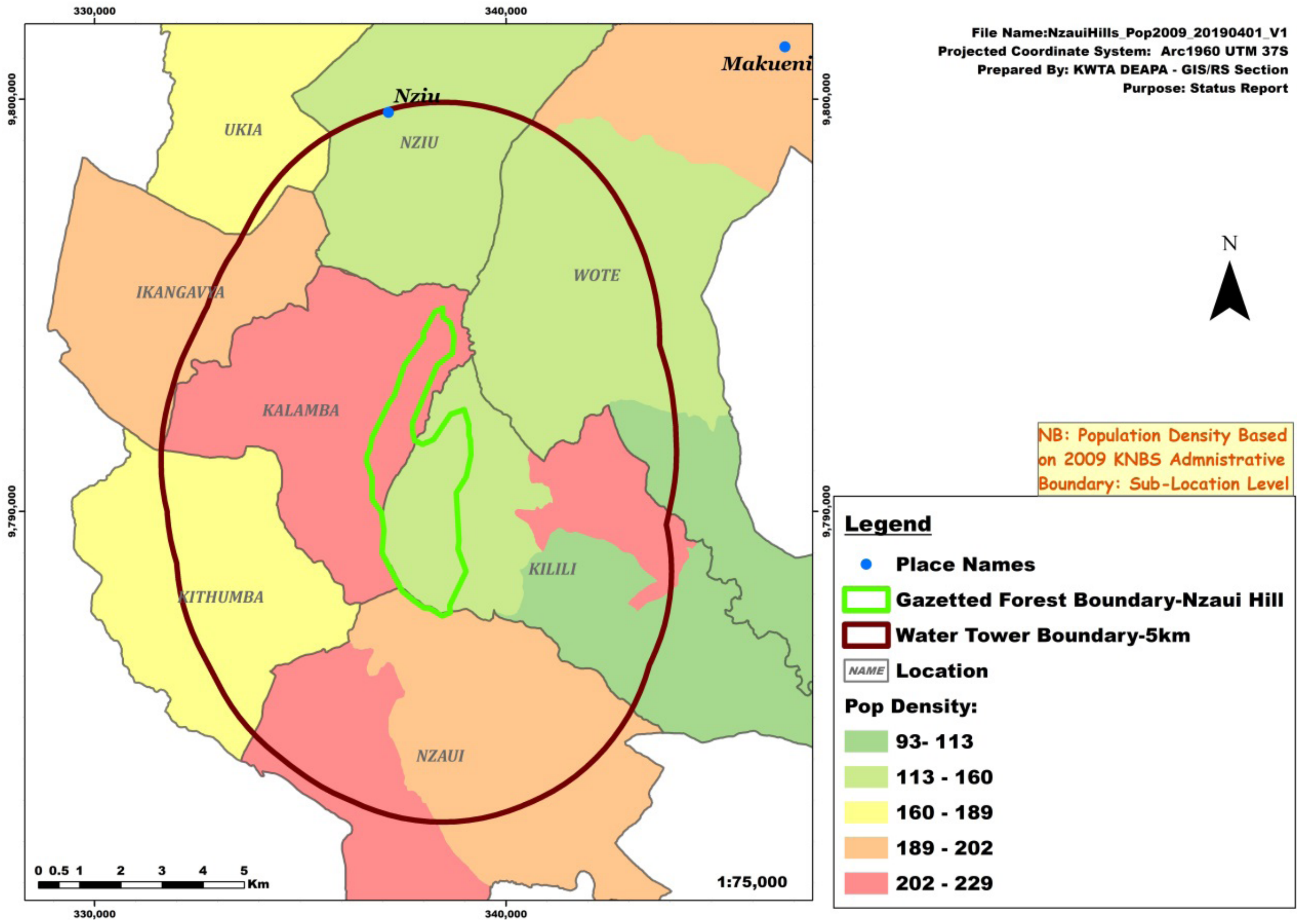


Figure 1.2: Population density (people/km²) in Nzaui Water Tower (Census data 2009)

The 2009 population census established that the County population has 43.8% of the population between 0 and 14 years, and 5.1% aged 65 years. The study considered HH mainly within the three locations Kawala, Kilili and Kalamba with a few from Nziu and Wote locations

1.4 Ecological Conditions

Makueni County falls within the arid and semi-arid lands of Kenya. The area is prone to frequent droughts negatively affecting agriculture which is the main economic activity of the Counties residents. The lower dry side of the County receives rainfall between 300 mm to 400 mm annually making it hardly to sustain the growing of major staple food crops of maize and beans. This has had negative impact on food security Livestock keeping remains therefore to be the most viable economic activity undertaken by the local people in the lower region.

1.5 Climatic Conditions

The County experiences two rainy seasons- long rains occur in March/April/May while short rains occur in November/December. The hilly parts of Mbooni and Kilungu receive 800-1200mm of rainfall per year. High temperatures of 35.8^{0}_{C} are experienced in the low-lying areas causing high evaporation worsening the dry conditions. The areas to the North such as Kilungu, Iuani and Mbooni hills are usually cool with temperatures ranging from 20.2^{0}_{C} to 24.6^{0}_{C}, while the low-lying areas of the South such as Kitise and Kambu are usually hot. The County generally experiences high and low during the day and low. During the dry periods between May and October, the lower parts of the County experience severe heat.

Nzaui ecosystem fall within the ASAL (in full) of Kenya. It reveeives a mean annual rainfall of 800 to 1200mm with long rains occurring between March and May and the short rains between October and December. The higher end of the rainfall is received on top of the hills while the lower end of the rainfall on the lower parts neighbouring communities and within farms. However, the rainfall distribution is poor and mostly come in short storms followed by long dry spells. The low and erratic rainfall pattern has been the main cause of high crop failure based on the fact that the community mainly depends on rain fed agriculture. Nzaui ecosystem is characterized by low and high temperatures regimes. The temperatures on top of the hill is low while high the in low-lying .

1.6 Study Objective

To determine the Total Economic Value for Nzaui Water Tower and provide economic justification for promoting conservation and sustainable development as well as disincentifying unsustainable land use activities in Water Tower ecosystems in the country

Specific objectives

- To undertake a socioeconomic survey and establish all the resources derived by community from the ecosystem
- To establish market prices for the goods and services derived from the ecosystem.
- To establish floristic and structural status of higher plants as well as quantification of threats to plants and habitat disturbances in Nzaui Water Tower Ecosystem
- To establish both below and above ground plant carbon as well as below ground minerals
- To estimate economic value for all the ecosystem services offered by Nzaui Water Tower Ecosystem

1.7 Rationale/ Justification

Nzaui Water Tower just like other catchment areas in the country has undergone tremendous degradation and conversion of its forest land to other land uses. This is because the society don'tt recognize the varied values and benefits generated from the system. That notwithstanding, the current market captured a few components of the 'system' which can be priced and assimilated in private business transactions either as services or merchandises. This set-up is limited since it doesn't fully reflect ecological values for a sound decision making process (MA, 2005; Turner *et al.*, 2003). Most of ecosystem services and benefits have received little attention either due to lack of knowledge or complexity in monetary quantification. Primary amongst these benefits are the ecological services provided by Water Tower ecosystem, 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 for comparison with the economic values of activities that may compromise them. The ecosystems provide basic goods and services to society however due to overexploitation resulting from population pressure and other elements, it has led to apparent decrease of stock and flow the goods and service. Nzaui ecosystem has been affected by over exploitation despite the existence of laws protecting and guiding the desired utilisation to ensure sustainability.

Nonetheless, even without any subsequent valuation, the very process of listing all the services derived from an ecosystem presents a recognition in any local and national discourse. This makes the analysis of ecological systems more transparent and can help inform decision makers of the relative merits of different options (Costanza ***et al.***, 2017). Valuation is critical, since many decisions involve trade-offs between ranges of assets that affect human wellbeing. Valuation is also a self-reflection and transparent way to inform society on the consequences of the choices we makes on our natural environment. It acknowledges the costs of conservation and can promote more equitable, effective and efficient conservation practices (TEEB, 2010b). The study intends to generate scientific information to justify that valuation does not mean 'price tagging' but rather a reflection on marketed and non-market goods and services. Furthermore, ecosystem worthiness can clearly be demonstrated through ecosystem service (ES) valuation (Chee, 2004; McCauley, 2006).

The study will also generate insight on resource use and non-use values necessary for policy review and adjustment as the globe advances to genuine progress contrary to the 'business as usual' progress (TEEB, 2010b). It further presents one of the credible avenue for the contrary and special interest spin on values, and the only way to discourage wasteful environmental investments or ones that are not in the public interest (TEEB, 2010a). It provides a means to justify and set priorities for programs, policies or actions that protect or restore ecosystems and their services as reported in earlier studies (ELD, 2013). A proper understanding of the economic values and contributions of Nzaui Water Tower 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.

Valuation and appreciation of all Ecosystem values will provide justification for fair and equitable allocation of public resources into its conservation., Information on Water Tower Total economic value 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 & Luckert, 2002; Mariara & Gachoki, 2008) and may provide a key step towards sustainable use and management of this forest ecosystem.

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 & Anderson, 2007). The information generated from this study will assist the government and other stakeholders in developing conservation strategies for optimizing forest resources to achieve economic and social objectives in line with national aspirations as contained in Vision 2030. Overall, the total economic concept will play an important role in promoting rational thinking, environmental policy review, payment of ecosystem services schemes, development of watershed ecosystem standard analysis and decision-making.

KWTA is mandated by law to coordinate and oversee the protection, rehabilitation, conservation and sustainable management of the Water Towers in Kenya. The Agency takes lead in economic valuation of Water Towers. This generates important information such as stocks and flows of ecosystem goods and services and their linkage to the economy. It envisages sustainable utilization, rational and equitable resource allocationand policy justification to invest in conservation in small but critical Water Towers ecosystem in ASAL regions in the Country such as Nzaui.

1.2 Valuation Techniques for Forest Products and Services

A number of methods have been developed by economist to capture the total economic values of ecoystems. However, none of the techniques so far is able to capture the values of services. This necessitates the application of appropriate technique to a services or goods and later individual ES values are computed to estimate the total monetory value. To eliminate double accounting of ecosystem benefits, the study focused mainly on processed products, intermediate services and final services using Boyd and Banzhaf (2007) and Fisher et al., (2009) approaches. The study identified all forest benefits extracted and utilized by the community and within and beyond the Water Tower and assigned appropriate valuation method as provided in (Appendix 1).

The survey established quantities extracted by individual households on a daily or monthly basis and was then extrapolated to capture quantities for the whole year. Prevailing market prices for uch commodities was established through a market survey and used in the valuation exercise. This was done by multiplying the quantities extracted annually and by using the average local market price less the transaction costs as suggested by Godoy and others (1993). To ensure that the prices used in calculations reflect prevailing market value, average market prices were used. The total net value 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 (equation 3)

$T_n = (P \times Q) - C$...................Equation 6

Where Tn is total net value, P is commodity price, Q is the Quantity harvested or purchased at household and C is production or transaction cost.

Since not all the ES are traded in markets, valuation can either be through direct market pricing or indirect market pricing. Direct market pricing include the market price for goods, services and products (an estimate of the contribution of a certain ecosystem service to the production of other marketable good) that can be bought and sold in commercial markets and their production function (Bertram & Rehdanz, 2013). Indirect market pricing are commodities that cannot be traded in any commercial market, their value can be inferred using consumer preferences (revealed and stated) such as biodiversity (Nijkamp et al., 2008; Remoundou et al., 2009).

Revealed preference for instance are pricing of commodities based on observed consumer behaviour and include hedonic pricing, travel cost and replacement cost methods for analysing individuals' preferred choices (Haab & McConnell, 2002; Pagiola et al., 2004). The hedonic pricing method serves to calculate the value of ecosystem services and goods such as landscape, air quality, and noise (Turner et al., 2010). This method evaluates the price that individuals are willing to pay for the relevant ecosystem characteristics based on house prices, the time, and money spent on recreational trips or other expenses (Turner, et al., 2010). The replacement cost method, on the other hand, quantifies the cost of replacing or restoring an ecosystem service (Balmford et al., 2002). The above valuation techniques are summarized as shown below (Figure 1.3).

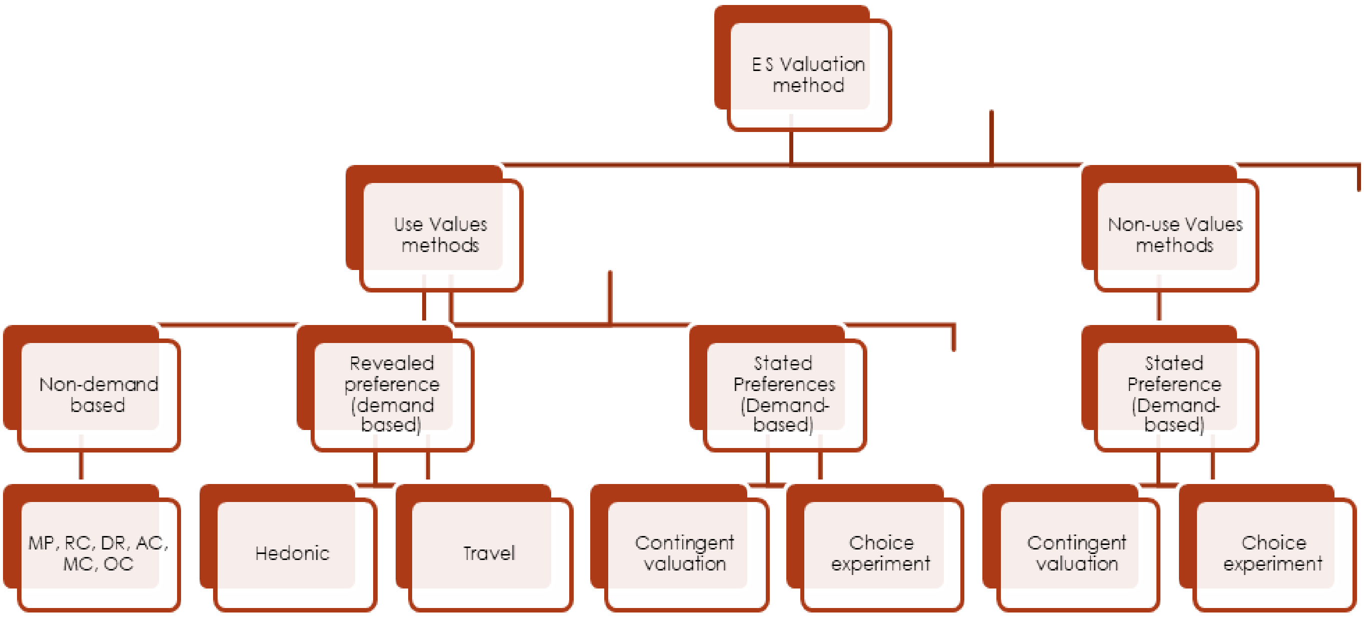


Figure 1.3: ES Valuation techniques based on preference

CHAPTER TWO

2.1 Materials and Method

The chapter details the approach that the study employed to aquire relevant information on socio-economic characteristics, biophysical and market surveys and valuation of ES for Nzaui Hill Water Tower. This chapter elaborates the study design; sampling design;; data collection, valuation techniques and analysis.

2.2 Study Design and Approach

TEV survey involved two main components, biophysical and socio-economic. The biophysical survey involved plant sampling and assessment, below ground minerals (soil nutrient) assessment and carbon stock sampling and assessement. The socio-economic approach involved identification and ranking of ecosystem services, type of ecosystem services, number of beneficiaries, community resource use, demand and supply and market survey (prevailing market prices, demand and supply). The biophysical data was collated from 32 randomly selected sampling plots within the Water Tower (the forest and buffer zone) while the socio-economics data was generated through the four sampling frames (HH, FGD, PRA and KII) from the community living around the Water Tower clustered in administrative locations. The data generated was grouped into various ecosystem services for estimation of the total economic value.,.

Total economic valuation adopted a three-phase approach partly adopted from Economics of Land Degradation (ELD) Initiative framework (ELD, 2015; Noel & Soussan, 2010) and the ELD 2013 & 2015 report. Valuation of ecosystem services included market and non-market services, based on public and private benefits. However, study categorized ecosystem services (ES) into independent component valued separately without duplicating the value of a single service across ES categories. Ultimately, individual values were summed up to estimate the total economic value of the subject ecosystem service.

Phase one included inception stage, desktop analysis of geographical characteristics of the target ecosystem.. Phase two involved identification and categorization of ecosystem services through stakeholder consultation in the study area. Phase three determined economics of ES and its role to the local community livelihoods and overall development by attaching prices to the ecosystem benefits-The Total Economic Values.

2.2.1 Socio-Economic Assessment

Data was generated from four sampling frames;. Household Interviews, Focused Group Discussion (FGD), Participatory Rural Appraisal (PRA) and Key Informant Interviews (KII). Primary Sampling Units (PSU) were administrative Sub-locations around the Water Tower guided by their respective population. Administration of questionnaires were administered per location based on a selected number of Households as per table 1 below. For easier survey execution and projectable inferences, the study was undertaken in a three phase, beginning with selection of Enumeration Area (EA) from the six locations representing the forest blocks within the Water Tower. The second stage involved random selection of households from each enumeration area. Within each EA, between one and three key informants and focused groups were also selected for interview. Gender balance was taken into consideration during the interviews.

The administration of the questionnaires was done to the HH head and preferably permanent residents within the Water Tower.

The data collection was based on livelihood framework with identification of assets endowment structured on social, financial, physical, human and natural capital. . Key informant survey was used to validate information from household survey. Focused group discussion on the other hand was used to validate information from HH interviews and Key informants as well as collect more information on ecosystem services from the water tower.

The study conducted market survey in the neighbouring trading centres to collate information on prevailing retail prices for forest products, quantities trades and demand and supply. Surrogate pricing was used where there was unclear market prices.

2.3 Sample Size Determination

The sample size was determinied as a factor of the population of the locations around the water tower. The 2019 projected population for Makueni County stood at 1,016,462 consisting of 494,954 males and 521,508 females. This was an increase from 884,253 persons as per the 2009 Kenya National Population and Housing Census. The annual population growth rate stands at 1.4 per cent while the male-female sex ratio stands at 1:1. Youth account for 23.6% of the total population. The 2009 Kenya National Bureau of Statistics Household Census data was used as the baseline population.

Nzaui Sub-county had a population of 36,951 in 2009 based on county annual population growth of 1.4%. The projected population by 2019 wasestimated at 42,463 persons. The average household size was estimated at 5 persons and based on projected population, Nzauihad 8493 households (KNBS & SID, 2013; Makueni County, 2013). Sample size for the households was determined using the formula in equation 1 (Mugenda and Mugenda 1999).

$$n = \frac{Z^2pq}{d^2}$$ ....Equation 2

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 8493 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, $$n = \frac{(1.96)^2(0.5)(0.5)}{(0.05)^2} = 384$$

Though the desired population is 384 i.e. for population greater than 10,000, however, the study target household estimated at 8493 based on projected 2019 population (less than 10,000), and the desired sample size is calculated using the second formula in equation 2 below according to Mugenda and Mugenda, (1999).

$$n_f = \frac{n}{1 + n/N}$$ ....Equation 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 targeted population (8,493) distributed across the six administrative locations.

$$n_f = \frac{384}{1 + {}^{384}/_{8493}} = 367$$

Therefore according to the equation 2, the total desired household sample size is 367. However, due to time and resource constrain the study managed to sample 284 household distributed across the administrative sub-locations as indicated in (Table 2.1)

Table 2.1 Sample size of households by location in Nzaui Sub-county

Location	Sub-Location	Approx. No of Households	Desired Sample Size	Actual Household Sample Size	Proportion (%)
Kilili	Kathatu	625	27	21	7
	Kilili	616	27	21	7
	Mulenyu	457	20	15	5
	Wee	487	21	16	6
Kawala	Maviaume	693	30	23	8
	Kawala	1,032	45	35	12
	Ndovea	796	34	27	9
Kalamba	Kalamba	2,321	100	78	27
	Kwa Kalui	1,466	63	49	17
TOTAL		**8493**	**367**	**284**	**100**

2.4 Sampling Procedures and Data Collection

2.4.1 Households Sampling

Data collection was done on digital platform where trained enumerators were deployed to the respective sub-locations with set target of household supervised by KWTA technical staff. Random sampling was applied in selection of the first Household and Systematic sampling was applied in selection of subsequent householdsby skiping one homesteads for the subsequents homesteads and replicating the same in the entire study area.

Both Structured and semi-structured questions were used to obtain data on forest use, frequency visit, quantities collected per visit, time spent, and number of household members involved, costs of forest activities. The household survey was further obtained through socioeconomic and demographic data on household income and source, HH assets, education, household size among other). Household contextual factors such as distance to the forest and market, ethnicity, and distance to markets were also collected.

2.4.2 Key Informants

Purposive sampling was used to select key informants. At least one key informant was sampled from each sub-location based on familiarity with the area and information gathered from the local people; having a broad and in-depth knowledge about his/her village;

its households and the forest issues in general.. Key informant were interviewed to obtain relevant information on Ecosystem Services within the Water Tower.

2.4.3 Focused Group Discussion (FGD) and Participatory Rural Appraisal (PRA)

Focused Group Discussion (FGD) and Participatory Rural Appraisal (PRA) were used to generate information on benefits and ecosystem services The PRA helped identify key products and services for the development of research tools for valuation of the resources. FGDs validated or enriched information obtained from key informants and HH interviews. The grouping composition considered gender balance and wider scope of user groups that included, charcoal burners, traditional herbalist, herders, bee keepers, fuel wood collectors etc. State institutions involved included KFS, Administration, and County Government while non-state involved included WRUAs, CFA, and other NGOs.

Plate 1: Participatory Rural Appraisal (PRA) at Kalamba

Plate 2: Focused Group Discussion

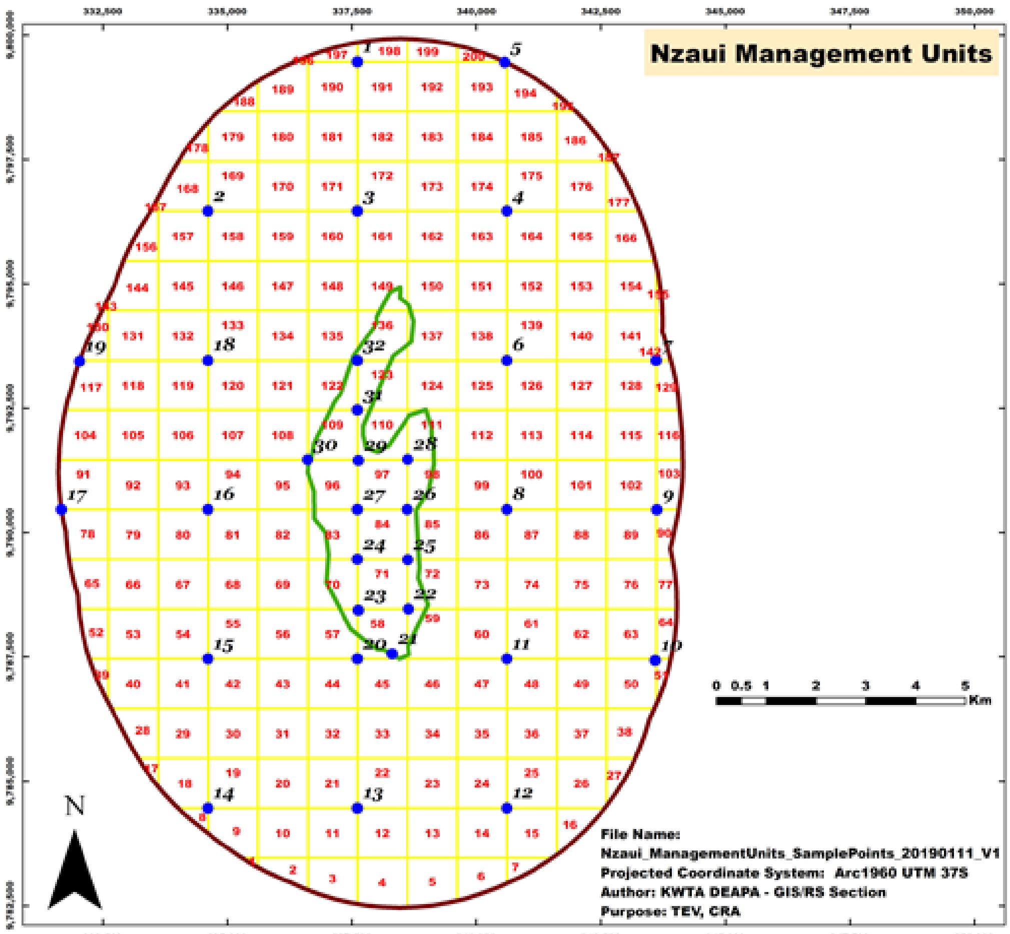
2.5 Biophysical and Ecological Survey

Biophysical/ Plant survey involved assessment of floristic and plant composition of plants (Trees, Shrubs and Herbs) and habitat disturbances *(plant structure, abundance and evenness; vegetation cover mapping and disturbance)*. Plant diversity, community association, evenness of distribution and species richness were also assessed from randomly selected plots within the gazetted forest and the commnnity buffer zone. Similarly, forest structural features such as basal area, canopy, and the population structure were also assessed to understand forest growth characteristics and its productivity potential in the context establishing ecosystem health and resilience. Changes in vegetation cover over time and plant abundance were established through interpretation of high resolution satellite imagery to supplement direct count and measurements mentioned above. The physical count was conducted in randomly selected plots within the Water Tower.

2.5.1 Sampling Design

The study applied systematic sampling design, with geo-referenced sample grids of 1km by 1kmdistributed over the Water Tower generated through GIS application. Smaller sampling plots of 100m by 100m were ramdomly selected inside the larger grids (Figure 2.1). 12 line transects were established 12 line transects with six running parallel and the other six running perpendicular to the Water Tower gradient at an espacement of 1km within state forest and 3km in the buffer zone. The line transects were established along the existing grids as provided below. Sampling plots of 100m x 100m were set at the respective convergence points of the transcects. This translated to 32 plots, twelve within the state forest and 20 distributed across the buffer zone. Plant and carbon assessment was then undertaken within the 32 plots where One sub-plot of 25m x 25 m was established at the centre of each of the 32 plots.

Soil samples will collected at the NE (in full)corner of the sub-plots. The depth for soil sample ranged from 0-15 cm, 15-30 cm for nutrient survey and 0-30 cm and 30-60 cm for soil density. Geographical positioning system (GPS) was used to locate the exact position for the sampling plots.



ID	X	Y
1	337,610	9,799,464
2	334,610	9,796,464
3	337,610	9,796,464
4	340,610	9,796,464
5	340,570	9,799,456
6	340,610	9,793,464
7	343,610	9,793,464
8	340,610	9,790,464
9	343,621	9,790,460
10	343,589	9,787,433
11	340,610	9,787,464
12	340,610	9,784,464
13	337,610	9,784,464
14	334,610	9,784,464
15	334,610	9,787,464
16	334,610	9,790,464
17	331,668	9,790,464
18	334,610	9,793,464
19	332,034	9,793,446
20	337,610	9,787,464
21	338,310	9,787,564
22	338,634	9,788,465
23	337,630	9,788,442
24	337,610	9,789,464
25	338,622	9,789,458
26	338,610	9,790,464
27	337,610	9,790,464
28	338,622	9,791,470
29	337,630	9,791,450
30	336,610	9,791,464
31	337,610	9,792,464
32	337,610	9,793,464

Projected Coordinate System: Arc1960 UTM 37S

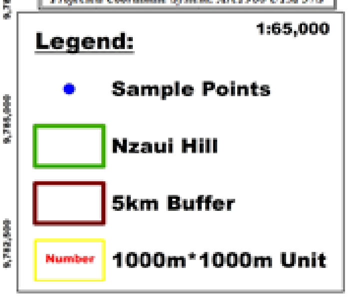


Figure 2.1 Study Sampling Points

Twenty two circular plots of radius 14.11m (625 m^2) were demarcated for biophysical assessment within the Water Tower. Sampling was done at the centre of each randomly selected sample plot generated from geo-referenced grid across the Water Tower map located using hand held GPS. All vascular plants (Trees, Shrubs and Herbs) occuring in this plot were recorded for DHB, Height, Canopy characteristics, threats inside theplot, and specimens selectively collected and processed following Foreman & Bridson (Bridson & Forman, 1992). Diameter at Breast Height (DBH) were measured at 1.3 meters from ground level, tree heights were determined using a Suunto clinometer and thereafter estimated and canopy estimates made. Saplings or small regenerating plants were sampled in single nested plots measuring 10m X 10M plots

Plate 3: Establishing Sample Plots

Plate 4: Packaging of Shrubs for pressing

Plate 5: Recording of Shrub information on a digital platform

Plate 6: Sampling team moving to a point within the forest

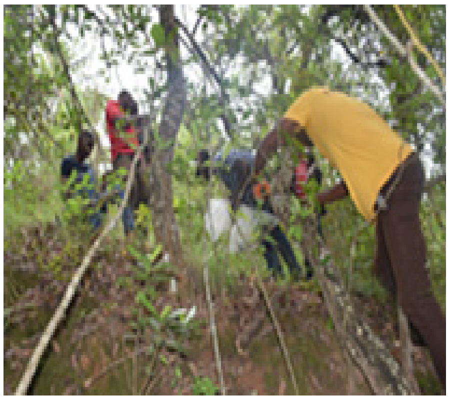


Plate 7: Sampling higher plants within the forest

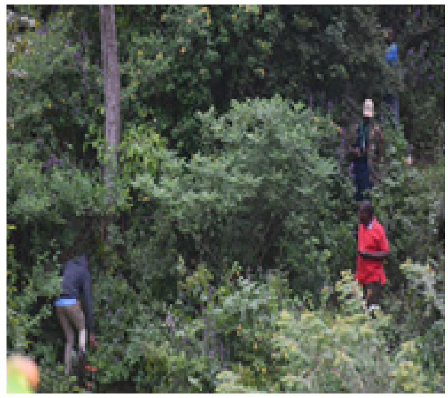


Plate 8 Tree and sapling sampling

A total of 22 such plots were sampled. Seedlings and herbaceous vegetation were sampled in 5 nested plots measuring 1 m^2 on the peripheries and centre of the major plot. A total of 110 such plots were sampled. Herbarium voucher specimens were collected for the species that were difficult to identify in the field. Specimen identification was done at the East African herbarium using identification keys found in various monographs that included numerous volumes of the Flora of Tropical East Africa (FTEAs), Kenya Trees Shrubs and Lianas (KTSL) and the Upland Kenya Wild Flowers (UKWF). Where necessary, specimens were further confirmed by comparing them with already correctly identified herbarium reference specimens at National Museums of Kenya.

Additionally, habitat disturbance was quantified in each plot using visible disturbance indicators. Other important descriptions and observations were also recorded.

2.5.1.1 Carbon Assessment Mapping

Field based carbon stock mapping survey was undertaken where non-destructive approach was applied where trees, shrubs and lianas dimensions (diameter at breast height-DBH; canopy diameter and height) were measured and recorded to avoid felling trees and shrubs for physical measurement. Tree dimensions were recorded in excel and later screened using pivot tables. The measurements were then converted to carbon estimate using regression models. This was done on two major tree carbon pools i.e. stem and root biomass of any tree with DBH≥ 5 cm, shrubs and lianas. Trees with DBH below 5 cm were treated as conservative in relation to carbon stock. Sampling plots established for mapping of both aboveground and below ground biomass was based on IPCC 2006 framework.

Plate 9: Measurement of DBH inside state forest

Plate 10: Measurement of DBH at Farm land

The study adopted species specific allometric models developed by Wildlife Works Kenya particularly for species similar to the ones in Kasigau Corridor Project. Plants without species specific allometric model adopted general genus model of the same study. However the study developed regression model using tree dimensions recorded during the survey for species with neither genus or species models available. Specific tree DBH was used to estimate tree biomass using the equation 3. Biomass of the species was generated from species wood densities derived from global wood densities (World Agroforestry Centre (ICRAF), 2012; Zanne *et al.*, 2009).

$$B = \alpha DBH^{\beta}$$ ....Equation 3

B is tree species biomass derived from global wood densities; DBH is tree diameter at breast height (1.4m) while α & β are model coefficient.

2.5.1.2 Below Ground Mineral Mapping

The survey sampled soil from randomly selected plots where a hand held GPSequipment was used to locate the sampling points on the ground during soil sampling. The representative composite soil samples were collected considering the following factors: soil type, drainage condition, topsoil colour, topography, crop performance, saline areas, management practices (fertilizer and manure application), rockiness, different cropping patterns, soil moisture status and cultural practices (Muriuki and Qureshi, 2001; Gachene and Kimura, 2003). In every selected soil unit (soil type), representative composite samples (depending on the size) were collected at the depths of 0-20cm, 20-40cm and 40-60cm using a soil auger and packed into polythene bags. Soil sample labeling included land use / vegetation type, village and depth.

Plate 11: Soil sample collection

Plate 12: Soil collection preparation

Plate 13: Bulk Density Soil Sampling

Plate 14: Sampling team moving downhill for the next sample point

2.5.1.3 Soil and Organic Carbon Analysis

Soil samples were analysed at KEFRI soil laboratory. Parameters that were analyzed included physical and chemical soil variables such as soil texture, bulk density, infiltration rate, water holding capacity, pH and Electro-Conductivity (E.C), organic matter, soil organic carbon, nitrogen, phosphorus and potassium as per laboratory analysis procedure detailed by (Okalebo *et al.,* 2002)A total 56 and 28 soil samples were analysed for chemical and physical characteristics respectively.

Table 2.2 Summary of Soil Chemical Properties Analysis

Property	Methodology
Soil PH	Potentiometric (pH meter)
Electrical conductivity	Potentiometric (Conductivity meter)
Total nitrogen	UV- Spectrophotometer
Soil Organic Carbon (SOC)	Walkley Black/Loss on Ignition
Organic Matter	Loss on Ignition
Extractable phosphorus	UV- Spectrophotometer
Potassium	Atomic Absorption Spectrophotometer (AAS)/EDX Fluorescence

Table 2.3 Testing Methods for physical properties

Property	Methodology
Infiltration rate	Anderson and Ingram (1993) and Okalebo et al (2002)
Water holding Capacity	Anderson and Ingram (1993) and Okalebo et al (2002)
Soil moisture analysis	Anderson and Ingram (1993) and Okalebo et al (2002)
Texture /particle size analysis	Hydrometer method of Bouyoucos (1962)
Bulk Density analysis	Methods of Blake (1965) and Hinga et al (1980)

The result of the analysis was utilized to estimate soil organic carbon for from the water tower. The findings were also used to determine the spatial and temporal variability of soil nutrient within the Water Tower ecosystem and to assess the suitability of different sustainable land management (SLM) practices. This was important in designing efficient nutrient management for land use within the buffer zone.

2.6 Data Analysis

The similarity of sampled plots in terms of shared species was evaluated using Non-metric Multidimensional Scaling (NMDS), cluster linkages and similarity percentages (SIMPER). All these parameters generated using PRIMER software utilizes square root transformation of the Bray-Curtis Euclidean similarity distances. The NMDS provides a simple graphical presentation of sites' similarity based on location of samples on the plot space. The nearer the sample to each other, the higher the similarity while the wider the gap, the lower the similarity. The 22 samples of Nzaui were plotted on a NMDS graph, to observe inter and intra relationship status, regarding individual samples and sampling site level

CHAPTER THREE

3.1 Study Findings

This chapter describes the results based on the objectives of the study. The results presented are the socioeconomic characterization of the sampled population, direct forest use values by the local community, indirect use and non-use values and the estimate values for regulatory and cultural values i.e. Total Economic Value (TEV). The report presents result in this sequence; socioeconomic and market survey; floristic and structural status of higher plants as and habitat disturbances; and total economic value to include provisioning services; regulatory services (below and above ground biomass and organic carbon); support services and cultural services derived from Nzaui Water Tower.

3.2 Socio-Economic Survey

3.2.1 Household Characteristics

The survey covered Nzaui Water Tower Ecosystem in Makueni County, Nzaui Sub-County where 284 of the households were sampled in Kilili (37.5%), Kalamba (39.2%), Kawala (22.6%) and Mumbuni (0.7%) location in 54 Villages. The household sampled were female (53.2%) while 46.5% were male. Majority of the sampled households were married 66% with single and widowed accounting for 16% respectively. Separated families account for 1.4% with the minority divorced and cohabiting accounting for 0.4% respectively of the sampled household.

