EFFECTS OF CLEAR-CUT ON WATER QUALITY, COARSE PARTICULATE ORGANIC MATTER AND PERIPHYTON IN CHEPKOO RIVER, KENYA

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A thesis submitted to the Graduate School in partial fulfillment for the requirements of Master of Science Degree in Environmental and Occupational Health of Egerton University

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DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not been submitted or presented for examination in any other institution either in part or as a whole.

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Recommendation

This thesis has been presented for examination with our approval as university supervisors.

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DEDICATION

This work is dedicated to my parents Mr. John Komen and Mrs. Sally Chebsoo who did all they could to establish the best foundation of my education.

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ABSTRACT

Rivers are essential ecosystems that assist in maintaining and supporting functions and ecological processes that are important for sustaining the biodiversity and providing services and resources to people. However, in the tropics they are under threat of deterioration as a result of human encroachment and more so, removal of riparian vegetation. This study aimed at assessing the effects clear-cut of Tumoo forest on water quality, coarse particulate organic matter (CPOM) and benthic algae in Chepkoo River, with a view of enhancing environmental and human health. Three sampling sites were purposely selected to capture the effects of clear-cut along this river. It was hypothesized that clear cutting of riparian vegetation had a direct influence on water quality, CPOM quantity and periphyton abundance and diversity. Sampling was done in the months of April to June 2017, and entailed measurements of physico-chemical parameters, water nutrients, collection of CPOM and periphyton at the three sites. Among the physico-chemical parameters measured, temperature differed significantly among the sites, being higher at midstream site ($F_{(2, 24)} = 16.423$, $p < 0.05$). Total phosphorous and soluble reactive phosphorus were in high concentration than the other nutrients in the three sites, whereby the midstream recorded the highest mean value of 0.223±0.038 mg/L. However, the mean difference was not statically significant amongst the sampling sites ($F_{(2, 24)} = 0.225$, $p > 0.05$). There occurred a significant difference in mean periphyton abundance among the sites (, $p < 0.05$) with midstream recording the lowest value (Tukey HSD, $\alpha = 0.05$). The quantity of CPOM (pooled data from the riverbanks) collected among the sites differed significantly ($F_{(2, 24)} = 12.427$, $p < 0.001$) with the midstream site having the highest value (Tukey HSD, $p < 0.05$). The mean difference of CPOM retention within the stream channel was statistically significant ($F_{(2, 24)} = 8.053$, $p < 0.001$) with the upstream site recording the highest amount. Vegetation diversity, using Shannon Wiener diversity index indicated that upstream (2.2), > downstream (1.9), > midstream (1.7). Approximately 32% of the plant species were similar among the three sampling sites. This study confirms that reduced canopy cover leads to reduced water quality, periphyton abundance as well as in-stream CPOM along Chepkoo River. County and national government agencies need to do campaigns on the need for afforestation and reforestation of clear-cut sites on the river's watershed. Such an intervention strategy will lead to better water quality, and improved human and environmental health.

TABLE OF CONTENTS

DECLARATION AND RECOMMENDATION .... **ii**
COPYRIGHT .... **iii**
DEDICATION .... **iv**
ACKNOWLEDGEMENTS .... **v**
ABSTRACT .... **vi**
TABLE OF CONTENTS .... **vii**
LIST OF TABLES .... **x**
LIST OF FIGURES .... **xi**
LIST OF PLATES .... **xii**
CHAPTER ONE **1**
INTRODUCTION **1**
1.1 Background information 1
1.2 Statement of the Problem 2
1.3 Objectives 3
1.3.1 Broad Objective 3
1.3.2 Specific Objectives 3
1.4 Hypotheses 3
1.5 Justification 4
1.6 Scope of the study 5
1.7 Assumptions of the study 5
1.8 Definition of terms 5
CHAPTER TWO **7**
LITERATURE REVIEW **7**
2.1 Human activities and deforestation 7
2.2 Physico-chemical variables 8
2.2.1 Temperature of the water in the river and its effects on other water parameters 8
2.2.2 Dissolved oxygen in river water and its effects 9
2.2.3 pH and its effects on water quality 9
2.2.4 Sediment in the river channel and its effects 10
2.3 Nutrients in rivers and the Effects on water quality and Aquatic organisms 11
2.4 Stream Periphyton 13
2.5 Coarse particulate organic matter 13

2.6 Vegetation composition along a river 14
2.7 Influence of agricultural activities on water quality of a river 14
2.8 Conceptual framework 15
CHAPTER THREE 17
MATERIALS AND METHODS 17
3.1 Study Area and the study site 17
3.1.1 Location of study area and topography 17
3.1.2 Study design 18
3.2. Sampling and Sample processing 20
3.2.1 Determination of the physico-chemical characteristics of the river 21
3.2.2 Collection of water samples, periphyton and coarse particulate organic matter 21
3.2.3 Characterization of riparian vegetation 21
3.2.4 Samples processing 22
3.3 Data analysis 24
CHAPTER FOUR 26
RESULTS 26
4.1 Physico-chemical characteristics of the studied sites 26
4.2 Nutrients in the three sites of Chepkoo River 26
4.3 Abundance and diversity of benthic periphyton in Chepkoo River 27
4.3.1 Benthic periphyton species list and abundance 27
4.3.2 Periphyton diversity, similarity and evenness 30
4.4 Coarse particulate organic matter on the banks and in the streambed 31
4.4.1 CPOM on the banks 31
4.4.2 CPOM in the stream channel 34
4.5 Vegetation composition, diversity, evenness and similarity 37
4.5.1 Vegetation composition 37
4.5.2. Vegetation diversity, evenness and similarity 39
4.6 Correlation Analysis 40
CHAPTER FIVE 41
DISCUSSION 41
5.1 Physical variables in the study sites 41
5.2 Nutrient along the three sites of Chepkoo River 42
5.3 Benthic Periphyton 43

5.4 Coarse particulate matter on the banks and in the stream channel................................44
5.5 Vegetation composition along Chepkoo River 45
5.6 Relationship between physico-chemical variables and periphyton...............................46
CHAPTER SIX 47
SUMMARY OF THE FINDINGS, CONCLUSIONS AND RECOMMENDATIONS...47
6.1 SUMMARY OF THE FINDINGS...47
6.2 CONCLUSIONS 47
6.3 RECOMMENDATIONS...48
REFERENCES...49
APPENDICES 62

LIST OF TABLES

Table 4:1: The physical variables measured in Chepkoo River. 26

Table 4.2: Taxa list of periphyton collected in the upstream, midstream and downstream sites. 28

Table 4.3: Summary of five dominant periphyton in the study sites of Chepkoo River per a litre of water 29

Table 4.4: Periphyton diversity, evenness and similarity in Chepkoo River................................ 31

Table 4.5: Summary of the dry weight value of the CPOM (g/m2) in the left bank (a) and right bank (b) at the three study sites. 34

Table 4.6: The measured dry weight value (g/m2) of CPOM 36

Table 4.7: Presence or absence of different types of vegetation in upstream, midstream and downstream 37

Table 4.8: Summary of percentage contribution of vegetation types in the banks of the three study sites 39

Table 4.9: Vegetation diversity, evenness and similarity at the three sites along Chepkoo River 39

Table 4.10: The diversity, evenness and similarity of vegetation composition in Chepkoo River, comparing the left bank and right bank of each study site 40

Table 4.11: Summary of the Pearson correlation coefficient matrix between Physico-chemical parameters, CPOM and periphyton in Chepkoo River. 40

LIST OF FIGURES

Figure 2.1: Conceptual framework. 16
Figure 3.1: Map of Kenya showing study sites... 17
Figure 4.1: Nutrients means (mg/L) and ± standard error among the three study sites of Chepkoo River 27
Figure 4.2: Periphyton abundance (indiv. /L) in the three study sites of Chepkoo 29
Figure 4.3: Dominating periphyton in each study site... 30
Figure 4.4: Total CPOM dry weight (pooled) collected on the banks at the three sites............... 31
Figure 4.5: The dry weight of CPOM (g/m2) in the left and right bank of each study site.......... 32
Figure 4.6: Percentage contribution of plant litter category in (a) left and (b) right bank of each study site in Chepkoo River... 33
Figure4.7: The dry weight of CPOM (g/m2) in river channel along the three study sites of Chepkoo River 35
Figure 4.8: Percentage contribution of plant litter category in river channel along the three study sites of Chepkoo River 36
Figure 4.9: The relative abundance of vegetation types in the three study sites of Chepkoo River.. 38

LIST OF PLATES

Plate 1: The upstream site 19
Plate 2: The midstream site 20
Plate 3: The downstream site 20

LIST OF ABBREVIATIONS AND ACRONYMS

APHA	American Public Health Association
CPOM	Coarse Particulate Organic Matter
DO	Dissolved oxygen
EC	*Escherichia coli*
EMC	Elgeyo-Marakwet County
GF/C	Glass Fibre Filter
FAO	Food and Agricultural Organization of the United Nations
NEMA	National Environmental Management Authority
NH_4-N	Ammonium – Nitrogen
NO_{3}-N	Nitrate- Nitrogen
NTU'S	Nephelometric Turbidity Units
WHO	World Health Organization.
SDGs	Sustainable Development Goals
SRP	Soluble Reactive Phosphorus
TSS	Total Suspended Sediments
USEPA	United States Environmental Protection Agency

CHAPTER ONE

INTRODUCTION

1.1 Background information

Globally, it is estimated that 13 million hectares of forest per year are converted to agricultural land (FAO 2005). Notably, there is reduced landscape restoration and reforestation of about 7.3 million hectares per year (FAO 2005). Some parts of Africa and South America have experienced the highest rate of forest loss that is between 4.3 million and 4.0 million hectares per year (Chopra *et al*., 2000). DeTroyer *et al*., (2016), attributed water quality deterioration in East Africa to rapid deforestation. Kiage *et al*., (2007), estimated the deforestation rate in Kenya to be at 0.3% per year due to agricultural expansion, population growth and industrialization (FAO, 2010). There are 80 countries worldwide, which had stabilized their forest covers by 2010. They had either maintained or increased their forest cover; Kenya is not among these countries (FAO, 2011).

Rivers are lotic ecosystems that receive their energy from primary production by aquatic and other nearby plants, and from externally produced non-living organic matter (Vannote *et al*., 1980, Cummins *et al*., 1989). Many studies have described the effect of deforestation on rivers and head water points to be more direct and profound. Reduction in forest cover leads to reduced evapotranspiration and increased runoff as well as sediment and nutrient transport (Kreutzweiser and Capell, 2001; Haggertry *et al*., 2004; Jackson, 2007; Dewson *et al*., 2007a, 2007b; Thomson *et al*., 2009). The significant global impacts of clear-cut in both temperate and tropical forest are the variability in rainfall patterns and the earth's surface temperature. The hydrological cycle has been weakened by a reduction in moisture circulation, and evapotranspiration models that suggest that about 80% reduction of annual rainfall can be attributed to deforestation (Hasler *et al*., 2009).

Surface temperatures in some areas are predicted to increase by a maximum of $3^{\circ}C$, which is caused by a reduction in evaporative cooling that is associated with loss of vegetation (Snyder, 2010). Clear- cut forests are characterized by increased surface runoff and flash flood risk (Bradshaw *et al*., 2007). There can be an increase of diseases such as yellow fever and malaria due to the removal of forest. Increased temperatures are likely to alter pathogen reproductive cycles (Vittor *et al*., 2006; Patz *et al*., 2008). Forests play significant role in capturing runoff, by creating roughness on the ground surface and therefore, reduce the speed of the water, allowing high infiltration rate, which end up reducing the runoff. The trees also help in building up organic matter content that enhances soil fertility and protects rivers from the erosive power of runoff (Depietri, 2015).

Plants loosen the soil, and this increases the infiltration rate of runoff. Sediment removal is affected as they are deposited on the tissues of the plants. There is a high maintenance of organic matter in the soil, which is ideal for facilitating the process of denitrification and many other biochemical processes. Riparian vegetation is also useful in the removal of pollutants, which are dissolved in soil waste, while essential nutrients are incorporated into the plant tissues. Plants play an important role in stabilizing stream and riverbanks and thus help in modifying the temperatures, humidity, and light within the river and the riparian zones (Newman *et al*., 2014).

Water quality significantly affects the ecosystem functions and ecological processes, some of which support critical habitats for aquatic organisms. Therefore, the aquatic ecosystems are the fundamental part of our environment. According to Wohl *et al*. (2015), aquatic ecosystems play an integral role in maintaining the quality of water, and thus they are a significant indicator of water quality as well as sustainability of water resources for other uses.

Therefore, clearing of forests adjacent to lotic and lentic ecosystems may lead to losses of stream habitats (Sultana *et al*., 2014), loss of species, and associated ecosystem services. The naturally occurring drainage is interrupted when the riparian soils are compacted because there is an increase in sedimentation. Furthermore, increase in solar radiation penetrating to the water and this will affect the temperature of the river, which ends up negatively influencing the surrounding activities in the watershed (USEPA, 1995). According to UNEP report (2003), some of Keiyo south forests have been clear-cut for instance the Tumoo Forest, that stand at 1951.99 hectares. Therefore, the primary aim of this study was to determine the effects of clear-cut of Tumoo native forest on the quality of water in Chepkoo River.

1.2 Statement of the Problem

Tree clearance at catchment level and along river corridors impacts negatively on river health. Increased temperatures, reduced organic matter inputs and changes in invertebrate community composition and diversity are the likely outcomes associated with clearance of riparian zones. Unstable banks lead to increased sedimentation and siltation of downstream recipient water bodies like lakes and ponds. Water cleaning ability of streams especially nutrient removal associated with agricultural activities is largely lost. This poses health risk to water users especially for domestic purposes. Consumption of contaminated water by resident communities would lead to increased costs of medication and time spent in health facilities. Further, the effects of clear- cut of Tumoo forest on the functionality of Chepkoo River are largely unknown. It is on this basis that a study on Chepkoo River was proposed with a view of establishing a link between deforestation of Tumoo forest through clear-cutting and water quality as well as stream health.

1.3 Objectives

1.3.1 Broad Objective

To determine the water quality, benthic organic matter and periphyton based on levels of riparian corridors clearance at Chepkoo River.

1.3.2 Specific Objectives

1) To determine the physico-chemical parameters (temperature, dissolved oxygen, pH and suspended sediments) of the river water among the sampling sites.
2) To determine nutrient concentrations among selected sampling sites along Chepkoo River.
3) To assess the abundance and diversity of benthic periphyton (diatoms) in Chepkoo River.
4) To determine the variation of benthic coarse particulate organic matter amongst the sampling sites of the river.
5) To assess vegetation composition and diversity at the selected sampling sites.

1.4 Hypotheses

H_{01}: There is no significant difference in physico-chemical variables (temperature, dissolved oxygen, pH and suspended sediments) of the river among the sampling sites.

H_{02}: The concentrations of nutrients in water are the same among the selected sites along the river.

H_{03}: Periphyton abundance and diversity is the same across the sampling sites.

H_{04}: There is no significant difference in the benthic coarse particulate organic matter among the sampling sites in Chepkoo River.

H_{05}: Composition and diversity of riparian vegetation is similar among the three sampling sites.

1.5 Justification

Vision 2030 blue print by the government of Kenya under the social pillar envisions an environment that is largely clean, secure and sustainable to support human life. This goal also aim at ensuring water is available and accessible by all (Njagi, 2018). Removal of forest along the river, interfere with the normal functioning of the river by directly influencing the quality and quantity of water. The findings of this study will help achieve Kenyan vision 2030, by meeting the target of having a cohesive and just community with a clean and secure environment.

Sustainable Development Goals 2030, goal 15 focuses on protection, restoration, and promotion of the sustainable use of the terrestrial ecosystems by sustainably managing the forest, combating desertification, halting and reversing land degradation and stopping biodiversity loss. This goal will not be achieved if we cannot start addressing issues of deforestation in local areas. Therefore, the findings from this study will help to meet goal 15 of the SDGs (Osborn *et al*., 2015). The Kenyan constitution 2010, chapter five aims at protecting the ecosystems, encourage public participation in sustainable utilization of resources as well as sound management of natural resources to achieve development and prosperity of all without damaging the environment. Article 42, of the Kenyan constitution, entitles every citizen to clean and healthy environment and without water in both good quality and quantity, this right will be violated. Therefore, the findings from this study will be of much help to the residents who live near Chepkoo River and other related areas.

There is a need for continuous research and preparation of an inventory of the effects of clear-cut of the native forests on the water quality, for ecological services and ecosystem support. Some of the findings from this study will be used to inform policymaking with respect to land use and land cover management issues. This study thus aims to address the effects of clear-cut of Tumoo forest on water quality in Chepkoo River to enhance human and environmental health. The findings can form a basis of river management in future.

1.6 Scope of the study

The study was carried out in Chepkoo River along Tumoo forest, Elgeyo-Marakwet County. Three sampling sites (upstream, midstream and downstream) were selected based on the variability of anthropogenic disturbances and the ease of accessibility. The sites were at stretch of about one kilometer apart to capture the effect of clear cut and after the clear cut downstream. The parameters studied were; temperature, dissolved oxygen, pH, suspended sediment, canopy cover, nutrient loading, benthic periphyton (diatoms), coarse particulate organic matter and vegetation composition. The study was undertaken for three months, from April to June 2017.

1.7 Assumptions of the study

Assumptions for this study were:-

i. River water quality is reflective of the human activities on the catchment area.
ii. The quantity of CPOM and abundance of periphyton is reflective of the river's water quality as well as the riparian vegetation density.

1.8 Definition of terms

Clear cut: This is a practice whereby trees are uniformly cut down, leaving less than 10% of the area covered by trees of more than three meters high.

Coarse particulate organic matter: this refers to any organic matter that is greater than 1 mm in size and is found on the riverbank and the river channel.