Table 3.1 Respondent Age

Respondent Age	Frequency	%
18-30	62	21.8
30-45	94	33.1
45-60	86	30.3
More than 60	40	14.1
No response	2	0.7
Total	**284**	**100.0**
(Source: socio-economic 2019)		

The majority of HH respondents sampled were between 30-45 years (33.1%) followed by 45-60 years (30.3%) (**Table 3.1**). There was a literacy level variation between male and female Men had higher literacy compared to women. Mof the women (83%) had never attended school **(Figure 3.1).**

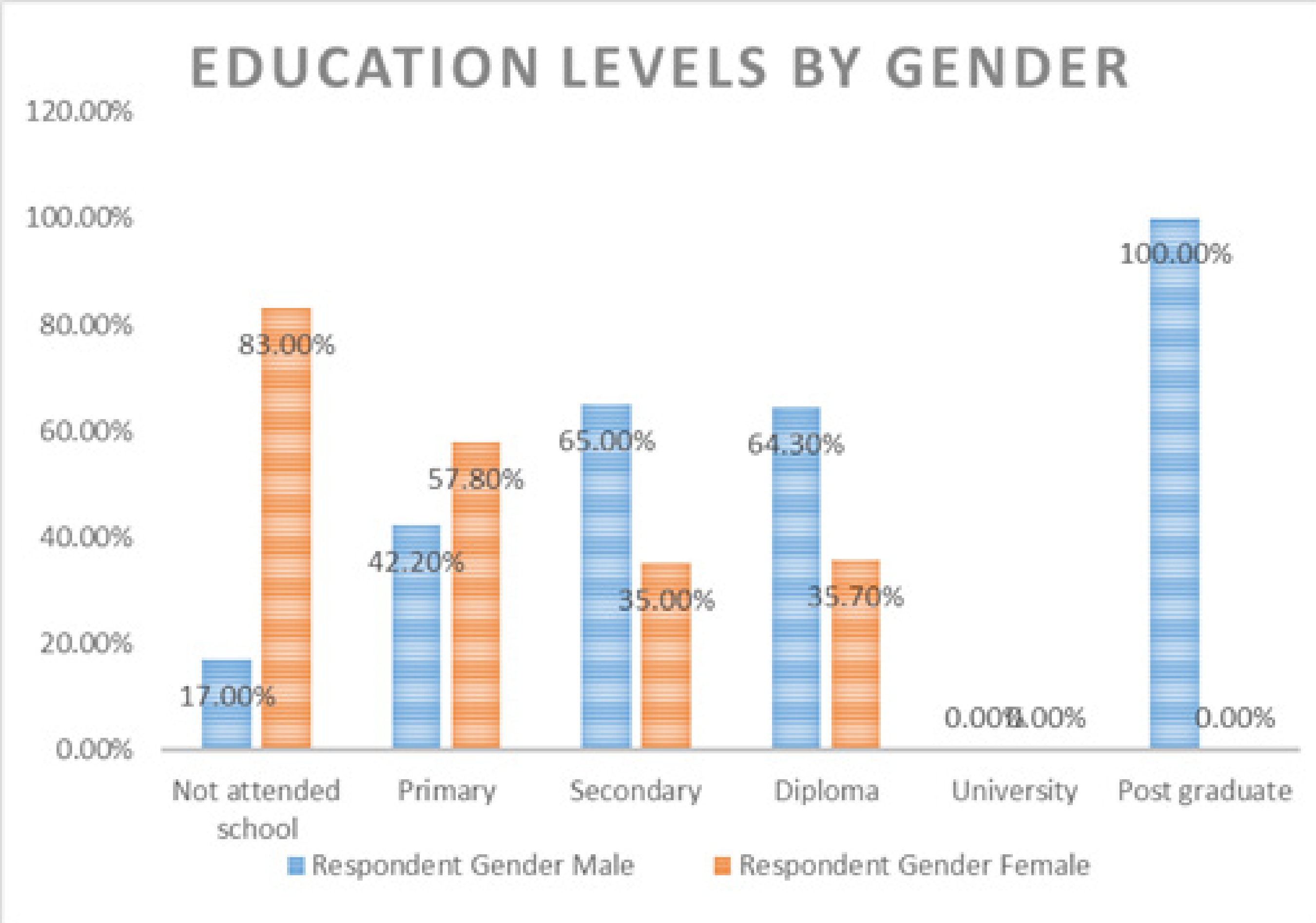


Figure 3.1 Level of Education in Nzaui Sub-County

Employment Status

53.9% of respondents were government employees, 26.1% were casual labourer and 11.6% self employed (Table 3.2). Most of the respondent indicated agriculture (46.3%) as their main profession. This was attributed to fact that the Nzaui Ecosystem has climatic conditions that favour agricultural production . 25.1% of the respondents were business people. (Table 3.3). Other professions included construction, banking, driving and community leadership.

Table 3.2 Employment Status

Employment Status	Frequency	%
Not engaged in any formal employment	10	3.5
Employee of private institution/Agency	10	3.5
Self Employed	33	11.6
Casual labourer	74	26.1
Government Employee	153	53.9
Retired/Pensioner	3	1.1
No response	1	.4

Table 3.3 Household Profession

Profession/Interest	%
Economist/Financial	.7
Agriculturalist	46.3
Business oriented	25.1
Social right activist	.7
Local community	5.7
Hospitality industry	.7
Educationist	2.1
Others	18.7

Household Income

In terms of income, majority (46.6%) of the households had a monthly income of between Ksh. 0-4999 and KES. 5000-10000 (25.8%) with a few having an income over KES. 30000 (**Fig. 3.2**).

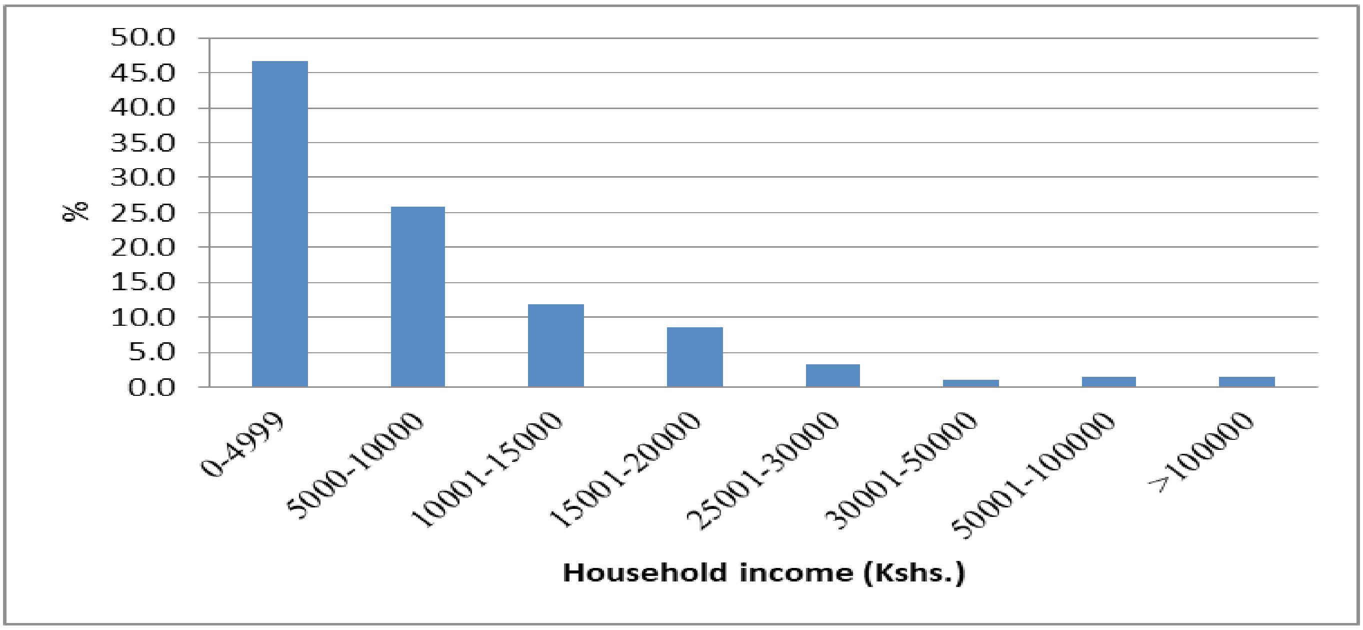


Figure 3.2: Respondent Household Income.

3.2.2 Income Generation Activities

55% of the households practiced crop farming as the main income generation activity. 13.4% practiced animal rearing and 16.9% practiced mixed farming of crops and livestock as the while nature based enterprises were practiced by 2.8 % (**Fig. 3.3**). Similarly, different HH's generated somerevenue from milk and other livestock products. Bee keeping was practiced on small scale despite the areas' great potential for bee keeping. Butterfly farming, herbs and spices are not practiced as income generation activities within the area.

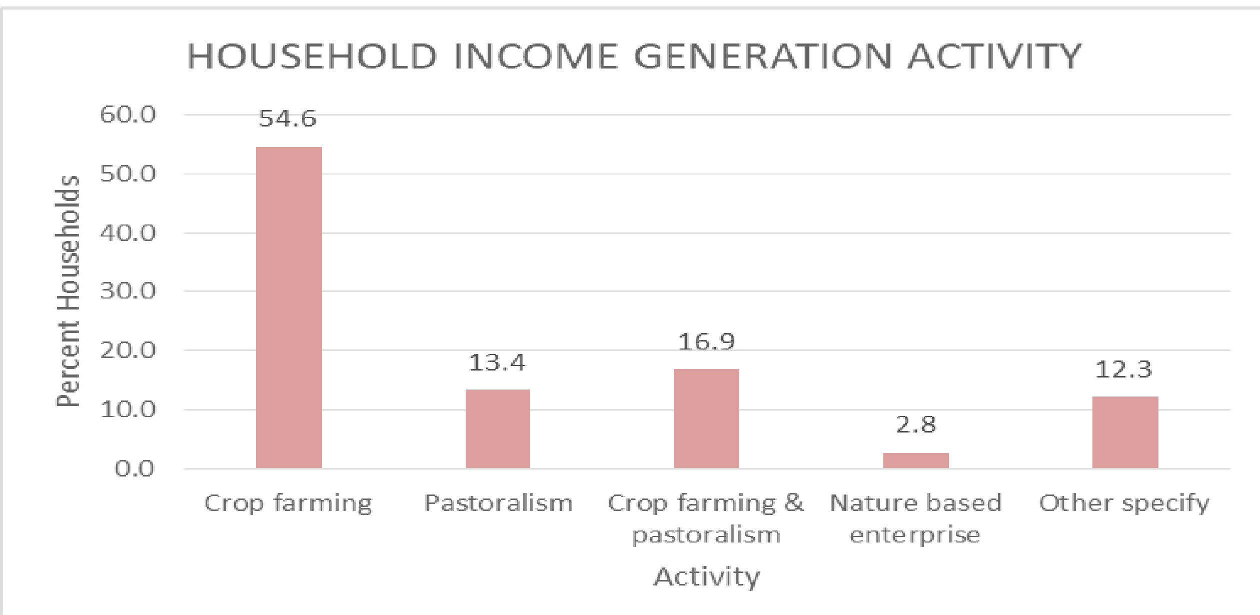


Figure 3.3: Household Income Generation Activity

The research revealed that 53% of the HH practiced food crop farming and 46% practiced fruit farming for commercial purposes. The production within the HH differed considerably with 17% producing less than 100Kg, 10%, 7% and 6% producing between 101-200, 201-300 and 301-400 respectively per season (**Fig. 3.4**). 77% of the household did not sell any produce. About 12% earned less than KES 10,000 fromsale of surplus food crops. 4% earned between KES 10,000 and 20,000 and another 4% earning more than KES 30,000 monthly. This low production was attributed to the small land sizes owned by the farmers averaging 1-3acres (Makueni County CIDP).

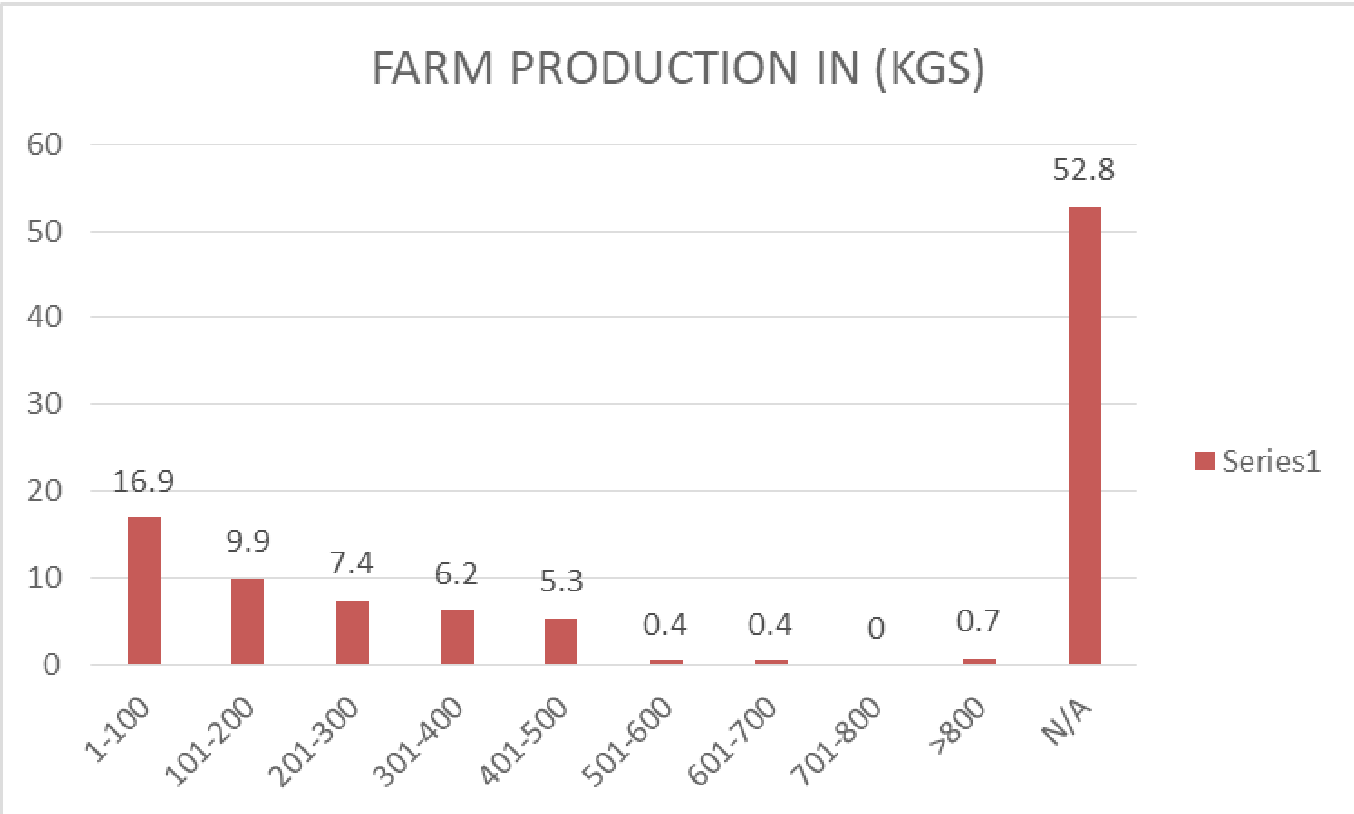


Figure 3.4: Farm production

Fruit cash farming generated income to the community at different seasons of the year. The main fruit trees were pawpaw, Vicks, mangoes and oranges. The trees are grown together with other food crops and re harvested in different seasons. 7.8 % of the HH who sold the fruits earned more than KES 30,000 monthly. Although alarge number responded that the question was not applicable observation revealed majority of the HH engaged in fruit farming and thus generated income from them. The majority (85%) did not have records of income from the cash crops/fruits captured though through observation they owned fruit trees. About 8.5% earned less than KES 10,000 monthly from the cash crops (**Fig. 3.5**).

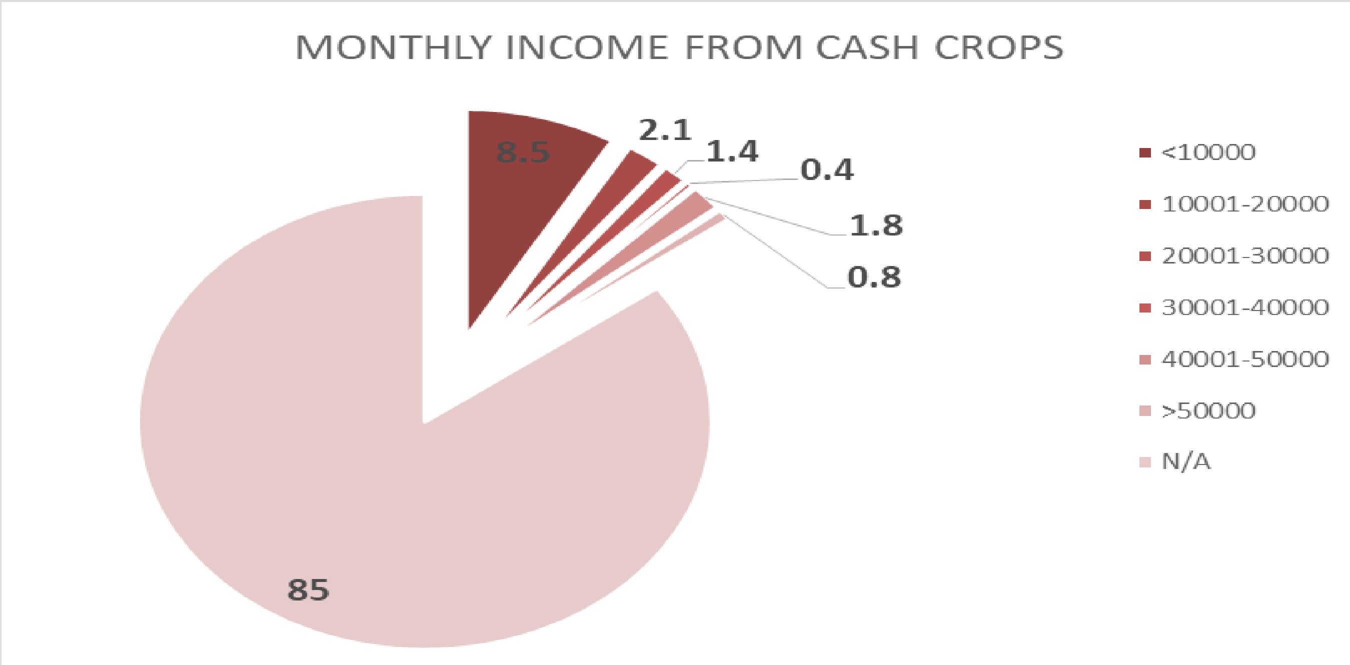


Figure 3.5 : Monthly Income from Cash Crop

Household Resource Extraction and Use

Table 8 present findings of household extraction and use of Water Tower resources. These include direct use resources such as wood and non-timber forest products that household derive from the Water Tower Ecosystem as presented in table 3.4 below

Table 3.4: Household Water Tower Resource Extraction and Use

Resource Extracted	Level of Extraction and Use
Industrial Wood	The findings show that 98% of the HH respondents do not collect industrial wood. Only 2% collected the industrial wood for domestic (1.4%) and sale purposes (0.7%). The industrial wood collected is obtained from household farm (1.1%), state forest (0.7%) and 0.4% from customary land with the mode of transport being head load, vehicles and bicycles. The time taken to collect the industrial wood from the source was indicated to be between 3-5 hrs (1.4%) with 0.7% taking 1-2 hrs. The average quantity harvested per month is 20 pieces and average value of the industrial wood per unit on a year analysis at Ksh. 30,000. There was no substitute for the industrial wood of the household sampled.
Timber	Only (1%) of household collected timber for domestic purposes normally obtained from the state forest (0.7%) and household farm (0.4%). The modes of the transport used for the timber from the source include head load, motorcycle and vehicles according to 0.4% of the respondents indicate percentages if you are to use respectively. The average time taken to collect the timber is between 3-5 hrs (0.7%) with 0.4% of the respondent indicating to take more than 5 hours. The average quantity of the timber collected is about 20 pieces with the highest collecting 500 pieces per month. The average value per unit on a year analysis is Ksh. 23 per feet and annual cost of Ksh. 30,000. No substitute was mentioned for the timber.

Resource Extracted	Level of Extraction and Use
Fuel wood	Most of the household (63.1%) collected fire wood. The main purpose of the fuel wood collected is for domestic use (60.6%) and for sale (2.1%). Fuel wood is mainly obtained from household farm (41%), state forest (10.2%) and customary land (7%) with 4% from all the three sources (HH farm, state forest and customary land). The mode used to transport fuel wood from the source is mainly head load (41.5%) followed by back load (16.5 %). The time taken to collect range between half-one hours (27.5%) according to the majority of the respondents.The average quantity of the fuel wood collected per month is 1-5 back loads with the average value of KES. 200 per backload on a year basis. The main substitutes for the fuel wood are gas, paraffin and charcoal which are purchased from local market and charcoal obtain from house hold farm respectively. Average quantity of the substitutes include 2-6 kg of gas, 1-3 litres of paraffin and 1-5 sacks of charcoal per month with an average cost of KES. 1,000 per unit.
Charcoal	10.9% of the households s sampled harvest charcoal for both domestic and sale accounting for 8.1% and 2.5% respectively. Charcoal was mainly obtained from house hold farms (4.6%). Head load was the main mode of transport. The average time taken to harvest charcoal was between 3-5 hrs, with average quantity ranging between 1-5 sacks per month. The average amount of charcoal per year ranged between KES. 750-1,000 per sack. Gas and paraffin were used as substitutes for the charcoal that were purchased from local market. The average gas used was 6kgs with the cost ranging between KES. 1000-1050 and 1 litre of paraffin at KES. 160 per litre in a month respectively.
wood carvings	No wood for carvings was collected or harvested
Wood for poles	Most of the respondents (99.6%) did not collect wood for the poles. The few that (percentage) obtain it for domestic purposes and head load used as the mode of transport. With only 15 poles per reqired for house construction no estimated time was indicated by the respondent and no substitute for poles that was mentioned.
Fruits/Nuts/ Seeds/Roots/ Berries	Fruits, nuts, roots and/or berries were collected/harvested by 10.3% of respondents where Fruits obtained are for sale stood at (8.1%) and domestic consumption (2.1%). Most of these fruits are obtained from house hold farms and state forest. The main mode of transport being head load (4.2%). Other modes of transport included use of basket, wheel barrow and pocket. The average time taken was between half and an hour. The average quantity of fruits/nuts/roots/berries collected per month ranged from 500-2000 kg with an annual average value of KES. 20, 000-40,000.
Mushrooms	About 2% of the respondents harvested mushroom for domestic purposes mainly from house hold farms. The average time taken to collect/harvest was between 1-2 hours with 1kg on average being collected/harvested only during the rainy season. The value of mushrooms per unit on a year was KES. 120 per Kg

Resource Extracted	Level of Extraction and Use
Fodder	About 23.5% of HHs collected/ harvested fodder for both domestic (22.9%) and sale (0.4%). Household farm (18.3%) was the main source of the fodder, followed by customary land and community forest accounting to 2.1% respectively. Head load was the main mode of transport. Other mode of transport included back load and use of wheelbarrow. Majority of HHs took between 1-2 hours to collect/harvest the fodder with an average quantity of 30-60 bales collected per month earning an annual average of KES. 10,000-20,000. Grazing on household farm was one of the fodder substitutes with an average consumption of 70sq. metre per month.
Rattan	No rattan was collected or harvested
Plant medicines	Few HHs (6%) collected plant medicines for domestic purposes mainly from state forest. Head load was used as the mode of transport. Other modes of transport include pocket, paper bag and use of basket. The average time taken to harvest or collect the plant medicines was half an hour (2.8%) followed by 1-2 hours (2.1%). About 1kg on average was collected with an annual average of KES.100-120per unit. No appropriate substitutes for the plant medicines were stated.
Herbs and spices	0.4% of the respondents collected herbs and spices for domestic purposes from their farms. Bowl being used as the mode of transport. The average time taken was half an hour and an average quantity of 1Kg per month. The herbs and spices were not sold and did not have substitutes.
Seeds collection	Seeds were collected by a few of the households' (2%) for domestic and sale purposes. The source of the seeds wasfrom state forest (1.1%) and household farm (0.7%). Motorcycle was the mode of transport used. Other modes included use of pocket, paper bag and basket. The average time taken to collect seeds was between 1-2 hours and 3-5 hours to 0.7% respectively. The average quantity collectedwas between 1-5 kg with average annual value of KES. 5 per 1Kg.. The respondents indicated packed seedlings sourced from agro vets and shops to be substitutes for the seeds collected. The cost to obtain the substitute was stated at KES 200 per kg.
Fibre/Withies (for rope)	6.7% of the households collected fibres/withies for domestic use (4.9%) and sale (1.8%). These were mainly obtained from household farms and head load was used as the mode of transport. Other modes of transport were backload, basket and hand load. The average time taken to collect the fibre from the source was about 1 to 2 hrs. The average quantity collected varyied between 10-60 pieces per month with average value of KES. 20 per rope.
Wildlife products	No wildlife products were collected or harvested
Honey collection	5% of households collected honey for domestic (2.1%) and sale (1.4%). Honey collection was mainly obtained from household farms, customary land and community land. mode of transport included use buckets. The average time taken to collect honey was between 1-2 hours with average quantity collected per year ranging from 10- 20Kgs at ksh. 650 average value per Kg.

Resource Extracted	Level of Extraction and Use
Butterfly farming	No butterfly farming was carried out
Essential oils	No essential oils were harvested
Gem/Resin	No essential oils were harvested
Thatch grass	Thatch grass was collected for domestic purpose and was obtained from household farm and community forest. The main mode of transport used is head load, donkey, cart and back loads. The average time taken to collect is between 1-2 hours at an average quantity of 10 bales. Iron sheet used as a substitute for thatch grass is sourced from local market with an average of 7-13 sheets being used per month at an average cost between Ksh.1200-1500 per unit.
Green energy	Green energy was harvested for domestic purpose obtained from household farms. Average quantity harvested per month from the solar panel being 100watts.
Handcrafts	No handcrafts were collected/harvested
Others	Manure was collected for purposes of soil fertility improvement mainly obtained from community forest and state forest. Wheel barrow and head load were the main mode of transport. The average time taken to collect the manure ranged between 2-3 hours at an average cost of Ksh.100 per wheel barrow.

3.3 Market Survey

The most common forest based products found in the local markets (Wote, Matiliku, Kalamba, Enziu etc.) included timber 18.4%, charcoal 13.6%, sisal ropes 10.5%, industrial poles 7.9%, grass sweeper brooms, and fire wood each 5.2%, tree seedlings, fruit seedlings, grass seedlings, shoe repair needle's handles, wooden beds, axe handles, thatch grass, jembe/axe handle, cooking sticks, honey, water and puree each at 2.63%. Forest products sourced from Nzaui were sold in the nearby markets. The market price shows the willingness for people to pay for forest products. The market survey was carried out in different markets including Wote market which is the largest market in Nzaui, Matiliku Market, Kilili Market, Mutulani Market and Kalamba Market. Goods in Wote market and the village markets varied in prices. Goods sold in Wote market fetched higher price than the village markets due to additional transport cost and higher demand

3.4 Plant Assessment

This section presents floristic and structural status of higher plants as well as threats to plants and habitat and level of disturbances. It also presents the status on plant diversity, community association, evenness of distribution and species richness in the Water Tower. Forest structural features such as basal area, canopy, and the population structure were utilized to understand forest transitional growth and its productivity potential in the context of sustainability as well as support valuation analysis pegged on indicators.

A total of 22 circular plots measuring 625 m^2 were demarcated for vegetation sampling. Within the entire area, woody plants with diameters exceeding 5cm were identified and recorded. Diameters at breast height (DBH) were measured at 1.3 meters from ground, whereas reference heights were determined using a Suunto clinometer and thereafter estimated. Saplings or small regenerating plants were sampled in single nested plot measuring 100 m^2. A total of 22 such plots were sampled. Here, all individuals that exceeded 1.3 m and were below 5 cm DBH were enumerated. Seedlings and herbaceous vegetation were sampled in 5 nested plots measuring 1 m^2 on the peripheries and centre of the major plot. A total of 110 such plots were sampled. The difficult-to-identify specimens were collected for further identification at the East African Herbarium, National Museums of Kenya.

Indicators that suggest habitat disturbance were quantified in each plot. Other important descriptions and observations were also recorded.

3.4.1 Plant Composition and Diversity

Multiple habitat types observed in Nzaui forest and the surrounding buffer has enabled a high plant diversity. As the team traversed the ecosystem, mosaics formed by variable vegetation types were observed. On the higher elevations, patches of mature plantations of *Eucalyptus* and *Pinus* were alternately interspersed amid larger proportion of mixed indigenous forest. High and closed canopy sections were rarely encountered, and in most cases if they were, constituted exotic plantations.

On several sections of the Nzaui hill, almost pure stands of Palm *(Phoenix reclinata)* occur on large tracts, whereby a fern - *Pteridium aquilinum* - dominated its ground. On few other upland sections suspected to have had past fire incidences, there were formations of *Pteridium- Triumfetta brachyceras* thickets, with signs of vegetation recovery. On the lower slopes of Nzaui, the vegetation type was mainly scrubland/ bushland, with dominance of *Croton dichogarmus, Gnidia latifolia, Dichrostachys cinerea, Combretum sp.* and the invasive *Lantana camara.*

This survey yielded 388 species belonging to 259 genera and 79 families. Leguminous plants were the most dominant followed by Graminae (Poaceae), Compositae (Asteraceae), Euphorbiaceae and Rubiaceae figure 9 belwo.). 28 families (35%) contributed to single species each. Species with highest frequencies in descending order included *Combretum molle, Lantana camara, Rapanea melanophloeos, Psidium guajava, Croton megalocarpus, Dichrostachys cinerea, Solanum cacampylacanthum, Clausena anisate, Flueggea virosa and Indigofera arrecta* (Figure 3.6 & Table 3.5).

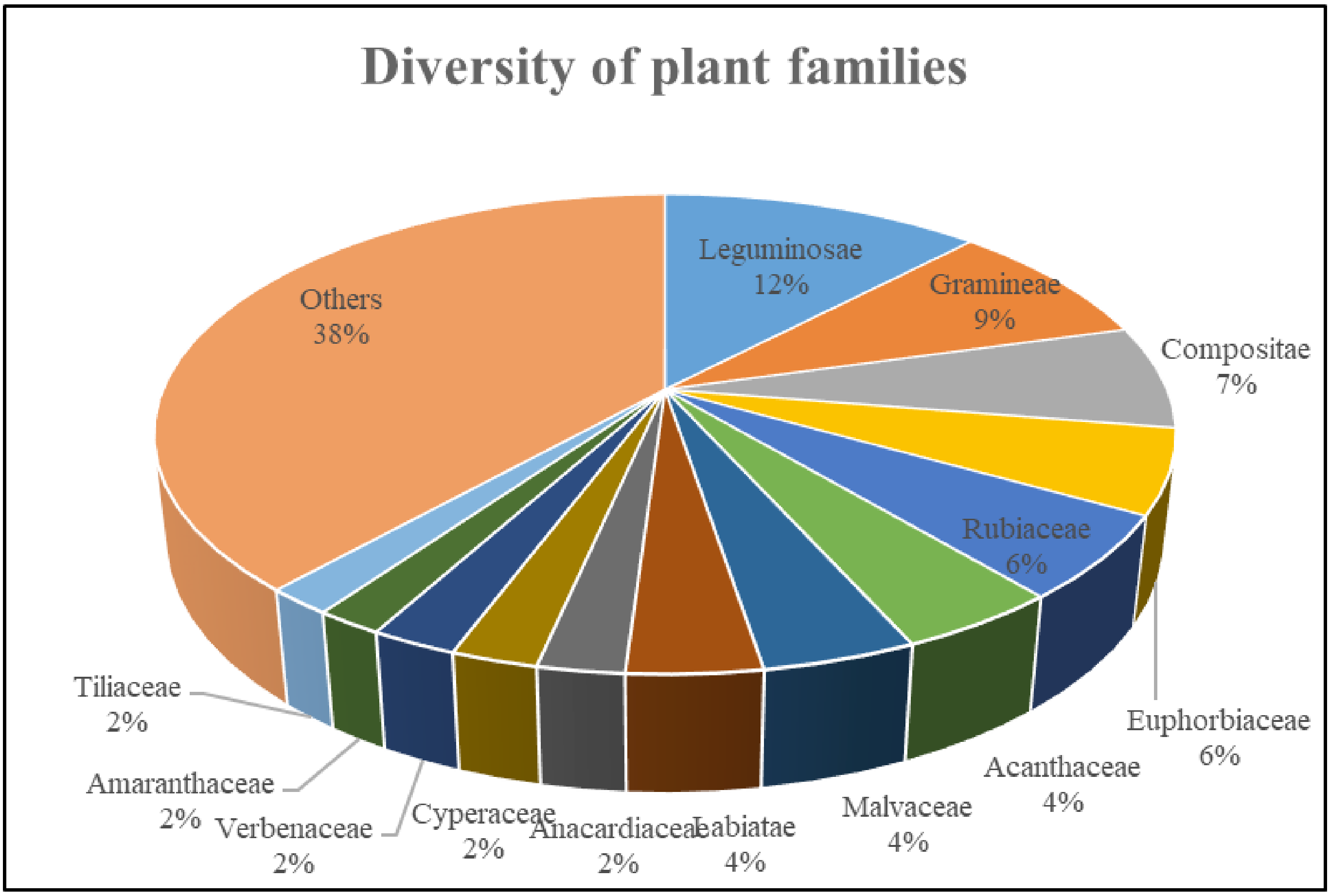


Figure 3.6 Diversity of plant families in Nzaui

Leguminosae, a wide family with distinctively unique sub-families, was also observed to vary within itself. The Papilionoideae was most represented (16 genera, 26 families). Mimosoidae contributed to 5 genera and 13 species while Caesalpinioideae had 3 genera and 8 species.

Table 3.5 Plant families' contribution to genera and species

Family	No. of genera	No. of species	Family	No. of genera	No. of species
Gramineae	22	33	Portulacaceae	2	2
Compositae	20	27	Proteaceae	2	2
Leguminosae-Papilionoideae	16	26	Santalaceae	2	2
Rubiaceae	15	22	Commelinaceae	1	5
Acanthaceae	11	17	Moraceae	1	4
Euphorbiaceae	10	22	Ochnaceae	1	4
Labiatae	9	14	Asparagaceae	1	3
Verbenaceae	7	9	Burseraceae	1	3
Amaranthaceae	7	7	Cupressaceae	1	2
Malvaceae	5	16	Solanaceae	1	2
Leguminosae-Mimosoideae	5	13	Actiniopteridaceae	1	1

Family	No. of genera	No. of species	Family	No. of genera	No. of species
Anacardiaceae	5	9	Aizoaceae	1	1
Cyperaceae	5	9	Anthericaceae	1	1
Capparaceae	4	6	Araliaceae	1	1
Vitaceae	4	6	Balanitaceae	1	1
Cucurbitaceae	4	5	Colchicaceae	1	1
Apocynaceae	4	4	Dennstaedtiaceae	1	1
Asclepiadaceae	4	4	Geraniaceae	1	1
Sapindaceae	4	4	Icacinaceae	1	1
Leguminosae-Caesalpinioideae	3	8	Lobeliaceae	1	1
Convolvulaceae	3	6	Myrsinaceae	1	1
Meliaceae	3	4	Oleaceae	1	1
Myrtaceae	3	4	Palmae	1	1
Sterculiaceae	3	4	Passifloraceae	1	1
Adiantaceae	3	3	Pedaliaceae	1	1
Annonaceae	3	3	Pinaceae	1	1
Boraginaceae	3	3	Pittosporaceae	1	1
Flacourtiaceae	3	3	Plumbaginaceae	1	1
Rhamnaceae	3	3	Polygalaceae	1	1
Rutaceae	3	3	Polygonaceae	1	1
Tiliaceae	2	7	Pteridaceae	1	1
Combretaceae	2	5	Ranunculaceae	1	1
Celastraceae	2	4	Rosaceae	1	1
Bignoniaceae	2	2	Sapotaceae	1	1
Crassulaceae	2	2	Simaroubaceae	1	1
Ebenaceae	2	2	Smilacaceae	1	1
Hyacinthaceae	2	2	Thymelaeaceae	1	1
Loranthaceae	2	2	Ulmaceae	1	1
Menispermaceae	2	2	Umbelliferae	1	1
Nyctaginaceae	2	2	Urticaceae	1	1
Orchidaceae	2	2			

3.4.2 Life Form Spectrum of Plants

In general, the Nzaui ecosystem can be described as open canopied due to domination by herbs (59%) and shrubs (30%). A very low proportion of trees was recorded (11%). From ground information, most of the covered area was recorded as open shrublands. With high penetration of sunlight, herbaceous vegetation would be expected to dominate. In comparing the two main sites sampled, the Water Tower buffer, i.e. outside the forest was dominated by herbs than the forest, as expected. In the forest, shrubs were almost as equally dominant as herbs. Trees were least dominant in both sites. (Figure 3.7, 3.8 & 3.9)

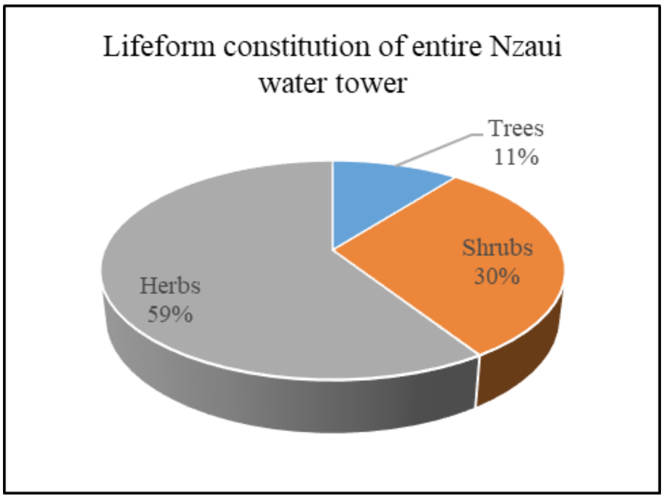


Figure 3.7 Life form of entire Nzaui

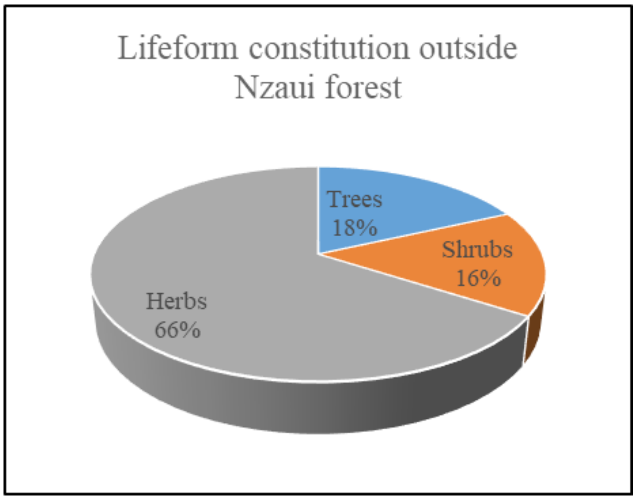


Figure 3.8 Life form outside Nzaui forest

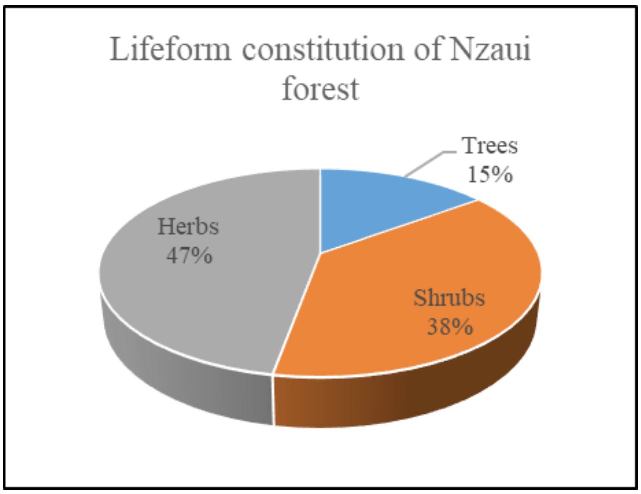


Figure 3.9 Life form constitution inside the forest

3.4.3 Species Accumulation Curve

The cumulative number of species recorded in the 22 plots sampled reached 388. However, the species accumulation curve generated did not reach asymptote (figure 3.10). This explains the high potential of Nzaui forest to yield more species with further exploitative sampling. More species were being recorded from plots outside the forest whereas accumulation rate of species in the forest plots was much slower. Lower species number inside the forest than in the buffer zone can be linked to various factors including a higher homogeneity in the forests, higher competition inside forest hence less survival of light demanding species or enriched plant diversity outside forests due to exotic and weed plants, among other possibilities.

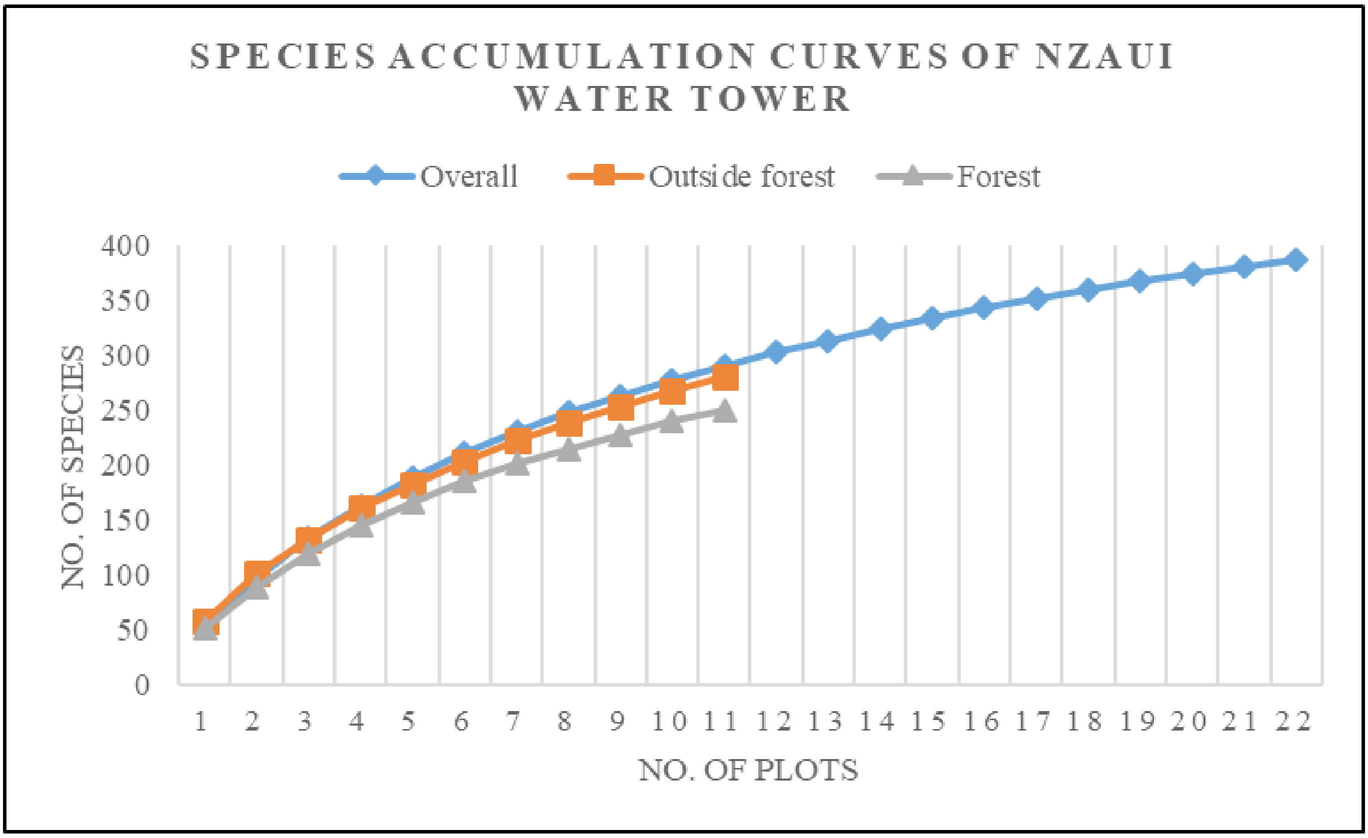


Figure 3.10 Species accumulation curves of Nzaui Water Tower

3.4.4 Biodiversity Measurement

In general, there was a high plant diversity in Nzaui, where a Shannon-Wiener diversity index of 5.2 was realized (Few plant assessments reaches 5). Despite having a lower number of species and richness, diversity of plants inside the forest was found to be higher because its species were more evenly distributed than in the buffer area (outside plots). Table 3.6 below shows the various attributes that describes plant diversity in Nzaui.

Table 3.6 Measures of biodiversity in Nzaui

	Outside forest	Forest	Overall
No. of species (S)	281	250	388
No. of individuals (N)	1099	1051	2150
Richness (d)	39.99	35.79	50.44
Evenness (J')	0.84	0.88	0.87
Diversity (H')	4.75	4.87	5.17

Similarities and Similarity Percentages (SIMPER)

There was a clear segregation of forest samples from samples of outside the forest, indicating some level of uniqueness of both sites. Samples outside the forest shared closer similarity among themselves whereas forest samples (despite an outright segregation).were not as closely related as of the buffer. Three forest samples were outliers, and were unique from others.

Non- metric Multi Dimensional Scaling (NMDS) of samples

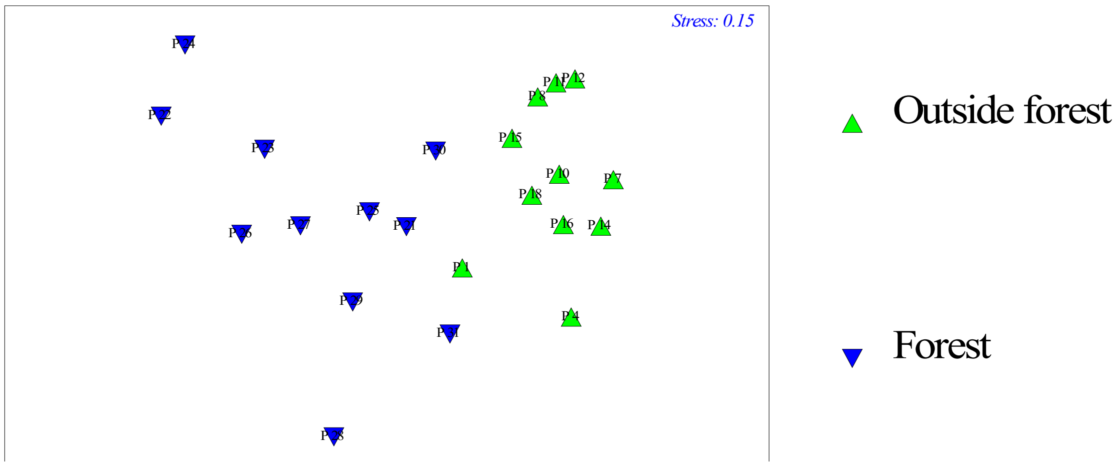


Figure 3.11 NMDS ordination of Nzaui Water Tower samples

Group average linkages

Hierarchical linkage based on species composition is drawn from first point of separation, where two of the three outlier sample plots delink from the rest at nearly 10% similarity. Plot pairs with highest closeness have similarity of over 40%. At the centre of cluster linkage, (nearly all) plots of the two site are shown to delink.

Group average similarity linkages between plots

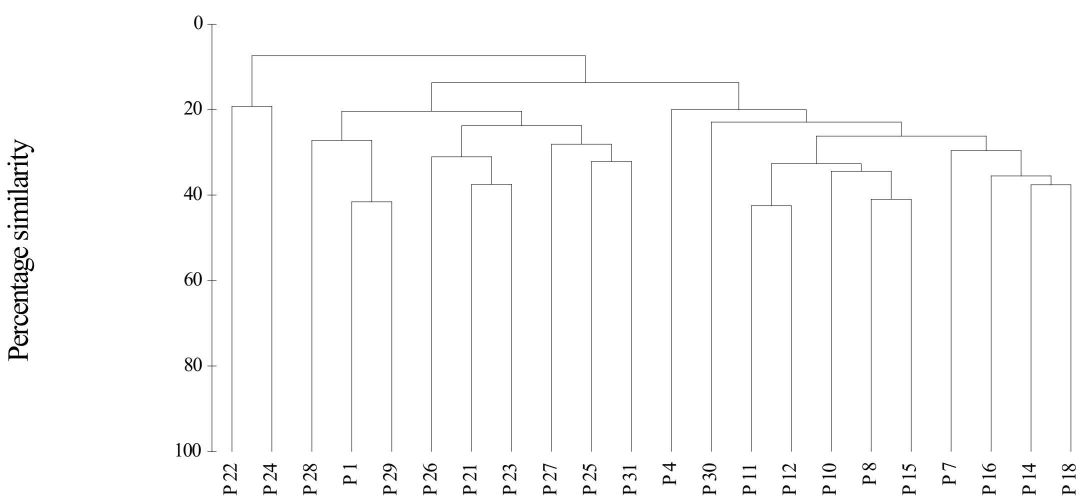


Figure 3.12 Group average similarity linkages between plots

Similarity linkages formed by Nzaui Water Tower samples

SIMPER ranks the lists of species that contribute most to percentage similarity (within sites) or dissimilarity (on pairwise comparison of sites). In the forest site where the average similarity is 17%, the species that contribute most to similarity include Lantana camara (17%), Triumfetta brachyceras (8.5%), Indigofera arrecta (4.8%), Clausena anisate (3.7%) and Ochna insculpta (2.7%). In outside forest plots where similarity average was 21%, species contributing most to similarity included *Solanum cacampylacanthum* (10.6%), *Lantana camara* (4.8%), *Maytenus putterlickioides* (3.8%), *Terminalia brownie* (3.7%) and *Indigofera arrecta* (3.3%). In comparing outside and forest sites where dissimilarity was at 90%, the following species were found to contribute most to their dissimilarity: - *Solanum cacampylacanthum (6.4 %), Lantana camara (4.8%), Triumfetta brachyceras (2.3%), Croton dichogamus (2.2%) and Dichrostachys cinerea (1.8%).*

3.4.5 Diameter Class Distribution

In a tropical forest, there is always the difficulty to correctly estimate ages of trees unlike in temperate regions where analysis of annual ring cores can be employed. For this reason, observation of stem transition through different DBH classes serves as an alternative way to monitor ageing process of a given forest and check whether there is a healthy succession. When the population of trees of different diameter classes is plotted on a graph and the resultant curve is similar to an inverse-J shape, then the forest transition is good, hence sustainability. In the case of Nzaui, the inverse-J shape is not fully attained; rather something between it and an inverse-L shape. The 'younger' trees of DBH class 5- 15 cm dominate but sharply drop in the following 15-25 cm class and subsequent classes. Reasons for this can be speculative, especially with knowledge that Nzaui is a dryland forest and therefore most of its species could be restricted in growth by ecological requirements. This assumption may be supported by the fact that this survey did not encounter trees exceeding 60 cm in diameter unlike montane forests where trees > 100 cm can be abundant. It can also be due to over-exploitation and particularly, selective harvesting that target age group 2 (15- 25 cm). In such a case, a cascading effect of low tree population in the subsequent age groups can begin. If true, then this can be the reason why trees with diameters > 25 cm remain consistently low.

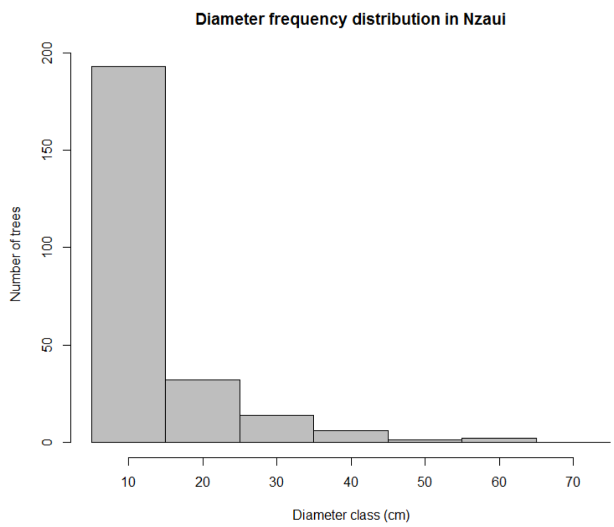


Figure 3.13 DBH class distribution of trees in Nzaui Water Tower

The diameter medians in the different sites, i.e. forest and outside forest was greatly influenced by their distribution patterns. At both sites, similar medians as well as lower and upper means were observed but level of variance differed. There was a high variance in the DBH sizes outside forest unlike inside forest. This may have resulted from the extremes of timber trees that are selectively left in farms to mature and the discarded fallows that are left with only small trees. Diameters in the forest were much closely related. The low variance in the forest meant minimal differences in diameters of trees across sample plots.

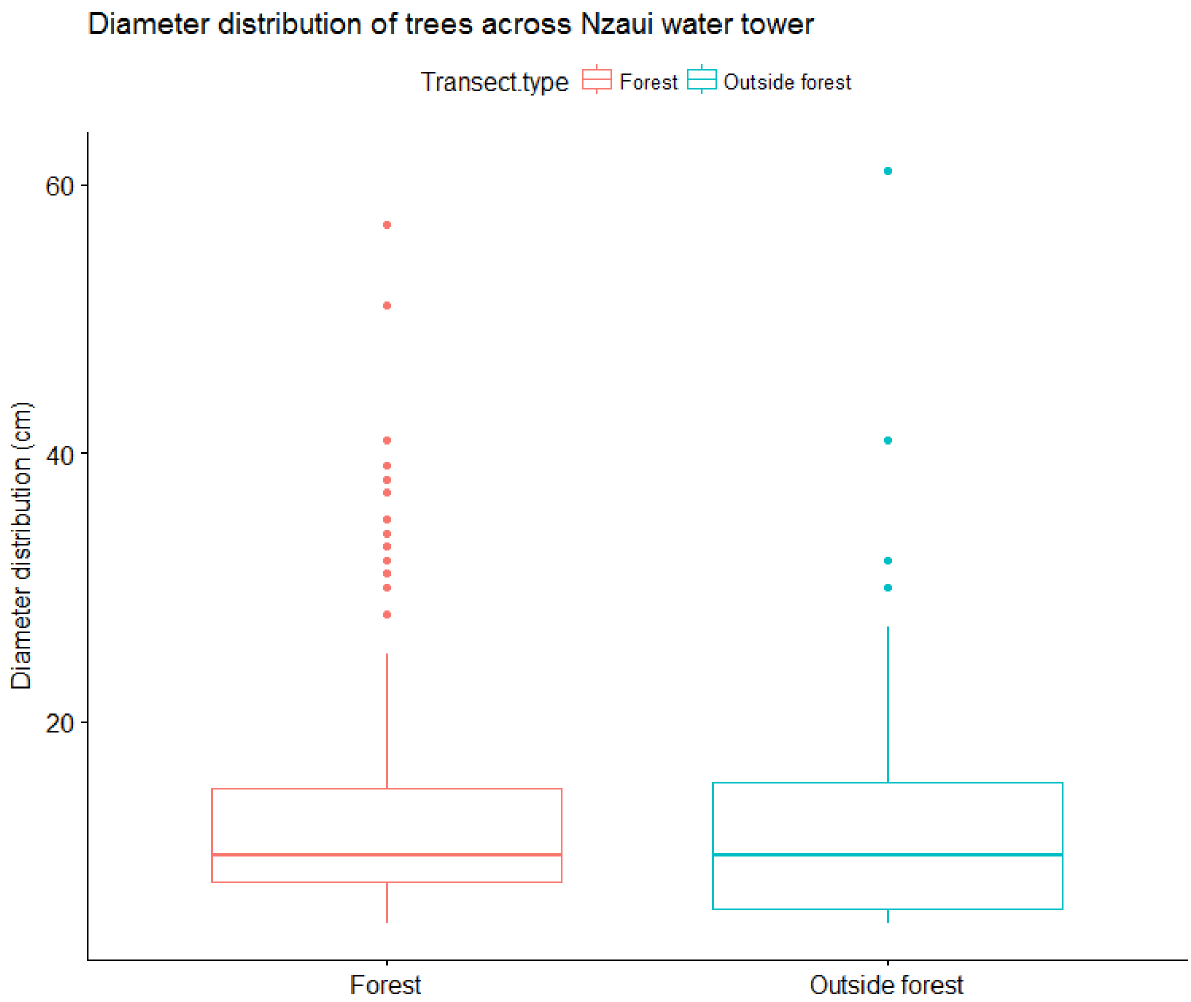


Figure 3.14 Distribution of tree diameters in Nzaui

3.4.6 Height Class Distribution

Nzaui ecosystem can be considered to be a short-statured forest. A greater proportion of trees fell in between heights of 4- 10 meters. Few trees grew beyond 10 meters and none reached the height of 25 m. Some of the trees whose heights were below 5 meters were pollard or broken due to natural causes.

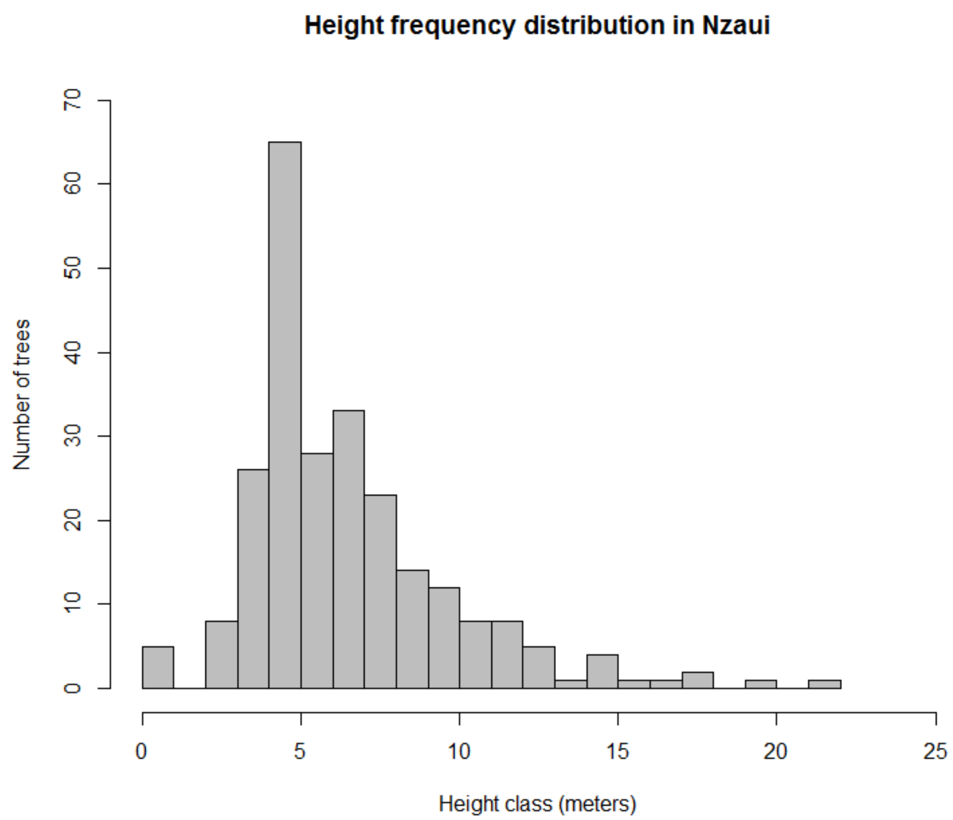


Figure 3.15 Height class distribution in Nzaui

Tree median height inside forest was highest compared to outside, with many of its heights distributed as outlies on the upper limit. Lowest and highest means/ observations were recorded in the forest, with a comparatively high variance than the outside. Despite the lower median height value outside forest, there was a low variance due to closer relationship between recorded heights there. Both sites had outlier upper heights but outside the forest recorded outlier height on the lower extreme, possibly due to mutilation.

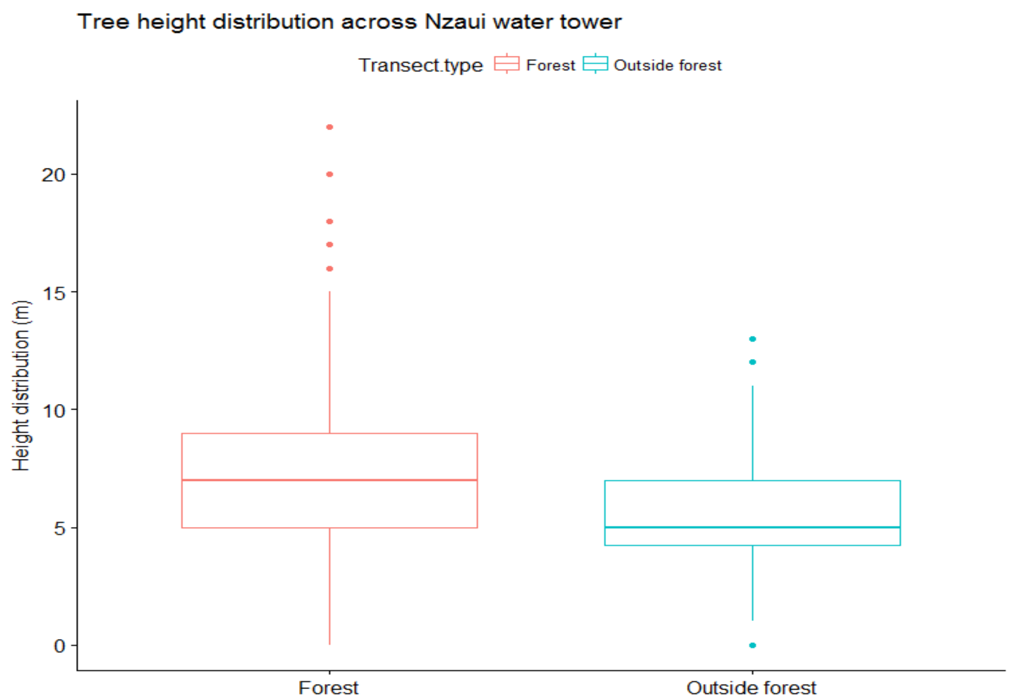


Figure 3.16 Tree height Distribution

3.4.7 Forest Structural Integrity and Productivity

A combined assessment of various factors such as important value index (IVI), basal area (BA), population structure, plant densities, regeneration ratios and observed extraction guided in understanding the production potential and gauging forest sustainability. The study sampled key forest health indicators (Table 3.7).

Table 3.7 Summary of measured parameters in Nzaui

	Measure of various parameters		
	Forest	**Outside forest**	**Overall**
Seedling density/ hectare	11818	5273	8545
Sapling density/ hectare	4391	4082	4236
Tree density/ hectare	246	115	180
No. of seedling species	21	12	29
No. of sapling species	77	46	106
No. of tree species	49	25	67
Tree basal area (m^2/ ha)	4.8	2.2	3.5
No. of measured trees	169	79	248

3.4.8 Important Value Index (IVI)

Important Value Index is a parameter that foresters utilize to rank tree species that are deemed 'most important' in formation of the forest structure and therefore points of focus in forest management exercises. The IVI is resultant of combination of three parameters namely, relative dominance, relative density and relative frequency. Table 3.8 below lists 15 most important tree species (and their IVI values) for the entire Nzaui and the two specific sites sampled.

Table 3.8: The list of the most important tree species in Nzaui

IVI Rank	List of trees with top IVI		
	Overall	**Outside forest**	**Forest**
1	*Combretum molle (18.9)*	*Psidium guajava (47.0)*	*Rapanea melanophloeos (25.2)*
2	*Rapanea melanophloeos (18.1)*	*Balanites aegyptiaca (24.7)*	*Acacia meansii (20.8)*
3	*Pinus patula (16.5)*	*Croton megalocarpus (23.9)*	*Pinus patula (20.2)*
4	*Psidium guajava (15.9)*	*Acacia tortilis (17.0)*	*Combretum molle (19.6)*

IVI Rank	List of trees with top IVI		
	Overall	Outside forest	Forest
5	*Acacia meansii (15.1)*	*Commiphora confusa (14.1)*	*Faurea saligna (11.5)*
6	*Croton megalocarpus (13.6)*	*Combretum molle (13.1)*	*Mangifera indica (10.9)*
7	*Balanites aegyptiaca (10.9)*	*Lannea schweinfurthii (8.6)*	*Cupressus lutitanica (8.9)*
8	*Mangifera indica (10.8)*	*Acacia hockii (7.9)*	*Eucalyptus sp. (8.4)*
9	*Faurea saligna (8.5)*	*Acacia polyacantha (7.0)*	*Croton sylvaticus (8.2)*
10	*Cupressus lutitanica (7.4)*	*Terminalia brownii (6.1)*	*Rhus vulgaris (7.6)*
11	*Lannea schweinfurthii (6.8)*	*Acacia nilotica (5.8)*	*Pittosporum viridiflorum (6.8)*
12	*Acacia tortilis (6.6)*	*Commiphora africana (5.7)*	*Markhamia lutea (6.7)*
13	*Eucalyptus sp. (6.1)*	*Mangifera indica (5.6)*	*Commiphora eminii (6.3)*
14	*Markhamia lutea (6.0)*	*Grewia plagiophylla (5.3)*	*Chrysophyllum sp. (6.3)*
15	*Chrysophyllum sp. (6.0)*	*Ficus natalensis (5.3)*	*Cordia africana (6.1)*

In consideration of the frequency of occurrence of the top 15 trees inside and outside the forest, and in overall, a few trees including *Combretum molle, Rapanea melanophloeos, Pinus patula, Acacia meansii, Croton megalocarpus, Balanites aegyptiaca* were regarded as the most important trees in terms of structural formation of Nzaui Water Tower. Presence of *Pinus*, a plantation tree in the list was due to the large diameters of individuals encountered.

To ensure structural integrity of the entire Nzaui ecosystem, sufficient stocks of most trees ranked at different growth stages needs to be maintained. In nature, regeneration of important trees is self-sustaining. However, factors such as grazing, fire, harvesting and changing climatic and environmental conditions may be hindrances. In such a situation, assisted regeneration may be necessary.

The population structures of some of the most important species was observed using dendograms to gauge their transitional health. To serve as guide, inverse-J shaped graphs were desired. It was observed none of the selected five had proper transition. Populations of these trees were also low. Excluding *Pinus,* none of the other species grew beyond 35 cm diameter.

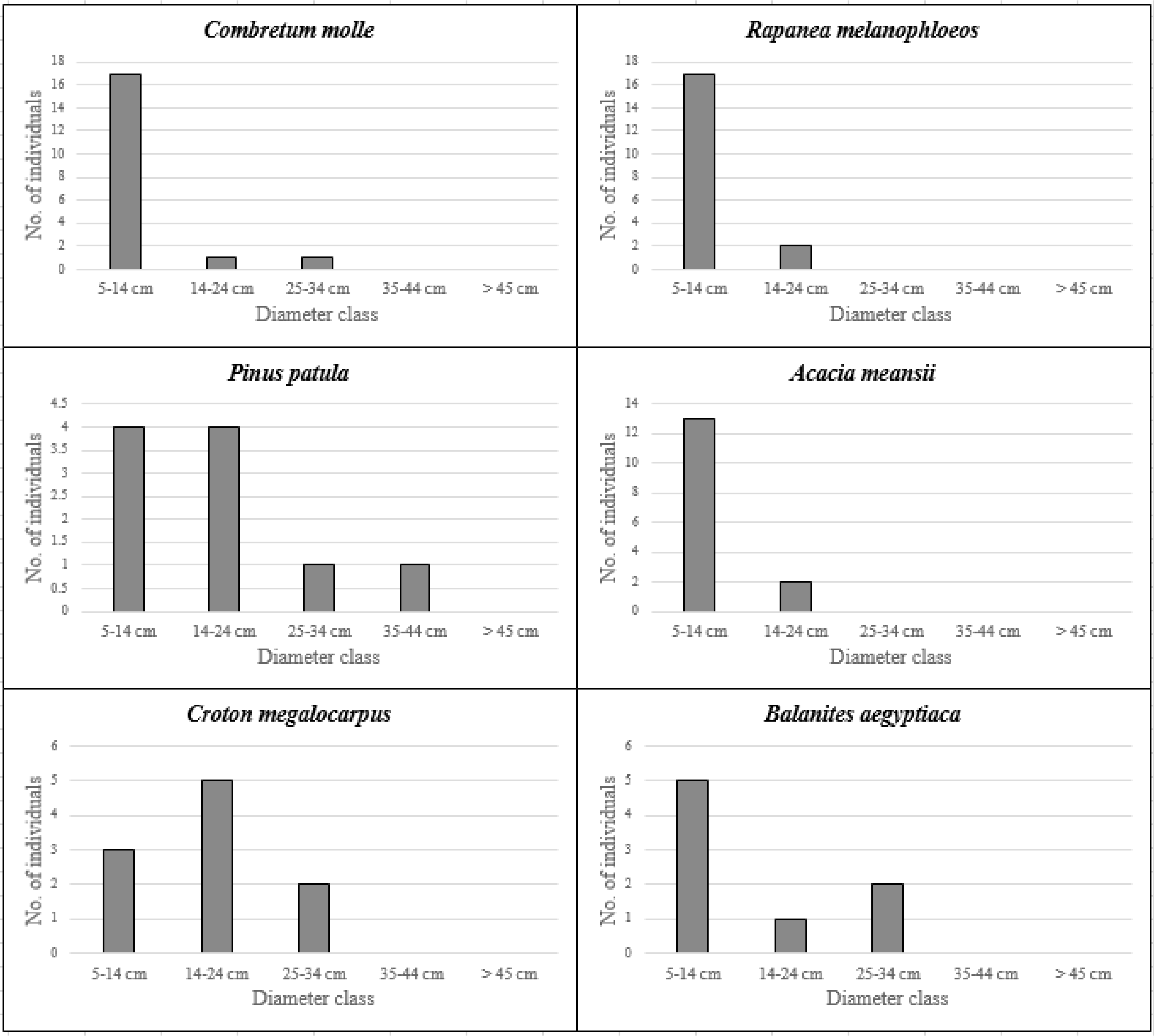


Figure 3.17: Population structures of some of the most important trees in Nzaui

3.4.9 Tree Basal Area (BA)

Basal area is defined as the total cross-sectional area of all stems in a stand measured at breast height, and expressed as per unit of land area. Trees in forest plots contributed highest total BA of 4.8 m^2/ ha while basal area in outside forest plots was 2.2 m^2/ ha. In average, Nzaui ecosystem has an estimated tree BA of 3.5 m2/ ha (figure 26). Inside the forest and in general, younger trees contribute the bulk of the BA, where the trend is seen to recede towards maturity. In the contrary, larger trees contribute to most BA outside the forests. The case of outside forest may be explain the tendency of land owners in the buffer area to selectively retain timber trees and remove smaller 'less usefull' indigenous plants.

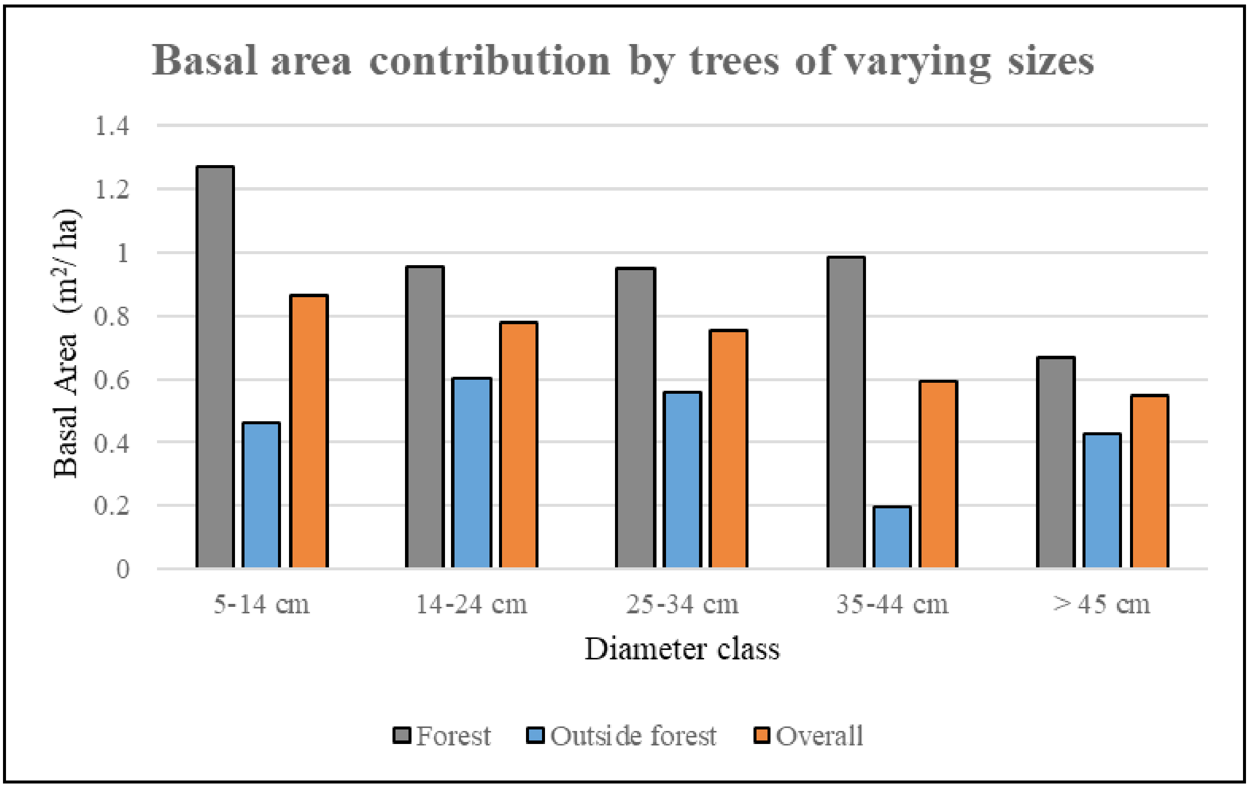


Figure 3.18: Basal area of different DBH classes in sampled sites

3.4.10 Sustainable Utilization

Sustainable Forest Management (SFM) can particularly succeed only when the population of merchantable trees categories are sufficient enough. Their sizes per unit area should be enough and the transitional growth should guarantee long-term sustainability. In Nzaui as shown in figure 27 below, the transition of density trend (blue line) may be depicting the inverse-J shape but the numbers are low for SFM to be initiated. Young trees measuring 5-15 cm, estimated at about 130 individuals per hectare with meagre BA of 0.95 m^2/ha is the most dominant group. Merchantable trees (DBH > 25 cm) each have small populations of < 20 individuals per hectare and a BA averaging just 0.6 m^2/ ha. With such observation therefore, there is need for intervention to boost forest production capacity before SFM concept is implemented.

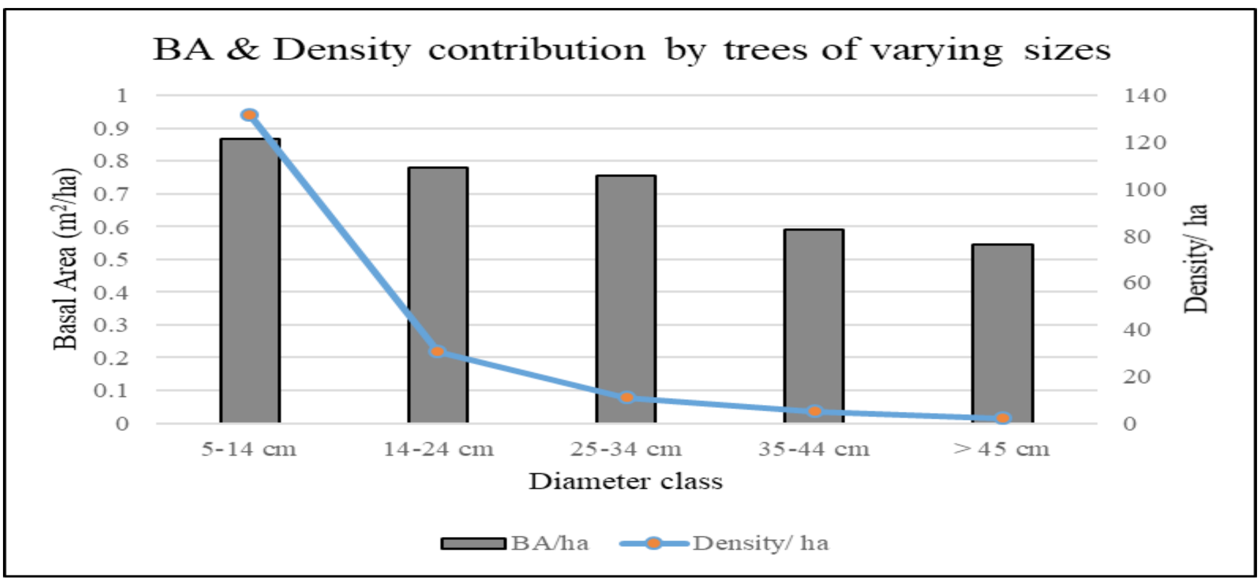


Figure 3.19: Basal area and density estimates of Nzaui trees

3.4.11 Forest Regeneration, Transition and Sustainability

A total of 29 species were recorded as seedlings, 21 and 12 were found inside and outside the forest respectively. 106 species were recorded as saplings and 77 of them were within the forest while 46 were outside the forest. For trees, 25 species were recorded outside the forest, 49 within forest and a total of 67 overall. Natural transition of plants from seedlings to mature trees thro sapling stage, is expected to display an inverse-J plot as their densities gradually regress. This can be likened with succession of trees through increasing diameter classes. As expected, the seedling density was highest and the trees was least. However, the sapling to tree ratio was too wide, suggesting a minimal progression of saplings into trees. This scenario can be attributed to natural factors such as competition and growth limits or to anthropogenic factors such as harvesting and other forms of disturbance.

Ochna insculpta, Apodytes dimidiata, Croton dichogamus, Croton megalocarpus, Grewia similis, Turraea robusta and Dichrostachys cinerea were among the most abundant seedlings. In terms of species progression, from seedlings to saplings, lesser species were shared (27) while a higher number (71) were available as sapling. Only 2 species were considered 'new' since they were recorded as seedlings and were not available as saplings. The species were Margaritaria discoidea and Dodonaea viscosa. This scenario can be due to many factors including, rarety of plant in the area, changing dispersal patterns, environmental factors or opportunistic failure to capture mature plants during sampling, among other possibilities.