Environmental health: this refers to the practice of assessing, correcting, controlling and preventing those factors in the environment that can potentially affect the health of the present and future generations adversely.

Nutrients: This refers to nitrates, nitrites, phosphates and ammonia, discharged into rivers through runoff.

Periphyton: They are organisms, which live as a community attached to the stream bottom substrates for instance rocks, woody debris, or vegetation. They include bacteria, algae, protozoa, and diatoms. For this study, only diatom algae was studied this is because their response to nutrients is predictable and can be used to develop nutrient criteria.

Suspended sediment: this refers to the sand, silt and clay-sized particles that are held in suspension because of the turbulence in the water.

Soil erosion: this refers to a process, driven by the lateral movement of water on the land surface and it involves the detachment of the soil particles, the transportation, and storage or sedimentation process of the detached soil.

Water quality: This refers to physical, biological and chemical parameters of water. It involves measuring the condition of water and is normally relative to requirements of biotic species, or to any human needs.

CHAPTER TWO
LITERATURE REVIEW

2.1 Human activities and deforestation

There is reduced freshwater quality around the globe, which is attributed to increased anthropogenic activities that produce a variety of pollutants to the water sources. Increased farming activities around the riparian zones have resulted to major disturbances of most watersheds leading to dynamics in the functioning and structure of stream ecosystems. Removal of riparian vegetation by man could lead to alterations of the physical and chemical characteristics of riverine ecosystems. These alterations among them, the suspended sediments and nutrient runoff as well as change of channel morphology and discharge have a great influence on the quality of water. Traditionally, the use of physico-chemical monitoring programs such as measuring the contents of suspended sediments and nutrient load are a vital guide to environmental change. Nonetheless, they only represent the short-term conditions found during the time of sampling. Therefore, the use of biological indicators such as periphyton can provide comprehensive evidence of interactions between the ecosystem integrity and environmental quality and can offer an extensive guide to alterations in the ecological conditions (Guasch *et al*., 2016).

Numerous investigations have addressed deforestation on local, regional and global levels. Global forest resource management that have been conducted by F.A.O since 1946 (F.A.O 2011). The assessment used remote sensing data, such as land sat image, to identify areas and estimate the change of forest areas over time. From FAO studies, 4 billion hectares of total forest area in the world is decreasing at a rate of 13 million hectares per year.

Based on Zhao *et al*., (2013), Africa forest covers 675 million hectares and around 35 million hectares per year have been lost in the last decade. Throughout 20th century, FAO (2007) describes that, there is an upward trend on how human activities are harming the river ecosystem. In Kenya, there are approximately 1.24 million hectares of indigenous forest, which have closed canopy (FAO 2011). The loss of forest cover is mainly due to the need to expand agricultural areas. The farmers' primary concerns are food security and sustained productivity, and thus the perception and appreciation of people towards the function of an ecosystem is limited (Passa, 2006).

One of the Principles of Dublin Convention is the use of participatory approach in the water resources management (Cosgrove and Loucks, 2015). The concept partly reflects the observation that people who inhabit an environment over time are often the ones most able to make decisions about its sustainable use. Water resources are being destroyed because the vast majority of people have become passive observers and a few people are making decisions for everyone else (Mutuma *et al*., 2015). Forests play significant roles in the livelihood of communities living near the river. Forest zones serve as grazing areas during dry seasons, and provide timber and firewood among other benefits. Traditionally, forest trees acted as source of medicine to local communities. Furthermore, the forests provide other environmental services to the communities such as purification of air hence making communities live in a healthy environment (Gupta, 2016).

2.2 Physico-chemical variables

2.2.1 Temperature of the water in the river and its effects on other water parameters

Clear-cutting of riparian forest increases the amount of sunlight, which penetrates the river, leading to a rise in river temperature. Temperature has a significant influence on the levels of dissolved solid sand because of increased molecular motion of the solid sand. Therefore, the temperature is an essential factor in determining the water quality. The variability of temperature can trigger algae blooms, which will negatively affect the quality of water (Hesslerová and Pokorny, 2010). Aquatic bacteria such as parasitic diseases are majorly favoured by warm water, (Feichtmayer *et al*., 2017), which encourages faster growth, multiplication, and development.

High temperatures will lead to increase in evaporation, and this will lower the volume of water in rivers. Furthermore, there will be an increase in the water temperature because there is no rapid dilution of water (Gerten and Adrian, 2001). Most of the energy fluxes that influence stream temperature are controlled by riparian microclimate, which is set by conditions that surround the river. When a forest near the river is cut down, this will have an impact on riparian microclimate and will subsequently affect the terrestrial ecosystem, which can lead to increased water temperatures and can eventually have a deleterious effect on aquatic organisms (Johnson, 2004).

The forest canopy can reduce the impact of solar radiation, intercept rainfall and it reinforces the long wave radiation because the forest canopy usually is warmer and has a higher emissivity as compared to the sky being clear (Hesslerová and Pokorny, 2010). Forest canopies play an essential role in reducing the diurnal air temperature (Paiewonsky, 2017) and at night the water temperatures at forested areas are higher by 1˚C than in open (Spittlehouse *et al*., 2004).

2.2.2 Dissolved oxygen in river water and its effects

Dissolved oxygen is a factor, which indicates if water can support the aquatic life. This is because aquatic lives require oxygen, which is dissolved in water (Brack *et al*., 2016). After clear cutting there is lowering of dissolved oxygen (D.O), this is due to leaching of fertilizers or organic matter into the stream. In many cases, forests are cut to pave way for agricultural activities, and hence a lot of fertilizer application takes place for productivity improvements. Subsequently runoff resulting from bare ground will have an impact on the dissolved oxygen (Zhang, 2016). Reduced oxygen amounts in river water will negatively influence the river community. This may lead to lowered diversity of river organism and alteration of metabolic cycles for both the river and its inhabitants (Kalff, 2002).

2.2.3 pH and its effects on water quality

In natural waters, pH content is mainly related to quantitative ratios of carbonic acid, and its ions. Waters, which contain a lot of dissolved carbonates are acidic because of the carbonic acid in the surface of the water (Manoj and Padhy, 2015). Therefore, pH is an important guiding index. This parameter attributes to many activities in a river, particularly the biochemical activities in the river. An assessment of river pH provides an outlook of conditions facing the aquatic organisms of the assessed system.

There is a rapid change of pH resulting from high concentration of chemicals entering a river channel. Notably, it may increase when there is a high pollution of excess nutrients or due to the increased temperatures of that river (Wetzel, 2001). In a river, there is normally a spatial variation in pH, caused by the changes in the river temperatures (Bala *et al.,* 2007).Despite the fact that there may be a small variation in the pH of the river and it is not likely to cause a direct effect on the aquatic life. The change in pH greatly influences the availability of chemicals and affects their solubility, which ends up exacerbating the problems associated with nutrients. For instance, when there is variation in pH, it may lead to increase of phosphorus solubility, and thus plants can acquire more amount of phosphorous dissolved. When this happens, there will be a significant impact on the demand for the dissolved oxygen (Wetzel, 2001).

2.2.4 Sediment in the river channel and its effects

Removal of riparian vegetation may alter the plant composition along the river, and result to an increase in sediment load during high intensity of rainfall (Kostaschuk *et al*., 2002; Walling and Fang, 2003; Bouraoui *et al*., 2004). The sediment loads delivered to the water source normally comes from the cultivation of fields and due to bank erosion (Spellman, 2016). Anthropogenic activities have led to increased particulate organic matter, which increases the concentration of sediment in water of a river (M'Erimba *et al*., 2006). An important part of river system is caused by erosion process and sediment delivery, and therefore, the organisms can cope up with the small quantities. Excess of it may lead to massive death of organisms in the river (Walling, 2006). This is probably caused by an increase in cultivation of lands, rendering soils to be susceptible to erosion even with light showers of rain (Greg *et al.*, 2005).

Sediment loading in rivers and streams could introduce pollutants into these systems, which is normally a fate of many agricultural and industrial contaminants (Warren *et al*. 2003; Collins *et al*., 2005). Presence of suspended sediments in water can act as an important indicator of contaminants such as phosphorus, heavy metals and microorganisms since they are attached onto them (Neal *et al*., 1999, Haygarth *et al*., 2005). Toxins can settle out and remain persistent in sediment, and when the sediments are disrupted, they release these pollutants to the water (USEPA, 2009). The released toxins can negatively affect water quality and the life of aquatic animals (Paerl, 2014). According to Hatch (2001) an attachment of phosphorous to the sediment alter the water chemistry. Furthermore, high amounts of sediment encourage fast growth rate of coliforms bacteria, which lead to deterioration of water quality (Shittu *et al*., 2008; Ojo *et al*., 2012).

Sediments provide attachment to pathogens, which allows them to survive for a long period, but if there were less amount of sediment in the water, the pathogens that enter the water body would die off (Huang, 2016). Since most families near Chepkoo River use pit latrines and open defecation at times, sediments from runoff could provide attachment surfaces for pathogens like *Escherichia coli* that eventually find their way into streams. High amounts of sediments can reduce sunlight penetration (UV light) into water bodies that could kill some of these pathogens. Pathogens may be harmless in water body until they get to humans via the fecal-oral route or through other means (USEPA, 2009). Removal of vegetation cover reduces the filtration of sediments over time, and they normally act as buffer zones for the removal of large particles like sand (Hunter and Walton, 2008). Removal of sediments may be affected by the slope of the land, soil structure, density, the type of riparian vegetation, drainage pattern of subsurface and intensity of rainfall (Shields, 2006).

When there is a significant amount of suspended sediment in a river, the water becomes of poor quality in that it makes water to be murky, and of poor clarity. This has a direct impact in that the water cannot be used for drinking and bathing. A significant amount of sediment found in a river makes treatment of this water difficult (USEPA, 2009; USEPA, 2013). Large amounts of sediments found in a river will affect some of the basic goods and services, which are normally depended by many households as water for irrigation, swimming, aesthetic value and habitat for fish is affected (Henley *et al*., 2000). Sediments fill river channels (pools) thus reducing their storage capacity, which may lead to flooding of the riverbanks. When there is an increased inflow of the river, there will be an imbalance between the suspended sediment supplied and the sediment transported causing the river channel instability (Rakovan and Renwick, 2011).

2.3 Nutrients in rivers and the Effects on water quality and Aquatic organisms

Nutrient movement within the forest ecosystem involves the uptake and retention by the biota, which retards chemical or nutrient movements to the surface water, and thus vegetation composition play a key role. Nutrients can occur naturally, but recently most nutrients in water bodies are caused by anthropogenic activities for example farming near the riverbanks and from manure (Zamxaka *et al*., 2004). The major source of nutrient input into the stream and in rivers is from agricultural lands, which contribute 70% of total loads of nitrogen and phosphorus every year (Bowes *et al*., 2014).

Nutrients can get into the water through surface flows, or subsurface flows either in dissolved form or attached to the soil component (Schoumans *et al*., 2014). Nitrates are transported via subsurface flow. Whereas phosphorus enters the waterways while still attached to the soil components and organic materials in a runoff after precipitation (Ferreira, 2015). Riparian buffers have been found to be an effective filter for these nutrients (Connecticut River Joint Commission, 2005).

Riparian forest is an effective filter for removal of nitrates and nitrites, primarily from agricultural runoff. However, in areas with high water table and low organic carbons, the denitrifying bacteria are efficient removers of nitrates (Anderson *et al.,* 2014). Although nitrate removal can be done effectively by vegetation, the retained nitrates in soil microbes are released back into the water system when they decay (Jasper *et al*., 2014). However, Öztürk *et al*., (2015) concluded that vegetation remains to be the most effective remover of nitrates. The trees have roots that remove the nitrates found deep in the soil. The trees utilize the nitrates by converting it to organic nitrogen in plant tissues.

Forests near the river can provide a good sink for phosphorus, but they are not effective as when removing sediments and nitrogen (Pärn *et al*., 2012). Riparian vegetation is the main mechanism of removing phosphorus especially that is deposited in the sediments (King *et al*., 2015). In areas where clay particles containing high levels of aluminum and iron it can remove a high percentage of dissolved phosphorus in runoff water through the process of adsorption (Davis and Liu, 2014). According to Haygarth *et al*. (2015) riparian vegetation remove the dissolved phosphorous that has been acummulated in clay of the riparian soil. In areas with a high amount of phosphorus, it will be inefficiently adsorbed. Therefore, in a few years, soils become saturated with phosphorus leading to reduced water quality (Davis and Liu, 2014). Similarly, to nitrogen, phosphorus is also taken up and is used by vegetation as well as soil microbes (King *et al*., 2015). According to Habibiandehkordi *et al*. (2017) it was determined that despite the removal of phosphorous by forest buffer there is also a high release of phosphorous during light shower of rains.

Excess nitrates affect the quality of water because it exacerbates eutrophication in rivers (Beutel *et al*., 2016). Excessive plant growth in the river depletes the dissolved oxygen and therefore increases the undesirable taste, odours and colour due to decaying of organic matter. This will affect the ability of the stream to support aquatic animal life (USEPA, 2013). Some of the algae can form toxins, which have a direct harmful impact on aquatic organisms and human beings as well (Viviane, 2009). There are other types of nutrients, which can directly poison humans and animals. According to Habermeyer *et al*., (2015) high levels of nitrates cause methemoglobinemia in infants and may be associated with an elevated risk of birth defects as well as cancer of the stomach in adults.

Notably, the health of livestock is affected when they drink nitrate-contaminated water, in addition to nitrates in animal feeds. Continuous exposure to nitrate poisoning in livestock has indicated negative impacts. The animals experience physical defects like reduced blood pressure and lactation, abortion, vasodilation, and anorexia among other reproduction problem (Nixon, 2009; WHO, 2016). When dissolved phosphorous are in a high amount in a water body, it will have a negative impact on the biological productivity of livestock (Davis, 2006; Price *et al*., 2003).

2.4 Stream Periphyton

Periphyton plays an important role in using the inorganic substances to synthesize the organic material, which then are consumed by other heterotrophic organisms (Romaní *et al*., 2016). They contribute significantly to the energy budget that enables the organisms in the flowing water to thrive in. Periphyton assist in improving the water quality as it purifies the water. They can remove phosphorous and nitrogen in a substantial amount (Wang and Wang, 2015). This makes water to be more useable. Various studies concluded that when the nutrients accumulate as periphyton biomass, then removal of periphyton by the floods makes water in a river more useable (Welch *et al*., 1998; Smith *et al*., 2003; Dodds and Welch, 2000; Dodds and Biggs, 2002).

Periphyton acts as environmental indicators whereby most varieties of aquatic organisms tend to grow healthy. They help in providing food for invertebrates (Finlay *et al*., 2002). High temperatures lead to excessive growth of periphyton (Zhao *et al*., 2018). High temperature is associated with increased agricultural operations near the river and deforestation among other factors (Giorgi and Malacalza, 2002; Siva and John, 2002; Wu, 2016). Furthermore, periphyton has been used to develop nutrient pollution index as they respond to nutrients in water (Stevenson *et al.*, 2008).

2.5 Coarse particulate organic matter (CPOM)

In a forested catchment, CPOM plays an important role as a source of energy in streams and rivers as indicated by many authors (Wantzen *et al*., 2008; Dosskey *et al*., 2010; Straka *et al*., 2012). CPOM provide habitat for algae and macroinverterbrates that are in the stream (Schneider and Winemiller, 2008). They also offer protection against predators (Braccia, 2001) as well as source of food for the algae and macroinverterbrates (Testa *et al*., 2011). CPOM may get into the river through aerial input, may be carried by currents from upstream or from bank runoff input (Scalley *et al*., 2012).

Coarse particulate organic matter (CPOM) are both functional and structural component of the stream. Whereby, it has a great influence on the channel morphology and the stream processes, for example, nutrient dynamics and retention of fine sediment (Diez, 2000; Gomi *et al*., 2002, Webb and Erkine, 2003b; Quinn *et al*., 2007). Clear-cut of the forest near the rivers results in decreased CPOM stored in the river as a result of a reduction of inputs from the allochthonous material (Burrows *et al*., 2014). CPOM standing stocks can be altered through the dynamics of the hydrological regime (Davis *et al*., 2005). Therefore, when a clear cut is undertaken near the stream, it leads to increase in the CPOM exported and thus the CPOM stored in the stream decline tremendously.

2.6 Vegetation composition along a river

Vegetation has a key role in influencing various properties of the riparian ecosystems (Tabacchi and Planty-Tabacchi, 2001). Notably, the riparian plants affect the river discharge rates, local climate and ground water levels particularly through the process of evapotranspiration. In low order streams, riparian forest reduces the solar heating, which assists in controlling the microclimate. In stream geomorphology, the vegetation has an influence on the rates of sedimentation and a key factor on responding to the soil erosion during the flood events (Tabacchi *et al*., 1998). Therefore, this process modifies the transportation of sediment especially in low gradient environment by physically entrapping materials and in other circumstances, and they could alter the hydraulics of the channel (Hultine *et al*., 2010).

Furthermore, plants have various influences on the properties of soils, which is a factor dependent on the rate of their litter production and the decomposition rate of litter. In addition, many studies have indicated that organic matter from the riparian vegetation is an important source of nourishment for the organism in aquatic system. According to Kropp *et al*. (2017), riparian vegetation controls the movement and reduction of nonpoint source of pollution, which could result from the agricultural watershed or through sedimentation process (Groffman *et al*., 1992). However, despite many key roles riparian vegetation play, they are facing many threats, for instance in Northern hemisphere, they have altered them to allow for agriculture and navigation (Vitousek *et al*., 1997).

2.7 Influence of agricultural activities on water quality of a river

Agricultural activities within the catchment influence the water quality of the river, Raburu and Okeyo- Owuor, (2005), which is a major stressor to both rivers and streams. Kenya is among the water-scarce countries and therefore a need for proper management of activities taking place within the river catchment to ensure supply of good water quality throughout the year (Loucks and Van, 2017). Agricultural activities affect water quality through the release of nutrients due to fertilizer application and the management of soil in the water environment (Gordon *et al*., 2010). Richardson *et al.* (2007) described that the changes in land use on the catchment regions is associated with unsustainable activities that include, human settlement, clearing of forest for agricultural activities, and reclamation of wetland. Practicing agriculture along the river leads to riverbank erosion, and increased sediment problems downstream (Gordon *et al*., 2010).

Urbanizing rural areas around Chepkoo River watershed has made the forest surrounding the river to be clear-cut. This has led to alteration of the attributes of the river, which include the water quality, the hydrological regime and how the biological components of the river interact. Notably, there is a change from forested land to agricultural land, affecting the physico-chemical environment of the river. There has been no study undertaken before on this river. Thus, the study aimed to fill this gap.

2.8 Conceptual framework

Water quality is determined by the natural factors as well as human factors. The human activities have exerted more pressure on the water quality. The main driving force is human factors, which end up affecting water quality, this include deforestation, agriculture, and settlement. The focus of protecting and managing water resources is to safeguard human health, at the end, protecting the aquatic ecosystem and the terrestrial environment. It is, therefore, important to quantify the existing state of water quality. When assessing the water quality at the global, regional, national and by river basin, it is important to consider the driving forces, which are the needs of humankind. The pressure that is exerted on the water to meet these human needs and the state of water quality, which is caused by variability in physical and chemical characteristics of the environment. Furthermore, the impact of these factors on water quality and how they respond to the outcome. Therefore, the main factors considered in assessing the water quality of a river should involve, the driving force, the pressure, the state, the impact and the respond (DPSIR) thus getting a clear outlook of what is influencing it (Song and Frostell, 2012).

Sediment load affects the water quality (Figure 2.1) in that it will attract more pollutants such as pathogens and chemical pollutants, which may be discharged into the river. The suspended sediment will prevent penetration of UV radiation, which normally helps in killing the pathogens. Most of the homesteads near the river wholly depend on the raw water of the rivers.

In high concentration, especially for nutrients it will increase the primary productivity and end up affecting the water quality. Various anthropogenic activities among them; farming practices, logging, channel modification and linen washing bring changes on the physico-chemical variables thus affecting water quality. Periphyton has been used to develop nutrient criteria because their response to nutrients is predictable. All these variables (Figure 2.1) end up interacting in different ways and influence the water quality, the abundance and diversity of periphyton and the amount of CPOM in Chepkoo River.

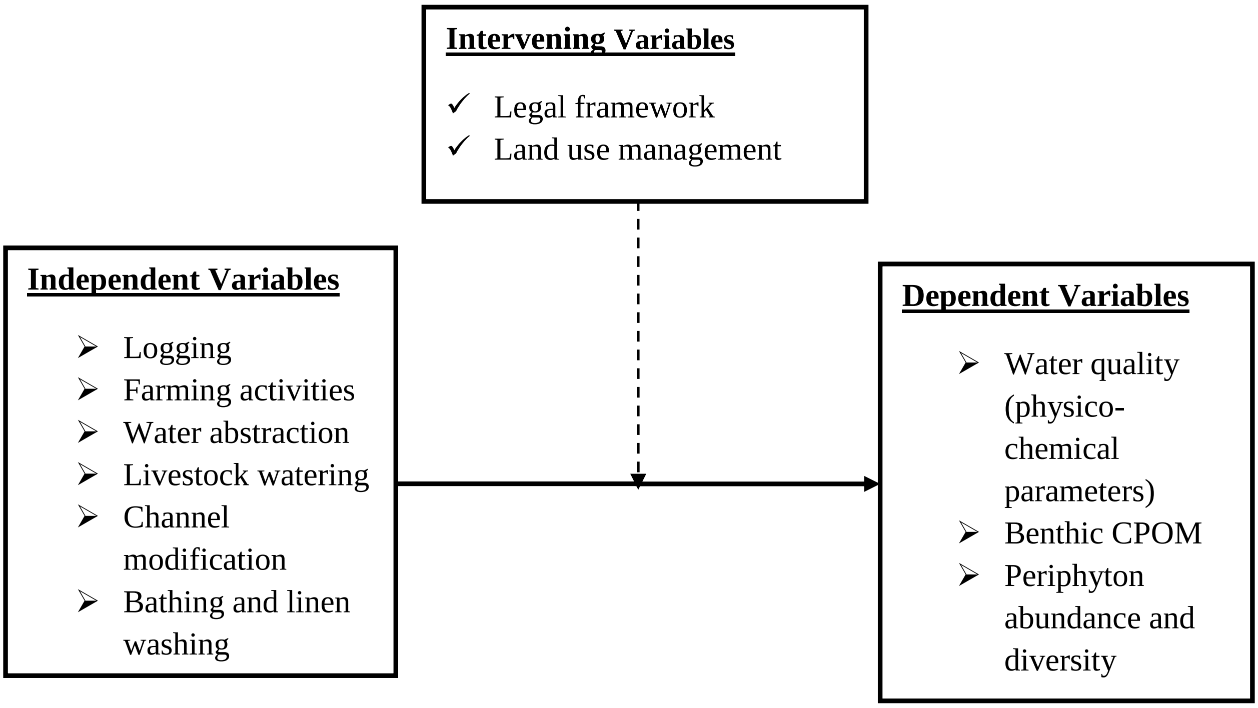

Figure 2.1: Conceptual framework. Source: (Modified from Song and Frostell, 2012)

CHAPTER THREE
MATERIALS AND METHODS

3.1 Study Area and the study site

3.1.1 Location of study area and topography

The study was carried out in Chepkoo River, in Keiyo south, Elgeyo-Marakwet County (Figure 3.1)

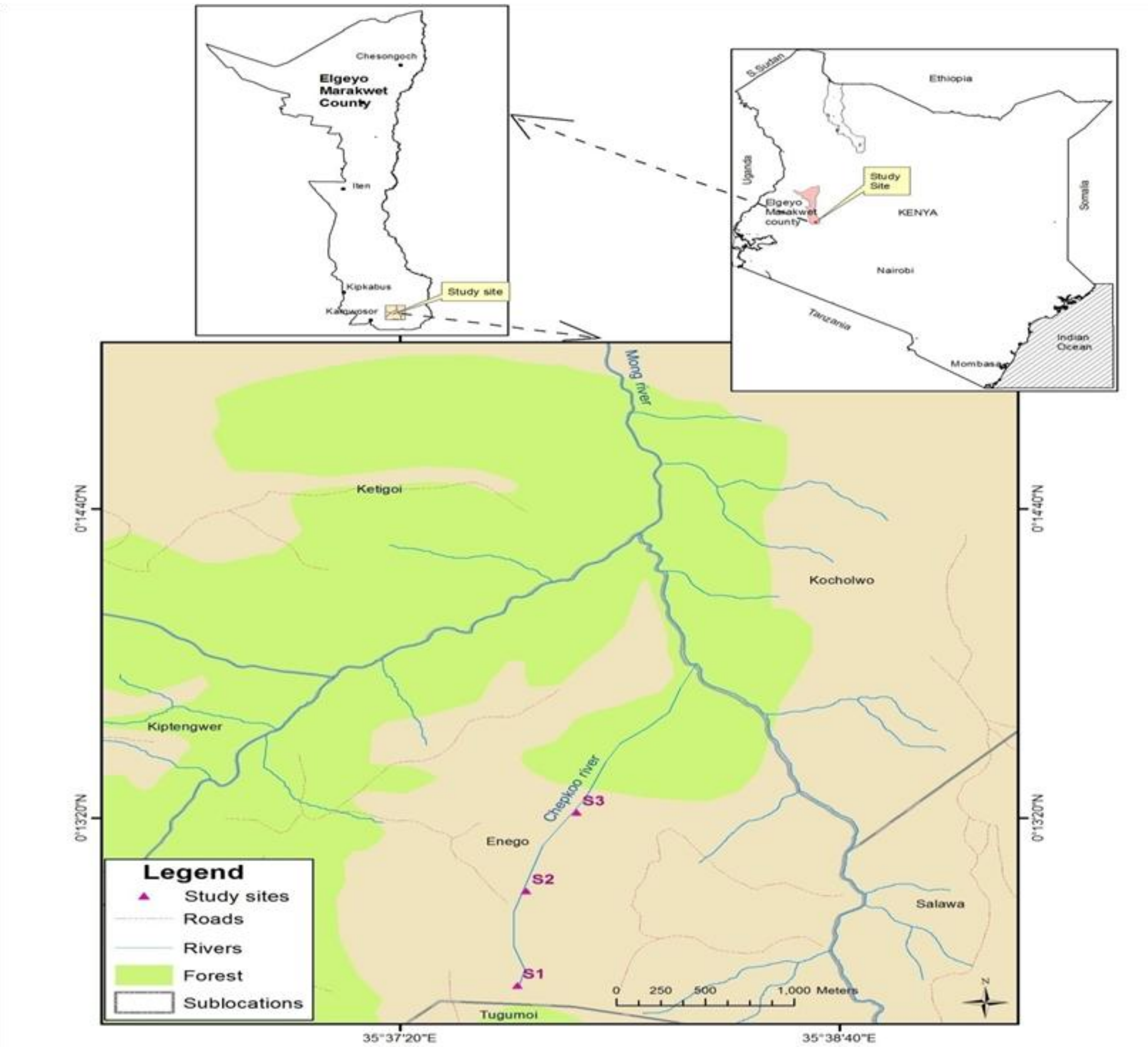

Figure 3.1: Map of Kenya showing study sites (Source: topographical map of Kenya, 2014)

Tumoo forest, which is bordering Chepkoo River is located in Elgeyo- Marakwet County, Keiyo south Sub County at latitude 0˚12' 17", 0˚15'28" North, longitude 35˚36' 19", 35˚39'17" East, with an average elevation of 2,347 meters. Keiyo South Sub County is divided into three topographical zones, which run parallel to each other; the highland "Tengunin", escarpment "Mosop" and lowland "soin". Tumoo Forest is located within the forested escarpment and the highland region, which is part of Kerio catchment area. The altitude of the highlands rises up to an altitude of between 2300 to 2700 meters above the sea level. When viewed from highland the valley provides a magnificent scenery. The great range of altitude brings considerable variability in climatic and physical conditions (Kipkore *et al*., 2014). Rivers in this region run parallel to the escarpment, in the south-Northern direction. It is within this escarpment that Chepkoo River finds its tributaries.

Climatic conditions and Vegetation

In the valley the mean temperatures is estimated to be approximately 26˚C, while in the highland it is estimated to range between 14˚C to 18˚C, but a times it can drop to as low as 6˚C (Kipkore *et al*., 2014). There is a considerable variability in rainfall patterns, which the dry conditions dominate in the valley while in the highland areas, there is high rainfall. Erosion is severe at the isolated spots on the steep slopes bordering the valley. The main vegetation types in Tumoo Forest consist of mountain bamboo mainly *Arundinaria alpina*, African pencil cedar, *Juniperus procera* and climbing trees among many other tree species (Kipkore *et al*., 2014).

Demographic profile

In the last few decades, area around Tumoo Forest has experienced high growth rates of both people and livestock. The residents of this area are the Keiyo community, which are part of the Kalenjin tribe who are residing in Rift Valley. Approximately 20,354people live within Kocholwo location where Tumoo forest is located (KNBS, 2010).

3.1.2 Study design

Ecological research design was used in the study, whereby the study sites were purposely selected to capture the effects of clear-cut along Chepkoo River. Three sampling sites (upstream, midstream and downstream) were selected based on the variability of anthropogenic disturbances and the ease of accessibility. The upstream site was located at altitude of1934 m above sea level, and it was georeferenced as 00˚12'36.8" N, 35˚38'37.8" E. A canopy cover of approximately 0-35% characterized the site and the banks of this point were gentle. Furthermore, the site had little disturbance, as compared to the other sites since it had minimal agricultural activities. The bottom substrates were mainly rocks and mud. Few people and livestock frequented the site (Plate1).

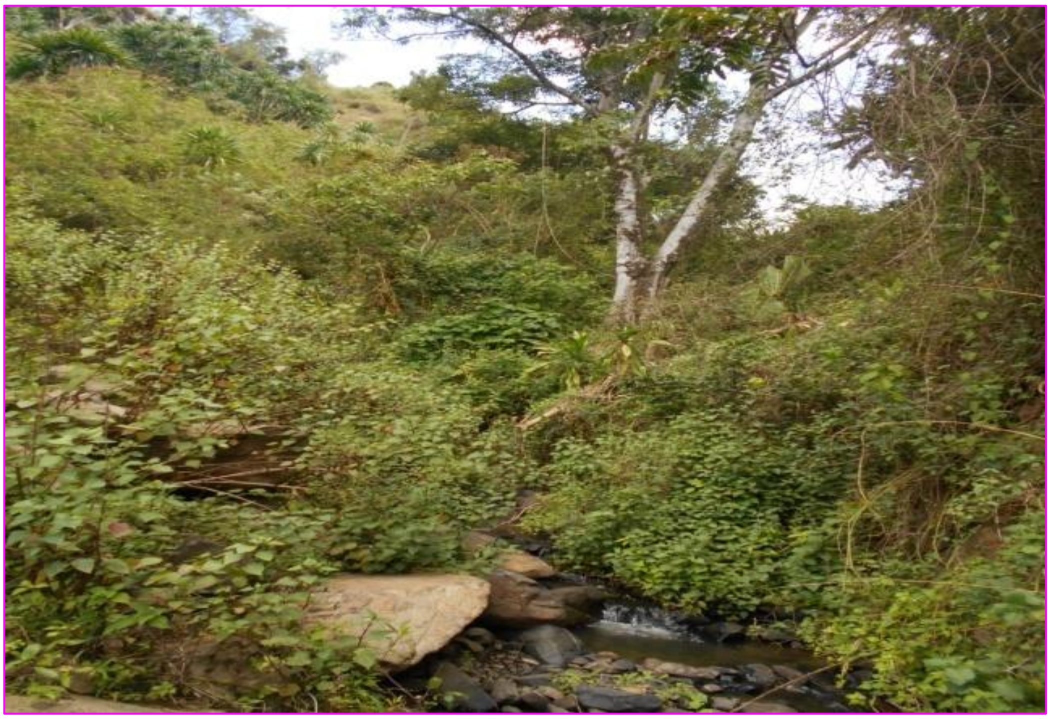

Plate 1: The upstream Site. Photo by the author 22/4/2017

The second sampling site was located approximately 1km downstream and was georeferenced as 00˚12'47.3" N, 035˚38'43.5" E, at an altitude of 1910 m above sea level. It was the main part of the river, where the inhabitants of this region practice agricultural activities such as farming. The site had a canopy cover of approximately 0-5%. The right bank was steep, while the left bank was gentle. The channel was composed mainly of pebbles, gravel, wooden materials and rocks (Plate 2). The third sampling site (plate 3) was located at an altitude of 1871 m above sea level, georeferencing of $00^0$12'51.3" N, and Longitude $035^0$38'47.0"E. The canopy cover was approximated to be 0-10%, at this site, with many human activities taking place, which included coffee farming, people drawing water, animals watering and linen washing. The streambed had wooden materials, gravel, pebbles and rocks. The site had a gentle slope on both banks. It is at this site where the weir is well conspicuous that connects communities across the river (Plate 3).

Plate 2: The midstream site. Photo by the author 22/4/2017

Plate 3: The downstream site. Photo by the author 22/4/2017

3.2. Sampling and Sample processing

Sampling was done during low flow between April and June 2018.

3.2.1 Determination of the physico-chemical characteristics of the river

Three readings of physical parameters of the river among them; temperature, conductivity dissolved oxygen and pH were measured *in situ* using the appropriate electronic probes. Dissolved oxygen (DO) was measured using HACH HQ 30d whereas pH, conductivity and temperature were determined by HACH HQ 40d.

3.2.2 Collection of water samples, periphyton and coarse particulate organic matter (CPOM)

i) Water samples

Sterilized sample bottles (500ml) were used to collect three water samples from the river channel at each site. All the water samples were properly marked and transported to Egerton University, Department of Biological Sciences in cool box for nutrient analysis.

ii) Sampling for periphyton

Submerged rocks (usually three) within a defined area were picked by hand, scrubbed on a clean tray, concentrated to 500ml, and labeled at each sampling site. The bottles were put in a cool box after fixing with 3 drops of iodine to maintain the structure of the collected periphyton cells. They were later transported to the lab for further processing.

iii) Collection of coarse particulate organic matter (CPOM)

Collection of CPOM commenced at the downstream site, moving upstream within the stream channel to minimize the physical disturbance while sampling. Samples were also collected from both riverbanks at each site. Within the stream channel, three CPOM samples were collected using a quadrat (effective sampling area = 0.29 m^2) thrown at random. This was repeated on the banks to collect a total of six samples three from each bank. The samples were kept in well-labeled polythene bags and transported to the laboratory for further processing.

3.2.3 Characterization of riparian vegetation

An area measuring 50 x 30 m was delineated at every study site. Vegetation was observed along three transects within the delineated area approximately 25 m apart. Vegetation species composition was noted, counted and recorded every 1m along each transects. This was done on both the right and left banks at each site.

3.2.4 Samples processing

i) Determination of total suspended solids (TSS)

Total Suspended Solids were determined gravimetrically as described in APHA (2005). The glass fiber filters were oven dried at 105^{0}C overnight and their constant weight (W_f) obtained. A known volume of water (500ml) from the triplicates samples was filtered in laboratory using the pre-weighed glass fiber filters (pore size = 0.45 µm) and reweighed (weight of the filter paper and filtrate-Wc), the glass fiber containing the filtrate were oven dried to a constant weight. The TSS was worked onto as per the indication in equation 1.