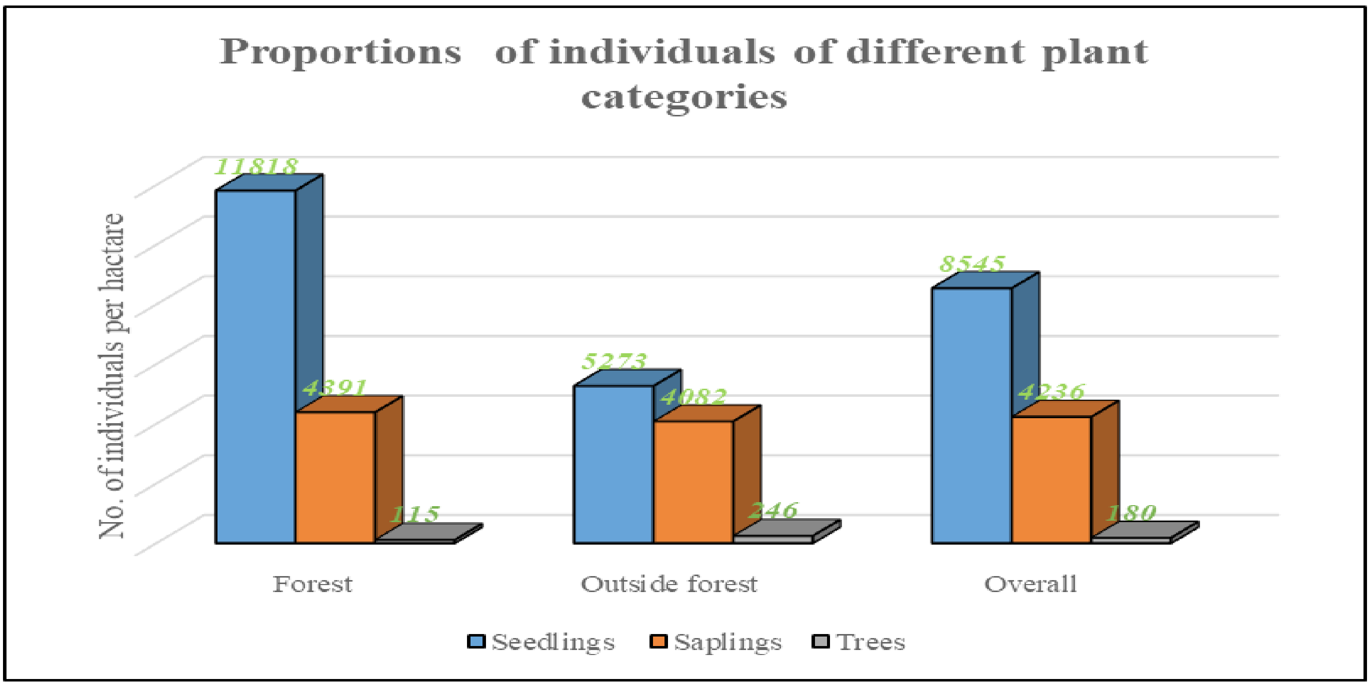


Figure 3.20 Regeneration steps of Nzaui forest

Table 3.9 The most abundant seedlings in Nzaui

	List of the most abundant seedling species (projected individuals/ha)		
Rank	Overall	Forest	Outside forest
1	*Ochna insculpta (1636)*	*Ochna insculpta (3273)*	*Croton megalocarpus (727)*
2	*Apodytes dimidiata (727)*	*Apodytes dimidiata (1455)*	*Dichrostachys cinerea (727)*
3	*Croton dichogamus (455)*	*Grewia similis (909)*	*Lantana camara (545)*
4	*Grewia similis (455)*	*Turraea robusta (909)*	*Acacia hockii (545)*
5	*Turraea robusta (455)*	*Ludia mauritiana (727)*	*Acacia tortilis (545)*
6	*Croton megalocarpus (364)*	*Psychotria lauracea (727)*	*Ormocarpum kirkii (545)*
7	*Dichrostachys cinerea (364)*	*Croton dichogamus (545)*	*Croton dichogamus (364)*
8	*Lantana camara (364)*	*Allophylus rubifolius (364)*	*Acacia brevispica (364)*
9	*Ludia mauritiana (364)*	*Clausena anisata (364)*	*Acacia nilotica (364)*
10	*Psychotria lauracea (364)*	*Flueggea virosa (364)*	*Psychotria kirkii (182)*
11	*Acacia brevispica (273)*	*Margaritaria discoidea (364)*	*Acacia mellifera (182)*
12	*Acacia hockii (273)*	*Lantana camara (182)*	*Combretum collinum (182)*
13	*Acacia tortilis (273)*	*Acacia brevispica (182)*	
14	*Ormocarpum kirkii (273)*	*Psychotria kirkii (182)*	
15	*Acacia nilotica (182)*	*Combretum molle (182)*	

Table 3.10: The most abundant saplings in Nzaui

	List of the most abundant saplings species (projected individuals/ha)		
Rank	Overall	Forest	Outside
1	Lantana camara (618)	Lantana camara (564)	Lantana camara (509)
2	Croton dichogamus (536)	Croton dichogamus (364)	Dichrostachys cinerea (255)
3	Dichrostachys cinerea (268)	Rapanea melanophloeos (273)	Acacia tortilis (218)
4	Rapanea melanophloeos (136)	Triumfetta brachyceras (255)	Senna singueana (182)
5	Triumfetta brachyceras (127)	Ludia mauritiana (182)	Acacia hockii (182)
6	Acacia tortilis (109)	Gnidia latifolia (164)	Croton dichogamus (173)
7	Senna singueana (109)	Turraea robusta (155)	Ormocarpum trachycarpum (100)
8	Acacia hockii (91)	Ochna insculpta (136)	Flueggea virosa (82)
9	Gnidia latifolia (91)	Ficus sur (118)	Maytenus putterlickioides (73)
10	Ludia mauritiana (91)	Millettia vatkei (118)	Premna oligotricha (73)
11	Turraea robusta (77)	Clausena anisata (109)	Acacia mellifera (53)
12	Ochna insculpta (68)	Psychotria lauracea (91)	Acacia nilotica (55)
13	Flueggea virosa (59)	Carissa spinarum (82)	Dalbergia melanoxylon (55)
14	Ficus sur (59)	Combretum molle (64)	Rhus natalensis (45)
15	Millettia vatkei (59)	Antidesma venosum (55)	Thespesia garckeana (45)

3.4.12 Disturbance/ Threats and Species of Conservation Concern

Harvesting of wood as indicated by stumps was present in 68 % of all plots. Livestock or human tracks/ paths, a sign of anthropogenic activity or human movement in the ecosystem was high at 77%. Grazing of livestock had 27% prevalence at moderate intensity. The rate of tree harvesting in the entire Nzaui was estimated at 40 trees per hectare, based on the number of stumps encountered. Harvesting of trees was lower outside the forest (13 stems/ ha) than inside the forest (67 stems/ ha). This study could not categorize stump sizes of trees harvested but based on population structure of trees, missing stems of moderate sized plants could indicate their preference for exploitation. Out of the stumps that were recognized with distinguishing features, most vulnerable species were identified as Combretum molle, Croton dichogamus, Bridelia micrantha, Rhus natalensis, Ochna sp. and Gnidia latifolia. It was observed that the numerous stumps of Pinus patula and Cupressus lusitanica were as a result of past commercial logging by the forest authorities and may be inconsequential in the discussion of community linked exploitation.

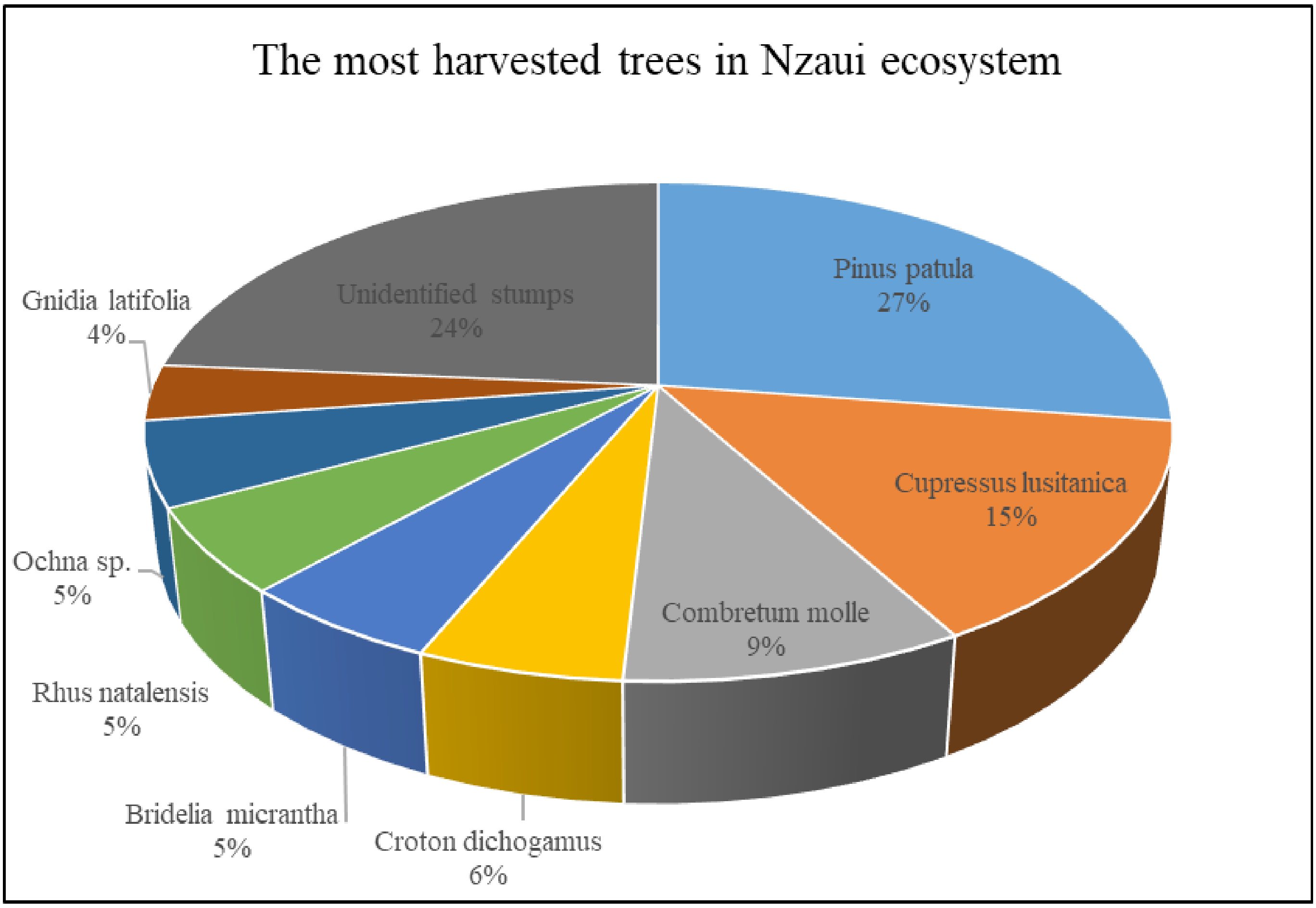


Figure 3.21 Most Harvested trees in Nzaui Ecosystem

CHAPTER FOUR

4.1 Total Economic Values of Ecosystem Services

The section presents economic valuation for ecosystem services potentially derived from Nzaui Water Tower Ecosystem. Valuation was based on two approaches; revealed preference (Market based) (direct and indirect marketvalues, such as the travel cost method and hedonic pricing and Value/ Benefit Transfer approach (BT). Valuation data sourced from secondary material or generated from the field survey. The preference approach is derrived from the value humans attach to ecosystem producst and services. This form of economic value is related to the maximization of human wellbeing or at least improving human welfare. Because of scarcity, resources are not available in quantities adequate to meet all human wants and hence the need to make a choice (trade-offs)(Kipkoech *et al.*, 2011).

The types of economic value to be found in Water Tower ecosystem are *use values* and *non-use values*. The values arise from the estimated rates of loss of forest areas and, hence, in terms of the services they provide humans. Forests not only provide timber but regulate local and global climate, enhance soil retention and water quality, ameliorate extreme weater events, facilitate pollination, improve landscape aesthetics and provide habitats for a vast store of species, and genetic information yet to be uncovered. Use values refer to willingness to pay to make use for instance forest goods and services. Such uses may be *direct*, e.g. extractive uses or *indirect*, e.g. watershed protection or carbon storage. Use values may also contain *option values*, willingness to pay to conserve the option for future use even though no use is made of the forest now. Such options may be retained for one's own use or for another generation (sometimes called a 'bequest' value). Non use values relate to willingness to pay, which is independent of any use made of the forest now or any use in the future. The sum of individual use and non-use values is the total economic value (TEV).

From the household interviewed, majority (52%) perceived that Nzaui ecosystem was extremely important in provision of goods and services to them (Fig. 4.1). 27 % and 4.6% perceived that the ecosystem was important and fairly important respectively. 4.3% do not know the importance of the ecosystem to them and 12% perceived that the ecosystem did not play any role in their livelihoods and economic improvement.

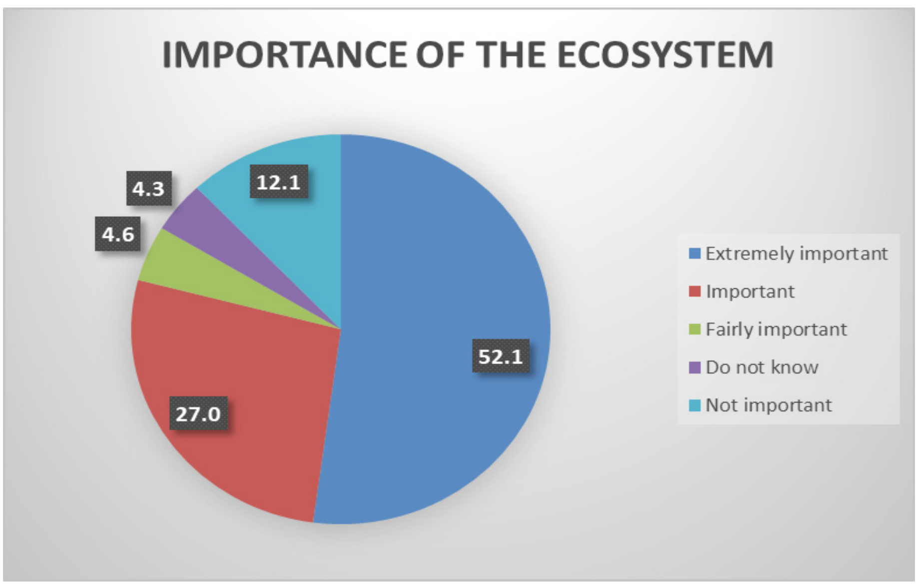


Figure 4.1 Importance of the Ecosystem

The ecosystem contributed in different ways to the livelihoods. Despite about 49 percent not being certain of the specific contribution of the ecosystem, 29 percent (**Fig. 4.2**) of the community agreed that the ecosystem plays a regulatory role specifically on climate. This may be a reason that the areas within and around Nzaui do not depict the typical ASAL conditions. 16.2% and 3.2% associated the ecosystem with the provisioning service of water and fuel wood. The ecosystem was also a source of fodder and in reducing the cost of living, source of manure, source of building materials, source of charcoal, pollination areas for bees and boost the economy. Further analysis indicated that water is the most accessible good obtained from the ecosystem. The local community also perceived that the ecosystem attracted rainfall, modified the climate, contributed to economic growth and livelihood improvement both directly and indirectly. The other benefits were source of cooking energy, source of fodder, provision of recreational sites, tourists' attraction, and manure and support crop pollination areas for bees.

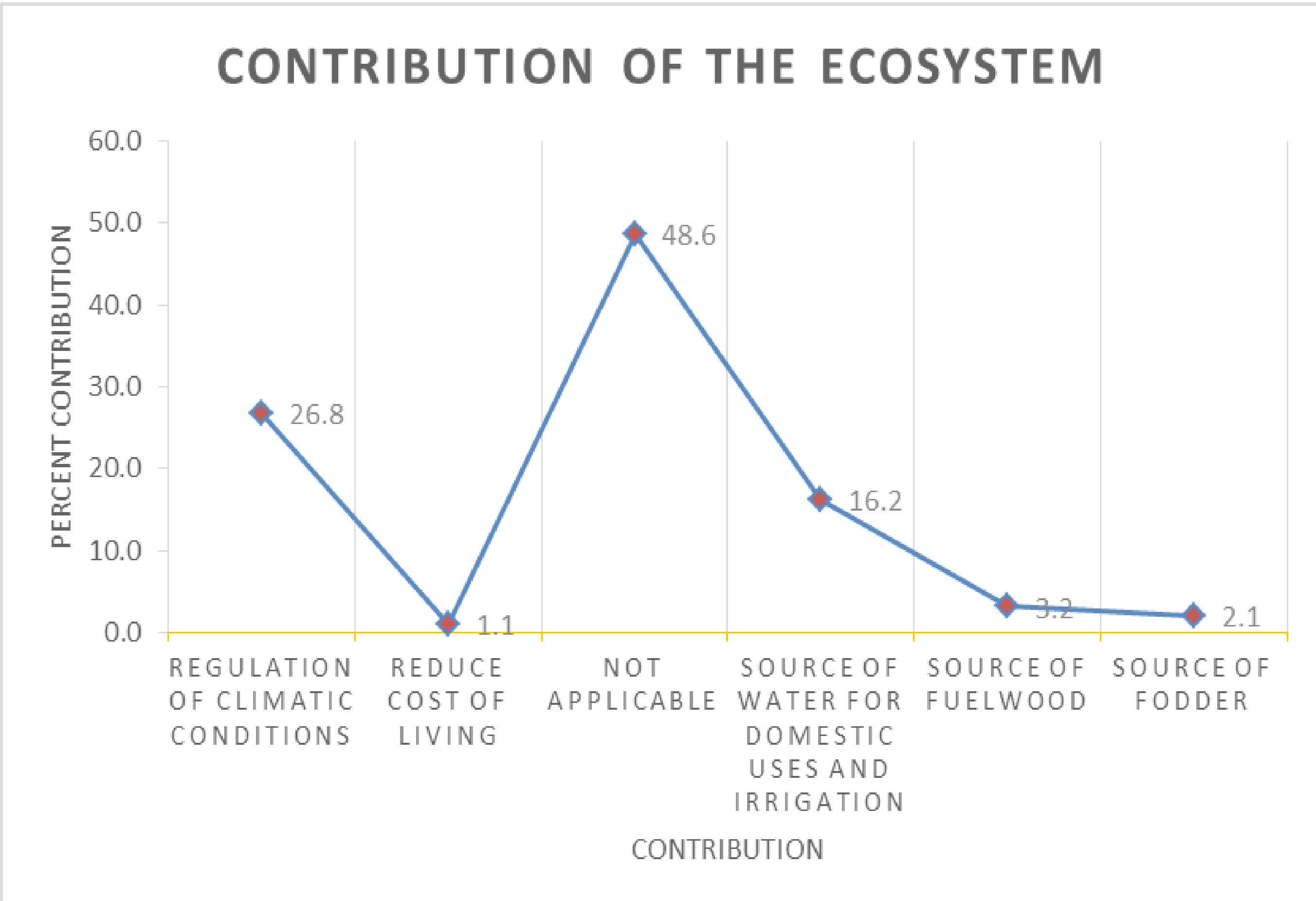


Figure 4.2 Contribution of the Ecosystem

Nzaui valuation under the TEV framework has been grouped into four ecosystem services according to Millennium Ecosystem Assessment (2005). This includes provisioning Services, regulatory Service, cultural Services and supporting Services.

4.2 Provisioning Services

Direct use values such as Water, food, wood and other goods are some of the material benefits people obtain from ecosystems categorized as "provisioning services". Most of these services are traded in markets and in fact in many regions, rural households directly depend on this services for their livelihoods. In this case, the services value may be much more important than is reflected in the prices they fetch on local markets(FAO, 2019). Agriculture, forestry and fisheries are either influenced or influence ecosystem service stock and flow (TEEB, 2010b).

To measure direct-use values (provisioning services), a basis for valuation was provided by each household's own reported values for forest products collected. Household heads or respondents provided information about the weekly or monthly amount of each product harvested by the household for domestic consumption or for sale, and the cash amount received from sales of these products. This was then extrapolated for the whole year. Overall, about 88% households perceived Nzaui Water Tower Ecosystem as important. Majority (75.1%) of the households collect fuel wood from the Water Tower and about 33% of the household produced charcoal from the Water Tower. Other products collected by most households include herbal medicine (6.4% and 98%) own collection and purchased respectively, Thatch (4.7%), poles (2.1%) barks withies/ reeds (6.7%) timbers (7.7%) while honey is collected by about 1% of the household. In addition, 15 individuals from Kilili Sub-location practice apiary. Furthermore, about 33% of the household either harvest or purchase fodder from Nzaui ecosystem (Table 14). Hhouseholds collect food products such as indigenous fruits (13.1.0%), mushrooms (2%), game meat (1%) and honey (1%) and low number of households reportedly obtain them from other sources (own farms, neighbors and markets). Most of these products are widely traded in local markets and hence have local market prices. For such forest products, the household's own reported quantities and local market prices were used in the valuation exercise as provided in the table.

Table 4.1 Summary of Provisioning Service Derived from Nzaui Ecosystem by the Household

Ecosystem Services and Benefits			Proportion (%)	Actual Quantity Per HH per month	Unit	Unit Cost (KES)- 5/= per 20ltr	Estimated Value per year (KES)
Bio-chemical & pharmaceutical	Natural Medicine	Collected	6.4	1	Kg	110	717,488.60
		Purchased	98	1	Kg	110	274,663,620.00
	Pharmaceutical					-	-
Food	Wild Fruits		13.1	60	Kg	5	4,005,298.80
	Game Meat		0	0	Kg		0.00
	Honey	Wild	5	2	Kg	650	6,624,540.00
		Apiary	1	80	Kg	650	624,000.00
		Individuals (BK)	15	48	Kg	650	468,000.00
	Mushroom		2	1	Kg	120	244,598.40

Ecosystem Services and Benefits			Proportion (%)	Actual Quantity Per HH per month	Unit	Unit Cost (KES)- 5/= per 20ltr	Estimated Value per year (KES)
Freshwater	Domestic Water		100	6	M^3	250	152,874,000.00
	Livestock	Cattle	100	4.5	M^3	250	114,655,500.00
		Goats/ sheep	100	3.75	M^3	250	95,546,250.00
	Shallow wells					30	79,056,000.0
	Industrial		1	1058	M^3	200	2,540,000.00
	Irrigation		13.1	84	M^3	100	112,148,366.40
Fibre and fuel	Firewood		75.1	4	Back load	200	61,149,600.00
	Charcoal		32.8	5	Bag	850	23,678,484.00
	Industrial Wood		2	20	Feet	125	5,095,800.00
Construction Materials	Thatch		4.7	12	Bales	100	5,748,062.40
	Poles		2.1	15	Pieces	300	9,631,062.00
	Barks						
	Withies/ Reeds		6.7	35	Pieces	20	4,779,860.40
	Rattan						
	Billets						
	Timbers		7.7	120	Ft	23	21,659,188.32
	Standing Timber						49,642,560
Green Energy			0.4	1	Watts	1500	611,496.00
Resin							
Seed Collection			4.2	3	Kg	5	64,207.10
Dying and Tanning						-	-
Hand Craft						-	-
Ornamental resources						-	-
Manure					Wheel Barrow	100	
Fodder			31.3	70	Bale	300	54,824,489.00
Insect Farming			0				-
Essential Oil			0				-
Nutrient supply							-
Craft supply							-
Grazing			100				40,766,400.00
Genetic Resources							
							1,109,854,422.42

The Total economic Value was computed by multiplying the quantities extracted per year by the average local market price (Pm) less the transaction costs and the net total value (NT) of the marketable product was computed using the formula (Eqn 5)

$$NT = ((Q_i - P_i) - (C_i)) \times (\partial \times N_i) \text{.........Eqn 4}$$

Where, Qi is the quantity of good extracted; Pi is the forest gate price of the product (in the absence of externalities), Ci is the transaction cost (costs of collection, transport, and sale), ∂ is the proportion (percentage) of local households deriving benefit from the local forest, and Ni is the total number of households in 2019 within the five-kilometer forest boundary (Langat, 2016). Therefore the total economic value for provisioning services was estimated at **KES 1,109,854,422.50 (US$ 10,988,657.65).**

4.2.1 Water Resources

Though located in a water scarce region, Nzaui Water Tower play a vital role in providing the flow and storage of fresh water and it is critical source of fresh water for populations living in the study area and beyond. Human activities have led to high rates of deforestation thus severely reducing water catchment capacity. Degradation of the catchment, primarily due to agricultural expansion is associated with population growth. A critical catchment assessment established 16 springs in the Water Tower and most of them serve as sources for water to the local communities (Figure 4.3). According to the Critical Catchment report (KWTA 2019) 50% of these springs are found in Kalamba location and 44% in Kilili locations. Nziu has only 1 spring that converts to 6% of the springs falling within the Water Tower (KWTA, 2019).

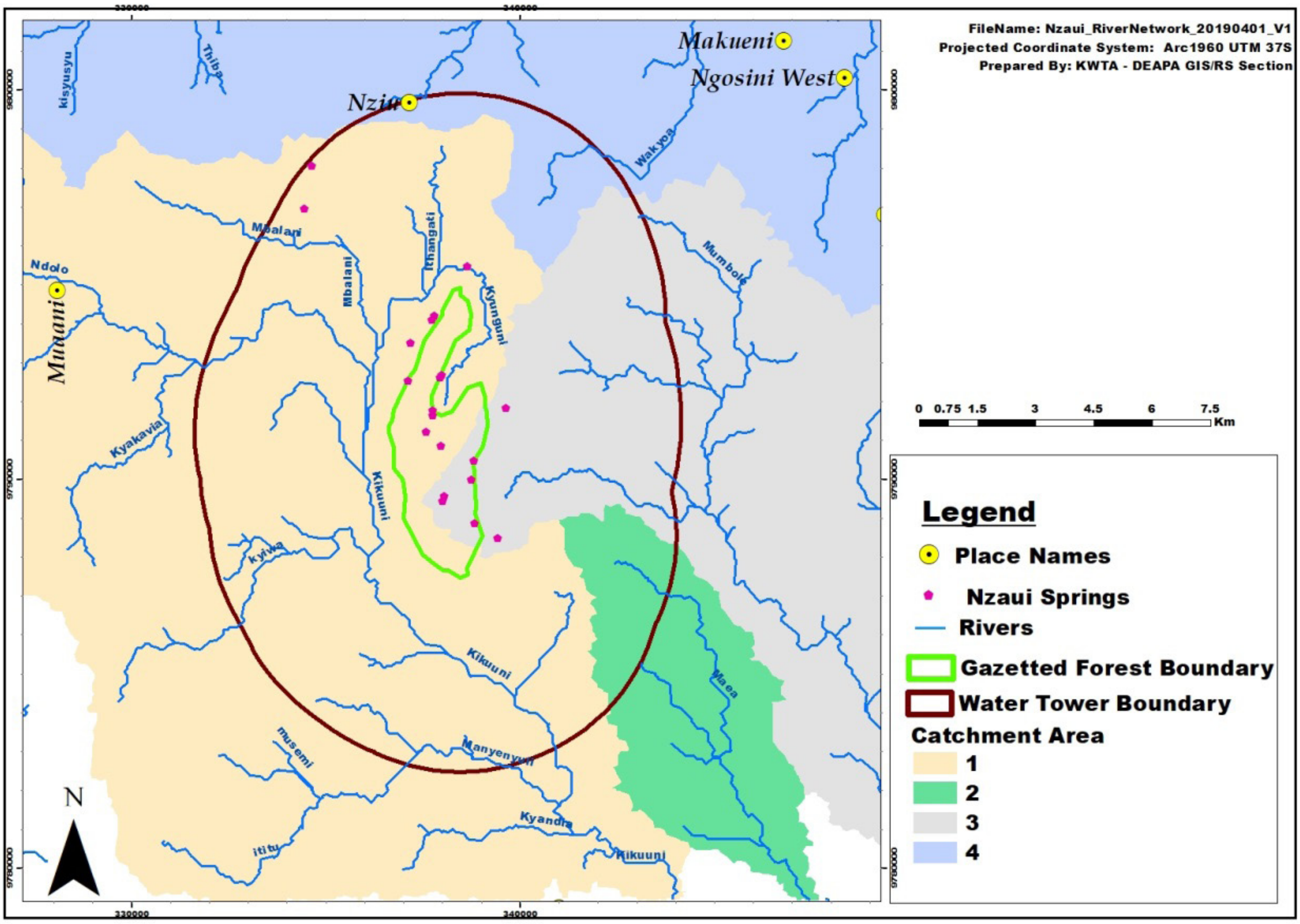


Figure 4.3 Drainage of Nzaui Water Tower

4.2.2 Water Abstraction and Use Values

The Socio-economic survey found out that the major sources of water during wet season for the residents of Nzaui were the rivers, springs and springs (63.1%) , tap water (25.9%) and boreholes (23%). During dry season which extends for 8 month, the community dig shallow wells on the river beds to meet their domestic water requirements. For those who did not have tapped water, majority travelled an average of less than a kilometre (63.3%) to get water. 68.1% of the respondents indicated that they depended on springs and streams that originated from the Nzaui Water Tower. On average most respondent households (89.6%) used between one and 200 litres of water per day for domestic use. The abstraction of water for livestock use was also practised with a majority of households (46.3%) using between 20 – 35 Litres per day. This translates to monthly domestic consumption estimated at 22,931.1m^3 and livestock at 25,479m^3. The abstraction of water for livestock for households was estimated at (46.3%) using between 20 – 35 Litres per day (Table 4.2).

Table 4.2: Usage and Sourcing of Water in Nzaui

Water Sources and Usage	Response	Frequency	Respondent Percent
Principal water source	River/Stream/Springs	178	63.1
	Tap water	73	25.9
	Boreholes	23	8.2
	Shallow wells	4	1.4
	Roof harvesting	4	1.4
Distance Travelled to Fetch Water (Unpiped water Users)	< 1 Km	180	63.8
	1- 5 Km	101	35.8
	6- 10 Km	1	.4
Dependence on Streams/Rivers from Water Tower	Yes	193	68.4
	No	89	31.6
Quantity Abstracted for per Household per Day for Domestic Use	1- 200 Litres	173	89.6
	201- 500 Litres	12	6.2
	501- 1000 Litres	8	4.1
Quantity Abstracted per Household per Day for Livestock Use	1- 10 litres	36	20.6
	11- 20 Litres	58	33.1
	20- 35 Litres	81	46.3

4.2.3 Irrigation in Nzaui

The Water Tower is a major water source for the streams and rivers that flow in the area. While these streams and rivers are not permanent they play a major role in addressing the water shortage in the area. Of particular importance is the 'Kikuu' a major river in the area that serves several functions including irrigation. Though majority (86.9%) of respondent indicated not practicing irrigation, at least 13.1% of the households reported to undertake small scale irrigation on fruit trees where 7% of the household use pumps to irrigate their farms. On average between two hours and five hours (26.3%) per day was the time taken for pumping water for irrigation (Table 4.3). The estimated water use for irrigation was 93,456.97m3. Mango processing plant utilizes 1058m^3 on average per month. Overall, water consumption demand per month was estimated at 142,925.1m^3.

Table 4.3 household Practice of Irrigation and Pumping Period

Irrigation Practices	Response	Frequency	Respondent (%)
Practice of Irrigation Reliant on Springs or Streams	Yes	37	13.1
	No	245	86.9
Type of Irrigation	Pumped	20	7.0
	Not Pumped	17	6.0
Pumped (Hours per Day)	1	1	5.3
	2	5	26.3
	3	2	10.5
	4	5	26.3
	5	3	15.8
	6	1	5.3
	7	1	5.3
	8	1	5.3
Not Pumped (Hours per day)	1	3	20.0
	2	6	40.0
	3	3	20.0
	6	1	6.7
	8	1	6.7

4.2.4 Marginal Cost for Water Reservoir

As aforementioned, Nzaui Water Tower falls in dry region of the country where most of the surface stream water flow only last for 2-3 month thus experience about eight month of dry period. This then leads to the locals establishing shallow wells locally known as "Mfuko" meant to harvest ground water for various household water needs including irrigation. The community use power driven pumps that discharges underground water to storage tanks in homesteads. Though no substantial records on discharge is available, few farmers interviewed reported that a well can discharge 4-6m^3 per hour when propelled withpumps. This translates to about 120m^3 per day per well. Using the average operating cost of KES 30/M^3 (WASREB 2010) and KES 50/M^3 average water tariff, thus the value of water is KES 20/M^3. Therefore, given the annual yield as presented in (Table 4.4), the total value for Surplus water from shallow is estimated at KES **76,056,000/ (US$ 782,732.70).**

Table 4.4 Value of Surplus water from Shallow wells

Water Source	Yield per day (M3)	Yield Per year (M3)	No. (10 wells per location)	Operating Cost Per Unit (KES/M3)	Average Water Tariff (KES/M3)	Total Value (KES)	Total Value (US$)
Shallow Wells	120	43,920	60	20	50	79,056,000.0	782,732.70
Rivers/ Springs/ intakes	No data	No data					
Totals						**79,056,000.0**	**782,732.70**

Other water sources include sand dams, earth dams and rock water harvesting methods. The springs within the Water Tower have been conserved differently and some have been harnessed while others are not. The picture below show two springs within the Water Tower.

Plate 15: Residence of Kilili Queue for water from a water kiosk sourced from Nzaui

Plate 16: Intake inside Nzaui Water Tower

4.2.5 Medicinal resources

Natural ecosystems provide a variety of plants and mushrooms which offer medicinal value. They are used in traditional medicine, and for developing pharmaceuticals. Though few households (6%) collect medicinal plants for domestic purposes mainly from state forest (Table 4.5), 99.6% of the household admit to acquire natural medicinal plants and products from local herbalists sourced from Nzaui (Table 4.6). About 1kg on average is collected with an average value of ksh.100-120 per unit on a year analysis. No appropriate substitutes for the plant medicines were stated.

Table 4.5 Source of Plant Medicines

Source of Plant medicines	Frequency	Proportion (%)
Not Applicable	267	94
HH Farm	7	2.5
Customary Land	1	0.4
Community Forest	1	0.4
State Forest	7	2.5
All the above	1	0.4
Total	**284**	**100**

Table 4.6 Acquisition of natural herbs and medicine sourced from Nzaui

Acquiring Plant Medicine, Herbs and Spices	Response	Frequency	Proportion (%)
Purchase of plant medicines	Yes	283	99.6
Source	All the above	1	.4
Mode of Transport	Bucket	1	.4
Cost of transport from the Mkt in % of unit price	0-5	1	.4
Price variation in the last 5yrs	No change	1	.4
Purchase herbs & spices	Yes	1	.4
	No	280	99.6

4.2.6 Herbs and Spices

Few of the household respondents (0.4%) collect herbs and spices for domestic purposes from their farm. Bowl being used as the mode of transport. The average time taken was half an hour and an average quantity of 1Kg per month. The herbs and spices are not sold and no substitute for them

On average 288 kg of medicinal plant and products are acquired by the respective household annually. At a unit cost of KES 110 and 98% of the household acquiring annually, the total estimated value of this products is **KES 278,107,654.23 (US$ 2,753,541.13).**

4.2.7 Value of Grazing

Nzaui Water Tower is an important grazing area all year round. Similarly, some households harvest fodder for commercial and for their livestock. Currently there are no arrangements on payment for grazing within the Water Tower, however grazing valuation though free at the moment is estimated from the commonly charged grazing fee as prescribed by KFS at KES 100 for Cattle and 40 for sheep and goats per month. Therefore the aggregated grazing value is estimated by multiplying the number of livestock per household by the grazing fee charged thus the total estimated value for grazing is **KES 40,766,400/ (US$ 403,627.72)** (Table 4.7). Just show you arrived at the figure or value

Table 4.7 Value of Grazing within Nzaui Water Tower

Location	No. HH	Total No. of Goat and Sheep (5- per HH)	Total No. Cattles (3- Per HH)	Total Grazing Value of goat and sheep per Month (@ KES 20/)	Total Grazing Value of Cattle per Month (@ KES 100)	Total Annual Grazing Value (KES)
Nzaui	8493	42,465	25,479	849,300.00	2,547,900.00	**40,766,400.00**

4.2.8 Standing Timber

Nzaui Water Tower has about 11% under plantation estimated at 18,000 individual trees of *Cupressus lusitanica, Pinus patula, Eucalyptus* spp. and *Grevillea robusta.* The average DBH is recorded at 25cm and 30m tree heig

ht. The average age of the plantation was estimated at 25 years. Estimated number of trees per Ha for Nzau Forest is 170 individuals. The estimated area under plantation is about 106.37 Ha and using the general order of 2012, the estimated value of the plantation is derived by multiplying the expected Volume per Ha by the value of meter cubic wood, estimated at KES 2233/M^3. The total economic value is **KES 49,642,560/ (US$ 491,510.50).**

Volume/ ha= 3.14r^2xhx No. trees per Ha (r=radius, h=height of tree)

Volume/ ha= 3.14 x 0.125 x 0.125 x 30 x 170= 209m^3

Value= Volume/ha x Unit Price/ha x No of Ha

Value= 209m3/ha x KES 2233 X 106.37ha= KES 49,642,560/=

4.3 Regulatory Services

Regulating local and regional climate, maintaining the quality of air and soil, providing flood and disease control, or pollution control, shade, water availability locally and regionally, pollinating crops are some of the 'regulating services' provided by ecosystems. They are often invisible and therefore mostly taken for granted. When they are lost, the resulting losses can be substantial and difficult to restore. Below is the interaction and value attached to the different production systems and types of ecosystem services according to The Economics of Ecosystems and Biodiversity (TEEB), 2010. Ecosystems influence the local climate and air quality.

Air pollutants have an effect on agricultural crops as it they influences yield. Crops,have the potential to clean the air. Livestock can have a negative influence on local air quality, especially through emission of green house ammonia gas (NH3). Installing filters in barns can help reduce this impact. Fisheries and aquaculture are directly impacted by water and air temperature changes through impacts to reproduction cycles, , disease risks and fish habitats, such as coral reefs, which are susceptible to temperature changes.