$TSS\ (mg/L) = ((Wc - Wf)x\ \ 10^{6}/V)$ ……………………...…………………Equation 1

Where TSS (mg/L) = total suspended sediments, Wc = constant weight of filter + residue; W_f = weight of pre-dried filter (g); V = volume of water samples used (ml).

ii) Determination of nutrients

Nutrients were analyzed as per APHA, (2005).Nutrients such as soluble reactive phosphorous (SRP), Ammonium nitrogen (NH_4-N), Nitrite-Nitrogen (NO_2-N) and nitrate- nitrogen NO_3-N were analyzed from the filtered water sample. Whatman GF/C filter of pore size 0.45 µm was used to filter the water sample and then the filtrates were refrigerated at 4˚C. Ascorbic acid method was used to analyze SRP with absorbance read at wavelength of 885 nm. This was achieved by mixing of reagents that consisted of ammonium molybdate solution (A), sulphuric acid (B), ascorbic acid (C) and potassium antimonyltartrate solution (D) in a ratio of 2:5:2:1=A:B:C:D. Eventually, the final solution made, was added into the water sample filtered in a ratio of 1:10.

Persulphate digestion of unfiltered water was used to determine the total phosphorus (TP). Whereby 1 ml of warm potassium sulphate was added to 25 ml of unfiltered water sample for the total phosphorous forms to be digested. The resulting mixture was autoclaved for 90 minutes at 120 º C, 1.2 atm. Evaporated water was replaced after digestion, and the TP was analyzed as SRP using the ascorbic acid method.

Sodium-salicyclate method was used to analyze nitrate-nitrogen (NO_3-N).1 ml of freshly prepared Sodium salicylate l was added to 20 ml of the filtrate of the water sample. The resulting sample was kept in an oven and evaporated completely to dryness at 95˚C. The residue was dissolved using 1ml of Conc H_2SO_4, after which 40 ml of distilled water and 7ml of potassium- sodium hydroxide-tartrate solution was added respectively. Using a GENESYS 10µv scanning spectrometer, the reading was done at wavelength 420nm.

While a reaction between N-Naphthyl-(1) ethylendiamin-dihydrochloride and sulfanilamide was used to analyze Nitrite-Nitrogen (NO_2-N) with the absorbance read at wavelength of 543 nm using a GENESYS 10 uv scanning spectrophotometer.

Ammonium nitrogen (NH_4-N) was analyzed through the reaction between sodium salicyclate and hypochloride solution on the filtered water sample. The obtained mixture was incubated in the dark for 90 minutes, then absorbance was read at wavelength of 665nm using a GENESYS 10 uv scanning spectrophotometer.

iii) Laboratory analysis of periphyton

In the laboratory the water slurry was stirred, 4ml of periphyton (diatoms) slurry was removed using pipette and transferred on a microscope slide with defined field of observation. The diatoms cells were observed under a microscope (Magn. X 1000) enumerated, counted and identified to the lowest level possible using the keys by Gasse (1986). Since this method was suitable for determining diatoms, other non-diatoms periphytons present were recorded as present or absent. Diatoms diversity was determined using the Shannon Wiener Index (Shannon and Wiener, 1963) equation 2.

$H' = \Sigma piInpi$……………………………….……………………………Equation 2

Where,

H'= Shannon Wiener index

p_i= proportion of individuals found in species

n= number of individuals in each species

Evenness was determined using Shannon's Equitability index (E_H) equation 3, and similarity index was calculated using Sorensen's coefficient of community (CC) equation 4 (Shannon and Wiener, 1963).

$E_H = H'/\ln S$.…………………………………….....………………………Equation 3

Where,

$E_{H=}$ Shannon's Equitability Index

H'= Shannon-wiener diversity index

S= Total number of species in the community

$CC = 2c/(S_1 + S_2 + S_3)$……………………………………..………………. Equation 4

Where,

C= number of species common in the three study sites

S_1= number of species in the upstream

S_2=number of species in the midstream

S_3= number of species in downstream

iv) Analysis of CPOM samples, vegetation abundance and diversity

In the laboratory, CPOM samples were dried in pre-weighed aluminium cups at 60˚Cfor 24 hours, and weighed to obtain the dry weights (DW) estimates. The dry CPOM was then separated into leaves, twigs, barks, fruits and others and their weight determined separately. Vegetation abundance, diversity, evenness and similarity indices were computed as described for periphyton (equations 2, 3 and 4).

3.3 Data analysis

Statistical Package for Social Science (SPSS) software version 20 was used in data analysis. The data was summarized into tables and graphs in excel and sigma plot version 11.0. The normality of the data was tested using the Shapiro-Wilk test and for the data that did not meet the normality test they were transformed into log (x+1). The homogeneity of data was tested using Bartlett test. The mean differences in the physico-chemical variables among the sites were analyzed using One-way ANOVA, except for the pH that was given as a range. The same test was used to analyze the mean difference in CPOM and periphyton among the three study sites. Vegetation data was expressed as the relative abundance. Pearson correlation was done to determine whether there existed any significant influence between the physco-chemical variables, periphyton as well as CPOM. Tukey's *post hoc* test was used to determine which parameters had variant means for data that showed statistical difference. All the significant test were performed at 95% confidence level (α = 0.05).

Table 3.1: Data analysis summary

Hypotheses	Variables	Statistical Tools
There is no significant difference in physical variables (temperature, dissolved oxygen, pH and suspended sediments) of the river among the study sites.	pH Temperature, Dissolved oxygen and Suspended sediment	Descriptive statistics, One-way ANOVA
There is no significant difference in nutrient concentrations at the three sites along the river.	Mean nutrient concentration (SRP, TP NO_3-N, NO_2-N, NH_4-N.)	Descriptive statistics, One-way ANOVA
There is no significant difference in the abundance and diversity of benthic periphyton along the selected sites of Chepkoo River.	Abundance of benthic periphyton	Descriptive statistics, One-way ANOVA)
There is no significant difference in the benthic coarse particulate organic matter among the study sites in Chepkoo River.	Dry weight of CPOM	Descriptive statistics, One-way ANOVA
There is no significant difference in vegetation composition among study sites of Chepkoo River.	Vegetation diversity and abundance	Descriptive statistics, One-way ANOVA

CHAPTER FOUR

RESULTS

4.1 Physico-chemical characteristics of the studied sites

The data of physico-chemical parameters in the three sampling sites on Chepkoo River are presented in Table (4.1). Statistical parameters are represented as means ± standard error (SE) except for pH, which is given as ranges. The lowest temperature was recorded at the upstream site, while the highest was recorded at the downstream site (Table 4.1). The mean difference in temperature among the sites differed significantly ($F_{(2, 24)} = 16.423$, $p < 0.05$). Though the midstream site recorded the highest conductivity value, of 107.14±5.663µs/s the mean difference among the sites was not statistically significant. When dissolved oxygen was considered, the mean difference among the sites was not statistically significant ($F_{(2, 24)} = 0.024$, $p > 0.05$) though the downstream recorded a higher value of (7.26±0.212 mg/L). The midstream site recorded the highest value of 0.111 ±0.007 mg/Lin terms of TSS. This mean value did not differ significantly with the other two sites.

Table 4:1: The physical variables measured in Chepkoo River (values are means ± standard error except for pH that is given as ranges), P values; * = 0.05, **=0.001, n.s = not significant. Ұ = n = 3 for ONE- ANOVA to be performed.

Parameters	Upstream	Midstream	Downstream	F-Value
Temperature (°C)	19.089 ± 0.196	22.86±0.720	22.90±0.631	16.423**
Conductivity (µs/s)	91.211 ± 8.046	107.14±5.663	97.54±11.212	$0.912^{n.s}$
DO (mg/L)	7.20 ±0.240	7.23±0.231	7.26±0.212	$0.024^{n.s}$
TSS (mg/L)	0.102±0.005	0.111 ±0.007	0.104±0.006	$0.601^{n.s}$
pH	7.29-8.19	7.18-8.31	7.29-8.25	
Velocity (m/s)	0.562 ±0.038	0.858±0.076	0.710±0.060	Ұ
Discharge (m^3/s)	0.138±0.049	0.710±0.392	1.446±0.586	Ұ

4.2 Nutrients in the three sites of Chepkoo River

Total phosphorus and soluble reactive phosphorus were in higher concentration than the other nutrients in the three sites (Figure 4.1). The midstream site recorded a mean value of 0.223±0.038 mg/L, which was the highest in terms of TP. One-way ANOVA indicate that the mean value in TP among the sites was however, not statically significant ($F_{(2, 24)} = 0.225$, $p > 0.05$). The second most dominant nutrient was SRP, which ranged from 0.127±0.013 mg/L in the upstream site to 0.157±0.022 mg/L downstream site. The mean nitrite concentration recorded at the downstream site was higher than the other two sites though not statistically significant (one-way ANOVA, $F_{(2, 24)} = 1.047$, $p > 0.05$). Nitrates were in high concentration in midstream site whilst ammonia were in high concentration in the downstream site. The mean difference in NO_3-N and NH_4-N among the sites was not significant (one-way ANOVA, $F_{(2, 24)} = 1.333$, $p > 0.05$: $F_{(2, 24)} = 0.935$, $p > 0.05$).

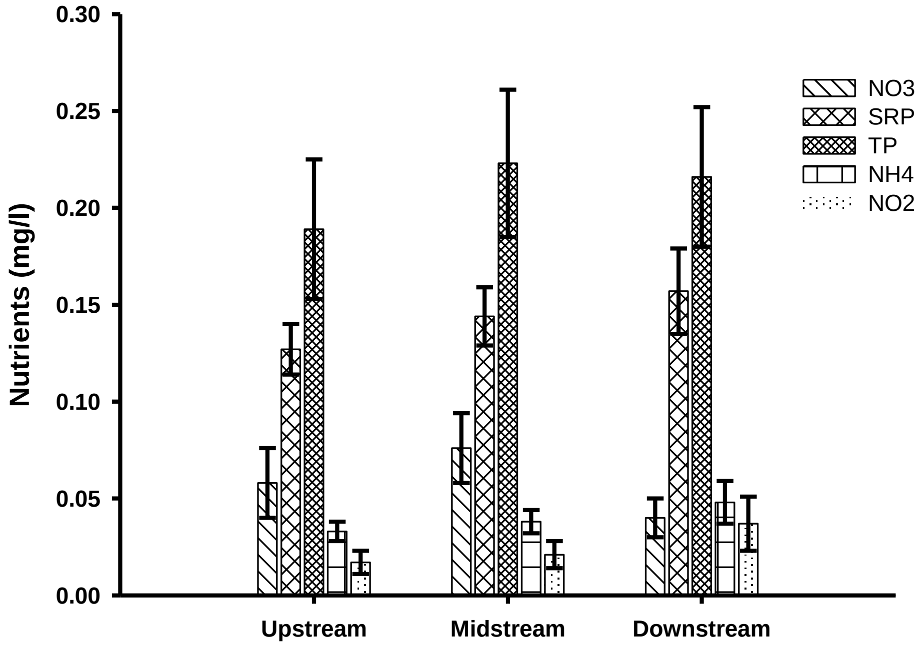

Figure 4.1: Nutrients (means±SE) among the three study sites of Chepkoo River

4.3 Abundance and diversity of benthic periphyton in Chepkoo River

4.3.1: Benthic periphyton species list and abundance

The species list of benthic periphyton collected in Chepkoo River study sites is presented in Table 4.2. Twenty nine (29) species were collected during this study and majority were diatoms of the species *Fragillaria ulna, Diatoma spp*., *Navicula spp.*, *Coconeis placentula,* and *Gomphonema punilum*t hat formed more than 50% of the total (Table 4.3). With exception of *Oedogonium spp.* that only appeared at the downstream site, the other four dominant taxa were represented in all the sites. The most dominant species out of the 29was *Fragillaria ulna* that comprised 28% followed by *Navicula spp.* at19%. Detailed information is given in appendix 1. About 11 taxa were restricted to the upstream site, 2 to the midstream site and 4 to the downstream site. The rest were common across the three sites (Table 4.2).

Table 4.2: Taxa list of periphyton collected in the upstream, midstream and downstream sites (+ means present and – means absent, S = number of species).

TAXA	Upstream	Midstream	Downstream
Achnanthes inflate	+	-	-
Achnanthidium linearis	+	-	-
Anabaena spp.	+	-	+
Botryococcus spp.	+	+	-
Chaetophorus spp.	-	+	-
Cladophora spp.	+	+	+
Closterium	-	-	+
Cocconeis placentula	+	+	+
Cymbella spp.	+	+	+
Diatoma spp.	+	+	+
Diatomella balfouriana	-	+	-
Encyonema minutum	+	-	-
Fragillaria ulna	+	+	+
Gomphonema augur	+	+	-
Gomphonema clavatum	+	-	-
Gomphonema minutum	+	+	-
Gomphonema pumilum	+	+	+
Gomphonema parvulum	+	-	-
Gomphonema spp.	+	-	+
Gomphonema truncatum	+	+	-
Microspora spp.	+	-	-
Navicula spp.	+	+	+
Netrium digitus	+	-	-
Oedogonium spp.	-	-	+
Pinnularia gibba	-	-	+
Pinnularia spp.	-	-	+
Surirella spp.	+	-	-
Synedra ulna	+	-	-
Other	+	-	-
S	23	13	13

Table 4.3: Summary of five dominant periphyton in the study sites of Chepkoo River.

Taxa	No. of taxa per m^{-2}	Percentage composition (%)
Fragillaria ulna	138000	28.1
Navicula spp.	95250	19.4
Diatoma spp.	34750	7.1
Coconeis placentula	8750	1.8
Gomphonema punilum	7250	1.5
Others	274,450	42.1
Total	**490500**	**100**

The midstream site had lowest abundance of benthic periphyton whilst the upstream site had the highest (Fig. 4.2). The mean difference among the sites was statistically significant (One-way ANOVA, ($F_{(2, 24)}$=1.047, P < 0.05). Tukey's HSD indicated that the mean abundance determined at midstream site was significantly lower than the other two sites (α = 0.05).

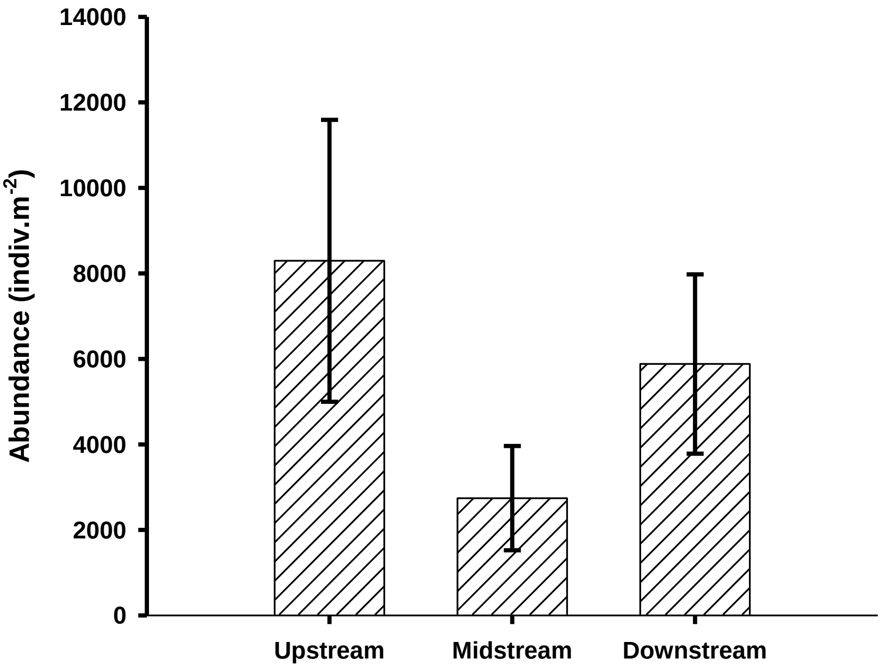

Figure 4.2: Periphyton abundance (indiv. m^{-2}) in the three study sites of Chepkoo River.

When sites were considered, three species dominated in the upstream site while four dominated the midstream and downstream sites (Fig. 4.3). The species composition changed with sites with *Flagillaria ulna* and *Navicula spp.* dominating in the upstream and midstream sites. In downstream the dominating periphyton was *Gomphonema punilum*, and was only present in this study site. It is worth noting that *Flagillaria ulna* and *Navicula spp.* was present in all the three study sites, while *Coconeis placentula* was present in the upstream and midstream sites, but absent in the downstream site. Notably, *Diatoma spp.* was present in both midstream and downstream sites but absent in the upstream as indicated in Figure 4.3.

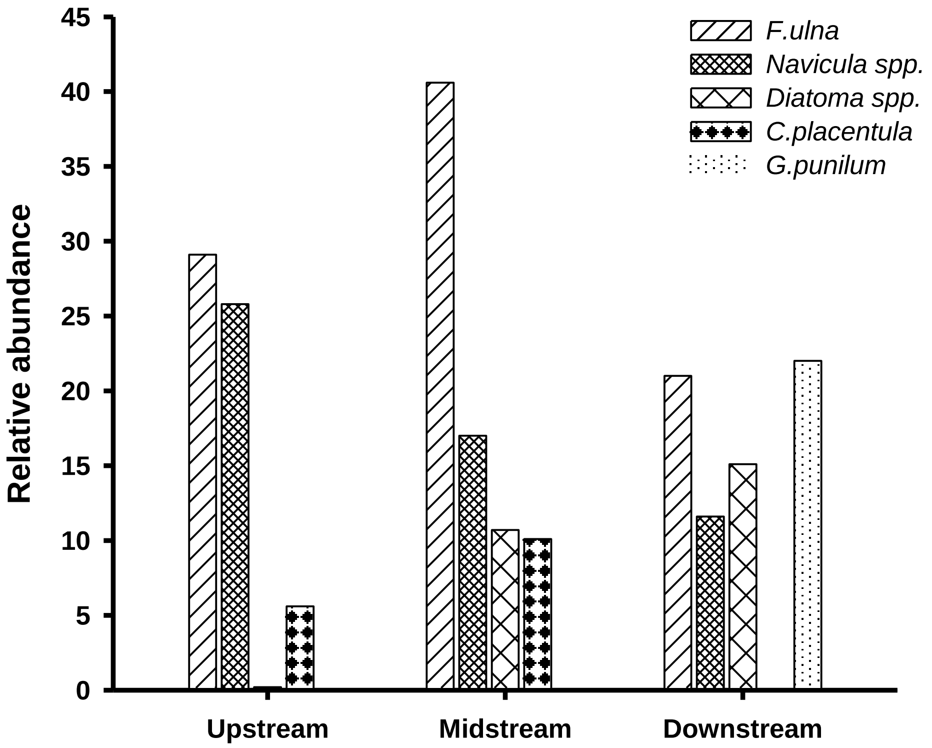

Figure 4.3: The main dominant periphyton growth of the three study sites

4.3.2 Periphyton diversity, similarity and evenness

The upstream site had 23 species of aquatic organisms while the other two had 12 each (see Table 4.2). The highest diversity was observed at the downstream stream site, followed by upstream and midstream (Table 4.4). The downstream site had the highest evenness followed by midstream and lastly upstream. In terms of similarity, 25% of the species were similar in the three sites as indicated by the Sorensen's Coefficient of Similarity (Table 4.4).

Table 4.4: Periphyton diversity, evenness and similarity in Chepkoo River

Sampling site	Shannon Index (H′)	Equitability Index (E)	Sorensen's Coefficient
Upstream	1.9	0.61	0.25
Midstream	1.8	0.72	
Downstream	2.0	0.80	

4.4 Coarse particulate organic matter (CPOM) on the banks and in the streambed

4.4.1 CPOM on the banks

The quantity of CPOM (pooled data) collected in the midstream site was higher than the other two sites as depicted in Figure 4.4.The difference in mean organic matter quantities collected among the three sites was statistically significant One-way ANOVA ($F_{(2, 24)} = 12.427$, $p < 0.001$). Low amounts of CPOM were recorded at the downstream site.

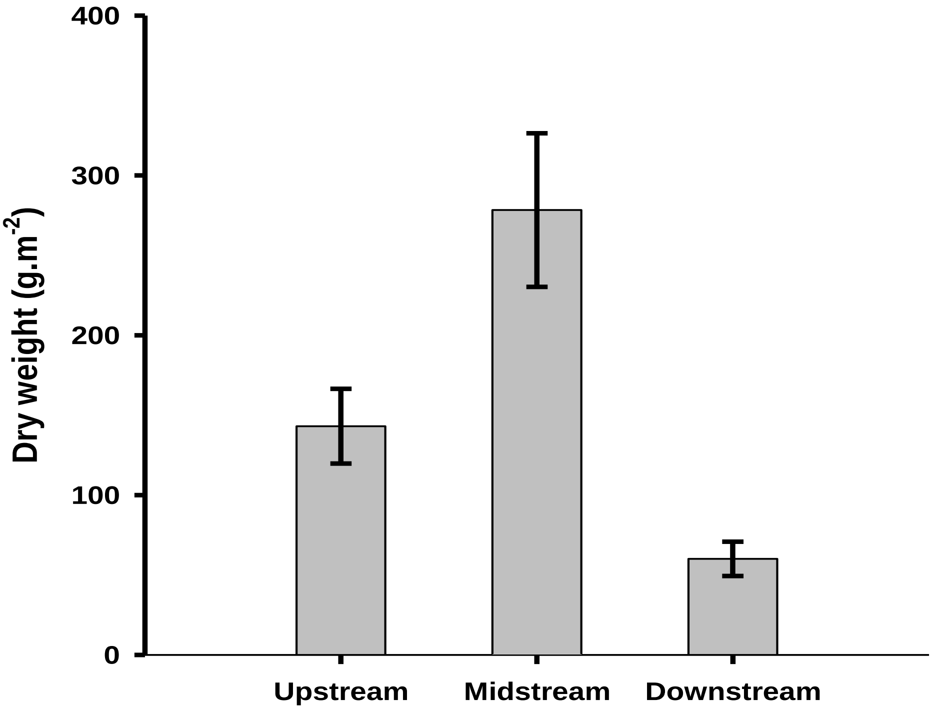

Figure 4.4: Total CPOM dry weight (pooled) collected on the banks at the three sites

When the banks were considered, the amount of CPOM collected on the left bank differed significantly among the three sites ($F_{(2, 24)} = 17.882$, $p < 0.001$), whereby the downstream site recorded the lowest amount ($F_{(2, 24)} = 3.374$, $p > 0.05$). However, when the right bank was considered there was no significant difference in the amount of CPOM among the three study sites ($F_{(2, 24)} = 3.374$), $p > 0.05$) (Fig. 4.5). Site-specific difference in terms of mean CPOM collected between the two banks was statistically insignificant (t value=1.889, d.f = 16, $p > 0.05$) (Fig. 4.5).

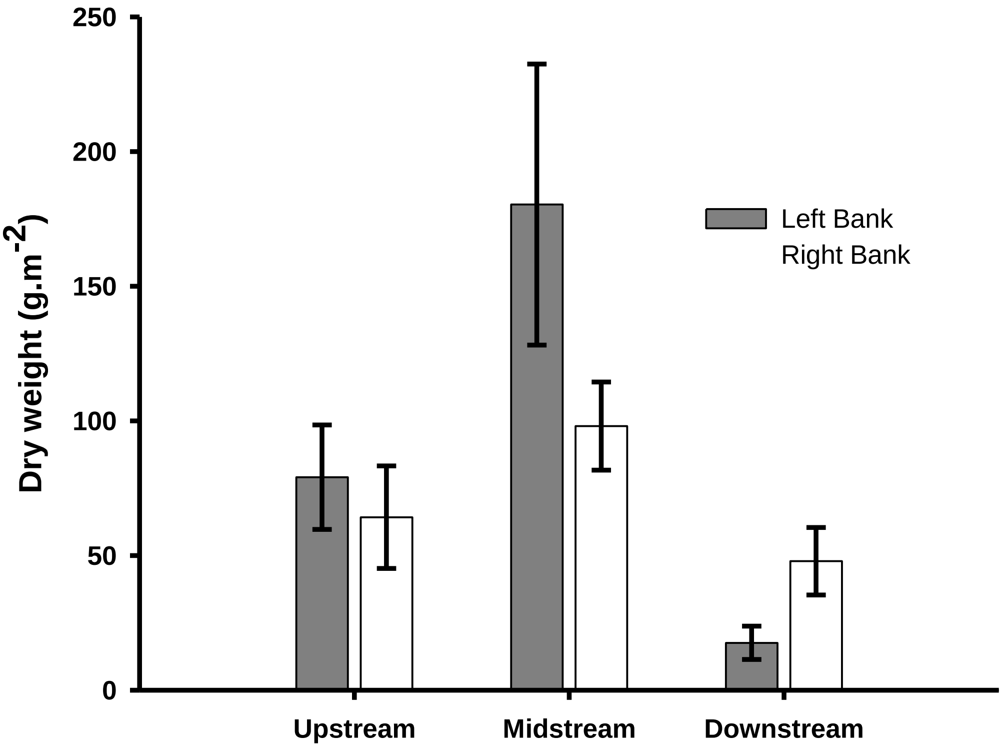

Figure 4.5: The dry weight of CPOM (g/m^2) in the left and right bank of each study site

In general, twigs dominated both left and right bank followed by leaves and barks (Fig. 4.6). The amount of twigs collected on the right bank was significantly higher than the other plant litter categories in all the sites (Table 4.5a) (One-way ANOVA, $F_{(2, 24)} = 5.598$, $P < 0.05$). Similarly, significantly more twigs were collected on the left banks of the three sampling sites except in the downstream site (Table 4.5b).

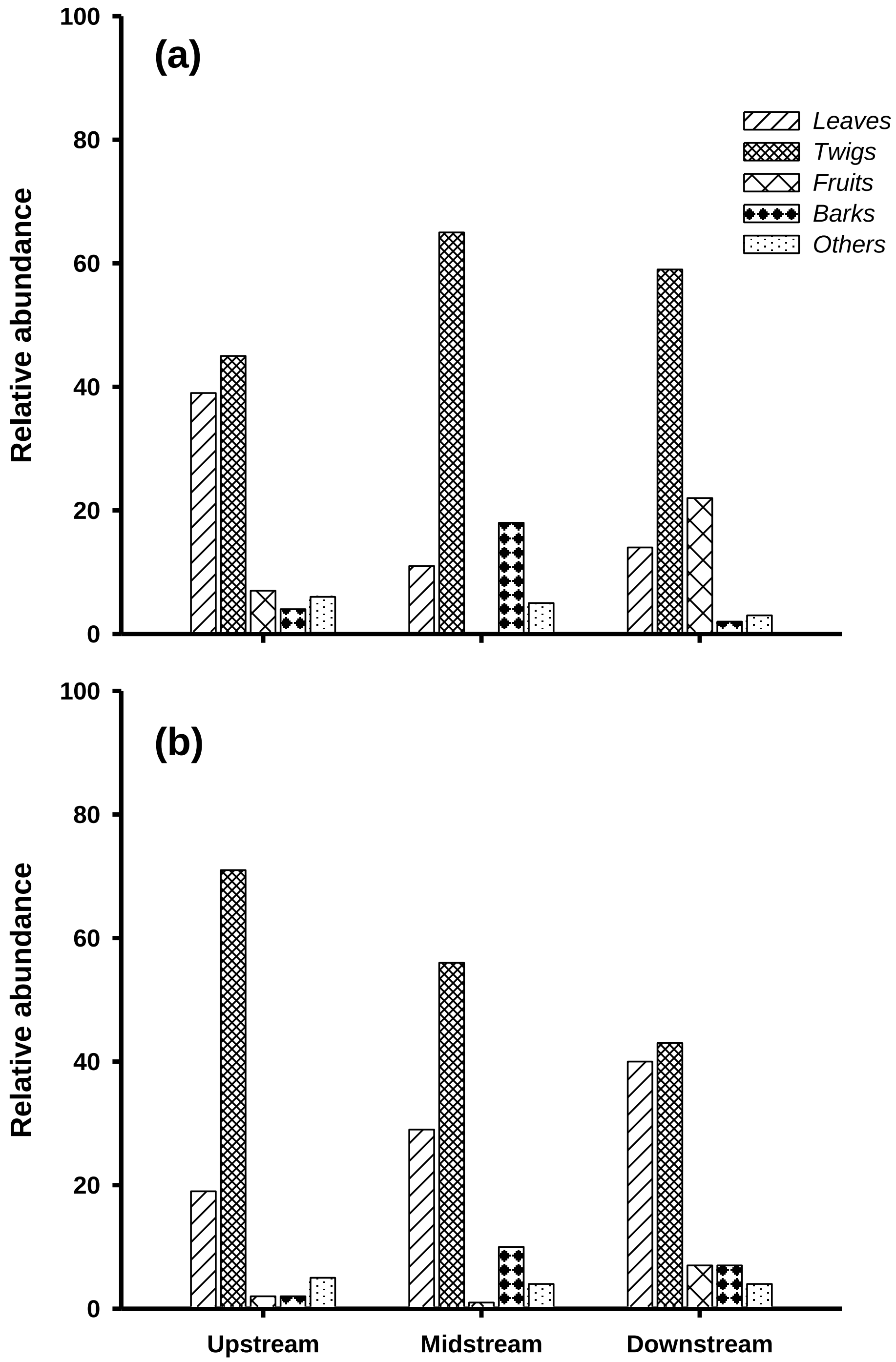

Figure 4.6: Percentage contribution of plant litter category in (a) left and (b) right bank of each study site in Chepkoo River

Table 4.5: Summary of the dry weight value of the CPOM (g/m^2) in the left bank (a) and right bank (b) at the three study sites, the bolded values are the means, bracketed values are the ± SE, P values: *= 0.05, **= 0.01, ***= 0.001, n.s= not significant.

	PLANT LITTER CATEGORY					
Sites	**Leaves (g/m^2)**	**Twigs (g/m^2)**	**Fruits(g/m^2)**	**Barks (g/m^2)**	**others (g/m^2)**	**F-value**
(a)						
Upstream	**30.94636**	**35.13**	**5.368**	**2.969**	**4.475**	**8.094*** **
	(8.427)	(12.00)	(2.406)	(1.775)	(1.913)	
Midstream	**20.065**	**117.096**	**1.908**	**32.586**	**8.636**	**6.270** **
	(10.444)	(55.953)	(1.394)	(23.701)	(5.186)	
Downstream	**2.418**	**10.425**	**3.816**	**0.429**	**0.467**	**$1.821^{n.s}$**
	(1.289)	(7.027)	(1.949)	(0.000)	(0.426)	
(b)						
Upstream	**12.51**	**45.659**	**1.502**	**1.061**	**3.456**	**19.728*** **
	(4.995)	(16.592)	(0.772)	(0.702)	(2.532)	
Midstream	**27.962**	**54.734**	**1.094**	**10.264**	**3.973**	**5.065** **
	(8.288)	(19.21)	(0.761)	(5.232)	(1.597)	
Downstream	**16.847**	**18.169**	**2.843**	**3.13**	**1.51**	**4.845** **
	(7.748)	(5.854)	(2.486)	(2.603)	(1.093)	

4.4.2 CPOM in the stream channel

The quantity of CPOM retained in the stream channel in the three sites is presented in Figure 4.7. The upstream site had the highest amount of CPOM followed by the downstream and the least was at the midstream site. The mean difference in the amount of CPOM among the three sites was statistically significant (One-Way ANOVA, $F_{(2, 24)} = 8.053$, $p < 0.001$). The upstream site differed significantly with the other two sites (Tukey HSD, $p < 0.05$).

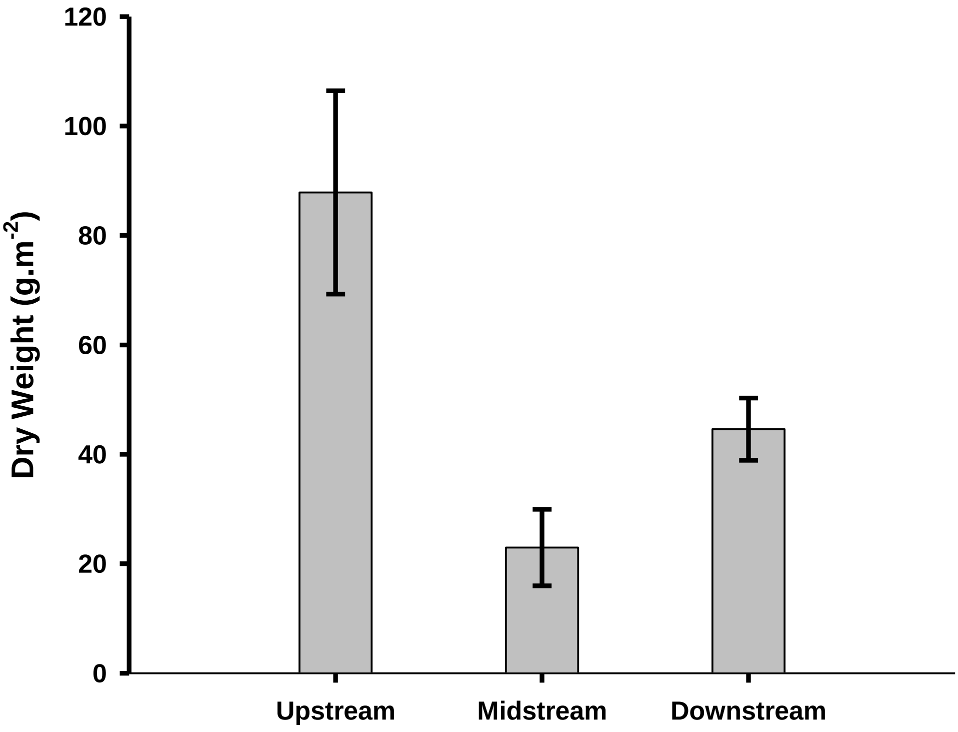

Figure4.7: Dry weight of CPOM (g/m2) in river channel along the three sampling sites of Chepkoo River

Leaves contributed the highest amount of CPOM dry weight in the midstream and downstream sites whilst twigs dominated in the upstream site (Fig. 4.8). Only two plant litter categories were collected in the downstream site, three in the midstream site and four in the upstream site.

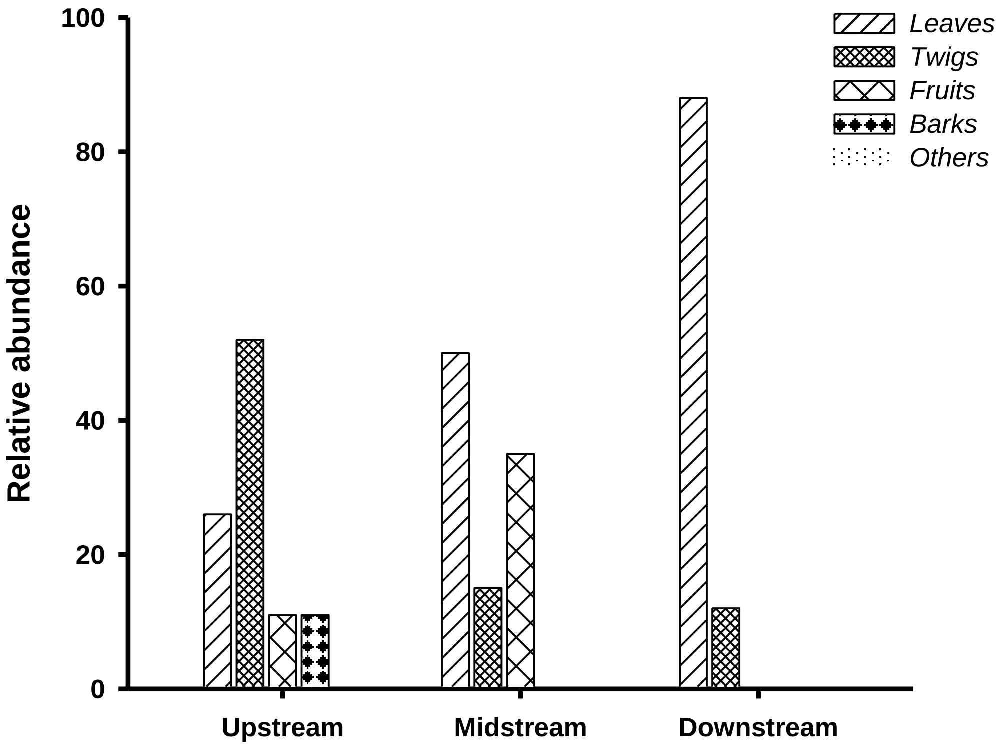

Figure 4.8: Percentage contribution of plant litter category in river channel along the three study sites of Chepkoo River

Twigs dominated other plant litter categories in the upstream site, whilst leaves dominated in the other two sites (Table 4.6).The amount of plant litter categories collected differed significantly across the three sites (One-way ANOVA, $F_{(2, 24)} = 7.856$, $P < 0.05$).