Forests can affect air quality in the following ways: (i) converting carbon dioxide to oxygen through photosynthesis;(ii) intercepting particulate pollutants (dust, ash, pollen and smoke) and absorbing toxic gases such as ozone, sulphur dioxide, and nitrogen dioxide, (iii) emitting various volatile organic compounds contributing to ozone formation in cities (iv) lowering local air temperatures (v) reducing building temperature extremes during summer and winter and consequently reduce pollution emissions from power-generating facilities(TEEB, 2010b).

4.3.1 Micro-climate Regulation

Water Tower ecosystem plays a critical role in influencing local, regional and global climate (we are repeating this sentence again see above). Water towers can either create short hydrological cycle (that facilitate local primary production and livelihood activities) or influence regional and/or global climate. Valuation of these micro-climate services is commonly based on ecosystem indicators such as values on enhanced rainfall, values for improved river flow and water availability and value for enhanced land productivity. In the absence of data on this key indicator, study can derive values from other studies similar or comparable to the study area using benefit/ value transfer (BT) approach. For the case of Nzaui, information on key indicators was not available at the time of the study thus benefit/value transfer approach was used to estimate the value of forest for micro-climate regulation. Values from Willy Kakuru study (Total Economic Value of Wetlands Products and Services in Uganda) were used. The study valued micro-climate at US$ 265 ha^{-1} yr^{-1} (Kakuru ***et al.***, 2013). Purchasing power parity data for the respective countries were derived from World Bank development indicators data base (World Bank, 2018). Micro-climate correction factor is assumed at 50% for forest area and 10% on the buffer zone. This suggests Nzaui Water Tower has almost half and tenth capacity on micro-climate regulation respectively compared with reference Wetlands. The value is then extrapolated to Nzaui Water Tower Ecosystem (Forest and Buffer zone). The total value are presented below (**Table 4.8**).

$$V_{NWT} = MCRV_{CX}\left[\frac{PPP_{GNPKenya}}{PPP_{GNPCountryx}}\right]^{E}$$ ..Equation 5

Where:

V_{NWT} is the Micro-climate regulation value of Nzaui Water Tower

MCR is the Micro-climate correction factor for the two sites

V_{cx} is the Micro-climate regulation value of study site in country x (Uganda)

PPP GNP is the purchasing power parity GNP per capita

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

V_{NWT}=0.5(265) [*3461.44135/2033.28739*]^*1.00*

V_{NWT}=0.1(265) [*3461.44135/2033.28739*]^*1.00*

Table 4.8 Values of Micro-climate for Nzaui Water Tower using Benefit/ Value Transfer

Zone	Area (ha)	Value Transfer Correction Factor	Value Transferred (US$)	PPP Ratio	Elasticity Value	Value (KES)	Value (US$)
Forest Section	967	0.5	32.5	1.7	1.00	21,999,491.75	217,816.75
Buffer zone	17335	0.1	26.5	1.7	1.00	78,875,116.75	780,941.75
Totals						**100,874,608.50**	**998,758.50**

4.3.2 Regulation of local Air Quality

Ecosystems influence the local climate and air quality. Trees play an important role in regulating air quality by removing pollutants from the atmosphere. The method commonly adopted involves forest absorption of pollutant. In the absence of the local value estimation method, Nzaui WaterTower study adopted a formula applied in a study undertaken from Xishuangbanna Biodiversity Conservation Corridors Initiative (BCI) Pilot site in China (Xi, 2009). It also adopted absorption value from the same study where the capacity of SO_2 by broadleaf forest and coniferous forest 88.65 and 215.6kg/ha/year respectively; HF 4.65 and 0.5kg/ha/year; NO_2 6.0 and 6.0kg/ha/year; Particulates 10.11 and 33.2t/ha/year respectively (Table 4.9). State forest is estimated to be 30% of the reference area while buffer zone is estimated at 15% of the reference area. Discharge proxies were derived from treatment cost to emit pollutants in Kenya according EMCA Air quality control regulation 2009

Table 4.9: Natural forest pollutant absorption capacity and respective discharge proxy

Pollutant	Absorption capacity (Kg/ha/year) of reference area		Absorption Capacity of Nzaui Water Tower- SF 30% & BZ 15% of Reference area (Kg/ha/year)				Pollutant discharge fee-Treatment cost (KES 5000 to emit pollutants) (MoE&F, 2014)
	Natural Forest	Exotic Forest	Natural Forest		Exotic Forest		
			SF	BZ	SF	BZ	
SO_2	88.65	215.6	26.60	13.30	64.68	32.34	1250/Kg
HF	4.65	0.5	1.4	0.7	0.15	0.075	1250/Kg
NOX	6	6	1.8	0.9	1.8	0.9	1250/Kg
Particulates ($PM_{2.5}$)	10.11	33.2	3.03	1.51	9.96	4.98	1250/Kg

$$V = \sum S_b Q_i C_i$$

…………………………………………………………………Equation 6

Where:
S_b——Area of forest (ha)
Q_i——Absorption or adsorption of the ith pollutant per unit area (Kg/ha)
C_i——Treatment cost of the ith pollutant (KES/Kg)
V——Value of air purification by forest per year (KES)

Using the equation 6 above, with varied absorption level and pollutant treatment proxy, the study estimated air quality regulation at KES 503,222,468.20 (US$ 4,982,400.68) as presented (Table 4.10)

Table 4.10 Values for air quality regulation by Nzaui Water Tower

Zone (area –ha)	Pollutants	Value for Broad leaf Forest 85% of forest area (AC_{NZWT} X ha X Fee)	Value for Coniferous forest -15% of the forest area (AC_{NZWT} X ha X Fee)	Annual Total Value Air Purification (KES)	Annual Value (US$)
State Forest (SF)-967ha	SO_2	27,329,837.50	11,727,292.50	39,057,130.00	386,704.26
	HF	1,438,412.50	27,196.90	1,465,609.40	14,510.98
	NOX	1,849,387.50	326,362.50	2,175,750.00	21,542.08
	Particulates ($PM_{2.5}$)	3,113,135.60	1,805,872.50	4,919,008.10	48,703.05
Buffer zone/ Farmland (BZ)-17,335ha	SO_2	13,833,330.00	350,383,687.50	364,217,017.50	3,606,109.08
	HF	758,406.25	812,578.10	1,570,984.35	15,554.30
	NOX	9,750,937.50	9,750.937.50	19,501,875.10	193,087.87
	Particulates ($PM_{2.5}$)	16,359,906.25	53,955,187.50	70,315,093.75	696,189.05
Totals				**503,222,468.20**	**4,982,400.68**

4.3.3 Climate Regulation

Water Tower ecosystems plays a key role in the global climate by capturing, storing as well as balancing greenhouse gases particularly CO_2. For example, as trees and plants grow, they remove carbon dioxide from the atmosphere and effectively lock it away in their tissues as a result release oxygen as a by-product.

4.3.4 Carbon Sequestration and Storage

Forests play a key role within the global carbon cycle, removing carbon-dioxide (CO_2) from the atmosphere and converting it to wood as they grow, and releasing carbon dioxide back into the atmosphere when trees are burned or decay. Deforestation contributes 10% of global greenhouse gas emissions (UoCS, 2013) and represents the second-largest source of annual CO_2 emissions after fossil fuel combustion(Blanco *et al.*, 2014). Halting deforestation and encouraging replanting or sustainable forestry management practices could potentially contribute over one-third of the total emissions reductions by 2030 (IUCN, 2015). Policymakers recognize the potential for forests and natural land area to combat climate change.. Forest timber sequester and store more carbon than other terrestrial ecosystems and thus play an important role in mitigating climate change (UN, 2018).

As aforementioned, non-destructive approach was applied where plant dimensions (diameter at breast height-DBH; canopy diameter and height) were measured and recorded from the field based on carbon stocks. Tree dimensions were recorded and later screened using pivot tables. The measurements were then converted to carbon estimate using regression models. From extrapolated results, the total estimated carbon for Nzaui is 28.14 Ton CO_2 ha^{-1} $year^{-1}$ for buffer zone (farm land) and 52.75 Ton CO_2 ha^{-1} $year^{-1}$ for the forest area (Table 23). Overall, the average carbon is 40.44 Ton CO_2 ha^{-1} $year^{-1}$ with about 24% and 76% representing shrub and tree biomass respectively.

Table 4.11 Estimated sum Tons of CO_2 ha^{-1} for Nzaui Water Tower

	Buffer zone		***Gazetted Forest***		**Grand Total**	**Overall average**
Plant Category	Total CO_2 (Ton ha^{-1})	*Average (Ton CO_2 ha^{-1})*	Total CO_2 (Ton ha^{-1})	*Average (Ton CO_2 ha^{-1})*		
Shrub	112.36	10.21	108.66	10.87	221.02	10.54
Tree	197.14	17.92	418.81	41.88	621.00	29.90
Grand Total	**309.51**	**28.14**	**527.46**	**52.75**	**842.14**	**40.44**

Estimating the CO_2 equivalent for each vegetation type is computed by multiplying per ha carbon stock by a factor of 3.73. 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).

The gross economic value of carbon sequestration of the Water Tower was then computed using annual net production of forests using the formula by (Xi, 2009; Patton *et al*., 2011).

$V = Q \times P \times S$ ....Equation 7

Where: V is the release or absorption service value; Q is the carbon sequestration (CO_2) per ha; 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 extensively on 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 CO2, however, the average price in the Clean Development Mechanism (CDM) was US$ 10.5 per ton of CO2. 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 is US$ 12/tCO2 (World Bank, 2014). An average of carbon tax and ETS of US$ 11.40/tCO2 was adapted.

Table 4.12 Price of carbon/unit ton of CO2 (Carbon tax) US$ from selected countries

Countries	Price of carbon/unit ton of Co2(Carbo1n 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

Therefore estimated value for carbon sequestered by Nzaui Water Tower based on unit price of KES 1151.40 (US$ 11.4) is KES 620,337,245/ (6,141,952.92) (Table 4.13). This translates to KES 33,894.50 (US$ 335.58) ha^{-1} $year^{-1}$.

Table 4.13 Estimated Values for Nzaui Carbon sequestration

Zone	CO_2/ha	Unit Price (KES)	Area (ha)	Value	
				KES	US$
Forest	52.7	1151.40	967	58,676,380.30	580,954.26
Buffer/ Community Land	28.14	1151.40	17335	561,660,864.70	5,560,998.66
Total				**620,337,245.00**	**6,141,952.92**

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).

$$6CO2(264g) + 12H_2O(180g) \rightarrow C_6H_{12}O_6(180g) + 6O_2(192g)$$

$$\downarrow$$

Polysaccharide（162g cellulose or starch） ....Equation 8

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. Thus the value for potential oxygen generation is KES 228,112,275.70 (US$ 2,276,537.43) (Table 26). This translates to Oxygen generation potential value KES 12,463.79 (US$ 123.40) ha^{-1} $year^{-1}$.

Table 4.14 Estimated Values for potential oxygen generation

Zone	CO_2/ha/ year	O_2 generated (Ton/ha)	Unit Price (KES)	Area (ha)	Value	
					KES	US$(1=KES 101)
Gazetted Forest	52.7	38.471	580.00	967	21,576,845.10	231,632.13
Buffer Zone	28.14	20.542	580.00	17335	206,535,430.60	2,044,905,30
Total					**228,112,275.70**	**2,276,537.43**

4.3.5 Soil Organic Carbon

Soil organic carbon is a measureable component of soil organic matter. Organic matter makes up just 2–10% of most soil's mass and has an important role in the physical, chemical and biological function of agricultural soils.

Organic matter contributes to nutrient retention and turnover, soil structure, moisture retention and availability, degradation of pollutants, carbon sequestration and soil resilience.

Estimation of average organic carbon is computed using the formula below:

$OC = (BD \times SOC \times D)^{E}$............Equation 9

Where OC is organic carbon (Ton); BD represent bulk density (%); SOC represent soil organic carbon per given depth; D represent the depth (m); and EErepresent correction factor.

Estimation value for organic carbon is computed by multiplying total organic with global carbon unit price. Using 20m as the depth and KES 1150.40 (US$ 11.40) as unit price, the total organic carbon and value is presented below (Table 4.15).

Table 4.15 Estimated Values for Organic Carbon for Nzaui

Row Labels	Average Bulk Density	Average of P (ppm)	Average of N (%)	Average of C (%)	Average of Organic Carbon (ton/ha)	Area (ha)	Total Organic Carbon	Total Value (KES)
Buffer Zone								
0-20 cm	0.99	2.6	0.13	1.69	32.79	17,335	568,414.65	631,508,676.15
20-40 cm	0.97	1.27	0.12	1.5	23.85	17,335	413,439.75	459,331,562.25
40-60 cm	0.98	2.39	0.08	1.19	17.56	17,335	304,402.60	338,191,288.60
Sub total	**0.98**	**2.09**	**0.11**	**1.48**	**25.24**	17,335		**1,429,031,527.00**
Gazetted Forest								
0-20 cm	0.85	6.69	0.27	2.76	45.68	967	44,172.56	49,075,714.16
20-40 cm	0.87	4.09	0.13	1.74	29.85	967	28,864.95	32,068,959.45
40-60 cm	0.86	4.04	0.1	1.16	19.79	967	19,136.93	21,261,129.23
Sub Total	**0.86**	**5.18**	**0.18**	**2.01**	**33.84**	967		**102,405,802.84**
Grand Total	**0.92**	**3.52**	**0.14**	**1.73**	**29.23**	967.00		**1,531,437,329.84**

4.3.6 Moderation of Extreme Events

Ecosystems and living organisms create buffers against natural disasters. They reduce damage from floods, storms, tsunamis, avalanches, landslides and droughts. In recent years, increasing climate variability has caused serious and frequent drought spells, which influence agricultural systems. Diversification and adjustment of cropping patterns reduce losses, thus mitigating the impact of droughts on the lives of the rural poor.

Extreme weather events and natural disasters pose threats to the world's forests, Deforestation can increase flooding and landslides during cyclones. However, the extent of large scale flooding in the lower parts of major river basins does not seem to be linked to the degree of forest cover and the management practices in the catchment area. Though forests cannot prevent large scale landslides and mass movements triggered by extraordinary rainfall events, it plays a key role in mitigating impact to household downstream. However, due to time and information the history of extreme events on how (complete this sentence), valuation was not undertaken. This is an area for further studies.

4.3.7 Biological Control (Pest and Disease)

The activities of predators and parasites in ecosystems that act to control populations of potential pest and disease vector were valued. Pests, diseases and weeds limit crop production, and are themselves limited by the action of their natural enemies, mostly arthropods and micro-organisms. Biological control, through an ecosystem approach, is a way to reduce pesticide use and enhance biodiversity while ensuring production.

Animal diseases cause heavy economic losses for individual farmers at national or regional levels. Gastro-intestinal nematode parasities is an important disease affecting s to small ruminant production in the sub-tropics and tropics. It is possible to biologically control gastro-intestinal nematodes of ruminants using predacious fungi. Poultry are also used to control ticks and other vectors of animal and human disease (TEEB, 2010b).

The biological control of pest in forests is often the preferred methodology since its stable environment guarantees less interference by pesticides or disturbing agricultural practices. Natural or sustainably managed forests are also great reservoirs of natural pest eradicators.

The analysis of diseases occurrence revealed the existence of several human and livestock diseases occuring with different frequencies. The main epidemics were tropical malaria, cholera and typhoid, fowl army worms (Maize), anthrax and East coast fever (**Fig. 4.4**).

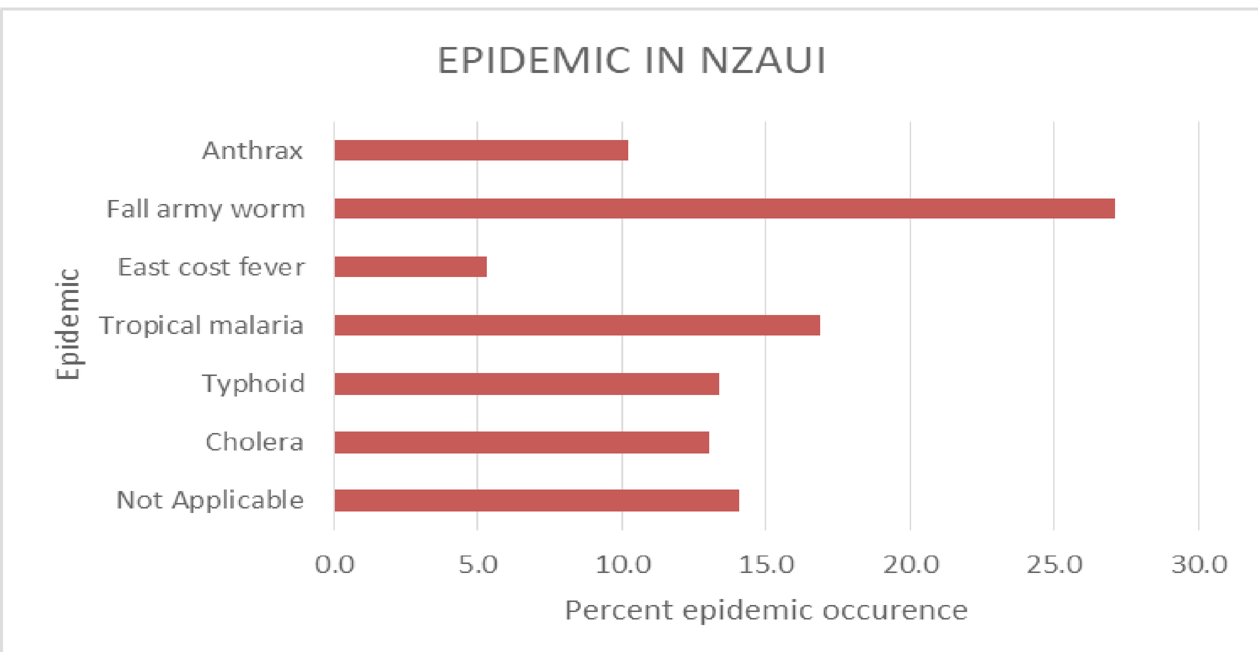


Figure 4.4 : Epidemic reports in Nzaui sub-county

Summary of analysis revealed that tropical malaria occurred frequently than Cholera and typhoid among the human diseases (**Table 4.16**). 35% reported frequent occurrence as compared to 24 and 16 frequent occurrences of typhoid and malaria. Anthrax was common than ECF among the livestock diseases.

Table 4.16 : Frequency of Epidemic

Frequency	ECF	Anthrax	FAW	Tropical Malaria	Typhoid	Cholera
Once	9	21	36	11	20	25
Twice	1	3	11	8	1	4
Frequent	6	11	49	35	24	16

Different suitable preventive and curative methods were applied by different households depending with situations to mitigate and control the diseases and effects. However, the study was not able to attach a value to biological regulation by Nzaui ecosystem because of gaps on epidemic reports and failure to connect occurrence of epidemics due to changes in the ecosystem. Nonetheless, this has huge potential for the ecosystem services value. The study recommends further valuation research on this component.

4.3.8 Valuation on Water Regulation

Water flow regulation is a key service provided by Water Tower ecosystem, but its dynamics are poorly understood by most policy makers and land management organizations. Agricultural production for instance is the largest consumer of water with huge impacts on water flow regulation. Management of farm land can contribute to flooding. Water Tower ecosystem influences the amount of water available and the timing of water delivery. Stream-flow regulation by forests is the result of processes in the forest canopy on the surface and below the ground – a combination of interception, transpiration, evaporation, evapotranspiration and infiltration. Sustainable forest management is key to the regulation of water flows.

Though it faces myriad of challenges such as deforestation, encroachment, prolonged drought, Nzaui Water Tower is critical in the supply of water to the population within and without. It receives between 800-1200mm of rainfall annually and discharges to rivers and other water reservoirs within the sub-county and beyond supporting more than 8000 HH in supply of fresh water. Like many watersheds characterized with natural and exotic vegetation manifests in 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.

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. One commonly adopted method is the rainfall storage method (Li Jinchang, 1997).

The rainfall storage method was applied to estimate water flow regulation functions (Li

Jinchang, (1997), Xue and Tisdalle, (2001) and Xi, (2009).

$V = Q \times C_{yt}$.....................Equation 10

$Q = S \times J \times R$................Equation 11

$J = J_O \times K$.....................Equation 12

$R = R_O - R_g$..................Equation 13

Where:

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

S- Area under forest in ha (indigenous vegetation only) =967ha

J- Annual precipitation runoff of the study area =850(Okelo, 2009)

J_o- Annual precipitation of the study area =1000

K- Ratio of precipitation runoff yield to total precipitation of the study area; = 0.85

R- Beneficial coefficient of reduced runoff of forest to non-forest area 1.0

R_o- Precipitation runoff rate under precipitation runoff condition in grazing (%) =1.2 (Ikobe, 2014)

R_g- Precipitation runoff rate under precipitation runoff condition in forests (%) =0.2(Okelo, 2009)

C_{yt}- Investment cost of reservoir construction per m3=254.34(Ikobe, 2014)

Therefore

V=(SX(J_o x K)x (R_o- R_g) x C_{yt}

V= (967(850x0.85)x (1.2-0.2) x 254.34)= 177,696,548.55/=

Thus water flow regulation function of Nzaui was estimated based on water storage method (Xi, 2009; Xue & Tisdell, 2001). The total value of this service was found to be about KES 177,696,548.55/ (US$ 1,759,371.77) or equivalent to KES 183,760.65 (US$ 1,819.4) ha-1yr-1.

4.3.9 Estimation of Value of Water Quality Regulation

The large burden of diarrhoeal diseases continues to drain important resources from developing countries. Approximately 88% of diarrhoea cases worldwide are attributable to unsafe water, inadequate sanitation, or insufficient hygiene. These cases result in 1.9 million deaths each year, the majority of which are preventable, mostly among children under the age of five(WHO, 2004). Disinfection is recommended for all water supplies used for human consumption. The value of water quality service provision by the forest was estimated using a method by (Xi, 2009; Xue & Tisdell, 2001).

$V = Q \times P$..............................Equation 14

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 KES 25for 150ml Water Guard treatment was obtained from local data in a World Health Organization (WHO) report (WHO, 2008). Variable considered include daily water demand (M^3/household), number of households neighbouring from Nzaui Water Tower, Proportion of households sourcing from forest, total water demand M^3/day, potential yearly water demand (M3) 100%HHs, the actual yearly demand of water from forest (M3), unit cost of water impurity removal using local water treatment system (KES)/M3 and ultimately the value of water quality purification (KES) as presented below.

Table 4.17 Data on Water Purification Proxies

Location	No. HH	Proportion of HH Using Water from WT	Average HH amount of H2O per Month (M^3)	Proxy Value HH H2O Treatment (Water Guard/ M^3)	Annual Value of H2O Purification	Value in US $
Nzaui Sub-County	8493	100	3	66	20,179,368.00	199,795.00

The value of the forest for water purification is about KES 20million (for all household and translates to about KES 2,376.00 (US$ 23.50) per household per year.

4.3.10 Soil Erosion Control/ Regulation

The soils in this water tower were developed from undifferentiated basement and igneous rock systems. These consist of vertisols (black cotton soils) found along river basins, marshes and depressions. These are usually waterlogged thus becoming saline or sodic. The soils on mountain hills are well drained, shallow and moderately deep to very deep, with an acid humic top layer. However, some areas portray shallow stones or rocks (Regosols) and sometimes sandy clay loam due to granite parent material. In the uplands, the soils are mainly sandy loam and sandy clay, usually brown to brownish red (Ferralsols) (Makuli Nguuta PFM).

Forests help to prevent soil erosion and minimize sedimentation in reservoirs and rivers, thus reducing the cost of maintaining water reservoir. 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 (Langat, 2016; Xue & 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:

$V_k = K \cdot G.\Sigma Si * (d_i - d_o)$..............Equation 15

Where: V_k is the economic value of soil conservation; K is the cost of 1 ton sediment removal- (Ikobe, 2014); Si 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 soil loss per ha categorized per vegetation types of forest (t/ha); d_o is the soil loss of a given subject land use (t/ha) e.g. Agricultural land.

In this study, the average cost of de-silting for Tana-Athi Drainage was KES 334/= per ton while the ratio of sediments entering rivers or reservoirs to total soil loss was assumed at 50% or G=0.5(Ikobe, 2014). The soil erosion values based on a local study in East Mau (Langat, 2016; Okelo, 2009; Xi, 2009) that is related to vegetation types of Nzaui Water Tower. In this regards, Nzaui forest zone was equated to deforested area with soil loss of 3.16 t/ha/year and the buffer zone equated as agricultural area with soil loss of 8.67t/ha/year.

V_k= 334*0.5*ha*3.16

The study assumed that Nzaui Water Tower initially had intact indigenous forest that was converted to different land use including agriculture, grazing etc. thus prone to soil erosion. Otherwise if it had remained natural with indigenous forest, then soil loss would have been zero. Maize production is used as proxy in this study.

Table 4.18 Estimated Values on Soil Erosion Control for Nzaui Water Tower

Ecosystem Service	Zone	Area	Proxy Value Based (De-silting Cost/ M^3 KES)	Soil Loss (Ton/ha/ year) & Loss	Value/ha/ year	Total Value (KES)	Value (US$)
Sediment Regulation	Forest Section	967	334	3.16	1,055.50	1,020,610.50	10,105.05
	Buffer (Farm land)	17,335	334	8.57	2,862.00	49,619,357.00	491,280.76
Soil Conservation	Forest section	967	2300	50%	25,000.00	24,175,000.00	239,356.44
	Buffer (Farm land)	17,335	2300	50%	25,000.00	433,375,000.00	4,290,841.60
Total						**508,189,967.50**	**501,385.82**

Table 4.19: Soil loss under different land use/vegetation types in Nzaui Water Tower

Adopted from Micro-filed Assessment of Soil Erosion and Surface Runoff Using Mini Rainfall Simulator in Upper River Njoro Watershed in Kenya (Okelo, 2009)

Land use / Vegetation type	Bulk density (g/cm3	Organic matter (%)	Soil pH	Soil Texture	Mean surface runoff (mm)	Soil loss(t/ ha)
Agricultural land	0.85	5.6	6.2	Clay Loam	18.74	8.57
Deforested forest area	0.78	10.1	5.8	Sandy Clay Loam	17.72	3.16
Grazing/pastures	1.05	5.0	5.9	Clay Loam	23.78	1.48
Plantation forest	0.95	6.2	6.4	Clay Loam	6.99	0.06
Indigenous forest	0.74	9.5	6.2	Sandy Clay Loam	0.31	

4.3.11 Nutrient Cycling

The forest also helps to maintain fertility since soil erosion may result in losses of N, P, K and organic substance which can be regarded as proxy for nutrient cycling function. Thus, for nutrient cycling the formula used is as follows:

$$V_f = D.S.\sum P_{1i}.P_{2i}.P_{3i}$$ ....Equation 16

Where:

V_f - Proxy Value for Nutrient Cycling

D - Erosion reduction in forest land compared to non-forest land

P1i- Content of N,P,K in forest soil (%)

P2i - Ratio of pure N, P, K to their fertility counterparts. The ratio of N, P, K to their fertilizer counterparts are 60/28,406/62,74.5/39 respectively (common fertilizers used are urea for N,

Calcium Superphosphate for P and Potassium Chloride for K).

P3i- Price of fertilizers. Price of urea, Calcium Superphosphate and Potassium Chloride are KES 46,000/t, KES 42,000/t and KES 68,000/t respectively.

The soil nutrient cycling value of Nzaui 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, 2009); (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 the Water Tower (Langat, 2016).

Nzaui Water Tower 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 Nzaui Water Tower for soil nutrient cycling was about KES 122,029,689.20 using proxies on cost avoided in de-silting of dam's equivalent to about KES 405 (US$ 4.5) ha-1yr-1.

Table 4.20 Proxy Values for Ecosystem Nutrient Cycling

Ecosystem Service	Land under crop production (ha)	Proxy Category	Proportion (%) HH	Cost Fertilizers/ ha/year	Total Value (KES/year)	Total Value (US$)
Nutrient Cycling	17,335	Inorganic Fertilizers	25	3,458.00	14,986,107.50	148,377.30
	17,335	Organic (Manure)	75	8,233.33.00	107,043,581.70	1,059,837.44
Total					**122,029,689.20**	**1,208,214.74**

4.3.12 Insect Pollination Value

Insect pollinators provide vital ecosystem services through its maintenance of plant biological diversity and its role in food production. Indeed, adequate pollination services can increase the production and quality of fruit and vegetable crops. This service is currently challenged by land use intensification and expanding human population growth (Picanço *et al.*, 2017). Productivity of many crops benefits from the presence of pollinating insects, so a decline in pollinator abundance should compromise global agricultural production. Motivated by the lack of accurate estimates of the size of this threat, we quantified the effect of total loss of pollinators on global agricultural production and crop production diversity(Marcelo ***et al.***, 2009). Pollination is required for production of a wide range of crops that include fruit trees (Mangoes, oranges, Vicks, Avocado etc.), cereals, fibre, and coffee among others(Klein ***et al.***, 2007) thus pollination is critical in sustainable food production and livelihood.

A number of methods and techniques can be used to estimate the value of pollination services. This approach include proportion of the total production attributed to insect pollination, pollinators replacement cost and direct managed pollination value.

The economic value of pollination service was calculated(Gallai ***et al.***, 2009) as follows:

$$EVIP = \sum_{i=1}^{I} (Pi \times Qi \times Di)$$ ....Equation 17

For each crop (Qi) is the quantity produced, (Di) is the pollination dependency ratio and (Pi) is the price per unit.

Table 4.21 List of studied crops, their pollination dependency ratio (PDR) and their area coverage

Crop	Pollination Dependence Ratio (PDR) FAO	Annual Production				Total Crop Value (KES)	Pollination Value (EVIP)
		Land size (ha)	Production Per ha (kg)	Total Annual Production (kg)	Unit Price (KES) Per Kg		
Beans, green	0.25	20	3	60	80	4,800.00	1,200.00
Bananas							
Dolichos (Njahi)	0.25	20	2	40	150	6,000.00	1,500.00
Chick peas	0.05			0			
Cow Peas	0.25	30	540	16200	77	1,247,400.00	311,850.00
Pigeon Peas	0.25	900	540	486000	60	29,160,000.00	7,290,000.00
Green grams	0.25	220	360	79200	103	8,157,600.00	2,039,400.00
Lentils	0.05			0	76		
Green peas	0.25			0	100		
Soya beans	0.25			0	100		
Onion	0.05			0			
Potatoes	0.05			0			
Maize	0	600	1800	1080000	38	41,040,000.00	
Pumpkins				0			
Head cabbage	0.05			0			

Crop	Pollination Dependence Ratio (PDR) FAO	Annual Production				Total Crop Value (KES)	Pollination Value (EVIP)
		Land size (ha)	Production Per ha (kg)	Total Annual Production (kg)	Unit Price (KES) Per Kg		
Tomatoes	0.05	38	12250	465500	104	48,412,000.00	2,420,600.00
Green pepper	0.05			0			
Red pepper	0.05			0			
Capsicum	0.05	12	3500	42000	60	2,520,000.00	126,000.00
Linseed	0.05			0			
Groundnut	0.05			0			
Butternuts	0.25	8	10000	80000	85	6,800,000.00	1,700,000.00
Melon	0.25	16	75000	1200000	120	144,000,000.00	36,000,000.00
Safflower	0.25			0			
Avocados	0.65	20	125000	2500000	30	75,000,000.00	48,750,000.00
Guavas	0.25			0			
Mangoes	0.65	860	35000	30100000	27	812,700,000.00	528,255,000.00
Citrus (oranges, lemon, pixies)	0.05	560	25000	14000000	42	588,000,000.00	29,400,000.00
Pawpaw	0.05	40	12000	480000	37	17,760,000.00	888,000.00
Cotton	0.25	20	500	10000	50	500,000.00	125,000.00
Coffee	0.25			0		-	
Total						**1,775,307,800.00**	**657,308,550.00**

Summary

The economic values of microclimate regulation, climate regulation, nutrient cycling, erosion control, and water flow and quality regulation are as presented below (Table 4.22). These results provide valuable information on the magnitude of the selected ecosystem services that could be relevant in decision-making concerning conservation and management of Nzaui Water Tower for enhanced ecosystem services and livelihood.

Table 4.22 Summary of Regulatory Services Values for Nzaui

Ecosystem Services and Benefits			Valuation Method	Actual Quantity	Unit Cost (KES)	Estimated Economic Value (KES/Year)	Value (US$)
Climate regulation	Micro-climate					100,874,608.50	998,758.50
	Production of Oxygen					228,112,275.70	2,258,537.38
	Carbon Sequestration	Plant Carbon				620,337,245.00	6,141,952.92
		Organic carbon				1,531,437,329.84	15,162,745.84
Water purification and waste treatment			Replacement proxy			20,179,368.00	199,795.72
Natural hazard							
Air quality regulation			Replacement proxy			503,222,468.20	4,982,400.68
Biological Regulation							
Erosion and Sediment regulation			Replacement Proxy			508,189,967.50	5,031,583.84
Nutrient cycling			Replacement proxy			122,029,689.20	1,208,214.74
Biogeochemistry Regulation							
Pollination (Crop Pollination)			Production factor			657,308,550.00	6,508,005.45
Seed Dispersal							
Total						**4,291,691,501.94**	**42,491,995.07**

4.4 Supporting Services

Nzaui Water Tower Ecosystem provide living spaces for plants or animals and maintain a diversity of plants and animals. Though degraded, it has a high number of species that makes it a 'biodiversity hotspot'. This ecosystem can give high yields , ensuring long term production when it is well managed. The conservation of this diverse ecosystem can provide options needed for coping disturbances and other stresses. This creates capacity of agro-ecosystem to maintain and increase productivity in long run. Overall, Water Towers are among the most important repositories of terrestrial biological diversity.

4.4.1 Estimating Biodiversity Value

Biodiversity may be described in terms of genes, species, and ecosystems, corresponding to three fundamental and hierarchically-related levels of biological organization (IUCN, 1994). Maintaining biodiversity is essential for organic waste disposal, soil formation, biological nitrogen fixation, crop and livestock genetics, biological pest control, plant pollination, and pharmaceuticals. Plants and microbes help to degrade chemical pollutants and organic wastes and cycle nutrients through the ecosystem(Pennyslyvania Land Trust Association, 2011).

While there is growing awareness of the value and importance of diversity ***per se***, there is a lack of consensus on how diversity can be defined and measured. For example, species richness is frequently the only accessible indicator of species diversity, although it is well known that a head count of the number of apparently different species in an area may not be a good proxy for the genetic distance between them. Some index or set of indices of biodiversity change is fundamental to any economic valuation. Valuing biodiversity would further require some idea of people's preferences (willingness to pay) for 'intrinsic values' (values in themselves and, nominally, unrelated to human use). Intrinsic values are relevant to conservation decisions, but they generally cannot be measured (Pearce & Moran, 1994). As a result, biodiversity valuation focuses on biological resources such as forests, wetland and marine habitats (undisturbed or sustainably managed) which maintain current or potential human uses. Such a focus is more tractable. Biological resources are subject to human preferences which places them firmly within the purview of economic analysis (Moran & Bann, 2000).

The economic value of this diversity is the subject of a rapidly growing literature but one that remains very unsatisfactory in terms of the reporting of values for forest types. Part of the problem lies in the confusion between the value of biological resources and the value of biodiversity. Many studies relate to the former and few to the latter. The essence of the value of diversity is that it embodies the value of information and insurance (Secretariat of the Convention on Biological Diversity (SCBD), 2001). Thus study applied Value transfer (VT) method to estimate biodiversity economic value Nzaui Water Tower. The procedure estimates the value of an ecosystem service by transferring an existing valuation estimate from a similar ecosystem (TEEB, 2010c). According to TEEB (2010) VT is the second most applied methodology to estimate services particularly for wetlands and watersheds. Therefore its application here to calculate the biodiversity value is justified. In reality, what valuation studies normally measure is the economic value of 'biological resources' rather than biodiversity (Bann, 1997). Other studies suggest that the value of biodiversity should be expressed as or should at least include the value of medicinal and pharmaceutical extracts from the forest (Abeysinghe, 2010). This suggests that Nzaui ecosystem might be a source of different medicinal properties such as specific antibacterial features. This is based on the likely discovery of forests plants with economic medicinal and pharmaceutical extracts (Secretariat of the Convention on Biological

Diversity (SCBD), 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 (UNEP, 2011) using the benefit transfer formula below:

$$V_{NWT} = BV_{cx} \times \left(\frac{PPP_{GNPKenya}}{PPP_{GNPCountry\,x}}\right)^{E}$$ ......Equation 18

Where:

VNWT is the biodiversity value of Nzaui Water Tower

B is the biodiversity correction factor for the two sites

Vcx is the biodiversity value of study site in country x

PPP GNP is the purchasing power parity GNP per capita10

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). Between US$ 5 & 10 was applied in Kenya i.e. Mau East forest ecosystem(Kipkoech*, et al.*, 2011), this similar values were transferred to Nzaui where US$ 5 was applied for biodiversity within the buffer zone and US$ 10 for forest section though both reduced by 30% implying Nzaui has low biodiversity than Mau East. To account for the uncertainty associated with the transfer of values from one site to another, the study developed a risk and simulation approach that assigns possible error distributions and performs Monte Carlo simulations to evaluate the possible net benefits of conservation investment. The total values are as presented below (Table 4.23).