Table 4.6: The measured dry weight value (g/m^2) of CPOM at the three sites. Bolded values represent the means, while the bracketed values are ± SE; P values: *= 0.05, **= 0.01, ***= 0.001, n.s= not significant.

	PLANT LITTER CATEGORY					
River channel	**Leaves (g/m^2)**	**Twigs (g/m^2)**	**Fruits(g/m^2)**	**Barks(g/m^2)**	**Others(g/m^2)**	**F-value**
Upstream	**22.529**	**45.356**	**9.992**	**9.724**	**0.249**	**8.564*** **
	(6.224)	(13.805)	(5.291)	(8.565)	(0.000)	
Midstream	**11.464**	**3.521**	**7.973**	**0.000**	**0.000**	**5.426** **
	(4.075)	(2.35)	(7.939)	(0.000)	(0.000)	
Downstream	**33.506**	**4.471**	**0.000**	**0.000**	**0.000**	**34.232*** **
	(7.210)	(0.000)	(0.000)	(0.000)	(0.000)	

4.5 Vegetation composition, diversity, evenness and similarity

4.5.1 Vegetation composition

The species list of vegetation observed at Chepkoo River study sites is presented in Table 4.7, whereby 20 plant species were recorded. The upstream site had 16 plant species, the midstream site had 13, while the downstream site had 9 plant species. The three study sites had 6 species in common. Some species were restricted to upstream site, among them were *Arundinaria alpina,* C*ynodon dactylon, Solanum nigrum* and *Stephania abyssinica*. While *Lantana camara* was present in the midstream site and absent in all the other two-study sites (Table 4.7).

Table 4.7: Presence or absence of different types of vegetation in upstream, midstream and downstream (+ means present and – means absent, S = number of species)

Plant Species	Upstream	Midstream	Downstream
Acacia tortilis	+	+	-
Acanthus eminens	+	+	+
Arundinaria alpine	+	-	-
Caesalpina spinosa	-	+	+
Croton macrostachyus	+	+	+
Croton megalocarpus	-	+	-
Cupressus lusitanica	-	+	+
Cynodon dactylon	+	-	-
Eucalyptus saligna	+	+	-
Ptendium spp.	+	-	+
Lantana camara	-	+	-
Olea welwischii	+	-	-
Oplismenus burmannii	+	+	+
Pandanus kirkii	+	-	-
Pennisetum clandestinum	+	+	+
Plectranthus spp.	+	+	-
Sadge	+	+	+
Solanum nigrum	+	-	-
Stephania abyssinica	+		-
Vernonia lasiopus	+	+	+
S	**16**	**13**	**9**

The study sites comprised of five vegetation types namely; trees, shrubs, forbs, grass and climbers. Shrubs dominated the upstream and downstream sites (Fig.4.9). Trees dominated in the upstream site but were less than 40% of the total. All the five vegetation types were well represented in the upstream site but climbers were missing in the other two sites.

When banks were considered in terms of each vegetation category, the left bank had the highest number of trees compared to the left bank in the upstream site. The opposite was observed in both midstream and downstream sites (Table 4.8). Shrubs dominated the right bank in the upstream and downstream sites whilst forbs dominated the left bank in the upstream and midstream sites. This was not the case in the downstream site, where they were only evident on the right bank. The upstream and midstream banks had grass but it only appeared on the right bank of the downstream site. Notably, climbers were only evident on the left bank of the upstream site but were absent in all the banks at the other two sites.

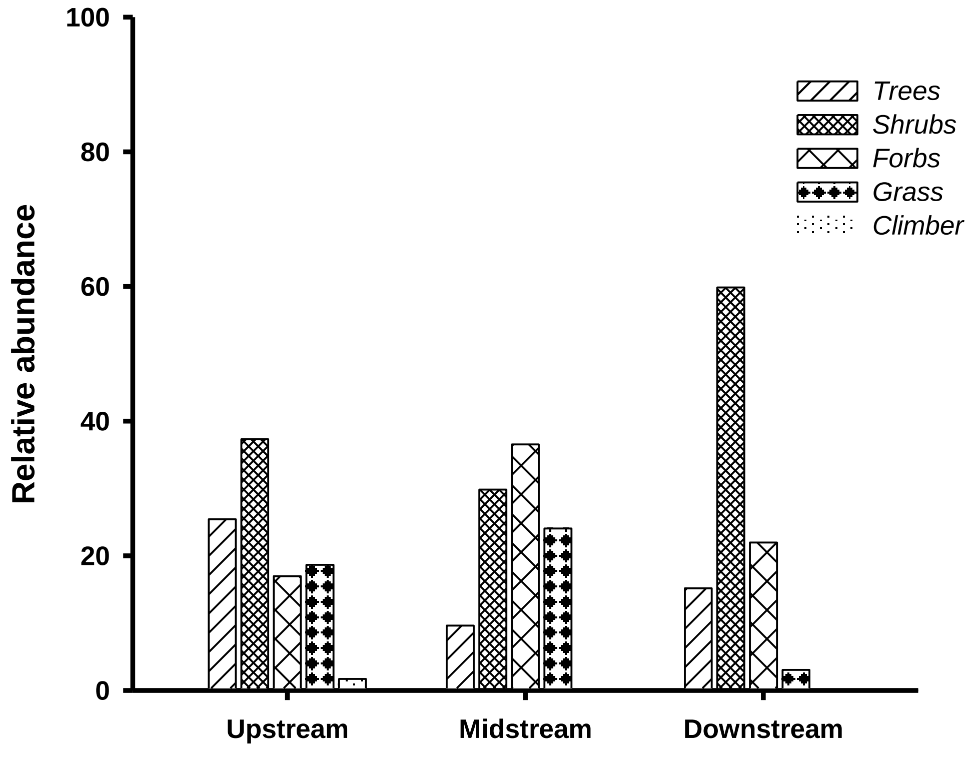

Figure 4.9: The relative abundance of vegetation types in the three sampling sites of Chepkoo River

Table 4.8: Summary of percentage contribution of vegetation types on both banks of the three sampling sites

Vegetation type	Upstream		Midstream		Downstream	
	Left	**Right**	**Left**	**Right**	**Left**	**Right**
Trees	60	40	5	95	44	56
Shrubs	31.1	68.9	88.7	11.3	39.2	60.8
Forbs	55	45	51.3	48.7	0	100
Grass	21.2	78.8	54	46	0	100
Climbers	100	0	0	0	0	0

4.5.2. Vegetation diversity, evenness and similarity

The highest diversity was observed at the upstream site, followed by downstream and midstream respectively (Table 4.9). The downstream site had the highest evenness followed by upstream and lastly midstream. In terms of similarity, 32% of the species were similar in the three sites as indicated by the Sorensen's coefficient of similarity (Table 4.9).

Table 4.9: Vegetation diversity, evenness and similarity at the three sites along Chepkoo River

Sampling site	Shannon index (H')	Equitability index (E)	Sorensen's coefficient
Upstream	2.15	0.78	0.32
Midstream	1.68	0.70	
Downstream	1.94	0.88	

When the banks of each study site were considered, the right bank of upstream recorded the highest vegetation diversity H' whereas the opposite was observed in the midstream and downstream sites. Vegetation was more evenly distributed on the right banks of upstream and midstream sites. Vegetation similarity ranged between 30 – 35% among the banks in the three study sites.

Table 4.10: The diversity, evenness and similarity of vegetation composition in Chepkoo River, comparing the left bank and right bank of each study site

	Upstream		Midstream		Downstream	
	Left	**Right**	**Left**	**Right**	**Left**	**Right**
Shannon index (H')	1.0282	1.459	0.6886	0.5623	0.7033	0.1486
Equitability index (E)	0.4465	0.5688	0.3842	0.2345	0.0923	0.3382
Sorensen's coefficient	0.30		0.35		0.31	

4.6 Correlation Analysis

The relationship between periphyton and physicochemical variables of the stream is presented in Table 4.10. The measured physico-chemical parameters had strong influence on periphyton abundance except electrical conductivity and soluble reactive phosphorous. Temperature and pH had a negative correlation with periphyton abundance in Chepkoo River. Detailed correlation matrix is presented in Appendix 7.

Table 4.11: Summary of the Pearson correlation coefficient matrix between Physico-chemical parameters and periphyton in Chepkoo River, r- values are the correlation coefficient, * correlation is significant at α=0.05

Parameter	R	p-value
Temperature (°C)	-0.589	**0.002****
EC (µS/ cm)	0.282	0.162
DO (mg/L)	0.453	**0.020***
NO_3^- (mg/L)	0.739	**0.000****
SRP (µg/L)	0.352	0.078
TP (µg/L)	0.496	**0.010***
NH^+-N (µg/L)	0.664	**0.000****
NO_2^--N (µg/L)	0.716	**0.000****
pH	-0.754	**0.000****

CHAPTER FIVE
DISCUSSION

5.1 Physical variables in the study sites

According to Vannote *et al. (*1980), there is a predictable trend in the physical characteristics of the stream in a longitudinal dimension. The river continuum concept (RCC) predicts high oxygen levels and low temperatures at upstream sites due to increased canopy cover and turbulence. This changes from the distance downstream with increased temperatures as the shading of the stream reduces due to agricultural activities. Oxygen is expected to reduce downstream as temperature increase. Conductivity, which is a measure of dissolved ions, is expected to increase downstream as well. The upstream site had significantly low temperature than the downstream sites. Stream temperature can be influenced by factors like canopy cover (Garner *et al*., 2017). Furthermore, Campbell *et al*., (2018) indicated that there is temperature reduction in a river section under a forest cover than a site, that with less canopy cover. Contrary to the expectations, there was no significant difference in the values of conductivity among the three study sites. Indicating that the river drains in a catchment that has similar geological characteristics. The highest value of conductivity was recorded in the midstream (107.14±5.663µs/s), as compared to upstream that recorded the lowest value, and this can be attributed to the human activities going on in the midstream site. For instance, in the midstream there was farming activities going on near the bank of the river. Therefore, the agricultural inputs like fertilizers and the use of herbicides can be attributed to the high recorded value of conductivity in the midstream. This is because the fertilizers and the chemicals the farmers use cause an increase of ions in water, and when the conductivity value is high in the river, there is likelihood that it can cause variation in the water quality (Andoh, 2014).

There was no significant difference in DO among the three study sites. The upstream had the least amount of dissolved oxygen, which can be most likely attributed to low velocity in the site. Low velocity leads to low turbulence in water movement hindering the oxygenation of water in the river. Furthermore, the low levels of D.O might be attributed to the breakdown of high amount of CPOM that was recorded in the site. Notably, the dissolved oxygen in the three study sites of Chepkoo River is within the recommended levels of the water used for domestic purposes. Thus, the lack of the excess organic matter in the river, can be attributed to high D.O in the river. Furthermore, the river is in a region that is considered rural, thus no many domestic organic matter is dumped to the river. The results observed in the river were consistent with the earlier studies, which were carried out by Rosa *et al*., (2017), whereby the headwater points had depleted dissolved oxygen that could have resulted from mineralization of organic matter.

TSS levels were relatively high in the midstream site as compared to the other two sites. However, there was no significance difference in mean value of TSS among the three study sites. The high amount of TSS in the midstream can be attributed to the anthropogenic activities that is occurring at the site, farming was notably the major activity that was occurring near the midstream site. Coupled with the terrain of the area, soil conditions and reduced riparian vegetation on the right bank. Furthermore, since the midstream was more sloppy compared to the other sites, this accelerates surface run off causing an impact on the amount of TSS. In addition, to the sloppy area, there was an increase of TSS due to riverbank erosion. Encroachment of humans on the river could have a direct effect on the water quality of Chepkoo River. In upstream site, the low levels of TSS observed could be attributed to high density of vegetation in the area, which is likely to minimize excess amount of silt deposited in the river. While, at the downstream, it was noted that the site is relatively flat and the riverbank was mainly composed of rocks, making the amount of TSS to be lower. The findings from this study are consistent with Hartwig *et al*. (2016) who observed a change in TSS of Steppe River from upstream to downstream. Furthermore, Raburu and Okeyo - Owuor (2005) observed that in Nyando River basin, the TSS levels were high in the region the river was cutting across.

5.2Nutrient along the three sites of Chepkoo River

Generally, there were relatively low levels of nitrates (NO_3^-N) in the three study sites of Chepkoo River. However, midstream recorded the high value as compared with the other two sites. This can be attributed to the high discharge in midstream as well as agricultural activities that are intense in the site. Since the area has very little riparian vegetation, the runoff will discharge the NO_3^-N directly from the fields into the river. In contrast to our expectations, downstream site recorded lower NO_3^-N value, as compared to the upstream site. This can be attributed to the fact that in downstream no agricultural activities were going on, only that the community used the site to fetch water for domestic purposes, and for animal watering. Therefore, the study is in support of Mbaye *et al*. (2016), who observed that nitrates concentration decreased downstream due to low human impact.

Notably, the three sites high concentration of soluble reactive phosphorous (SRP) and total phosphorous (TP). During the time of sample collection, it was observed that linen washing and bathing was undertaken in the three sites. Therefore, the recorded high values of SRP and TP at Chepkoo River can be linked to the two anthropogenic activities.

5.3 Benthic Periphyton

Periphyton plays a key role in removing substantive quantities of dissolved contaminants in water due to their sorptive nature and their large surface area. These organisms are the primary producers and they are key mediators of anthropogenic impacts in a river ecosystem. Addition of excessive inorganic nutrients particularly phosphorous can result to increased growth of periphyton, which at long run alter the community structure of the lotic ecosystem (Schiller *et al*., 2007). However, periphyton has short life cycles and they respond quickly to environmental changes (Singh *et al*., 2018).

It was noted that *Flagillaria ulna* was the dominating species contributing 28% of the total periphyton recorded. This is in support of the study conducted by (Ekhator, (2010), whereby *Flagillaria ulna* was dominating in the Benin Owen River. There is a likelihood that the environmental conditions in Chepkoo River were favorable for *Flagillaria ulna* thriving in all the sites. The upstream site had the highest number as compared to the other sites. Periphyton growth and diversity is influenced by light availability as well as other factors like water discharge and velocity. Therefore, since the upstream site had 0-35% canopy cover, there was sufficient amount of light reaching the streambed and thus the highest number of periphyton in the upstream site. However, the midstream site had an open canopy approximately 0-5%, to our expectation the site could have recorded the highest diversity due to the influence of light but the discharge was higher at this site and periphyton was most likely washed away by the water flow. Onyema, (2007), attributed low diversity of periphyton to scouring effects by floodwaters that dislodge the periphyton from the attached substrates.

Some species were only found in the upstream site and absent in the other two sites, and it can be an indication of a response to environmental changes. Some of these species include, *Achnantes inflate*, *Achnanthidium linearis*, *Chromonus spp.*, *cladophora spp.*, *Encyonema minutum*, *Gomphonema clavatum*, *Gomphonema purvulum*, *Netrium digitus*, *Surrella spp.* and *Synedra ulna*. It is worth noting that *Chaetophorus spp.*, was only present in midstream site of Chepkoo River and can most likely be used as an indication of disturbance such as clear-cut and farming activities for this river.

5.4 Coarse particulate matter on the banks and in the stream channel

Coarse particulate organic matter (CPOM) is vital in streams as they support the food web. They also provide habitat for microbes in the river. The recorded difference in CPOM quantities from the three sites of Chepkoo River is of great interest in determining the stream biotic health. The quantities of CPOM are an important factor used to assess the effect of anthropogenic changes to the stream ecosystem (Masese, 2015).

It was observed that the banks of midstream site had the highest amount of CPOM despite the region being less vegetated. This can be attributed to the transportation of CPOM from other region and deposited in the midstream site. The left bank had a gentle topography and hence a likelihood of stream overflowing, resulting in CPOM retention. The site also had wood debris and rocks that were deposited on the banks and thus the materials intercepted the transported CPOM. However, the downstream site had less CPOM and this could be attributed to less vegetation in the area and the gentle topography, as well as few riverbank materials that could intercept the CPOM.

In terms of plant categories, leaves and twigs dominated the upstream site as opposed to twigs that dominated the other two sites. During the period of CPOM collection, some of trees in upstream site were undergoing leaf abscission leading to high amount of leaves collected in the site. While, in the midstream and downstream site, the banks had high quantities of twigs, which is an indication of high disturbance in the two sites. In terms of bank specificity, twigs dominated the right banks of the three sites as well as the left bank of both the midstream and downstream sites. This can be attributed to the retention capacity of this plant litter category. When there is no bank erosion or bank overflow, they tend to remain in the same area and thus the observed dominance in the various banks. Site-specific differences in the amount of CPOM were reported for the Njoro River and the Ellegirini River by M′Erimba *et al*. (2006; 2007).

When the river channel was considered, the collected CPOM was significantly different among the three sites. It was evident that the upstream site had the highest amount of CPOM collected than the other two sites. CPOM transportation is normally determined by the discharge and other retentive structures within the channel (Morara *et al*., 2003). Therefore, since the upstream site had low discharge than the other two sites, CPOM was likely to be retained for a long period than the other sites. In addition, other factors like the gentle gradient, river channel roughness could be responsible for the observed significant difference.

CPOM responds to quick flow rate and since the midstream site had a high discharge, it had low CPOM retained in the site. However, there was a higher retention of CPOM in downstream site than the midstream site, which can be attributed to the topography of the site. The downstream site had a gentle gradient, coupled with the size and type of the CPOM transported leading to a high amount of collected CPOM in the site. Differences in type and frequency of retentive structures are likely to result to differences in CPOM retention on stream channels (Mathooko, 2001a & b). Notably, the amount of leaves collected increased as the river flows downstream. This could be explained by the fact that leaves have low density and can be easily transported as opposed to twigs that are much heavier thus retained on the various points of the river. It is worth noting that the streambed was rough, and contained numerous pebbles and rocks, which intercepted the twigs leading to reduced quantities in the downstream sites as opposed to the upstream site.

5.5 Vegetation composition along Chepkoo River

Riparian vegetation is selective as to where it establishes, because it is sensitive to changes in flooding frequency and duration as well as soil type of the region. Vegetation composition is influenced by the overbank deposition of soil and debris materials. Many authors have established that a slight change in elevation either for a few centimeters or for meters can lead to an alteration in vegetation diversity and species evenness (Sagar *et al*., 2003; Pamela *et al*., 2008; Sunil *et al*., 2012). The use of riparian zone for agricultural purposes has been an ancient activity and it brings interference on the ecosystem services and the riparian ecology (Gopaland Junk, 2000; Michael *et al*., 2009). Therefore, extensive use of riparian zone has resulted to loss of biodiversity (Sultana, 2014) and stream pollution (Bere and Mangadze, 2014).

Vegetation composition along Chepkoo River is influenced by anthropogenic activities practiced along the river banks. Banks that were farmed had different species composition in comparison to those that were graced and so on. The upstream site recorded the highest number of species of vegetation as compared to the other two sites. The increased agricultural activities in the midstream and the downstream might have caused the variation in vegetation composition. According to Smakhtin, and Anputhas (2006), the intense use of riparian zone for farming activities has caused variation in the native species composition, richness and productivity. Notably, the shrubs and forbs were dominating the midstream and downstream sites, which is an indication that the disturbances along the riparian zone of Chepkoo River might be the cause of variation in the native species composition. This was in support of a study undertaken by Michael *et al*., (2009), found out that in Sonora riparian ecosystem, the disturbed site had low diversity of vegetation.

When the banks were considered, there was a clear variation in the midstream site, whereby the vegetation was not evenly distributed. Trees dominated the right bank of this site while shrubs dominated the left bank. This is attributed to the observed clear cut of vegetation on the left bank to pave way for farming, while on the right bank was encroached by exotic trees among them; *Cupressus lusitanica* and *Eucalyptus saligna*, leading to the observed variation. However, the species similarity among the three sites was low due to reduction of endemic species in Chepkoo riparian zone.

5.6 Relationship between physico-chemical variables and periphyton

In this study, nitrates and nitrites strongly correlated with the abundance of periphyton in the three study sites of Chepkoo River. The obtained results are in support of a study that was undertaken by Olsen *et al*., (2015), that showed periphyton increased with the increase in nitrates. However, it was in contrast to a study that was undertaken in low ordered stream of Oahu, whereby the authors established a relationship between the total phosphate concentration and the abundance of periphyton (Larned and Santos, 2000).

CHAPTER SIX

SUMMARY OF THE FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

6.1 SUMMARY OF THE FINDINGS

The major findings from this study included:

I. The highest temperature, conductivity and total suspended sediments were recorded in the midstream site.
II. Total phosphorous and soluble reactive phosphorous were in high concentration among the three study sites of Chepkoo River.
III. The midstream site (0%-5% canopy cover) had the lowest abundance of periphyton.
IV. Banks are important storage of CPOM than the stream Channel. Banks had approximately three folds of the measured CPOM than the stream channel.
V. Intensive cultivation of riparian zones causes variation in native vegetation.

6.2 CONCLUSIONS

The study confirms that reduced canopy cover along Chepkoo River, due to clear cut of Tumoo forest is negatively impacting on the river. There were clear differences among the sites in terms of physico-chemical parameters, periphyton and coarse particulate organic matter (CPOM). Furthermore, there is reduction of indigenous trees in the region and the dominance of shrubs as one moves downstream. The reduction in vegetation composition, as well as loss of biodiversity may cause stream pollution. In summary:-

I. Clear cut has a negative impact on water quality, more so on temperature, soluble reactive phosphorous (SRP) and total phosphorous (TP). Water quality in terms of nutrients is within the recommended values by NEMA standard.
II. Clear cut influences periphyton composition, abundance and diversity in streams.
III. Clear cut impacts negatively on the quality and quantity of CPOM received by streams.
IV. Sites that are clear cut have varied vegetation composition and low diversity than sites that are not clear cut.

6.3 RECOMMENDATIONS

The natural self-purification of Chepkoo River is getting compromised due to the anthropogenic activities. People depending on the water from this river are likely to have their health affected due to poor water quality and the risk of contracting water related diseases. There is need to protect Chepkoo River, which is an important source of water for the neighboring villages in the region. The following recommendations are proposed:-

I. To reduce further impact on water quality of Chepkoo River, the riparian zone regulations should be implemented. They should also practice good land management to reduce the increased bank erosion within Chepkoo River.

II. There is need for restoration and conservation of plant species. Therefore, replanting of riparian vegetation at clear-cut sites along river corridors can serve as a management strategy for tropical rivers to enhance water and habitat quality.

III. Future studies should consider bacteriological analysis of water in Chepkoo River.

REFERENCES

Anderson, T. R., Groffman, P. M., Kaushal, S. S. and Walter, M. T. (2014). Shallow groundwater denitrification in riparian zones of a headwater agricultural landscape. *Journal of environmental quality*, **43,**732-744.

Andoh, F. B. (2014). *Effects of anthropogenic activities on water quality of Streams: a case study of the Onyasia Stream in the Greater Accra Region* (Doctoral dissertation).

APHA. (2005). *"Standard methods for Examination of water and Wastewater".* Washinton D.C: American Public Health Assocotiaon WWA.

Bala, G., Caldeira, K., Wickett, M., Phillips, T. J., Lobell, D. B., Delire, C. and Mirin, A. (2007). Combined climate and carbon-cycle effects of large-scale deforestation. *Proceedings of the National Academy of Sciences*, ***104***, 6550-6555.

Bere, T. and Mangadze, T. (2014). Diatom communities in streams draining urban areas: community structure in relation to environmental variables. *Tropical Ecology* **55**, 271-281.

Beutel, M. W., Duvil, R., Cubas, F. J., Matthews, D. A., Wilhelm, F. M., Grizzard, T. J. and Gebremariam, S. (2016). A review of managed nitrate addition to enhance surface water quality. *Critical Reviews in Environmental Science and Technology*, **46**, 673-700.

Bouraoui, F., Grizzetti, B., Granlund, K., Rekolainen, S. and Bidoglio, G. (2004). Impact of climate change on the water cycle and nutrient losses in a Finnish catchment. *Climatic Change*, **66**, 109–126.

Bowes, M. J., Jarvie, H. P., Naden, P. S., Old, G. H., Scarlett, P. M., Roberts, C. and Collins, A. L. (2014). Identifying priorities for nutrient mitigation using river concentration–flow relationships: The Thames basin, UK. *Journal of Hydrology*, **517**, 1-12.

Braccia, A. B. (2001). Inverterbrates associated with woody debris in southeastern U.S.forested floodplain wetland. *Wetlands*, **21**, 18-31.

Brack, W., Ait-Aissa, S., Burgess, R. M., Busch, W., Creusot, N., Di Paolo, C. and Hollert, H. (2016). Effect-directed analysis supporting monitoring of aquatic environments—An in-depth overview. *Science of the Total Environment*, ***544***, 1073-1118.

Bradshaw, C., Sodhi, N., Peh, K. and Brook, B. (2007). Global evidence that deforestation amplifies flood risk and severity in the developing world. *Global Change Biology*, **13**, 2379-2395.

Burrows, R. M., Magierowski, R. H., Fellman, J. B., Clapcott, J. E., Munks, S. A., Roberts, S. and Barmuta, L. A. (2014). Variation in stream organic matter processing among years and benthic habitats in response to forest clear felling. *Forest ecology and management*, **327**, 136-147.

Campbell, A. J., Carvalheiro, L. G., Maués, M. M., Jaffé, R., Giannini, T. C., Freitas, M. A. B. and Menezes, C. (2018). Anthropogenic disturbance of tropical forests threatens pollination services to açaí palm in the Amazon River delta. *Journal of Applied Ecology*.

Chopra, K., Leemans, R., Kumar, P. and Simons, H. (2000). *Millennium Ecosystem Assessment: Summary for Decision-Makers.* Washington D.C: Island Press.

Collins, A.L., Walling, D.E. and Leeks, G.J.L. (2005). Storage of fine-grained sediment and associated contaminants within the channels of lowland permeable catchments in the UK. In: Sediment Budgets 1 . *International Association of Hydrologic Sciences Publication **291***, 259-268.

Connecticut River Joint Commission (2005). *Introduction to riparian buffers.* rom: Riparian Buffers for the Connecticut River Valley.

Cosgrove, W. J. and Loucks, D. P. (2015). Water management: Current and future challenges and research directions. *Water Resources Research*, ***51***, 4823-4839.

Cummins, K. W., Wilzbach, M. A., Gates, D.M., Perry, J.B. and Taliafarro, B. (1989). Shredders and riparian vegetation: leaf letter that falls into streams influence communities of stream invertebrates. *BioScience,* **391**, 24-31.

Davies, P. E., McIntosh, P. D.,Wapstra, M., Bunce, S.E.H., Cook, L. S. J., French, B. and Munks, S. A. (2005). Change to the headwater stream morphology, habitats and riparian vegetation recorded 15 years after pre-Forest practices code forest clear felling in upland granite terrain, Tasmania, Australia. *Forest ecology and management,* **217**, 331-350.

Davis, A. and Liu, J. (2014). "Phosphorus Speciation and Treatment Using Enhanced Phosphorus Removal Bioretention". *Environmental Science & Technology*,**48**, 607-614.

Davis, J. R. (2006). Eutrophication of Australian rivers, reservoirs and estuaries: A southern hemisphere perspective on the science and its implication. *hydrobiologia,* **559**, 23-76.

De Troyer, N., Mereta, S. T., Goethals, P. L. and Boets, P. (2016). Water quality assessment of streams and wetlands in a fast growing east African city. *Water*, ***8***, 123.

Depietri, Y. (2015). Ecosystem services in practice: well-being and vulnerability of two European urban areas.

Dewson, Z. S., James, A. B. W. and Death, R. G. (2007a). Areview of the consequances of decreased flow for instream habitat and macroinvertrabrates. *Journal of the North American Benthological Society,* **263**, 401-415.

Dewson, Z. S., James, A. B. W. and Death, R. G. (2007b). Stream ecosystem functioning under reduced flow conditions. *Ecological Applications,* **176**, 1797-1808.

Diez, J. L. (2000). Stream ecosystem functioning under reduced flow conditions. *Ecological applications,* **176**, 1797-1808.

Dodds, W. K. and Biggs, B. J. F. (2002). Water velocity attenuation by stream periphyton and macrophytes in relation to growth form and architecture . *Journal of the North American Benthological Society,* **21**, 2 –15.

Dodds, W. K. and Welch E. B. (2000). Establishing nutrient criteria in streams. *Journal of the North American Benthological Society,* **19**, 186-196.

Dosskey, M., philipine, G. vidon, P. G., Noel, J. A.,Craig, P. D. and Richard, T. (2010). The role of riparian vegetation in protecting and improving chemical water quality in streams. *Journal of American Water Resources Association,* **46**, 261-277.

Ekhator, O. (2010). Composition, occurrences and checklist of periphyton algae of some water bodies around Benin City, Edo State, Nigeria. *Ethiopian Journal of Environmental Studies and Management*, *3*.

FAO. (2005). Global Forest Resources Assessment 2005 – progress towards sustainable forest.

FAO. (2007). *"Managing forests for cleaner water for urban populations"* (Vol. 58). (S. a. Stolton, Ed.) Unasylva.

FAO. (2011). Global Forest Resources Assessment 2010 – main report. FAO Forestry Paper No. 163. FAO. State of the World's Forests 2011. Rome.

Feichtmayer, J., Deng, L. and Griebler, C. (2017). Antagonistic Microbial Interactions: Contributions and Potential Applications for Controlling Pathogens in the Aquatic Systems. *Frontiers in microbiology*, *8*.

Ferreira, C. S. S. (2015). *Land-use change impacts on hydrological and hydrochemical processes of peri-urban areas* (Doctoral dissertation, Universidade de Aveiro (Portugal).

Finlay, J. C. Khandwala, S. and Power, M. E. (2002). Spatial scales of carbon flow in a river food web. *Ecology,* **83**, 1845-1859.

Garner, G., Malcolm, I. A., Sadler, J. P. and Hannah, D. M. (2017). The role of riparian vegetation density, channel orientation and water velocity in determining river temperature dynamics. *Journal of Hydrology*, **553**, 471-485.

Gasse, F. (1986). East African diatoms. *Taxonomy, ecological distribution.* 201.

Gerten, D. and Adrian, R. (2001). Differences in the persistency of the North Atlantic Oscillation signal among lakes. *Limnology Oceanography,* **46**, 448–455.

Giorgi, A. and Malacalza, L. (2002). Effect of an industrial discharge on water quality and periphyton structure in a Pampeam stream. *Environmental Monitoring and Assessment,* **75**, 107-119.

Gomi, T. R., Sidle, C. and Richardson, J. S. (2002). Understanding process and downstream linkages of headwater systems. *BioScience,* **52**, 905-916.

Gopal, B. and Junk, W. J. (2000). *Biodiversity in wetlands: an introduction* (pp. 1-10). Backhuys Publishers.

Gordon, L. J., Finlayson, C. M. and Falkenmark, M. (2010). Managing water in agriculture for food production and other ecosystem services. *Agricultural Water Management,* ***97***, 512-519.

Groffman P. M., Gold A. J. and Simmons R. C. (1992). Nitrate dynamics in riparian forests: microbial studies. *Journal of Environmental Quality***, 21**, 666-71

Guasch, H., Artigas, J., Bonet, B., Bonnineau, C., Canals, O., Corcoll, N. and Navarro, E. (2016). The use of biofilms to assess the effects of chemicals on freshwater ecosystems. *Aquatic Biofilms*, 125

Gupta, S. (2016). Forest sustainability and development in hills of Uttarakhand, India: Can they move together? *Environment, development and sustainability*, **18**, 279-294.

Habermeyer, M., Roth, A., Guth, S., Diel, P., Engel, K. H., Epe, B. and Knorr, D. (2015). Nitrate and nitrite in the diet: how to assess their benefit and risk for human health. *Molecular nutrition and food research,* **59**, 106-128.

Habibiandehkordi, R., Lobb, D. A., Sheppard, S. C., Flaten, D. N. and Owens, P. N. (2017). Uncertainties in vegetated buffer strip function in controlling phosphorus export from agricultural land in the Canadian prairies. *Environmental Science and Pollution Research,* **24**, 18372-18382.

Haggerty, S. M., Batzer, D. P. and Jackson, C. R. (2004). Macroinvertebrate response to logging on coastal headwater streams of Washington,USA. *Canadian Journal of Fisheries and Aquatic Sciences,* **61**, 529-537.

Hartwig, M., Schäffer, M., Theuring, P., Avlyush, S., Rode, M. and Borchardt, D. (2016). Cause–effect–response chains linking source identification of eroded sediments, loss of aquatic ecosystem integrity and management options in a steppe river catchment (Kharaa, Mongolia). *Environmental Earth Sciences*, **75**, 855.

Hasler, N., Werth, D. and Avissar, R. (2009). Effects of tropical deforestation on global hydroclimate: a multimodel ensemble analysis. *Journal of Climate,* **22**, 1124-1141.

Hatch, L. K., Reuter, J. E. and Goldman C.R. (2001). Stream phosphorus transport in the Lake Tahoe Basin, 1989-1996. *Environmental Monitoring and Assessment,* **69**, 63-83.

Haygarth, P. M., Condron, L. M., Heathwaite, A. L., Turner, B. L. and Harris, G. P. (2005). The phosphorous transfer continuum: linking source to impact with an interdisciplinary and multi-scale approach. *Science of the Total Environment*, **344**, 5-14.

Henley, W. F., Patterson, M. A., Neves, R. J. and Dennis Lemly, A. (2000). Effects of sedimentation and turbidy on lotic food webs: a concise review for natural resource managers. *Reviews in Fisheries Science*, **8**, 125-139.

Hesslerová, P. and Pokorny, J. (2010). 'Forest clearing, water loss, and land surface heating as development costs'. *International Journal of Water,* **5**, 401–418.

Huang, T. (2016). *Fecal indicator bacteria removal by river networks* (Doctoral dissertation, University of New Hampshire).123.

Hultine, K. R., Belnap, J., Van Riper, C., Ehleringer, J. R., Dennison, P. E., Lee, M. E. and West, J. B. (2010). Tamarisk biocontrol in the western United States: ecological and societal implications. *Frontiers in Ecology and the Environment*, ***8***, 467-474.