V_{NWT}=0.7(10) [*1*] ^*1.0,*

V_{NWT}=0.7(5) [*1*] ^*1.00*

Table 23 Estimate Values for Biodiversity Conservation

Zone	Area (ha)	Value Transfer Correction Factor	Value Transferred (US$)	PPP Ratio	Elasticity Value	Value (KES)	Value (US$)
Forest Section	967	0.7	10	1	1.00	683,669.00	6,769.00
Buffer zone	17335	0.7	5	1	1.00	6,127,922.50	60,672.50
						6,811,591.50	**67,441.50**

4.4.2 Watershed Protection

Forest watershed value averaged at US$6.5/hectare/year) was derived from a study on Economic Value of Congo Basin Protected Areas Goods and Services by NLOM. (NLOM, 2011). Site correction is assumed at 50% suggesting Nzaui Water Tower has 50% low capacity on watershed protection function compared with Congo Basin Protected area.

$$V_{NWT} = WSPV_{CX}\left[\frac{PPP_{GNPKenya}}{PPP_{GNPCountryx}}\right]^{E}$$ ....Equation 19

Where:

V_{NWT} is the watershed protection value for Nzaui Water Tower

WSP is the watershed protection correction factor for the two sites

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

PPP GNP is the purchasing power parity GNP per capita

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

V_{NWT}=0.5(6.5) [3461.441353 /5652.078216 *1*] ^*1.00*

V_{NWT}=0.5(6.5) [3461.441353 /5652.078216 *1*] ^*1.00*

Table 4.24 Estimated Value for Watershed Protection

Zone	Area (ha)	Value Transfer Correction Factor	Value Transferred (US$)	PPP Ratio	Elasticity Value	Value (KES)	Value (US$)
Forest Section	967	0.5	6.5	0.6	1.00	190,450.65	1,885.65
Buffer zone	17335	0.5	6.5	0.6	1.00	3,414,128.25	33,803.25
						3,604,578.90	**35,688.90**

4.4.3 Habitat/Refugia

Habitat/ Refugia values (Monetary value US$ 439 ha^{-1} yr^{-1}) were derived from Willy Kakuru study on the Total Economic Value of Wetlands Products and Services in Uganda (Kakuru***, et al.***, 2013). Purchasing power parity data for the respective countries were derived from World Bank development indicators data base (World Bank, 2018). Habitat/Refugia correction factor is assumed at 50% for forest area and 10% on the buffer zone. This suggests Nzaui Water Tower has almost half and tenth capacity on provision of habitat/refugia respectively compared with reference Wetlands. The value is then extrapolated to Nzaui Water Tower Ecosystem (Forest and Buffer zone).

$$V_{NWT} = MCRV_{CX}\left[\frac{PPP_{GNPKenya}}{PPP_{GNPCountryx}}\right]^{E}$$ ……………………………………………Equation 20

Where:

V_{NWT} is the Habitat/Refugia value of Nzaui Water Tower

MCR is the Habitat/Refugia correction factor for the two sites

V_{cx} is the Habitat/Refugia value of study site in country x (Uganda)

PPP GNP is the purchasing power parity GNP per capita

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

V_{NWT}=0.5(439) [*3461.44135/2033.28739*]^$^{1.00}$

V_{NWT}=0.1(439) [*3461.44135/2033.28739*]^$^{1.00}$

Table 4.25

Zone	Area (ha)	Value Transfer Correction Factor	Value Transferred (US$)	PPP Ratio	Elasticity Value	Value (KES)	Value (US$)
Forest Section	967	0.5	439	1.7	1.00	36,444,441.05	360,836.05
Buffer zone	17335	0.1	439	1.7	1.00	130,664,816.05	1,293,711.05
						167,109,257.1	**1,654,547.1**

Table 4.26 Summary of Support Service Values

Ecosystem Services and Benefits	Valuation Method	Actual Quantity	Unit Cost (KES)	Annual Estimated Economic Value (KES)	Annual Value (US$)
Primary production					
Watershed protection	Value transfer			3,604,578.90	35,688.90
Soil formation					
Nutrient cycling					
Water cycling					
Biodiversity	Value transfer			6,811,591.50	67,441.5
Refugia/ Habitat provision	Value Transfer			167,109,257.1	1,654,547.1
Totals				**177,525,427.40**	**1,757,677.50**

4.5 Cultural Services

Society derive non-material benefits and services from Nzaui ecosystem categorized as 'cultural services' that include aesthetic inspiration, cultural identity, sense of home, and spiritual experience related to the natural environment. Typically, opportunities for tourism and recreation activities are also considered within the group. Cultural services are deeply interconnected and often connected to provisioning and regulating services. For instance, firewood collection may not necessarily be fuel wood collection but rather avenue socializing with other women, discuss about their respective families. This social grouping though initially intended to collect fuel connects with women grouping to discuss their family experience thus becomes a way of life. In many situations, cultural services are among the most important values people associate with nature and thus critical to understand and value as presented hereunder.

4.5.1 Recreation and Mental and Physical Health

Nzaui Water Tower provides wide range of opportunities for recreation for both mental and physical health as well as potential sporting opportunities such as mountain hiking, rock climbing among others. Socio-economic survey undertaken presented Nzaui Water Tower as an important ecosystem both for cultural and recreational activities where 31% of the local community used the Water Tower for recreation purposes. Visitation was at varied intervals , 70% of the locals visited the ecosystem once a year, 17% visited once a month, 4% visited weekly and 9% visited daily (**Fig. 4.5**).

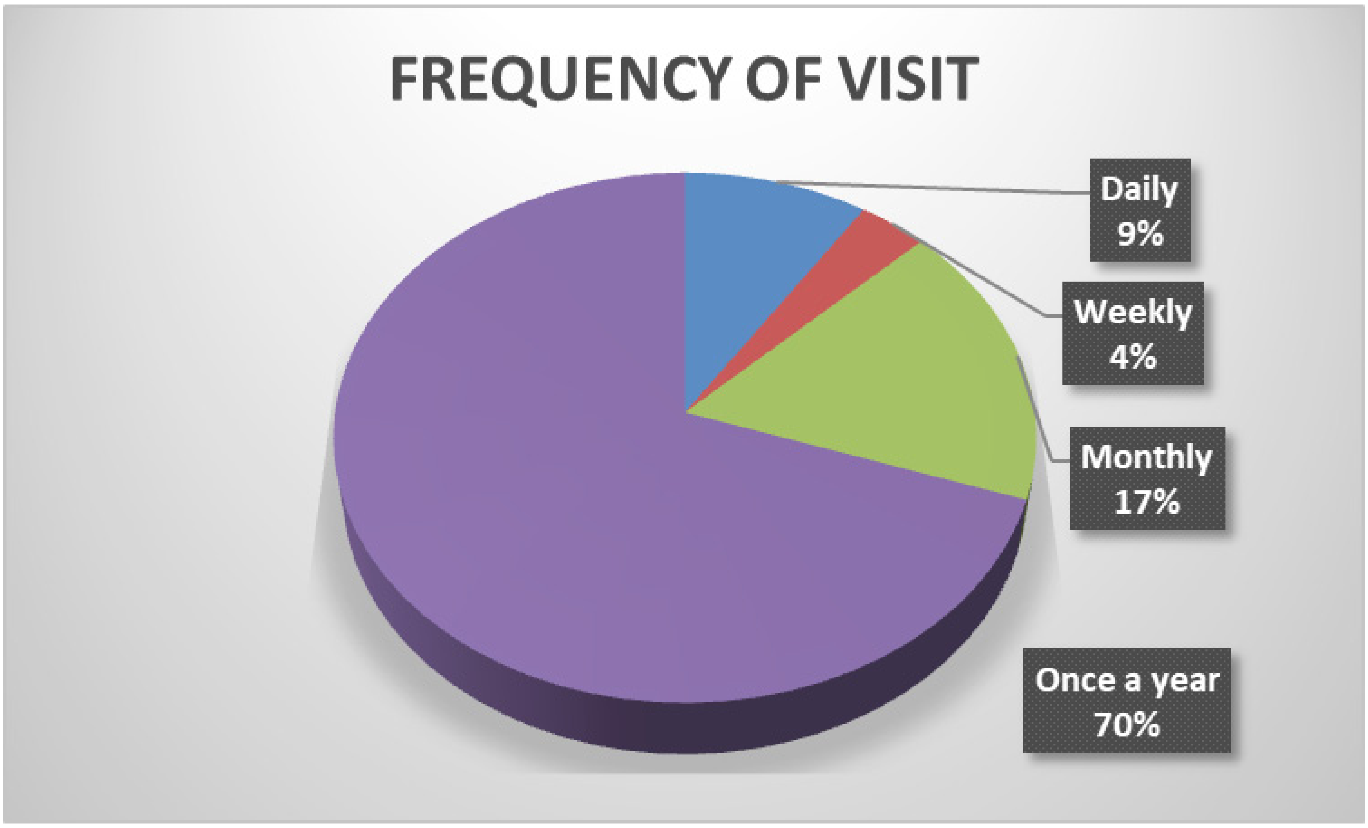


Figure 4.5 Frequency of Visit

However, due to unavailability of data on visitation charges, the study applied travel cost derived from daily wages for agricultural casual labour from other areas category as a proxy (KES 349/). Using the above proxy the study was able to estimate recreational value for Nzaui Water Tower KES 557,274,645.51 (US$ 5,517,570.75) (Table 27).

Table 27 Estimated values of recreation service from Nzaui Water Tower

Ecosystem Services and Benefits		No. of Beneficiaries or/and HH (2009 Census)	Projected population 2019 (1.4% growth)	Proportion (%) of use	Proxy- Minimum daily Wage –Agricultural general worker other areas (KES)	Estimated Recreational Value per year using projected pop. (KES)	Value (US$)
Recreational services	Category Once a year	36,951	42,463	70	349.50	10,388,572.95	102,857.16
	Once a month	36,951	42,463	17	349.50	30,275,269.74	299,755.15
	Once a week	36,951	42,463	4	349.50	28,453,607.04	281,718.88
	Daily	36,951	42,463	9	349.50	488,157,195.78	4,833,239.56
Total						**557,274,645.51**	**5,517,570.75**

The local valued the water tower for its cultural importance.. The frequency and numbers of visits for cultural purpose was varied but a close analysis revealed that about 29 % visited the ecosystem for cultural purposes at least once in a year. The local community had folklores and stories inspired by the ecosystem with 30% of the respondents' accepting that they had at least one or more stories or folklore connected with Nzaui Water Tower. From about 29% of the household visiting the Water Tower on cultural services and by adopting travel cost daily wages as a proxy, the value is **KES 4,303,837.40 (US$ 42,612.25)**

Table 28

Ecosystem Services and Benefits	No. of Beneficiaries or/and HH (2009 Census)	Projected population 2019 (1.4% growth)	Proportion (%) of use	Proxy- Minimum daily Wage – Agricultural general worker other areas (KES)	Estimated Recreational Value per year using projected pop. (KES)	Value (US$)
Cultural services	36,951	42,463	29	349.50	**4,303,837.40**	**42,612.25**

Table 29 Summary for cultural services

Ecosystem Services and Benefits	Valuation Method	Beneficiaries	Unit Cost (KES)	Annual Estimated Value (KES)	Value (US$)
Recreation and tourism	Travel cost		349.50	557,274,645.51	5,517,570.75
Cultural heritage (Socio-cultural, spiritual/ religious values, Existence of Nature)	Travel cost			4,303,837.40	42,612.25
Aesthetic value	Travel cost				
Total				**561,578,482.91**	**5,560,183.0**

Summary of the Valuation

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

$$TEV = Duv + Iuv + Bv + Ov \text{.......Equation 21}$$

(KEFRI, 2018)

Where TEV is total economic value; Duv is the direct-use value; Iuv is the indirect-use value; Bv is bequest or existence value; and Ov is option value. All of the values are defined in the report. All ES values were assumed to accrue in perpetuity; therefore, the Net present value was computed using the following discounting formula:

$$NPV(i, N, R) = \sum_{i=0}^{N} \frac{R_t}{(1+i)^t} \text{..........Equation 22}$$

Where *NPV* is the Net present value *N* is the total number of period, t is the period, R is the cash flow *i* is the discounting rate of 13.2% adopted from 2018 Twenty-Year Fixed Coupon Treasury Bonds (CBK, 2018). The discount rate was applied in this study because we assumed the flow of ES from the Water Towers in perpetuity and the present uses are sustainable without negative externalities.

The valuation results reveals that Nzaui Water Tower value is estimated at KES 6.15 billion (US$ 61 Million) provided annually by the Nzaui Water Tower ecosystem translating to **KES 336,172 (US$ 3,328.43) per ha per year**. **Regulatory Services** contributes the largest portion of benefits estimated at **KES 4.17billion** (US$ 41.3million/year) accounting for 68%, followed by **provisioning services** at KES **1.12billion** (US$11.1million/year) accounting for 18%, while **Cultural services** was valued **at KES 561.58million** (US$5.56million/year) accounting for 9% and **Support services** at **KES 295.95million** (US$2,93million/year) accounting for 5% as presented in (Figure 4.6, 4.7 and appendix 3). The Net Present Value for a period of 10 years is estimated at KES 48.86 B (US$483.7 million).

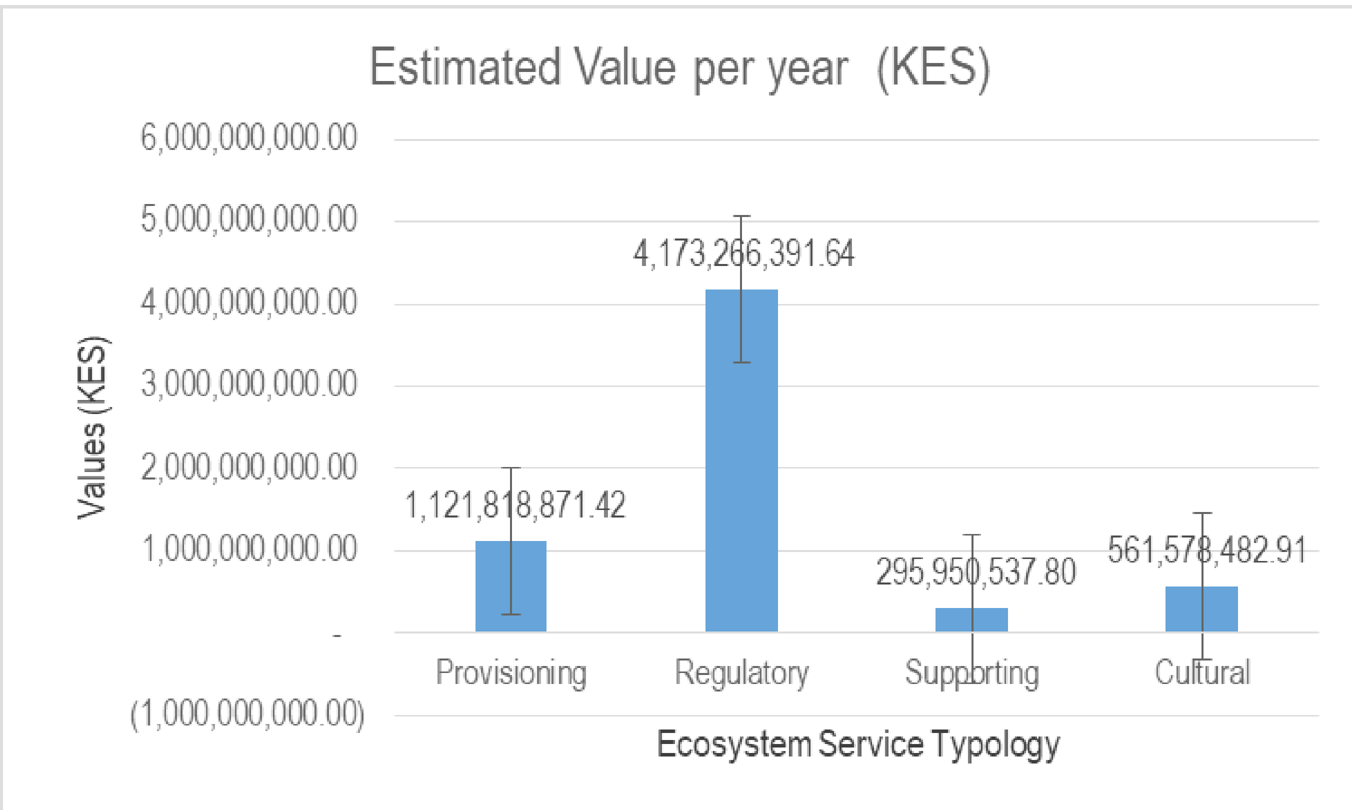


Figure 4.6: Summary of ES Category Values (KES)

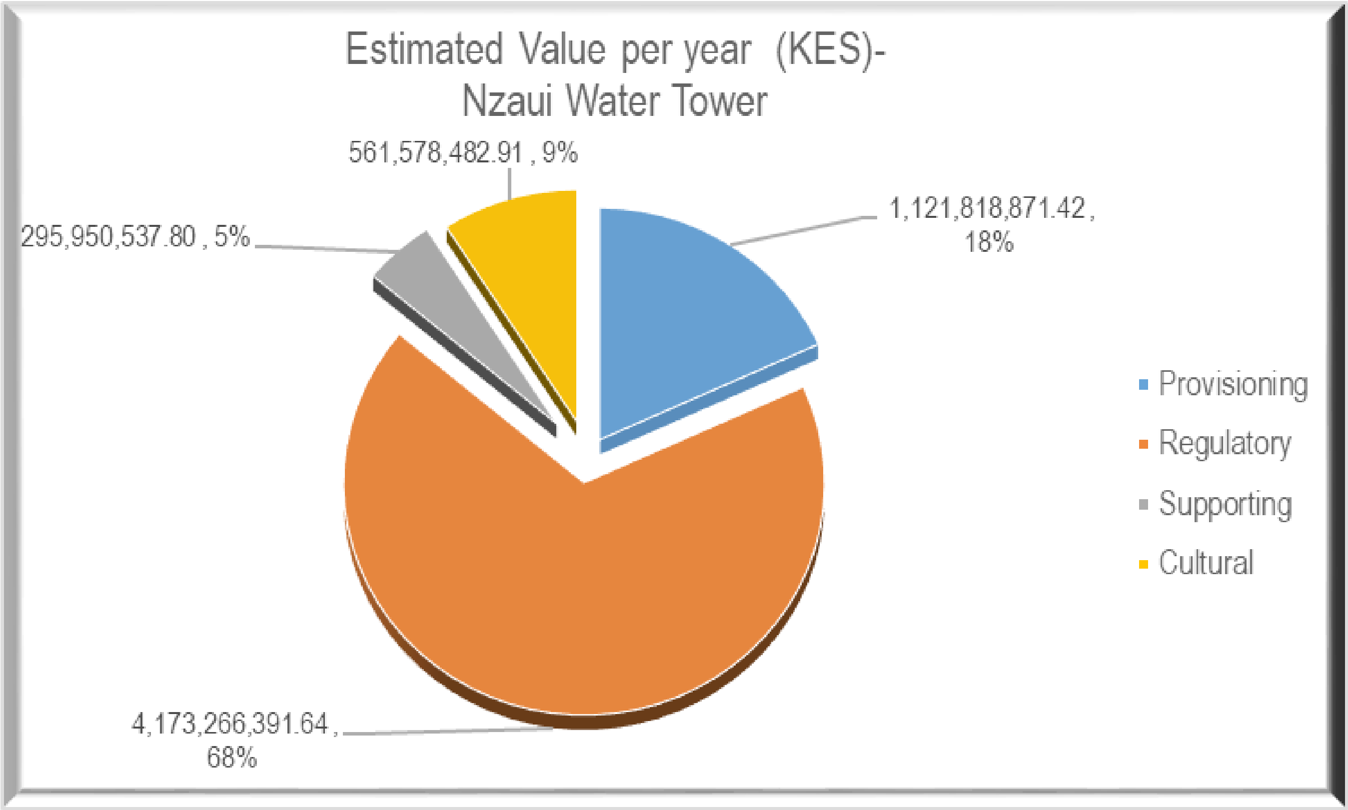


Figure 4.7 Proportion of Economic Value for ES Typology

CHAPTER FIVE

5.1 Discussion and Conclusion

Kenya's Constitution of Kenya and Vision 2030 highlights the need for increased forest cover targeting a 10 percent forest cover by 2022. The Kenya Water Towers Agency Strategic Plan 2016–2020 (KWTA, 2016) recognizes the importance of ecosystem services valuation in supporting County Integrated Development Plans and ecosystem conservation plans. The Kenya National Forest Programme 2016–2030 (GoK, 2016) also highlights challenges in forest financing, including inadequate data on the Total Economic Valuation of forests and their contribution to the national GDP. The achievement of these strategic goals can only be met with increased allocation of resources to support protection of existing forest and water tower resources as well as rehabilitate degraded areas.

From the results, economic benefits provided by Nzaui Hills Water Towers are critical in support of community livelihoods. Central to the anthropogenic activities is the dependence of the people on forest products and services for livelihoods support. These challenges threaten biodiversity and future ecosystems functions and thus community livelihoods. Moreover, most natural ecosystems services in the area are not traded in the market and therefore often true value of the water tower are obscured. Consequently, the total economic value of the water tower ecosystem is undervalued. The undervaluation of water tower resulted in marginalization in budget allocations, land-use change decisions, leading to degradation.

The Economic value suggest that Nzaui water tower has subsidized cost that the local community, county,national governments and the community would have otherwise incurred were it that the ecosystem is converted to other land uses. For instance, if every year, a loss of 1Ha of forest is experienced, this could translate to a loss of KES 336,172 (US$ 3,328.43) Ha-yr-.This Value therefore, provides an ideal scenario on the economic impacts of ecosystem degradation, land use change and biodiversity loss. This will provide a means to justify conservation of the water tower, set priorities for conservation programs, increased budgetary allocation and policies that steer protection and restoration of the ecosystem. The report should also inform public and private investments in water towers conservation.

The depletion and degradation of Ecosystem Services imposes costs on government (County and National), some of which affect the Gross National Product (GNP). As such, degradation of Ecosystem Services is likely to contribute towards a reduction in GNP. The evidence interms of Ecosystem Services available suggests that the costs of resource depletion and degradation are appreciable. Such estimates of Ecosystem Values can play a useful role in justifying development priorities in water towers. As the costs of resource depletion and degradation are increasingly recorded and accorded greater significance, county and national planners have clear incentives to prioritize these issues in their development plans and resource allocation.

Both national and the county government of Makueni should utilize the findings to prioritize programmes that promote sustainable management of water Towers. Where necessary either review or develop policies that support inclusion of natural resource values in planning and allocation of equivalent resources to the values of the Water Towers. This will reflect the ecological and socioeconomic importance of the Water Towers and such information will go a long way in sustaining Ecosystem Services and their contribution to the national development priorities.

Primary data collected in this study highlight the importance of understanding community dependence on forests when making decisions about natural-resource management. This report should be used to promote increased participation of community in Water Tower management.

The study acknowledges the contribution of the Kenya Water Towers in providing information for enhanced conservation of these critical ecosystems. Additionally, information provided can form a basis for establishing a Payment of Ecosystem Services (PES).

5.2 Conclusion

The Total Economic Valuation of Nzaui Hills Water Tower was carried out with the main goal of quantifying the contribution of Nzaui Hills Water Tower ecosystem Services to the local community, county and the national economy. This study highlights the important contribution of smaller water towers in Kenya. Thus, information on ecosystem services for Water Towers can be a tool for decision making to promote increased resource allocation, incentivised conservation practices and sustainable management of Water Tower ecosystem.

Accounting for Ecosystem Services

As mentioned above, national accounts are deficient in the treatment given to water towers environmental resources. Measures of economic activity ignore the resource flows that take place in the economy. These fail to record important activities that affect the sustainability of the economy and community well-being. Thus, there is need to modify national accounts that record “stocks” and “flows” of natural resources. GNP should account for depreciation of resource stocks (including water resources) in the same manner that it incorporates depreciation of human-induced capital. This would provide a measure of the ‘draw down’ on water ‘capital’ and the losses that accrue to human well-being from the use of goods and services provided by water resources. These adjustments involve economic valuation and buiding capacity of national accountants to appreciate such valuations and make the appropriate adjustments.

While methodological challenges and data inadequacies exist for economic valuation of ecosystems, as stated in this report, the results of our assessment forms a strong basis for water towers conservation and management for national and county Government. The study also provides an avenue for engaging both state and non-state actors in order to support an integrated approach to natural-resource stewardship. Further assessments could include understanding socio economic trends that drive realization of Kenya’s vision 2030, and the ‘Big Four’ agenda. This study provides an important step in the valuation of Kenya’s Water Towers at various scales, from their importance for household well-being to their global contribution to climate regulation.

Finally, information on the economic value of Water Towers just like Nzaui Hills can assist governments in setting policy and sectoral priorities. A comparison of the benefits and of the costs of planned changes in policy is required in order to establish whether they are potentially worthwhile. Total Economic Valuation can be used to influence the right decision against competing land use priorities.

Reccommendations

i. The Total Economic Valuation report for Nzaui Hills Water Tower should act as a catalyst to accelerate the development of natural accounting and a paradigm shift to economic valuations from a monetary one to one in which the values of natural capital, and the ecosystem services -which this capital supplies- are fully reflected in the mainstream of public and private decision-making.

ii. Total Economic Valuation demonstrates how different services are interlinked with each other and to the various components of ecosystem functioning and how they are impacted by the users. Sustainability (current use should not compromise the ability of the ecosystem to provide ecosystem services to the future generations) should be t key in planning.

iii. The Total Economic Valuation for Nzaui Hills provides an understanding of the risks this ecosystem and the economy is likely to face/suffer due to degradation. It is important to implement management strategies that can safeguard this vitally important component of the ecosystem.

iv. The Total Economic Valuation provides platform for sourcing funds to support water towers protection, conservation and rehabilitation from an informed point and minimize the cost of "business as usual'' scenario.

v. The report also highlights key threats and magnitude of the threat on the water towers ecosystem for timely interventions.

vi. In recognition of the Total Economic Value of Nzau Hills Water tower and its benefits to the surrounding community and the country, there is need for resource allocation in conserving the water tower by the development partners, county and national government

vii. There needs to be county-level natural-capital accounting systems to develop strategies, incentives, enhancing capacity of county officers and promoting programs that increase the flow of ecosystem services.

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APPENDICES

Appendix 1 Ecosystem Services and Valuation Method

ES Typology	Ecosystem Services and Benefits	Product	Mode	Valuation Method
Provisioning	Bio-chemical & pharmaceuticals	Natural Medicine (Plants and herbs)	Collected & purchased	Market Pricing
		Pharmaceutical		Market Pricing
	Food	Wild Fruits		Market Pricing
		Game Meat		Market Pricing
		Honey		Market Pricing
		Mushroom		Market Pricing
	Freshwater	Domestic Water		Market Pricing
	Fibre and fuel	e.g. Firewood		Market Pricing
	Construction Materials	e.g. timber		Market Pricing
	Green Energy			Market Pricing
	Resin			Market Pricing
	Seed Collection			Market Pricing
	Dying and Tanning			Market Pricing
	Hand Craft			Market Pricing
	Ornamental resources			Market Pricing
	Manure			Market Pricing
	Fodder			Market Pricing
	Insect Farming			Market Pricing
	Essential Oil			Market Pricing
	Nutrient supply e.g. nitrogen supply for crops,			Replacement cost
	Craft supply			Market Pricing
	Grazing			Market Pricing
	Genetic Resources			Market Pricing
Regulatory	Climate regulation	Micro-climate		Market Pricing
		Production of Oxygen		Replacement Cost
		Carbon Sequestration	Plant Carbon	Market Pricing
	Water purification and waste treatment			Unit Transfer
	Natural hazard regulation and Watershed Protection			Unit Transfer
	Air quality regulation			Unit Transfer
	Biological Regulation: (Disease regulation and pest controls)			Replacement Cost
	Erosion and Sediment regulation			Unit Transfer
	Waste regulation			Avertive cost
	Biogeochemistry Regulation			Avertive cost
	Pollination (Crop Pollination)			Unit Transfer
	Disease regulation; pest regulation			Replacement Cost
	Seed Dispersal			

ES Typology	Ecosystem Services and Benefits	Product	Mode	Valuation Method
Supporting	Primary production			Production function
	Soil formation			Replacement cost
	Nutrient cycling			Replacement Cost
	Water cycling			
	Biodiversity			
	Refugia/ Habitat provision			Value Transfer
Cultural	Recreation and tourism			Travel cost
	Cultural heritage (Socio-cultural, spiritual/ religious values, Existence of Nature)			Travel cost
	Aesthetic value			Travel cost

Appendix 2: Categories of Ecosystem Services and their examples

Categories of services	Definition	Examples	
Provisional	Material or energy outputs/ products obtained from the ecosystem	• Genetic resources • Food e.g. fish, fruits, • Fibre • Fresh water • Fuel wood • Timber • Mineral	• Building materials e.g. thatch, barks, poles • Shelter • Biodiversity • Bio-chemicals • Medicinal resources • Ornamental resources • Fodder
Regulatory	Benefits obtained from the regulation of the ecosystem processes	• Regulation of climate e.g. local climate(micro-climate) i.e. it influences rainfall and water availability both locally and regionally • Gas regulation e.g. sequestering of GHGs • Water purification • Water regulation • Air quality maintenance • Disturbance regulation • Biological regulation • Disease control • Gas regulation • Flood control	• Storm protection • Pollution control • Control soil erosion • Nutrient regulation • Waste regulation • Invasion resistance • Herbivory • Pollination • Seed dispersal • Natural hazard protection
Cultural	Non-material benefits obtained from ecosystem through spiritual enrichment, cognitive development/ reflection and aesthetic experience	• Education and inspiration • Knowledge system • Recreation • Social relation • Religion/spiritual value • Sport hunting	• Cultural identity • Historic • Hiking • Aesthetic/ sense of place • Existence value
Support services/	Ecosystem services that are necessary for the production of all other services	• Primary productivity • Soil formation and retention • biogeochemistry • Biomass production • Nutrient cycling	• Water cycling • Species habitat • Production atmospheric oxygen • Watershed protection • Nursery/ Refugia

Notwithstanding, In an ecological-economic system, there are interactions and feedbacks

Appendix 3 Summaries of Ecosystem Service and Beneficiaries Amount Extracted And Estimated Value

ES TYPOLOGY	Ecosystem Services and Benefits			No. of Beneficiaries or/and HH	Proportion (%) of use	Actual Quantity Per HH per month	Unit	Unit Cost (KES)- 5/= per 20ltr	Estimated Value per year (KES)	Potential Value
PROVISIONING	Bio-chemical & pharmaceuticals	Natural Medicine (Plants and herbs)	Collected	8493	6.4	1	Kg	110	717,488.60	7,103.85
			Purchased	8493	98	1	Kg	110	274,663,620.00	2,719,441.78
		Pharmaceutical							-	-
	Food	Wild Fruits		8493	13.1	60	Kg	5	4,005,298.80	39,656.42
		Honey	Wild	8493	5	2	Kg	650	6,624,540.00	65,589.50
			Apiary	1	100	80	Kg	650	624,000.00	6,178.22
			Individuals (BK)	15	100	48	Kg	650	468,000.00	4,633.66
		Mushroom		8493	2	1	Kg	120	244,598.40	2,421.77
	Freshwater	Domestic Water		8493	100	6	M^3	250	152,874,000.00	1,513,603.96
		Livestock	Cattle	8493	100	4.5	M^3	250	114,655,500.00	1,135,202.97
			Goats/ sheep	8493	100	3.75	M^3	250	95,546,250.00	946,002.48
		Shallow wells						30	79,056,000.00	782,732.67
		Industrial		1	100	1058	M^3	200	2,540,000.00	25,148.51
		Irrigation		8493	13.1	84	M^3	100	112,148,366.40	1,110,379.87
	Fibre and fuel	Firewood		8493	75.1	4	Back load	200	61,149,600.00	605,441.58
		Charcoal		8493	32.8	5	Bag	850	23,678,484.00	234,440.44
		Industrial Wood		8493	2	20	Feet	125	5,095,800.00	50,453.47
	Construction Materials	Thatch		8493	4.7	12	Bales	100	5,748,062.40	56,911.51
		Poles		8493	2.1	15	Pieces	300	9,631,062.00	95,357.05
		Withies/ Reeds		8493	6.7	35	Pieces	20	4,779,860.40	47,325.35
		Rattan		8493						-

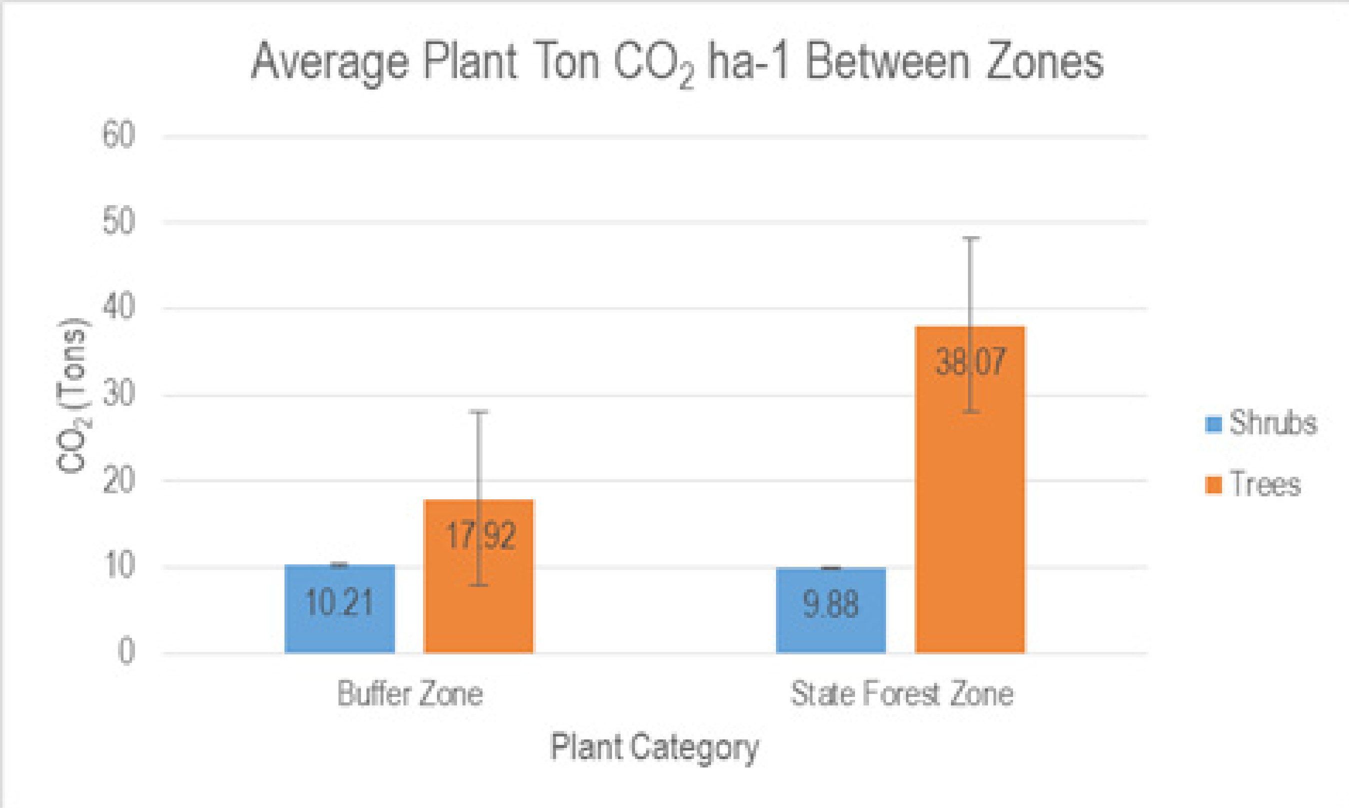
ES TYPOLOGY	Ecosystem Services and Benefits			No. of Beneficiaries or/and HH	Proportion (%) of use	Actual Quantity Per HH per month	Unit	Unit Cost (KES)- 5/= per 20ltr	Estimated Value per year (KES)	Potential Value
		Billets		8493						-
		Timbers		8493	7.7	120	Ft	23	21,659,188.32	214,447.41
		Standing Timber							49,642,560.00	491,510.50
	Green Energy			8493	0.4	1	Watts	1500	611,496.00	6,054.42
	Resin			8493	4.2	3	Kg	5	64,207.10	635.71
	Seed Collection									-
	Dying and Tanning			8493						-
	Hand Craft			8493						-
	Manure			8493	31.3	70	Bale	300	54,824,489.00	542,816.72
	Fodder			8493	0					-
	Insect Farming			8493	0					-
	Essential Oil			8493						-
	Craft supply			8493					40,766,400.00	403,627.72
	Grazing			8493						-
	Genetic Resources	Micro-climate							100,874,608.50	998,758.50
REGULATORY	Climate regulation	Production of Oxygen							228,112,275.70	2,258,537.38
		Carbon Sequestration	Plant						620,337,245.00	6,141,952.92
			Soil						1,531,437,329.84	15,162,745.84
	Water purification and waste treatment								20,179,368.00	199,795.72
	Air quality regulation								503,222,468.20	4,982,400.68
	Biological Regulation:								-	-
	Erosion and Sediment regulation								508,189,967.50	5,031,583.84

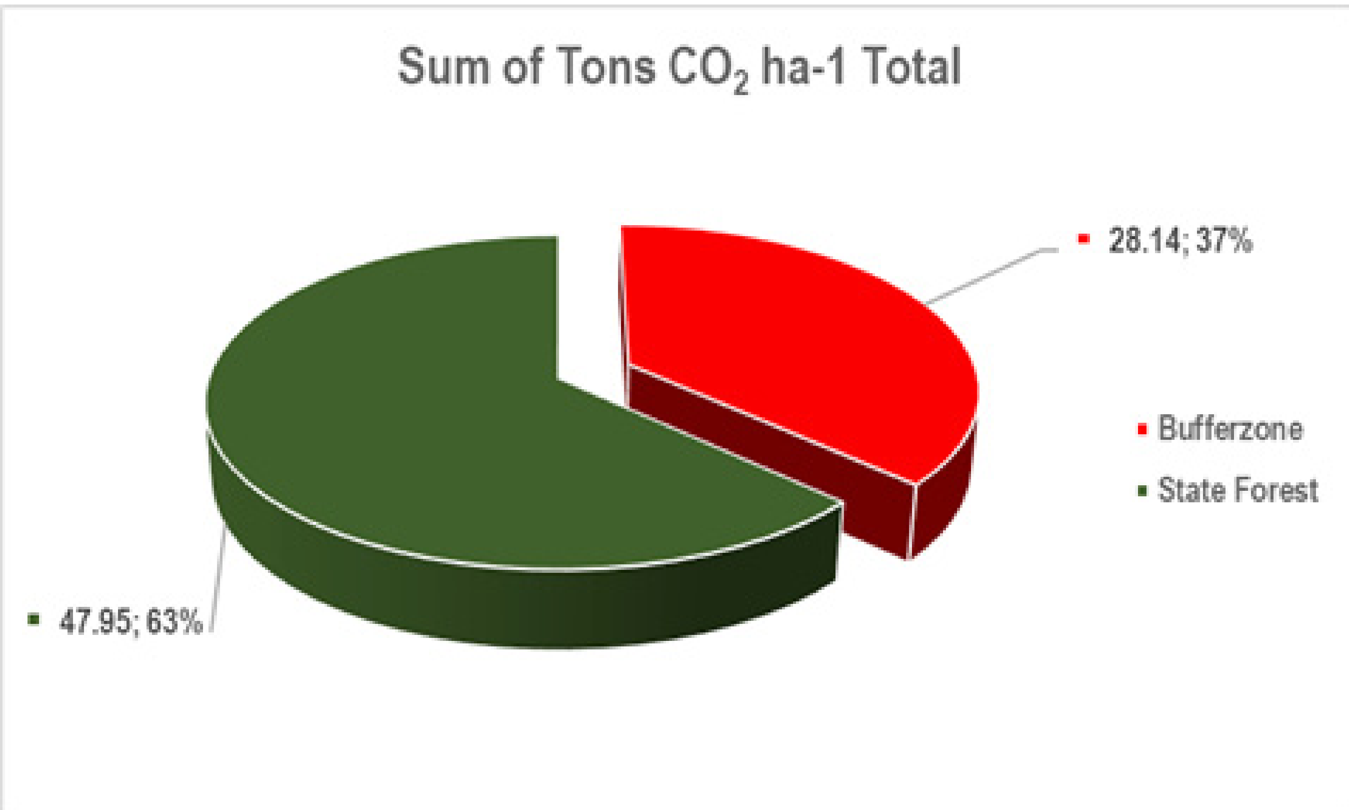
ES TYPOLOGY	Ecosystem Services and Benefits			No. of Beneficiaries or/and HH	Proportion (%) of use	Actual Quantity Per HH per month	Unit	Unit Cost (KES)- 5/= per 20ltr	Estimated Value per year (KES)	Potential Value
SUPPORT	Waste regulation								-	-
	Nutrient cycling								122,029,689.20	1,208,214.74
	Pollination	Value Transfer							657,308,550.00	6,508,005.45
	Disease regulation; pest regulation								-	-
	Seed Dispersal								-	-
	Soil formation								-	-
	Watershed Protection								3,604,578.90	35,688.90
	Biodiversity	Value Transfer							6,811,591.50	67,441.50
CULTURAL	Refugia/ Habitat provision	Travel cost							167,109,257.10	1,654,547.10
	Recreation and tourism	Travel cost						349.5	557,274,645.51	5,517,570.75
	Cultural Socio-cultural, spiritual	Travel cost						349.5	4,303,837.40	42,612.25
Totals									**6,152,614,283.77**	**60,916,973.11**

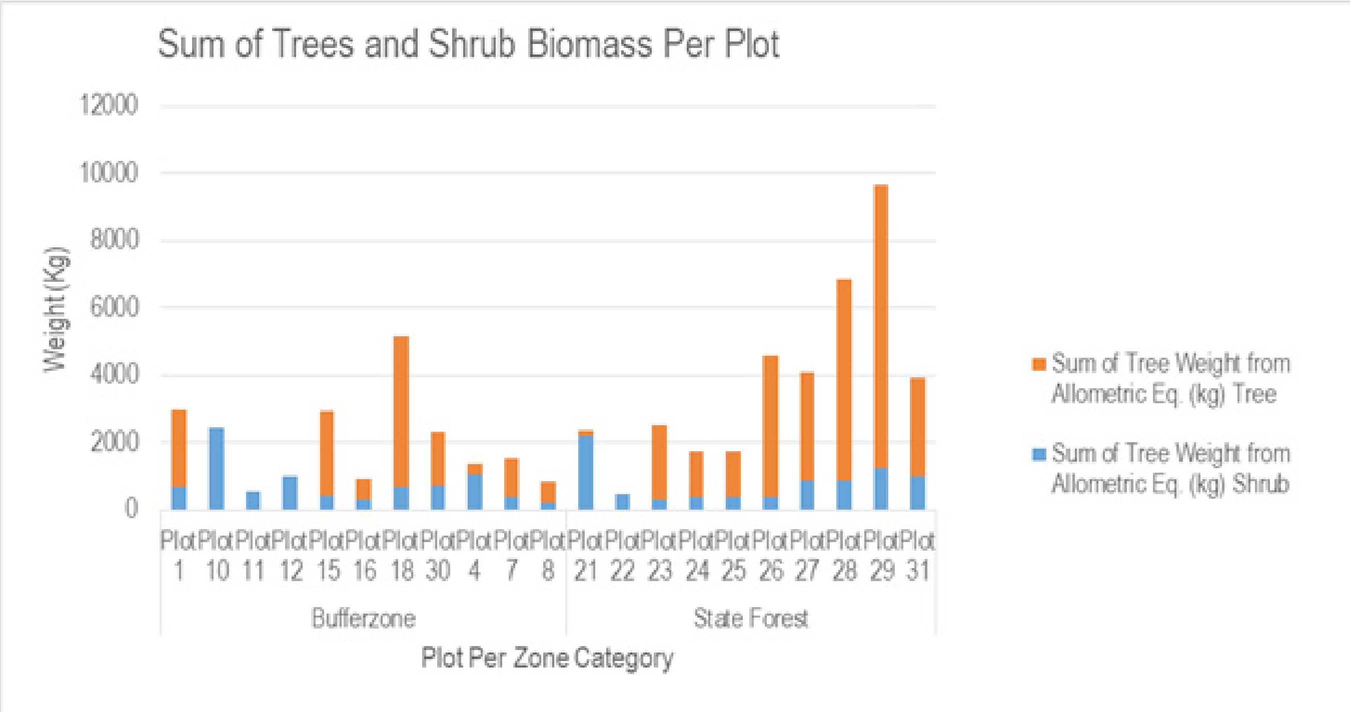
Appendix 4 Plant Biomass Estimates

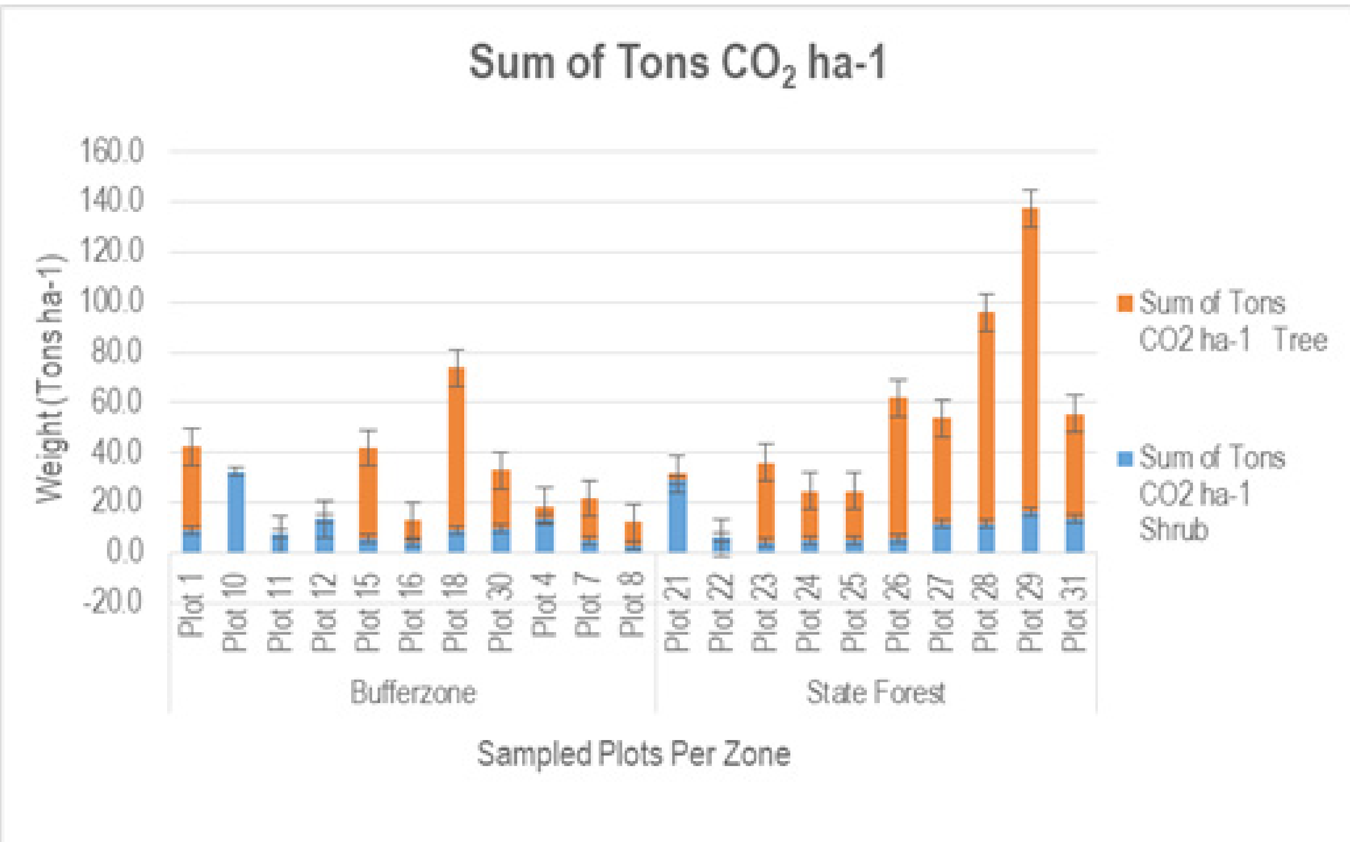
		Plant (Tree & Shrub) Biomass								
		Shrub			Tree					
Zone (Bufferzone & State Forest)	Plot No.	Sum of Above Ground Tree Biomass (t d.m. ha-1)	Sum of Tree Weight from Allometric Eq. (kg)	Sum of Tons CO2 ha-1	Sum of Above Ground Tree Biomass (t d.m. ha-1)	Sum of Tree Weight from Allometric Eq. (kg)	Sum of Tons CO2 ha-1	Total Sum of Above Ground Tree Biomass (t d.m. ha-1)	Total Sum of Tree Weight from Allometric Eq. (kg)	Total Sum of Tons CO_2 ha-1
Buffer zone	Plot 1	4.78	664.30	8.77	18.66	2330.43	33.52	23.44	2994.73	42.29
	Plot 10	17.56	2441.30	32.20				17.56	2441.30	32.20
	Plot 11	4.09	568.00	7.50	0.00	0.00	0.00	4.09	568.00	7.50
	Plot 12	7.38	1025.50	13.53	0.00	0.00	0.00	7.38	1025.50	13.53
	Plot 15	3.18	441.80	5.83	20.07	2506.79	36.06	23.25	2948.59	41.88
	Plot 16	2.38	330.60	4.36	4.78	597.35	8.59	7.16	927.95	12.96
	Plot 18	4.77	663.00	8.75	36.17	4518.39	64.99	40.94	5181.39	73.74
	Plot 30	5.31	737.20	9.73	12.88	1608.50	23.14	18.18	2345.70	32.87
	Plot 4	7.43	1032.30	13.63	2.78	346.95	4.99	10.21	1379.25	18.62
	Plot 7	2.84	395.00	5.21	9.23	1152.64	16.58	12.07	1547.64	21.79
	Plot 8	1.56	217.00	2.86	5.17	645.58	9.29	6.73	862.58	12.15
Buffer zone Total		**61.29**	**8516.00**	**112.36**	**109.73**	**13706.63**	**197.14**	**171.02**	**22222.63**	**309.51**
State Forest	Plot 21	15.96	2216.30	29.25	1.34	167.46	2.41	17.30	2383.76	31.66
	Plot 22	3.33	462.80	6.11	0.00	0.00	0.00	3.33	462.80	6.11
	Plot 23	2.23	310.30	4.10	17.72	2214.03	31.84	19.96	2524.33	35.94
	Plot 24	2.87	399.00	5.27	10.81	1350.36	19.42	13.68	1749.36	24.69
	Plot 25	2.82	392.20	5.18	10.79	1347.99	19.39	13.61	1740.19	24.56
	Plot 26	2.94	408.30	5.39	31.39	4183.04	56.39	34.33	4591.34	61.78
	Plot 27	6.33	879.00	11.60	23.54	3220.08	42.30	29.87	4099.08	53.90
	Plot 28	6.35	882.50	11.65	46.86	5955.93	84.19	53.21	6838.43	95.84
	Plot 29	8.93	1240.50	16.37	67.43	8422.98	121.15	76.36	9663.48	137.52
	Plot 31	7.49	1003.90	13.74	23.22	2924.00	41.72	30.71	3927.90	55.46
State Forest Total		59.27	8194.80	108.66	233.10	29785.86	418.81	292.37	37980.66	527.46
Grand Total		**120.56**	**16710.80**	**221.02**	**345.64**	**43844.09**	**621.00**	**466.26**	**60554.89**	**842.14**

Appendix 5 Summaries of CO2 Analysis for Nzaui Water Tower






Sum of Trees and Shrub Biomass Per Plot
12000
10000
8000
6000
4000
2000
0
Weight (Kg)
Plot 1
Plot 10
Plot 11
Plot 12
Plot 15
Plot 16
Plot 18
Plot 30
Plot 4
Plot 7
Plot 8
Plot 21
Plot 22
Plot 23
Plot 24
Plot 25
Plot 26
Plot 27
Plot 28
Plot 29
Plot 31
Bufferzone
State Forest
Plot Per Zone Category
Sum of Tree Weight from Allometric Eq. (kg) Tree
Sum of Tree Weight from Allometric Eq. (kg) Shrub


Sum of Tons CO2 ha-1
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
-20.0
Weight (Tons ha-1)
Plot 1
Plot 10
Plot 11
Plot 12
Plot 15
Plot 16
Plot 18
Plot 30
Plot 4
Plot 7
Plot 8
Plot 21
Plot 22
Plot 23
Plot 24
Plot 25
Plot 26
Plot 27
Plot 28
Plot 29
Plot 31
Bufferzone
State Forest
Sampled Plots Per Zone
Sum of Tons CO2 ha-1 Tree
Sum of Tons CO2 ha-1 Shrub

Appendix 6 Tree Population and Projected Densities in Nzaui Water Tower (Buffer zone)

Zone	Plot No.	Shrubs		Trees		Grand Total	
		Individuals per plot	Estimate No. of individual ha-1	Individuals per plot	Estimate No. of individual ha-1	Per Plot	Estimated No. of Individuals Ha-1
Buffer zone	Plot 1	13	208	6	96	19	304
	Plot 10	253	4050	0	0	253	4050
	Plot 11	77	1233	0	0	77	1233
	Plot 12	172	2753	0	0	172	2753
	Plot 15	46	736	10	160	56	896
	Plot 16	53	848	5	80	58	928
	Plot 18	51	816	12	192	63	1008
	Plot 30	56	896	7	112	63	1008
	Plot 4	56	896	5	80	61	976
	Plot 7	17	272	11	176	28	448
	Plot 8	9	144	3	48	12	192
Buffer Zone	**Average**	**73**	**1169**	**5**	**86**	**78**	**1254**

Appendix 7 Tree Population and Projected Densities in Nzaui Water Tower (Forest Section)

Zone	Plot No.	Shrubs		Trees		Grand Total	
		Individuals per plot	Estimate No. of individual ha-1	Individuals per plot	Estimate No. of individual ha-1	Per Plot	Estimated No. of Individuals Ha-1
State Forest	Plot 21	256	4098	2	32	258	4130
	Plot 22	27	432	0	0	27	432
	Plot 23	27	432	14	224	41	656
	Plot 24	203	3250	6	96	209	3346
	Plot 25	47	752	7	112	54	864
	Plot 26	38	608	22	352	60	960
	Plot 27	46	736	29	464	75	1201
	Plot 28	43	688	37	592	80	1281
	Plot 29	115	1841	35	560	150	2401
	Plot 31	71	1137	12	192	83	1329
State Forest	Total	873	13975	164	2625	1037	16600
	Average	87	1397	16	263	104	1660
Grand Total (Buffer Zone & State Forest)		1676	26829	223	3570	1899	30398
Average (Buffer Zone & State Forest)		80	1278	11	170	90	1448

Appendix 8 Summary on Below Ground Mineral Analysis Results

Senders Ref	Gps Coordinate	Depth	Depth Average	Bulk Density	PH(H_2O)	Ec (ms/cm)	P (Ppm)	N (%)	C (%)	Organic Carbon (Ton/ha)	CO_2 Ton/ha)
NZAUI WT	337563;9799410	0-20cm	20	1.09	5.933	0.016	1.06	0.08	0.98	21.33	78.3
	337563;9799410	20-40 cm	20	0.86	4.931	0.022	0.61	0.07	1.11	19.00	69.7
	337563;9799410	40-60 cm	20		4.791	0.028	0.15	0.07	0.62	0.00	0.0
	****	0-20cm	20	0.96	6.156	0.019	1.66	0.01	0.98	18.77	68.9
	****	20-40 cm	20		6.458	0.015	3.18	0.01	2.71	0.00	0.0
	343610;9793464	0-20 cm	20	0.90	7.559	0.102	163.39	0.2	2.4	43.01	157.8
	340610;9790464	0-20cm	20	0.82	6.509	0.028	0.91	0.17	2.09	34.46	126.5
	340610;9790464	20-40 cm	20	0.97	6.283	0.022	0.15	0.12	1.42	27.60	101.3
	340610;9790464	40-60 cm	20		6.149	0.023	0.61	0.07	0.8	0.00	0.0
	343580;9787445	0-20cm	20	1.01	5.91	0.075	0.91	0.09	1.54	31.17	114.4
	343580;9787445	20-40 cm	20	1.05	5.946	0.029	1.51	0.1	1.48	31.03	113.9
	343580;9787445	40-60 cm	20		5.856	0.022	0.15	0.04	1.23	0.00	0.0
	340610;9787464	0-20cm	20	1.01	5.811	0.033	0.15	0.16	1.35	27.18	99.8
	340610;9787464	20-40 cm	20	1.08	5.812	0.037	0.15	0.09	1.23	26.59	97.6
	340610;9787464	40-60 cm	20		6.075	0.03	0.91	0.11	1.23	0.00	0.0
	380610;9784464	0-20cm	20	1.13	6.718	0.027	2.42	0.09	0.98	22.14	81.3
	380610;9784464	20-40 cm	20	0.87	7.073	0.039	0.76	0.1	1.72	29.98	110.0
	380610;9784464	40-60 cm	20		7.186	0.06	1.21	0.03	1.6	0.00	0.0
	37.5ºSE;1.95ºS	0-20cm	20		6.612	0.034	2.42	0.13	1.78	0.00	0.0
	37.5ºSE;1.95ºS	20-40 cm	20		7.694	0.128	3.63	0.16	2.34	0.00	0.0
	37.5ºSE;1.95ºS	40-60 cm	20		7.844	0.108	1.36	0.07	1.54	0.00	0.0
	3787464;9787464	0-20cm	20	1.11	6.849	0.045	1.21	0.13	1.42	31.50	115.6
	3787464;9787464	20-40 cm	20		6.436	0.023	0.61	0.14	1.29	0.00	0.0
	3787464;9787464	40-60 cm	20		6.626	0.026	15.89	0.15	1.29	0.00	0.0
	334610;9790464	0-20cm	20	0.83	7.143	0.067	15.58	0.21	2.4	40.07	147.1
	334610;9790464	20-40 cm	20		6.612	0.031	1.51	0.17	1.6	0.00	0.0
	334610;9790464	40-60 cm	20		6.041	0.044	1.06	0.05	2.28	0.00	0.0
	334615;9793462	0-20 cm	20	1.04	7.006	0.065	0.61	0.18	2.71	56.12	206.0
	334615;9793462	20-40 cm	20		6.092	0.026	0.61	0.19		0.00	0.0
	334615;9793462	40-60 cm	20		5.482	0.017	0.15	0.16		0.00	0.0
	33831;9787564	0-20 cm	20		5.624	0.032	3.63	0.23		0.00	0.0
	33831;9787564	20-40 cm	20		5.309	0.022	1.66	0.13		0.00	0.0
	338634;9788465	0-20 cm	20		5.845	0.023	29.5	0.66		0.00	0.0
	337829;9788529	0-20 cm	20	0.59	4.592	0.033	1.66	0.25		0.00	0.0
	337829;9788529	20-40 cm	20	0.73	4.634	0.022	0.76	0.1		0.00	0.0
	337829;9788529	40-60 cm	20		4.673	0.015	0.3	0.15		0.00	0.0
	*****	0-20 cm	20	0.72	6.003	0.067	14.52	0.47		0.00	0.0
	*****	20-40 cm	20		5.376	0.043	22.09	0.23		0.00	0.0

Senders Ref	Gps Coordinate	Depth	Depth Average	Bulk Density	$PH(H_2O)$	Ec (ms/cm)	P (Ppm)	N (%)	C (%)	Organic Carbon (Ton/ha)	CO_2 Ton/ha)
	*****	40-60 cm	20		5.045	0.018	15.58	0.19		0.00	0.0
	33859;978957	0-20 cm	20		5.012	0.015	6.96	0.52		0.00	0.0
	338615;9790460	0-20 cm	20	0.83	5.184	0.024	0.76	0.2		0.00	0.0
	338615;9790460	20-40 cm	20		5.345	0.012	0.61	0.15		0.00	0.0
	338615;9790460	40-60 cm	20		5.325	0.018	0.15	0.13		0.00	0.0
	337610;9790464	0-20 cm	20	0.60	4.477	0.053	11.65	0.31		0.00	0.0
	337610;9790464	20-40 cm	20	0.69	4.436	0.032	7.11	0.22		0.00	0.0
	337610;9790464	40-60 cm	20		4.547	0.024	11.04			0.00	0.0
	3338622;9791470	0-20 cm	20	1.12	5.82	0.036	1.36			0.00	0.0
	3338622;9791470	20-40 cm	20	1.04	5.91	0.025	0.15			0.00	0.0
	3338622;9791470	40-60 cm	20		6.173	0.025	0.15			0.00	0.0
	337630;9791450	0--20cm	20	0.91	5.794	0.027	0.15			0.00	0.0
	337630;9791450	20-40 cm	20		5.715	0.013	0.15			0.00	0.0
	337630;9791450	40-60 cm	20		5.578	0.01	0.3			0.00	0.0
	336637;9791457	0-20cm	20	0.96	6.234	0.019	1.36			0.00	0.0
	337610;9792464	0-20 cm	20	1.04	4.97	0.017	2.04			0.00	0.0
	337610;9792464	20-40 cm	20	1.05	5.21	0.01	0.15			0.00	0.0
	337610;9792464	40-60 cm	20		5.251	0.01	0.76			0.00	0.0

Appendix 9 Nzaui/ Kalamba Ward Agricultural Statistics

Total area -198 Sq. Km	19,800 ha
Main Agro-ecological zone	LM3, LM4, UM3(small portion)
Arable area. 11,730 ha	11,730 ha - 59%
Non-Arable…80.7 Sq km	8,070 ha - 41%
Irrigation potential	200 ha
Exploited Irrigated land	130 ha
Land under food crops	9,400 ha
Land under fruit tree	1,400 ha
No. of locations-6	Kalamba, Kilili, Ikangavyya, Kithumba, Nzaui, Kawala
No. of sub/locations---15	Kilili, kathatu, wee, kawala, ndovea, mavia ume, matiliku, kyeeko, kithumba, nzeeni, ndumoni, kalamba, kwakalui, kalembwani, ikangavya.
Ward population--37,042 M…12948…../f…24094…. Source of info census 1987	--37,042 M-12948 F-24094
No. of households-----.6,174	.6,174
No. of farm families…5,865	5,865
Average household size-----6	6
Population working in Agriculture…80%	80%
Farmer staff ratio…1:3000	1:3000
Average farm size (large scale) .4 Ha to 8 Hac	4 Ha to 8 hac
No service providers	15 active
Annual precipitation and patterns… Annual (MAM & OND)	250mmls to 650mml per year
Note: Most farmers intercrop food crops with fruits	

Type of crop	Estimated ha	Production estimate per ha	remarks
1)FRUIT TREES(rain fed)			
Mangoes	860hac	35t/ha	Average production for mature trees and medium managed farm
Citrus	560 ha	25t ha	
Papaws	40 ha	12t/ha	
Avocados	20hac	125 ton/ha	

Type of crop	Estimated ha	Production estimate per ha	remarks
2)Food Crops(under rain fed) Maize Pigeon Peas Green Grams Cowpeas Dolichos	 600 ha 900 ha 220 ha 30 ha 20 ha	 20 bags/ha 6 bags 4 bags 6 bags 2 bags	 Average production for medium managed farm under rain fed on normal rains
Vegetables(under irrigation) Collards Tomatoes spinach Capsicum Melons Butternuts	 42 ha 38 ha 14 ha 12 ha 16 ha 8 ha	 1200kt /ha 12,25 t/ha 2t /ha 3.5t/ha 75t/ha 10 t/ha	 Average production on medium managed farm and improved seed varieties
Industrial Crops(rain fed) Cotton	 20 ha	 500kgs/ ha	Average production on medium managed farm and rain fed

Appendix 10 Agricultural Products Price (2019)

Price Information for April 18, 2019						
Product	Location	Quantity	Low (KSHS)	High (KSHS)	Price Per kg (KES)	Average Price
Avocado	karatina	90 Kg	0	0		
Avocado	Kisii	90 Kg	900	900	10	
Avocado	Nairobi	90 Kg	2,600.00	2,600.00	28.89	
Avocado	Mombasa	90 Kg	4,000.00	4,000.00	44.44	
Avocado	Kisumu	90 Kg	1,800.00	1,800.00	20	
Avocado	Nakuru	90 Kg	3,500.00	3,500.00	38.89	
Avocado	Eldoret	90 Kg	3,400.00	3,400.00	37.78	30
Beans Canadian	Nairobi	90 Kg	6,300.00	6,300.00	70	
Beans Canadian	Mombasa	90 Kg	0	0	0	
Beans Canadian	Kisumu	90 Kg	8,800.00	8,800.00	97.78	
Beans Canadian	Nakuru	90 Kg	7,000.00	7,000.00	77.78	
Beans Canadian	Eldoret	90 Kg	0	0	0	
Beans Canadian	karatina	90 Kg	0	0	0	
Beans Canadian	Kisii	90 Kg	0	0	0	81.85
Beans Mwitemania	Kisii	90 Kg	0	0	0	
Beans Mwitemania	Nairobi	90 Kg	5,850.00	5,850.00	65	
Beans Mwitemania	Mombasa	90 Kg	6,500.00	6,500.00	72.22	
Beans Mwitemania	Kisumu	90 Kg	0	0	0	
Beans Mwitemania	Nakuru	90 Kg	5,000.00	5,000.00	55.56	
Beans Mwitemania	Eldoret	90 Kg	9,000.00	9,000.00	100	
Beans Mwitemania	karatina	90 Kg	0	0	0	73.19
Beans Rosecoco	Kisumu	90 Kg	8,800.00	8,800.00	97.78	
Beans Rosecoco	Nakuru	90 Kg	8,500.00	8,500.00	94.44	
Beans Rosecoco	Eldoret	90 Kg	9,900.00	9,900.00	110	
Beans Rosecoco	karatina	90 Kg	0	0	0	
Beans Rosecoco	Nairobi	90 Kg	7,000.00	7,000.00	77.78	
Beans Rosecoco	Mombasa	90 Kg	6,200.00	6,200.00	68.89	89.78
Brinjals	Nairobi	44 Kg	2,550.00	2,550.00	57.95	
Brinjals	Mombasa	44 Kg	1,760.00	1,760.00	40	
Brinjals	Kisumu	44 Kg	1,500.00	1,500.00	34.09	
Brinjals	Nakuru	44 Kg	3,000.00	3,000.00	68.18	

Price Information for April 18, 2019						
Product	Location	Quantity	Low (KSHS)	High (KSHS)	Price Per kg (KES)	Average Price
Brinjals	Eldoret	44 Kg	0	0	0	
Brinjals	karatina	44 Kg	0	0	0	
Brinjals	Kisii	44 Kg	0	0	0	50.06
Cabbages	Nakuru	126 Kg	1,800.00	1,800.00	14.29	
Cabbages	Eldoret	126 Kg	3,000.00	3,000.00	23.81	
Cabbages	karatina	126 Kg	0	0	0	
Cabbages	Nairobi	126 Kg	1,950.00	1,950.00	15.48	
Cabbages	Mombasa	126 Kg	3,750.00	3,750.00	29.76	
Cabbages	Kisumu	126 Kg	2,500.00	2,500.00	19.84	20.63
Capsicums	Kisii	50 Kg	0	0	0	
Capsicums	Nairobi	50 Kg	3,500.00	3,500.00	70	
Capsicums	Mombasa	50 Kg	2,500.00	2,500.00	50	
Capsicums	Kisumu	50 Kg	2,600.00	2,600.00	52	
Capsicums	Nakuru	50 Kg	3,500.00	3,500.00	70	
Capsicums	Eldoret	50 Kg	3,000.00	3,000.00	60	
Capsicums	karatina	50 Kg	0	0	0	60.4
Carrots	Eldoret	138 Kg	5,400.00	5,400.00	39.13	
Carrots	karatina	138 Kg	0	0	0	
Carrots	Kisii	138 Kg	0	0	0	
Carrots	Nairobi	138 Kg	5,800.00	5,800.00	42.03	
Carrots	Mombasa	138 Kg	8,700.00	8,700.00	63.04	
Carrots	Kisumu	138 Kg	3,500.00	3,500.00	25.36	
Carrots	Nakuru	138 Kg	7,000.00	7,000.00	50.72	44.06
Cassava Fresh	karatina	99 Kg	0	0	0	
Cassava Fresh	Kisii	99 Kg	0	0	0	
Cassava Fresh	Nairobi	99 Kg	2,400.00	2,400.00	24.24	
Cassava Fresh	Mombasa	99 Kg	2,400.00	2,400.00	24.24	
Cassava Fresh	Kisumu	99 Kg	3,000.00	3,000.00	30.3	
Cassava Fresh	Nakuru	99 Kg	0	0	0	
Cassava Fresh	Eldoret	99 Kg	0	0	0	26.26
Cauliflower	Nakuru	39 Kg	0	0	0	
Cauliflower	Eldoret	39 Kg	0	0	0	
Cauliflower	karatina	39 Kg	0	0	0	

Price Information for April 18, 2019						
Product	Location	Quantity	Low (KSHS)	High (KSHS)	Price Per kg (KES)	Average Price
Cauliflower	Kisii	39 Kg	0	0	0	
Cauliflower	Nairobi	39 Kg	2,730.00	2,730.00	70	
Cauliflower	Mombasa	39 Kg	3,900.00	3,900.00	100	
Cauliflower	Kisumu	39 Kg	0	0	0	85
Chillies	Nairobi	38 Kg	2,660.00	2,660.00	70	
Chillies	Mombasa	38 Kg	3,500.00	3,500.00	92.11	
Chillies	Kisumu	38 Kg	1,500.00	1,500.00	39.47	
Chillies	Nakuru	38 Kg	4,000.00	4,000.00	105.26	
Chillies	Eldoret	38 Kg	0	0	0	
Chillies	karatina	38 Kg	0	0	0	
Chillies	Kisii	38 Kg	0	0	0	76.71
Cooking Bananas	Nairobi	22 Kg	550	550	25	
Cooking Bananas	Mombasa	22 Kg	600	600	27.27	
Cooking Bananas	Kisumu	22 Kg	300	300	13.64	
Cooking Bananas	Nakuru	22 Kg	250	250	11.36	
Cooking Bananas	Eldoret	22 Kg	1,500.00	1,500.00	68.18	
Cooking Bananas	karatina	22 Kg	0	0	0	
Cooking Bananas	Kisii	22 Kg	300	300	13.64	26.52
Cowpeas	Kisii	90 Kg	0	0	0	
Cowpeas	Nairobi	90 Kg	5,000.00	5,000.00	55.56	
Cowpeas	Mombasa	90 Kg	3,600.00	3,600.00	40	
Cowpeas	Kisumu	90 Kg	8,500.00	8,500.00	94.44	
Cowpeas	Nakuru	90 Kg	8,500.00	8,500.00	94.44	
Cowpeas	Eldoret	90 Kg	9,000.00	9,000.00	100	
Cowpeas	karatina	90 Kg	0	0	0	76.89
Cucumber	Kisumu	50 Kg	0	0	0	
Cucumber	Nakuru	50 Kg	0	0	0	
Cucumber	Eldoret	50 Kg	0	0	0	
Cucumber	karatina	50 Kg	0	0	0	
Cucumber	Kisii	50 Kg	0	0	0	
Cucumber	Nairobi	50 Kg	3,000.00	3,000.00	60	
Cucumber	Mombasa	50 Kg	3,000.00	3,000.00	60	60
Dry Maize	Nairobi	90 Kg	3,400.00	3,400.00	37.78	

Price Information for April 18, 2019						
Product	**Location**	**Quantity**	**Low (KSHS)**	**High (KSHS)**	**Price Per kg (KES)**	**Average Price**
Dry Maize	Mombasa	90 Kg	3,800.00	3,800.00	42.22	
Dry Maize	Kisumu	90 Kg	4,000.00	4,000.00	44.44	
Dry Maize	Nakuru	90 Kg	2,800.00	2,800.00	31.11	
Dry Maize	Eldoret	90 Kg	3,000.00	3,000.00	33.33	
Dry Maize	karatina	90 Kg	0	0	0	37.78
Eggs	Nakuru	0 Tray	280	280	280	
Eggs	Eldoret	0 Tray	300	300	300	
Eggs	karatina	0 Tray	0	0	0	
Eggs	Kisii	0 Tray	290	290	290	
Eggs	Nairobi	0 Tray	270	270	270	
Eggs	Mombasa	0 Tray	300	300	300	
Eggs	Kisumu	0 Tray	290	290	290	288.33
Finger Millet	Nairobi	90 Kg	7,200.00	7,200.00	80	
Finger Millet	Mombasa	90 Kg	6,750.00	6,750.00	75	
Finger Millet	Kisumu	90 Kg	7,600.00	7,600.00	84.44	
Finger Millet	Nakuru	90 Kg	6,500.00	6,500.00	72.22	
Finger Millet	Eldoret	90 Kg	7,650.00	7,650.00	85	
Finger Millet	karatina	90 Kg	0	0	0	79.33
Fresh Peas	Nairobi	51 Kg	4,700.00	4,700.00	92.16	
Fresh Peas	Mombasa	51 Kg	7,750.00	7,750.00	151.96	
Fresh Peas	Kisumu	51 Kg	2,500.00	2,500.00	49.02	
Fresh Peas	Nakuru	51 Kg	4,500.00	4,500.00	88.24	
Fresh Peas	Eldoret	51 Kg	6,120.00	6,120.00	120	
Fresh Peas	karatina	51 Kg	0	0	0	
Fresh Peas	Kisii	51 Kg	0	0	0	100.27
Green Gram	Nakuru	90 Kg	7,500.00	7,500.00	83.33	
Green Gram	Eldoret	90 Kg	10,800.00	10,800.00	120	
Green Gram	karatina	90 Kg	0	0	0	
Green Gram	Kisii	90 Kg	0	0	0	
Green Gram	Nairobi	90 Kg	10,000.00	10,000.00	111.11	
Green Gram	Mombasa	90 Kg	9,000.00	9,000.00	100	
Green Gram	Kisumu	90 Kg	8,800.00	8,800.00	97.78	102.44
Green Maize	Eldoret	115 Kg	2,600.00	2,600.00	22.61	

Price Information for April 18, 2019						
Product	Location	Quantity	Low (KSHS)	High (KSHS)	Price Per kg (KES)	Average Price
Green Maize	karatina	115 Kg	0	0	0	
Green Maize	Kisii	115 Kg	0	0	0	
Green Maize	Nairobi	115 Kg	3,000.00	3,000.00	26.09	
Green Maize	Mombasa	115 Kg	4,200.00	4,200.00	36.52	
Green Maize	Kisumu	115 Kg	3,000.00	3,000.00	26.09	
Green Maize	Nakuru	115 Kg	2,200.00	2,200.00	19.13	26.09
Groundnuts	Nakuru	110 Kg	13,000.00	13,000.00	118.18	
Groundnuts	Eldoret	110 Kg	10,350.00	10,350.00	94.09	
Groundnuts	karatina	110 Kg	0	0	0	
Groundnuts	Nairobi	110 Kg	12,500.00	12,500.00	113.64	
Groundnuts	Mombasa	110 Kg	10,800.00	10,800.00	98.18	
Groundnuts	Kisumu	110 Kg	10,000.00	10,000.00	90.91	103
Kales	Nairobi	50 Kg	1,750.00	1,750.00	35	
Kales	Mombasa	50 Kg	4,000.00	4,000.00	80	
Kales	Kisumu	50 Kg	4,000.00	4,000.00	80	
Kales	Nakuru	50 Kg	4,000.00	4,000.00	80	
Kales	Eldoret	50 Kg	3,200.00	3,200.00	64	
Kales	karatina	50 Kg	0	0	0	67.8
Lemons	Nairobi	95 Kg	2,850.00	2,850.00	30	
Lemons	Mombasa	95 Kg	2,600.00	2,600.00	27.37	
Lemons	Kisumu	95 Kg	1,700.00	1,700.00	17.89	
Lemons	Nakuru	95 Kg	2,700.00	2,700.00	28.42	
Lemons	Eldoret	95 Kg	0	0	0	
Lemons	karatina	95 Kg	0	0	0	
Lemons	Kisii	95 Kg	3,400.00	3,400.00	35.79	27.89
Lettuce	Kisii	51 Kg	0	0	0	
Lettuce	Nairobi	51 Kg	3,500.00	3,500.00	68.63	
Lettuce	Mombasa	51 Kg	4,200.00	4,200.00	82.35	
Lettuce	Kisumu	51 Kg	0	0	0	
Lettuce	Nakuru	51 Kg	0	0	0	
Lettuce	Eldoret	51 Kg	0	0	0	
Lettuce	karatina	51 Kg	0	0	0	75.49
Limes	Eldoret	13 Kg	0	0	0	

Price Information for April 18, 2019						
Product	Location	Quantity	Low (KSHS)	High (KSHS)	Price Per kg (KES)	Average Price
Limes	karatina	13 Kg	0	0	0	
Limes	Kisii	13 Kg	0	0	0	
Limes	Nairobi	13 Kg	1,300.00	1,300.00	100	
Limes	Mombasa	13 Kg	960	960	73.85	
Limes	Kisumu	13 Kg	0	0	0	
Limes	Nakuru	13 Kg	0	0	0	86.92
Mangoes Local	Nairobi	126 Kg	2,800.00	2,800.00	22.22	
Mangoes Local	Mombasa	126 Kg	0	0	0	
Mangoes Local	Kisumu	126 Kg	3,000.00	3,000.00	23.81	
Mangoes Local	Nakuru	126 Kg	5,000.00	5,000.00	39.68	
Mangoes Local	Eldoret	126 Kg	2,800.00	2,800.00	22.22	
Mangoes Local	karatina	126 Kg	0	0	0	
Mangoes Local	Kisii	126 Kg	0	0	0	26.98
Mwezi Moja	Nairobi	90 Kg	5,850.00	5,850.00	65	
Mwezi Moja	Mombasa	90 Kg	0	0	0	
Mwezi Moja	Kisumu	90 Kg	0	0	0	
Mwezi Moja	Nakuru	90 Kg	7,000.00	7,000.00	77.78	
Mwezi Moja	Eldoret	90 Kg	0	0	0	
Mwezi Moja	karatina	90 Kg	0	0	0	
Mwezi Moja	Kisii	90 Kg	0	0	0	71.39
Onions Dry	Mombasa	13 Kg	650	650	50	
Onions Dry	Kisumu	13 Kg	910	910	70	
Onions Dry	Nakuru	13 Kg	750	750	57.69	
Onions Dry	Eldoret	13 Kg	1,170.00	1,170.00	90	
Onions Dry	karatina	13 Kg	0	0	0	
Onions Dry	Kisii	13 Kg	700	700	53.85	
Onions Dry	Nairobi	13 Kg	850	850	65.38	64.49
Oranges	Kisumu	93 Kg	4,000.00	4,000.00	43.01	
Oranges	Nakuru	93 Kg	6,000.00	6,000.00	64.52	
Oranges	Eldoret	93 Kg	3,800.00	3,800.00	40.86	
Oranges	karatina	93 Kg	0	0	0	
Oranges	Nairobi	93 Kg	3,000.00	3,000.00	32.26	
Oranges	Mombasa	93 Kg	2,800.00	2,800.00	30.11	42.15

Price Information for April 18, 2019						
Product	**Location**	**Quantity**	**Low (KSHS)**	**High (KSHS)**	**Price Per kg (KES)**	**Average Price**
Passion Fruits	Nairobi	57 Kg	6,500.00	6,500.00	114.04	
Passion Fruits	Mombasa	57 Kg	6,500.00	6,500.00	114.04	
Passion Fruits	Kisumu	57 Kg	3,000.00	3,000.00	52.63	
Passion Fruits	Nakuru	57 Kg	5,500.00	5,500.00	96.49	
Passion Fruits	Eldoret	57 Kg	4,560.00	4,560.00	80	
Passion Fruits	karatina	57 Kg	0	0	0	
Passion Fruits	Kisii	57 Kg	0	0	0	91.44
Pawpaw	Mombasa	54 Kg	1,500.00	1,500.00	27.78	
Pawpaw	Kisumu	54 Kg	1,300.00	1,300.00	24.07	
Pawpaw	Nakuru	54 Kg	3,500.00	3,500.00	64.81	
Pawpaw	Eldoret	54 Kg	2,160.00	2,160.00	40	
Pawpaw	karatina	54 Kg	0	0	0	
Pawpaw	Kisii	54 Kg	700	700	12.96	
Pawpaw	Nairobi	54 Kg	2,800.00	2,800.00	51.85	36.91
Pineapples	Nairobi	13 Kg	1,040.00	1,040.00	80	
Pineapples	Mombasa	13 Kg	1,100.00	1,100.00	84.62	
Pineapples	Kisumu	13 Kg	650	650	50	
Pineapples	Nakuru	13 Kg	600	600	46.15	
Pineapples	Eldoret	13 Kg	1,170.00	1,170.00	90	
Pineapples	karatina	13 Kg	0	0	0	70.15
Red Irish Potatoes	Nairobi	50 Kg	3,000.00	3,000.00	60	
Red Irish Potatoes	Mombasa	50 Kg	3,500.00	3,500.00	70	
Red Irish Potatoes	Kisumu	50 Kg	3,000.00	3,000.00	60	
Red Irish Potatoes	Nakuru	50 Kg	0	0	0	
Red Irish Potatoes	Eldoret	50 Kg	3,000.00	3,000.00	60	
Red Irish Potatoes	karatina	50 Kg	0	0	0	62.5
Ripe Bananas	Nairobi	14 Kg	650	650	46.43	
Ripe Bananas	Mombasa	14 Kg	550	550	39.29	
Ripe Bananas	Kisumu	14 Kg	300	300	21.43	
Ripe Bananas	Nakuru	14 Kg	750	750	53.57	
Ripe Bananas	Eldoret	14 Kg	700	700	50	
Ripe Bananas	karatina	14 Kg	0	0	0	
Ripe Bananas	Kisii	14 Kg	0	0	0	42.14

Price Information for April 18, 2019						
Product	**Location**	**Quantity**	**Low (KSHS)**	**High (KSHS)**	**Price Per kg (KES)**	**Average Price**
Sorghum	Mombasa	90 Kg	3,600.00	3,600.00	40	
Sorghum	Kisumu	90 Kg	3,600.00	3,600.00	40	
Sorghum	Nakuru	90 Kg	4,000.00	4,000.00	44.44	
Sorghum	Eldoret	90 Kg	5,400.00	5,400.00	60	
Sorghum	karatina	90 Kg	0	0	0	
Sorghum	Kisii	90 Kg	0	0	0	
Sorghum	Nairobi	90 Kg	4,350.00	4,350.00	48.33	46.56
Spring Onions	karatina	142 Kg	0	0	0	
Spring Onions	Nairobi	142 Kg	3,200.00	3,200.00	22.54	
Spring Onions	Mombasa	142 Kg	4,700.00	4,700.00	33.1	
Spring Onions	Kisumu	142 Kg	2,500.00	2,500.00	17.61	
Spring Onions	Nakuru	142 Kg	4,500.00	4,500.00	31.69	
Spring Onions	Eldoret	142 Kg	1,800.00	1,800.00	12.68	23.52
Sweet Potatoes	Nairobi	98 Kg	3,300.00	3,300.00	33.67	
Sweet Potatoes	Mombasa	98 Kg	2,900.00	2,900.00	29.59	
Sweet Potatoes	Kisumu	98 Kg	3,000.00	3,000.00	30.61	
Sweet Potatoes	Nakuru	98 Kg	3,500.00	3,500.00	35.71	
Sweet Potatoes	Eldoret	98 Kg	4,500.00	4,500.00	45.92	
Sweet Potatoes	karatina	98 Kg	0	0	0	35.1
Tomatoes	Nairobi	64 Kg	7,200.00	7,200.00	112.5	
Tomatoes	Mombasa	64 Kg	7,000.00	7,000.00	109.38	
Tomatoes	Kisumu	64 Kg	8,500.00	8,500.00	132.81	
Tomatoes	Nakuru	64 Kg	5,000.00	5,000.00	78.13	
Tomatoes	Eldoret	64 Kg	5,500.00	5,500.00	85.94	
Tomatoes	karatina	64 Kg	0	0	0	103.75
Wheat	karatina	90 Kg	0	0	0	
Wheat	Kisii	90 Kg	0	0	0	
Wheat	Nairobi	90 Kg	0	0	0	
Wheat	Mombasa	90 Kg	0	0	0	
Wheat	Kisumu	90 Kg	0	0	0	
Wheat	Nakuru	90 Kg	0	0	0	
Wheat	Eldoret	90 Kg	3,000.00	3,000.00	33.33	33.33
White Irish Potatoes	Mombasa	50 Kg	3,500.00	3,500.00	70	

Price Information for April 18, 2019						
Product	**Location**	**Quantity**	**Low (KSHS)**	**High (KSHS)**	**Price Per kg (KES)**	**Average Price**
White Irish Potatoes	Kisumu	50 Kg	3,000.00	3,000.00	60	
White Irish Potatoes	Nakuru	50 Kg	2,400.00	2,400.00	48	
White Irish Potatoes	Eldoret	50 Kg	2,800.00	2,800.00	56	
White Irish Potatoes	karatina	50 Kg	0	0	0	
White Irish Potatoes	Kisii	50 Kg	0	0	0	
White Irish Potatoes	Nairobi	50 Kg	3,000.00	3,000.00	60	58.8

Source: (M-FARM, 2019)

Appendix 11 Revised Universal Soil Loss Equation (RUSLE)

Soil Loss per Land Use

The Revised Universal Soil Loss Equation (RUSLE) equates soil loss per unit area with the erosive power of rain, the amount and velocity of runoff water, the erodibility of the soil, and mitigating factors due to vegetation cover, cultivation methods and soil conservation. It takes the form of an equation where all of these factors are multiplied together

$A = R \times K \times LS \times (C * \times M) \times P$ ....Equation 24

A: Annual soil loss in t/ha

R: The rainfall erosion factor to account for the erosive power of rain, related to the amount and intensity of rainfall over the year. It is expressed in units described as erosion index units.

K: The soil erodibility factor to account for the soil loss rate in t/ha per erosion index unit for a given soil as measured on a unit plot which is defined as a plot 22.1 m long on a 9% slope under a continuous bare cultivated fallow. It ranges from less than 0.1 for the least erodible soils to approaching 1.0 in the worst possible case.

LS: A combined factor to account for the length and steepness of the slope. The longer the slope the greater the volume of runoff, the steeper the slope the greater its velocity. LS = 1.0 on a 9% slope, 22.1 m long.

C: A combined factor to account for the effects of vegetation cover and management techniques. **C*:** The vegetation cover factor. This accounts only for the effects of the natural vegetation or crop canopy (including leaf litter and residues accumulating during the life of the crop). These reduce the rate of soil loss, so in the worst case when none are applied, C = 1.0 while in the ideal case when there is no loss, C would be zero.

M: The management factor. This accounts for tillage methods, the effects of previous crop residues, previous grass or bush fallows, and applied mulches. These reduce the rate of soil loss, so in the worst case when none are applied, C = 1.0 while in the ideal case when there is no loss, C would be zero.

P: The physical protection factor to account for the effects of soil conservation measures. In this report conservation measures are defined as structures or vegetation barriers spaced at intervals on a slope, as distinct from continuous mulches or improved cultural techniques which come under the management techniques.

Equation 8 is used in the model to estimate topsoil loss under specified vegetation/crop cover and management conditions for each land utilization type (LUT) as defined in the crop, livestock and fuel wood productivity models. These estimates in turn are related to productivity losses and conservation needs

Appendix 12 Species Checklist (Herbaceous Plants, Lianas, Sapling and Trees)

Family	Species	Outside forest	Forest
Acanthaceae	*Barleria sp.*	×	
Acanthaceae	*Blepharis maderaspatensis (L.) Roth.*	×	×
Acanthaceae	*Crabbea velutina S.Moore*	×	×
Acanthaceae	*Crossandra subacaulis C.B.Clarke*	×	
Acanthaceae	*Dyschoriste sp.*	×	
Acanthaceae	*Hypoestes aristata (Vahl) Roem. & Schult.*	×	×
Acanthaceae	*Hypoestes forskahlii (Vahl) R.Br.*	×	×
Acanthaceae	*Justicia calyculata Deflers*	×	×
Acanthaceae	*Justicia debilis (Forssk.) Vahl*	×	×
Acanthaceae	*Justicia diclipteroides Lindau*	×	
Acanthaceae	*Justicia flava Vahl*	×	
Acanthaceae	*Justicia nyassana Lindau*		×
Acanthaceae	*Lepidagathis sp.*	×	
Acanthaceae	*Phaulopsis imbricata (Forssk.) Sweet*		×
Acanthaceae	*Ruellia prostrata Poir.*	×	
Acanthaceae	*Ruellia patula Jacq.*	×	
Acanthaceae	*Thunbergia alata Bojer ex Sims*		×
Actiniopteridaceae	*Actiniopteris radiata (Sw.) Link*	×	
Adiantaceae	*Adiantum sp.*	×	×
Adiantaceae	*Doryopteris kirkii (Hook.) Alston*		×
Adiantaceae	*Pellaea viridis (Forssk.) Prantl*	×	×
Aizoaceae	*Mollugo nudicaulis Lam.*	×	
Amaranthaceae	*Achyranthes aspera L.*	×	×
Amaranthaceae	*Aerva lanata (L.) Schult.*		×
Amaranthaceae	*Alternanthera pungens Kunth*	×	
Amaranthaceae	*Celosia sp.*		×
Amaranthaceae	*Gomphrena celosioides Mart.*	×	
Amaranthaceae	*Pupalia lappacea (L.) A.Juss.*	×	×
Amaranthaceae	*Sericocomopsis hildebrandtii Schinz*		×
Anacardiaceae	*Lannea rivae (Chiov.) Sacleux*	×	
Anacardiaceae	*Lannea schimperi (A.Rich.) Engl.*	×	×
Anacardiaceae	*Lannea schweinfurthii (Engl.) Engl.*	×	
Anacardiaceae	*Mangifera indica L.*	×	×

Family	Species	Outside forest	Forest
Anacardiaceae	*Ozoroa insignis Delile*	×	
Anacardiaceae	*Rhus longipes Engl.*		×
Anacardiaceae	*Rhus natalensis Krauss*	×	×
Anacardiaceae	*Rhus vulgaris Meikle*	×	×
Anacardiaceae	*Searsia natalensis (Krauss) F.A.Barkley*	×	×
Annonaceae	*Artabotrys likimensis De Wild.*	×	×
Annonaceae	*Monanthotaxis schweinfurthii (Engl. & Diels) Verdc.*	×	×
Annonaceae	*Uvaria lucida Benth.*	×	×
Anthericaceae	*Chlorophytum gallabantense Schweinf. ex Baker*	×	×
Apocynaceae	*Carissa spinarum L.*	×	×
Apocynaceae	*Cascabela thevetia (L.) Lippold*		×
Apocynaceae	*Landolphia buchananii (Hallier f.) Stapf*		×
Apocynaceae	*Tabernaemontana brachyantha Stapf*		×
Araliaceae	*Cussonia holstii Harms ex Engl.*		×
Asclepiadaceae	*Baseonema sp.*	×	
Asclepiadaceae	*Calotropis procera (Aiton) W.T.Aiton*	×	
Asclepiadaceae	*Edithcolea grandis N.E.Br.*	×	
Asclepiadaceae	*Secamone punctulata Decne.*	×	×
Asparagaceae	*Asparagus africanus Lam.*		×
Asparagaceae	*Asparagus racemosus Willd.*	×	×
Asparagaceae	*Asparagus setaceus (Kunth) Jessop*		×
Balanitaceae	*Balanites aegyptiaca (L.) Delile*	×	
Bignoniaceae	*Jacaranda mimosifolia D.Don*	×	
Bignoniaceae	*Markhamia lutea (Benth.) K.Schum.*		×
Boraginaceae	*Cordia africana Lam.*		×
Boraginaceae	*Heliotropium sp.*	×	
Boraginaceae	*Trichodesma zeylanicum (Burm.f.) R.Br.*	×	×
Burseraceae	*Commiphora africana (A.Rich.) Engl.*	×	
Burseraceae	*Commiphora confusa Vollesen*	×	×
Burseraceae	*Commiphora eminii Engl.*	×	×
Capparaceae	*Cadaba farinosa Forssk.*	×	
Capparaceae	*Capparis sp.*		×
Capparaceae	*Cleome monophylla L.*	×	×
Capparaceae	*Maerua angolensis DC.*	×	×

Family	Species	Outside forest	Forest
Capparaceae	*Maerua decumbens (Gilg) DeWolf*	×	
Capparaceae	*Maerua triphylla A.Rich.*		×
Celastraceae	*Maytenus heterophylla (Eckl. & Zeyh.) N.Robson*		×
Celastraceae	*Maytenus putterlickioides (Oliv.) Exell & Mendon¦a*	×	×
Celastraceae	*Maytenus undata (Thunb.) Blakelock*		×
Celastraceae	*Mystroxylon aethiopicum (Thunb.) Loes.*	×	×
Colchicaceae	*Gloriosa superba L.*	×	×
Combretaceae	*Combretum collinum Fresen.*	×	
Combretaceae	*Combretum molle G.Don*	×	×
Combretaceae	*Combretum paniculatum Vent.*		×
Combretaceae	*Combretum schumannii Engl.*		×
Combretaceae	*Terminalia brownii Fresen.*	×	×
Commelinaceae	*Commelina africana L.*	×	×
Commelinaceae	*Commelina benghalensis Wall.*		×
Commelinaceae	*Commelina diffusa Burm.f.*	×	
Commelinaceae	*Commelina imberbis Hassk.*	×	×
Commelinaceae	*Commelina sp.*	×	×
Compositae	*Acanthospermum hispidum DC.*	×	×
Compositae	*Achyrothalamus sp.*	×	×
Compositae	*Ageratum conyzoides L.*	×	×
Compositae	*Aspilia mossambicensis (Oliv.) Wild*	×	×
Compositae	*Bidens pilosa L.*	×	×
Compositae	*Conyza bonariensis (L.) Cronquist*	×	×
Compositae	*Crassocephalum montuosum (S.Moore) Milne-Redh.*	×	
Compositae	*Emilia discifolia (Oliv.) C.Jeffrey*	×	×
Compositae	*Galinsoga parviflora Cav.*		×
Compositae	*Gutenbergia cordifolia Benth. ex Oliv.*	×	
Compositae	*Helichrysum foetidum (L.) Cass.*		×
Compositae	*Helichrysum glumaceum DC.*	×	
Compositae	*Helichrysum odoratissimum (L.) Less.*		×
Compositae	*Helichrysum schimperi (Sch.Bip.) Moeser*	×	×
Compositae	*Kleinia squarrosa Cufod.*	×	
Compositae	*Launaea cornuta (Hochst. ex Oliv. & Hiern) C.Jeffre*	×	

Family	Species	Outside forest	Forest
Compositae	*Microglossa densiflora Hook.f.*		×
Compositae	*Schkuhria pinnata (Lam.) Kuntze*	×	×
Compositae	*Solanecio angulatus (Vahl) C.Jeffrey*		×
Compositae	*Sphaeranthus suaveolens (Forssk.) DC.*	×	
Compositae	*Tagetes minuta L.*	×	×
Compositae	*Tridax procumbens L.*	×	×
Compositae	*Vernonia brachycalyx O.Hoffm.*	×	×
Compositae	*Vernonia lasiopus O.Hoffm.*		×
Compositae	*Vernonia smithiana Less.*	×	
Compositae	*Vernonia sp.*	×	
Compositae	*Vernonia sp. (P14)*	×	
Convolvulaceae	*Astripomoea sp.*	×	
Convolvulaceae	*Evolvulus alsinoides (L.) L.*	×	
Convolvulaceae	*Ipomoea kituensis Vatke*	×	×
Convolvulaceae	*Ipomoea obscura (L.) Ker Gawl.*	×	
Convolvulaceae	*Ipomoea sp.*	×	
Convolvulaceae	*Ipomoea wightii (Wall.) Choisy*		×
Crassulaceae	*Crassula granvikii Mildbr.*		×
Crassulaceae	*Kalanchoe densiflora Rolfe*	×	×
Cucurbitaceae	*Citrullus lanatus (Thunb.) Mansf.*	×	
Cucurbitaceae	*Cucumis (specimen)*	×	
Cucurbitaceae	*Cucumis dipsaceus Spach*	×	
Cucurbitaceae	*Peponium vogelii (Hook.f.) Engl.*		×
Cucurbitaceae	*Zehneria scabra (L.f.) Sond.*	×	×
Cupressaceae	*Cupressus lutitanica Mill.*		×
Cupressaceae	*Cupressus sp.*		×
Cyperaceae	*Bulbostylis sp.*		×
Cyperaceae	*Cyperus distans L.f.*		×
Cyperaceae	*Cyperus rotundus L.*	×	
Cyperaceae	*Cyperus rubicundus Vahl*	×	
Cyperaceae	*Cyperus sp.*	×	×
Cyperaceae	*Kyllinga (short)*	×	
Cyperaceae	*Kyllinga sp.*	×	
Cyperaceae	*Lipocarpha sp.*	×	
Cyperaceae	*Pycreus sp.*	×	
Dennstaedtiaceae	*Pteridium aquilinum (L.) Kuhn*		×

Family	Species	Outside forest	Forest
Ebenaceae	*Diospyros scabra (Chiov.) Cufod.*	×	
Ebenaceae	*Euclea divinorum Hiern*	×	
Euphorbiaceae	*Acalypha fruticosa Forssk.*	×	×
Euphorbiaceae	*Acalypha sp.*		×
Euphorbiaceae	*Acalypha volkensii Pax*		×
Euphorbiaceae	*Antidesma venosum Tul.*	×	×
Euphorbiaceae	*Bridelia micrantha (Hochst.) Baill.*		×
Euphorbiaceae	*Croton dichogamus Pax*	×	×
Euphorbiaceae	*Croton macrostachyus Delile*	×	×
Euphorbiaceae	*Croton megalocarpus Hutch.*	×	×
Euphorbiaceae	*Croton sylvaticus Krauss*		×
Euphorbiaceae	*Drypetes gerrardii Hutch.*		×
Euphorbiaceae	*Euphorbia bicompacta Bruyns*	×	×
Euphorbiaceae	*Euphorbia candelabrum Kotschy*	×	
Euphorbiaceae	*Euphorbia heterophylla L.*	×	×
Euphorbiaceae	*Euphorbia hirta L.*	×	
Euphorbiaceae	*Euphorbia scheffleri Pax*	×	
Euphorbiaceae	*Euphorbia tirucalli L.*	×	
Euphorbiaceae	*Flueggea virosa (Willd.) Voigt*	×	×
Euphorbiaceae	*Margaritaria discoidea (Baill.) Webster*		×
Euphorbiaceae	*Phyllanthus fischeri Pax*	×	×
Euphorbiaceae	*Phyllanthus maderaspatensis L.*	×	
Euphorbiaceae	*Phyllanthus odontadenius Müll.Arg.*		×
Euphorbiaceae	*Tragia brevipes Pax*		×
Flacourtiaceae	*Dovyalis macrocalyx (Oliv.) Warb.*	×	×
Flacourtiaceae	*Ludia mauritiana J.F.Gmel.*		×
Flacourtiaceae	*Rawsonia lucida Harv. & Sond.*		×
Geraniaceae	*Pelargonium sp.*	×	
Gramineae	*Aristida adoensis Hochst.*	×	
Gramineae	*Aristida adscensionis L.*	×	
Gramineae	*Bothriochloa insculpta (A.Rich.) A.Camus*	×	×
Gramineae	*Brachiaria sp.*	×	
Gramineae	*Cenchrus sp.*	×	
Gramineae	*Chloris sp*	×	
Gramineae	*Chloris sp.*	×	
Gramineae	*Cynodon nlemfuensis Vanderyst*		×

Family	Species	Outside forest	Forest
Gramineae	*Dactyloctenium aegyptium (L.) Willd.*	×	
Gramineae	*Digitaria abyssinica (A.Rich.) Stapf*	×	×
Gramineae	*Digitaria velutina (Forssk.) P.Beauv.*	×	×
Gramineae	*Echnochloa sp.*	×	
Gramineae	*Eragrostis sp.*	×	
Gramineae	*Eragrostis superba Peyr.*	×	×
Gramineae	*Harpachne schimperi A.Rich.*	×	
Gramineae	*Heteropogon contortus (L.) Roem. & Schult.*	×	
Gramineae	*Hyparrhenia sp.*	×	
Gramineae	*Melinis repens (Willd.) Zizka*	×	×
Gramineae	*Oplismenus sp.*	×	
Gramineae	*Panicum 1*	×	×
Gramineae	*Panicum 2*		×
Gramineae	*Panicum adenophorum K.Schum.*	×	
Gramineae	*Panicum issongense Pilg.*		×
Gramineae	*Panicum maximum Jacq.*	×	×
Gramineae	*Paspalum sp.*		×
Gramineae	*Pennisetum purpureum Schumach.*	×	
Gramineae	*Rottboellia cochinchinensis (Lour.) Clayton*	×	
Gramineae	*Setaria plicatilis (Hochst.) Engl.*		×
Gramineae	*Setaria sphacelata (Schumach.) Moss*	×	
Gramineae	*Setaria verticillata (L.) P.Beauv.*	×	×
Gramineae	*Sporobolus pyramidalis P.Beauv.*	×	×
Gramineae	*Sporobolus sp.*	×	
Gramineae	*Zea mays*	×	
Hyacinthaceae	*Drimia sp.*	×	
Hyacinthaceae	*Ornithogalum sp.*		×
Icacinaceae	*Apodytes dimidiata Arn.*	×	×
Labiatae	*Fuerstia africana T.C.E.Fr.*	×	×
Labiatae	*Hoslundia opposita Vahl*	×	×
Labiatae	*Leonotis nepetifolia (L.) R.Br.*		×
Labiatae	*Leonotis ocymifolia (Burm.f.) Iwarsson*		×
Labiatae	*Leucas grandis Vatke*	×	×
Labiatae	*Leucas martinicensis (Jacq.) R.Br.*	×	
Labiatae	*Ocimum americanum L.*	×	×

Family	Species	Outside forest	Forest
Labiatae	*Ocimum gratissimum Forssk.*		×
Labiatae	*Ocimum kilimandischaricum Gurke*		×
Labiatae	*Ocimum obovatum Sebald*	×	×
Labiatae	*Plectranthastrum*	×	
Labiatae	*Plectranthus*		×
Labiatae	*Rotheca myricoides (Hochst.) Steane & Mabb.*	×	×
Labiatae	*Tetradenia riparia (Hochst.) Codd*		×
Leguminosae- Caesalpinioideae	*Bauhinia tomentosa L.*	×	
Leguminosae- Caesalpinioideae	*Chamaecrista mimosoides (L.) Greene*		×
Leguminosae- Caesalpinioideae	*Senna bicapsularis (L.) Roxb.*	×	×
Leguminosae- Caesalpinioideae	*Senna didymobotrya (Fresen.) Irwin & Barneby*	×	
Leguminosae- Caesalpinioideae	*Senna obtusifolia (L.) Irwin & Barneby*	×	
Leguminosae- Caesalpinioideae	*Senna occidentalis L.*	×	
Leguminosae- Caesalpinioideae	*Senna singueana (Delile) Lock*	×	×
Leguminosae- Caesalpinioideae	*Senna spectabilis (DC.) Irwin & Barneby*	×	
Leguminosae- Mimosoideae	*Acacia brevispica Harms*	×	×
Leguminosae- Mimosoideae	*Acacia hockii De Wild.*	×	×
Leguminosae- Mimosoideae	*Acacia meansii R.Br.*		×
Leguminosae- Mimosoideae	*Acacia mellifera (Vahl) Benth.*	×	
Leguminosae- Mimosoideae	*Acacia nilotica (L.) Willd. ex Del.*	×	
Leguminosae- Mimosoideae	*Acacia polyacantha Willd.*	×	
Leguminosae- Mimosoideae	*Acacia senegal (L.) Wild*	×	×
Leguminosae- Mimosoideae	*Acacia tortilis (Forssk.) Hayne*	×	×
Leguminosae- Mimosoideae	*Albizia amara (Roxb.) Boivin*	×	
Leguminosae- Mimosoideae	*Albizia anthelmintica Brongn.*	×	×
Leguminosae- Mimosoideae	*Dichrostachys cinerea (L.) Wight & Arn.*	×	×
Leguminosae- Mimosoideae	*Entada leptostachya Harms*	×	×
Leguminosae- Mimosoideae	*Leucaena leucocephala (Lam.) De Wit*	×	
leguminosae- Papilionoideae	*Cajanus cajan (L.) Millsp.*	×	
leguminosae- Papilionoideae	*Crotalaria axillaris Aiton*	×	
leguminosae- Papilionoideae	*Crotalaria goodiiformis Vatke*	×	
leguminosae- Papilionoideae	*Crotalaria incana L.*	×	×
leguminosae- Papilionoideae	*Crotalaria sp.*	×	
leguminosae- Papilionoideae	*Dalbergia melanoxylon Guill. & Perr.*	×	×

Family	Species	Outside forest	Forest
leguminosae- Papilionoideae	*Desmodium sp.*	×	
leguminosae- Papilionoideae	*Eriosema sp.*		×
leguminosae- Papilionoideae	*Erythrina abyssinica DC.*	×	
leguminosae- Papilionoideae	*Indigofera 2*		×
leguminosae- Papilionoideae	*Indigofera arrecta A.Rich.*	×	×
leguminosae- Papilionoideae	*Indigofera sp.*		×
leguminosae- Papilionoideae	*Indigofera tinctoria L.*	×	×
leguminosae- Papilionoideae	*Indigofera trita L.f.*	×	
leguminosae- Papilionoideae	*Indigofera vohemarensis Baill.*	×	
leguminosae- Papilionoideae	*Lonchocarpus eriocalyx Harms*	×	×
leguminosae- Papilionoideae	*Millettia vatkei P.K.Lôc*		×
leguminosae- Papilionoideae	*Neonotonia wightii (Graham ex Wight & Arn.) J.A.Lackey*	×	×
leguminosae- Papilionoideae	*Ormocarpum kirkii S.Moore*	×	
leguminosae- Papilionoideae	*Ormocarpum trachycarpum (Taub.) Harms*	×	
leguminosae- Papilionoideae	*Rhynchosia malacophylla (Spreng.) Bojer*		×
leguminosae- Papilionoideae	*Rhynchosia minima (L.) DC.*	×	×
leguminosae- Papilionoideae	*Stylosanthes fruticosa (Retz.) Alston*	×	×
leguminosae- Papilionoideae	*Tephrosia villosa (L.) Pers.*	×	×
leguminosae- Papilionoideae	*Vigna sp.*		×
leguminosae- Papilionoideae	*Zornia setosa Baker f.*	×	
Lobeliaceae	*Cyphia glandulifera A.Rich.*		×
Loranthaceae	*Englerina woodfordioides (Schweinf.) Balle*		×
Loranthaceae	*Erianthemum dregei (Eckl. & Zeyh.) Tiegh.*	×	
Malvaceae	*Abutilon sp.*	×	×
Malvaceae	*Hibiscus aethiopicus L.*	×	
Malvaceae	*Hibiscus calyphyllus Cav.*		×
Malvaceae	*Hibiscus canabinus L.*		×
Malvaceae	*Hibiscus fuscus Garcke*		×
Malvaceae	*Hibiscus meyeri Harv.*	×	×
Malvaceae	*Hibiscus micranthus L.f.*	×	
Malvaceae	*Hibiscus sp.*	×	×
Malvaceae	*Hibiscus vitifolius L.*		×
Malvaceae	*Malvastrum coromandelianum (L.) Garcke*	×	
Malvaceae	*Sida acuta Burm.f.*	×	×

Family	Species	Outside forest	Forest
Malvaceae	*Sida alba L.*	×	×
Malvaceae	*Sida ovata Forssk.*	×	
Malvaceae	*Sida rhombifolia L.*	×	
Malvaceae	*Sida sp.*	×	
Malvaceae	*Thespesia garckeana F.Hoffm.*	×	×
Meliaceae	*Lepidotrichilia volkensii (Gürke) J.-F.Leroy*		×
Meliaceae	*Trichilia emetica Vahl*		×
Meliaceae	*Turraea mombassana C.DC.*	×	×
Meliaceae	*Turraea robusta Gürke*	×	×
Menispermaceae	*Chasmanthera sp.*	×	
Menispermaceae	*Cissampelos pareira L.*	×	×
Moraceae	*Ficus natalensis Hochst.*	×	×
Moraceae	*Ficus sur Forssk.*		×
Moraceae	*Ficus sycomorus L.*		×
Moraceae	*Ficus thonningii Blume*	×	×
Myrsinaceae	*Rapanea melanophloeos (L.) Mez*	×	×
Myrtaceae	*Eucalyptus sp.*		×
Myrtaceae	*Psidium guajava L.*	×	
Myrtaceae	*Syzygium cordatum Hochst.*		×
Myrtaceae	*Syzygium guineense (Willd.) DC.*	×	×
Nyctaginaceae	*Boerhavia sp.*		×
Nyctaginaceae	*Commicarpus grandiflorus (A.Rich.) Standl.*	×	
Ochnaceae	*Ochna cyanophylla N.Robson*		×
Ochnaceae	*Ochna holstii Engl.*		×
Ochnaceae	*Ochna insculpta Sleumer*	×	×
Ochnaceae	*Ochna ovata O.Hoffm.*		×
Oleaceae	*Jasminum fluminense Vell*	×	×
Orchidaceae	*Bonatea steudneri (Rchb.f.) T.Durand & Schinz*	×	
Orchidaceae	*Eulophia petersii Rchb.f.*		×
Palmae	*Phoenix reclinata Jacq.*		×
Passifloraceae	*Adenia sp.*	×	×
Pedaliaceae	*Sesamum calycinum Welw.*	×	
Pinaceae	*Pinus patula Schiede ex Schltdl. & Cham.*		×
Pittosporaceae	*Pittosporum viridiflorum Sims*	×	×

Family	Species	Outside forest	Forest
Plumbaginaceae	*Plumbago zeylanica L.*	×	×
Polygalaceae	*Polygala sadebeckiana Gürke*	×	×
Polygonaceae	*Oxygonum sinuatum (Meisn.) Dammer*	×	×
Portulacaceae	*Portulaca quadrifida L.*	×	
Portulacaceae	*Talinum portulacifolium (Forssk.) Asch. ex Schweinf.*		×
Proteaceae	*Faurea saligna Harv.*	×	×
Proteaceae	*Grevillea robusta R.Br.*	×	
Pteridaceae	*Pteris sp.*		×
Ranunculaceae	*Clematis simensis Fresen.*		×
Rhamnaceae	*Helinus mystacinus (Aiton) Steud.*	×	
Rhamnaceae	*Scutia myrtina (Burm.f.) Kurz*	×	
Rhamnaceae	*Ziziphus mucronata Willd.*		×
Rosaceae	*Moranthes sp*		×
Rubiaceae	*Catunaregam nilotica (Stapf) Tirveng.*	×	
Rubiaceae	*Coptosperma graveolens (S.Moore) Degreef*	×	
Rubiaceae	*Hymenodictyon floribundum (Hochst. & Steud.) B.L.Rob.*	×	
Rubiaceae	*Oldenlandia capensis L.*	×	
Rubiaceae	*Oldenlandia corymbosa L.*	×	
Rubiaceae	*Oldenlandia sp.*		×
Rubiaceae	*Pavetta teitana K.Schum.*	×	×
Rubiaceae	*Pentas bussei K.Krause*		×
Rubiaceae	*Pentas parvifolia Hiern*	×	×
Rubiaceae	*Pentas sp.*	×	
Rubiaceae	*Psychotria kirkii Hiern*	×	×
Rubiaceae	*Psychotria lauracea (K.Schum.) Petit*	×	×
Rubiaceae	*Psydrax schimperiana (A.Rich.) Bridson*	×	×
Rubiaceae	*Richardia brasiliensis Gomes*	×	×
Rubiaceae	*Rothmannia fischeri (K.Schum.) Bullock*	×	×
Rubiaceae	*Rothmannia urcelliformis (Guill. & Perr.) Baker*		×
Rubiaceae	*Rubia cordifolia Bullock*		×
Rubiaceae	*Spermacoce arvensis (Hiern) R.D.Good*	×	
Rubiaceae	*Spermacoce sp.*	×	
Rubiaceae	*Spermacoce/ Richardia sp.*	×	

Family	Species	Outside forest	Forest
Rubiaceae	*Tapiphyllum schliebenii Verdc.*	×	×
Rubiaceae	*Vangueria madagascariensis J.F.Gmel.*	×	×
Rutaceae	*Clausena anisata (Willd.) Benth.*		×
Rutaceae	*Toddalia asiatica (L.) Lam.*	×	×
Rutaceae	*Zanthoxylum chalybeum Engl.*	×	
Santalaceae	*Osyridicarpos schimperianus A.DC.*	×	
Santalaceae	*Osyris lanceolata Hochst. & Steud.*	×	×
Sapindaceae	*Allophylus rubifolius (Hochst.) Engl.*		×
Sapindaceae	*Deinbollia borbonica Scheffler*		×
Sapindaceae	*Dodonaea viscosa (L.) Jacq.*	×	×
Sapindaceae	*Pappea capensis Eckl. & Zeyh.*	×	×
Sapotaceae	*Chrysophyllum sp.*	×	×
Simaroubaceae	*Harrisonia abyssinica Oliv.*	×	
Smilacaceae	*Smilax anceps Willd.*	×	×
Solanaceae	*Solanum anguivi Lam.*	×	×
Solanaceae	*Solanum cacampylacanthum Hochst. ex A .Rich*	×	×
Sterculiaceae	*Hermannia alhiensis K.Schum.*	×	
Sterculiaceae	*Hermannia exappendiculata (Mast.) K.Schum.*	×	×
Sterculiaceae	*Melhania velutina Forssk.*	×	
Sterculiaceae	*Waltheria indica L.*	×	×
Thymelaeaceae	*Gnidia latifolia (Oliv.) Gilg*	×	×
Tiliaceae	*Grewia bicolor*		×
Tiliaceae	*Grewia bicolor Juss.*	×	×
Tiliaceae	*Grewia plagiophylla K.Schum.*	×	
Tiliaceae	*Grewia rob??*	×	
Tiliaceae	*Grewia similis K.Schum.*	×	×
Tiliaceae	*Triumfetta brachyceras K.Schum.*		×
Tiliaceae	*Triumfetta rhomboidea Jacq.*	×	×
Ulmaceae	*Trema orientalis (L.) Blume*		×
Umbelliferae	*Steganotaenia araliacea Hochst.*		×
Urticaceae	*Obetia radula (Baker) B.D.Jacks.*		×
Verbenaceae	*Chascanum sp.*	×	
Verbenaceae	*Clerodendrum eriophylloides Moldenke*	×	
Verbenaceae	*Clerodendrum johnstonii Oliv.*		×

Family	Species	Outside forest	Forest
Verbenaceae	*Lantana camara L.*	×	×
Verbenaceae	*Lippia kituiensis Vatke*		×
Verbenaceae	*Premna oligotricha Baker*	×	
Verbenaceae	*Premna resinosa (Hochst.) Schauer*	×	
Verbenaceae	*Stachytarpheta urticifolia Sims*	×	
Verbenaceae	*Vitex strickeri Vatke & Hildebrandt*	×	
Vitaceae	*Ampelocissus sp.*		×
Vitaceae	*Cissus quadrangularis L.*	×	
Vitaceae	*Cissus rotundifolia (Forssk.) Vahl*	×	×
Vitaceae	*Cyphostemma serpens (A.Rich.) Desc.*	×	×
Vitaceae	*Cyphostemma sp.*	×	×
Vitaceae	*Rhoicissus tridentata (L.f.) Wild & R.B.Drumm.*		×

KENYA WATER TOWERS AGENCY

Co-ordinated Environmental Protection

K.W.T.A