Hunter, H. M. and Walton, R. S. (2008). Land-use effects on fluxes of suspended sediment, nitrogen and phosphorus from a river catchment of the Great Barrier Reef, Australia. *Journal of Hydrology,* **356**, 131-146.

Jackson, C. B. (2007). Headwater streams and timber harvest channel, macroinvertebrate and amphibian resonse and recovery. *Forest Science,* **532**, 356-370.

Jasper, J. T., Jones, Z. L., Sharp, J.O. and Sedlak, D.L. (2014). Nitrate Removal in Shallow, Open-Water TreatmentWetlands. *Environmental Science Technology,* **48**, 11512–11520.

Johnson, S. (2004). Factors Influencing Stream Temperatures in Small Streams. *Substrate and a Shading Experiment Canadian Journal of Fisheries and Aquatic Sciences,* **61**, 913-923.

Kalff, J. (2002). *Limnology : Inland water ecosystems.* Upper saddle River: NJ: Prentice Hall.

Kenya National Bureau of Statistics (2010). The 2009 Kenya population and Housing Census. pp 48.

Kiage, L. M., Liu, K. B., Walker, N. D., Lam, N. and Huh, O. K. (2007). Recent land-cover/use change associated with land degradation in the Lake Baringo catchment, Kenya, East Africa: evidence from Landsat TM and ETM+. *International Journal of Remote Sensing,* **28**, 4285-4309.

King, K. W., Williams, M. R., Macrae, M. L., Fausey, N. R., Frankenberger, J., Smith, D. R. .and Brown, L. C. (2015). Phosphorus transport in agricultural subsurface drainage: A review. *Journal of environmental quality*, **44**, 467-485.

Kipkore, W., Wanjohi, B., Rono, H., and Kigen, G. (2014). A study of the medicinal plants used by the Marakwet Community in Kenya. *Journal of ethnobiology and ethnomedicine, **10***, 24.

Kostaschuk, R., Terry, J. and Raj, R. (2002). Suspended sediment transport during tropical cyclone floods in Fiji. *Hydrological Processes,* **17**, 1149–1164.

Kreutzweiser, D. P. and Capell, S. S. (2001). Fine sediment deposition in streams after selective forest harvesting without riparian buffers. *Canadian Journal of Forest Research,* **3112**, 234-2142.

Kropp, H., Ogle, K., Vivoni, E. R. and Hultine, K. R. (2017). The Sensitivity of Evapotranspiration to Inter-Specific Plant Neighbor Interactions: Implications for Models. *Ecosystems*, ***20***, 1311-1323.

Larned, S. T. and Santos, S. R. (2000). Light-and nutrient-limited periphyton in low order streams of Oahu, Hawaii. *Hydrobiologia*, ***432***, 101-111.

Loucks, D. P. and Van Beek, E. (2017). *Water resource systems planning and management: An introduction to methods, models, and applications*. Springer.

Manoj, K. and Padhy, P. K. (2015). Discourse and Review of Environmental Quality of River Bodies in India: An Appraisal of Physico-chemical and Biological Parameters as Indicators of Water Quality. *Current World Environment*, **10**, 537.

Mathooko, J. M., Morara, G. O. and Leichtfried, M. (2001a). The effect of different anthropogenic disturbances on benthic plant coarse particulate organic matter in a tropical Rift Valley stream. – *African Journal of Ecology*. **39**, 310–312.

Mathooko, J. M., Morara, G .O. and Leichtfried, M. (2001b). Leaf litter transport and retention in a tropical Rift Valley stream: an experimental approach. – Hydrobiologia, **44,** 9–18.

Mbaye, M. L., Gaye, A. T., Spitzy, A., Dähnke, K., Afouda, A. and Gaye, B. (2016). Seasonal and spatial variation in suspended matter, organic carbon, nitrogen, and nutrient concentrations of the Senegal River in West Africa. *Limnologica-Ecology and Management of Inland Waters*, ***57***, 1-13.

Masese, F. O. (2015). *Dynamics in organic matter processing, ecosystem metabolism and trophic sources for consumers in the Mara River, Kenya*. CRC Press/Balkema.

M'Erimba C.M., Mathooko J.M. and Leichtfried, M. (2006). Variations in coarse particulate organic matter in relation to anthropogenic trampling on the banks of the Njoro River, Kenya. *African Journal of Ecology*, **44**, 282-285.

M'Erimba, C. M., Leichtfried, M. and Mathooko, J. M. (2007). Particulate organic matter (POM) on the humid and wet zones of the Ellegirini River, Kenya. *International Review for Hydrobiologia*, **92**, 392 – 401.

Michael, L. S., Pamela, L. N., Edward, P. G., Cory, L. J., Joseph, A. E., Carlos V., Elizabeth, W. R., Patrick, B., Donna, L. L. and Gomez, L. E. (2009). Assessing the extent and diversity of riparian ecosystems in Sonora, Mexico: Toward refining conservation strategies. *Biodiversity and Conservation.* **18**, 247-269.

Morara, G. O., Mathooko, J. M. and Leichtfried, M. (2003). Natural leaf litter and retention in a second-order tropical stream: the Njoro River, Kenya. – *African Journal of Ecology*, **41**, 277–279.

Mutuma, E., Mahiri, I., Murimi, S. and Njeru, P. (2015). Adoption of water resource conservation under fluctuating rainfall regimes in Ngaciuma/Kinyaritha watershed, Meru County, Kenya. In *Adapting African Agriculture to Climate Change*, 159-169.

Neal, C., Jarvie, H. P. and Oguchi, T. (1999). Acid-available particulate trace metals associated with suspended sediment in the Humber Rivers: a regional assessment. *Hydrological Processes*, ***13***, 1117-1136.

NEMA (2006). *Environmental management and co-ordination (water quality) regulations*. Nairobi: Ministry of Environment and Natural Resources.

Newman, J. P., Kabashima, J. N., Merhaut, D., Haver, D. L., Gan, J. and Oki, L. R. (2014). Controlling runoff and recycling water, nutrients, and waste. *Container nursery production and business management manual. UCANR Publications*, 95-118.

Nixon, S. (2009). Eutrophication and the macroscope. *Hydrobiologia*, **629**, 5-19.

Ojo, O. O. (2012). Groundwater: Characteristics, Qualities, Pollutions and Treatments:An Overview. *International Journal of Water Resources and Environmental Engineering,* **4**, 162-170.

Njagi, C. W. (2018). Vision 2030 and the Gender Question in Kenya. *Jumuga Journal of Education, Oral Studies, and Human Sciences (JJEOSHS)*, *1*(1), 18-18.

Olsen, S., Chan, F., Li, W., Zhao, S., Søndergaard, M. and Jeppesen, E. (2015). Strong impact of nitrogen loading on submerged macrophytes and algae: a long-term mesocosm experiment in a shallow Chinese lake. *Freshwater Biology*, ***60***, 1525-1536.

Onyema, I. C. (2007). The phytoplankton composition, abundance and temporal variation of a polluted estuarine creek in Lagos, Nigeria.

Osborn, D., Cutter, A. and Ullah, F. (2015). Universal sustainable development goals. *Understanding the Transformational Challenge for Developed Countries*.

Öztürk, M., Ashraf, M., Aksoy, A., Ahmad, M. S. A. and Hakeem, K. R. (Eds.). (2015). *Plants, pollutants and remediation*. Springer.

Paerl, H. W. (2014). Mitigating harmful cyanobacterial blooms in a human-and climatically-impacted world. *Life*, **4**, 988-1012.

Paiewonsky, P. (2017). *State Dependency of the Forest-Tundra-Short Wave Feedback: Comparing the Mid-Pliocene and Pre-Industrial Eras Using a Newly-Developed Vegetation Model* (Doctoral dissertation, State University of New York at Albany).

Pamela, L. N., Edward, P. G., Hinojosa-Huerta, O., Francisco, Z. and Keith, H. (2008). Riparian vegetation dynamics and evapotranspiration for the riparian corridor in the delta of the Colorado River, Mexico: Implications for conservation and management. *Journal of Environmental Management*, **88**, 864-874.

Pärn, J., Pinay, G. and Mander, Ü. (2012). Indicators of nutrients transport from agricultural catchments under temperate climate. *A review. Ecological Indicators*, **22**, 4–15.

Pasa, A. F. (2006). Assessment of environmental services towards rewarding a community-based forest management project in Midwestern Leyte Province, Philippines.

Patz, J., Olson, S., Uejio, C. and Gibbs, H. (2008). Disease emergence from global climate and land use change. *Medical Clinics of North America*, **92**, 1473-1491.

Price, J. S., Healthwaite, A.L. and Baird, A.J. (2003). Hydrological processes in abandoned and restored peatlands: an overview of management approaches. *Wetlands Ecology and Management*, **11**, 65-83.

Quinn, J. M., Philips, N. and Parkyn, S.M. (2007). Factors influencing retention of coarse particulate organic matter in streams. *Earth Surface Process and Landforms*, **32**, 1186-1203.

Raburu, P. O. and Okeyo- Owuor J. B. (2005). Impact of agro-industrial activities on the water quality of River Nyando , Lake. *In Odada et Al. (Eds.) Proceedings of the11th*

World Lakes Conference. 31st Oct. - 4th Nov. 2005, Nairobi, Kenya, **2**, 307–314.

Rakovan, M. T. and Renwick, W.H. (2011). The role of sediment supply in channel instability and stream restoration. *Journal of Soil and Water Conservation,* **60**, 40-50.

Richardson, D. M., Holmes, P. M., Esler, K. J., Galatowitsch, S. M., Stromberg, J. C., Kirkman, S. P. and Hobbs, R. J. (2007). Riparian vegetation: degradation, alien plant invasions, and restoration prospects. *Diversity and distributions*, ***13***, 126-139.

Romaní, A. M., Boulêtreau, S., Díaz-Villanueva, V., Garabetian, F., Marxen, J., Norf, H. and Weitere, M. (2016). Microbes in aquatic biofilms under the effect of changing climate. *Climate change and microbial ecology: Current research and future trends*, pp 83-96.

Rosa, M. B. S. D., Figueiredo, R. D. O., Markewitz, D., Krusche, A. V., Costa, F. F. and Gerhard, P. (2017). Evasion of CO2 and dissolved carbon in river waters of three small catchments in an area occupied by small family farms in the eastern Amazon. *Revista Ambiente and Água*, **12**, 556-574.

Sagar, R., Raghubanshi, A. S. and Singh, J. S. (2003). Tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. *Forest ecology and Management*, ***186***, 61-71.

Scalley, T. H.,Scatena, F. N., Moya, S. and Lugo A. E. (2012). Long term dynamics of organic matter and elements exported as coarse particulate from two Caribbean montane watershed. *Journal of Tropical Ecology*, **28**, 235-244.

Schiller, D. V., Martí, E., Riera, J. L. and Sabater, F. (2007). Effects of nutrients and light on periphyton biomass and nitrogen uptake in Mediterranean streams with contrasting land uses. *Freshwater Biology*, ***52***, 891-906.

Schneider, K. N. and Winemiller, K. O. (2008). Structural complexity of woody debris patches influences fish and macroinvertebrate species richness in a temperate floodplain-river system. *Hydrobiologia*, ***610***, 235-244.

Schoumans, O. F., Chardon, W. J., Bechmann, M. E., Gascuel-Odoux, C., Hofman, G., Kronvang, B. and Dorioz, J. M. (2014). Mitigation options to reduce phosphorus losses from the agricultural sector and improve surface water quality: a review. *Science of the Total Environment*, **468**, 1255-1266.

Shannon, C. E. and Wienner, W. (1963). *The mathematical theory of communication. University of Illinois. Press Urban, Illinois, 177. Cited by UNESCO 1991, Manual on marine experimental ecosystem.* UNESCO Tech. papers in marine Science, **61**, 1- 6.

Shields, F. D. (2006). A comparison of empirical and analytical approaches for stream channel design. Proceedings, Eighth Federal Interagency Sedimentation. *Conference, April 2-6, Reno, Nevada, Advisory Committee on Water Information, Subcommittee on Sedimentation, Washington, DC, CD-ROM.*

Shittu, O. B., Olaitan, J. O. and Amusa, T. S. (2008). Physico-Chemical and Bacteriological Analyses of Water Used for Drinking and Swimming Purposes in Abeokuta, Nigeria. *African Journal of Biomedical Research*, **11**, 285-290.

Singh, S., James, A. and Bharose, R. (2017). Biological Assessment of Water Pollution Using Periphyton Productivity: A Review. *Nature Environment and Pollution Technology*, ***16***, 559.

Siva, C. J. and John, J. (2002). Urban land use and periphytic diatom communities: a comparative study of three metropolitan streams in Perth, Western Australia. In *Proceedings of the 15 the international diatom symposium, Perth, Australia 28 September- 2 October 1998.* (pp. 125-134).

Smakhtin, V. U. and Anputhas, M. (2006). *An Assessment of Environmental Flow Requirements of Indian River Basins*. IWMI Research Report N 107, Colombo, Sri Lanka.

Smith, R. A., Alexander, R. B. and Schwarz. G. E. (2003). Natural background concentrations of nutrients in streams and rivers of the conterminous United States. *Environmental and science technology,* **37**, 2039–3047.

Snyder, P. (2010). The influence of tropical deforestation on the Northern Hemisphere climate by atmospheric teleconnections. *Earth Interactions,* **14**, 1-34.

Song, X., and Frostell, B. (2012). The DPSIR framework and a pressure-oriented water quality monitoring approach to ecological river restoration. *Water*, ***4***, 670-682.

Spellman, F. R. (2016). *Contaminated Sediments in Freshwater Systems*. CRC Press.

Spittlehouse, D. L., Adams, R. S. and Winkler, R. D. (2004). *Forest, edge, and opening microclimate at Sicamous Creek* (Vol. 24). British Columbia, Forest Science Program.

Stevenson, R. J., Hill, B. H. Herlihy, A. T. Yuan, L. L. and Norton, S. B. (2008). Algae-P relationship, thresholds, and frequency distributions guide nutrient criterion development. *Journal of the North American Benthological Society,* **27**, 783-799.

Straka, M., Syrovátka, V. and Helešic, J. (2012). Temporal and spatial macroinvertebrates variance compared: crucial role of CPOM in headwater stream. *Hydrobiologia,* **686**, 119-134.

Sunil, C., Somashekar, R. K. and Nagaraja, B. C. (2012). Riparian vegetation dynamics across two different landscapes along the river Cauvery in the Kodagu region of western ghats. *Journal of Mountain Science* **9**, 351-361.

Sultana, A., Hussain, M. S. and Rathore, D. K. (2014). Diversity of tree vegetation of Rajasthan, India. *Tropical Ecology* **55**, 403-410.

Tabacchi, E., Correll, D. L., Hauer, R., Pinay, G., Planty-Tabacchi, A. M. and Wissmar, R. C. (1998). Development, maintenance and role of riparian vegetation in the river landscape. *Freshwater Biology*, **40**, 497–516.

Tabacchi, E. and Planty-Tabacchi, A. M. (2001). Functional significance of species composition in riparian plant communities. *Journal of the American Water Resources Association*, **37**, 1629-1637.

Testa, S., Shields, F. D. and Cooper, C. M. (2011). Macroinvertebrates response to stream restoration by large wood addition. *Ecohdrology,* **4**, 631-643.

Thompson, R. M., Philips, N. R. and Townsend, C. R. (2009). Biological consequences of clear cut logging around streams- moderating effecys of management. *Forest Ecology and management*, **257**, 931-940.

UNEP (2003). United Nations Environment Programme: regionally based assessment of persistent toxic substances—global report, UNEP Chemicals, Châtelaine, Switzerland, 207.

U.S.E.P.A. (United States Environmental Protection Agency) (1995). National Water Quality Inventory: 1994 report to Congress. U.S. Environmental Protection Agency Office of Water. E.P.A. Publication 841- R-95-005. Washington, D.C. 497.

U.S.E.P.A. (2009). National Water Quality Inventory: 1996 Report to Congress. U.S. Environmental Protection Agency Office of Water. E.P.A. Publication 841-R- 97-008 . Washington, D.C.

U.S.E.P.A. (2013). National Rivers and Streams Assessment 2008-2009: A Collaborative Survey. EPA/841/D-13/001, 110.

Vannote, R. L., Minshall, G. W. Cummins, K. W., Sedell, J. R. and Cushing, C.E. (1980). The river continuum Concept. *Canadian Journal of Fisheries and Aquatic Sciences,* **37**, 130-137.

Vitousek, P. M., Mooney, H. A., Lubchenco, J. and Melillo, J. M. (1997). Human domination of Earth's ecosystems. *Science*, **277**, 494–499.

Vittor, A., Gilman, R., Tielsch, J., Glass, G., Shields, T., Lozano, W., Pinedo-Cancino, V. and Patz, J. (2006). The effect of deforestation on the human-biting rate of Anopheles darlingi, the primary vector of Falciparum malaria in the Peruvian Amazon. *American Journal of Tropical Medicine and Hygiene,* **74**, 3-11.

Viviane, M. (2009). Cyanobacteria and Cyanotoxin in the Billings Reservoir (Sao Paulo, SP, Brazil). *Limnetica*, **28**, 273-282.

Walling, D. E. (2006). Human impact on land-ocean sediment transfer by the world's river. *Geomorphology,* **79**, 192-216.

Walling, D. E. and Fang, D. (2003). Recent trends in the suspended sediment loads of the world‟s rivers. *Global and Planetary Change,* **39**, 111– 126.

Wang, M. H. S. and Wang, L. K. (2015). Environmental water engineering glossary. In *Advances in water resources engineering*. Springer International Publishing: 471-556.

Wantzen, K. M., Yule, C. M., Mathooko, J. M. and Pringle, C. M. (2008). *Organic matter processing in Tropical streams.* In Tropical Stream Ecology, Dudgeon D: Academic Press: London; 44-65.

Warren, N., Allan, I. J., Cater, J. E., House, W. A. and Parker, A. (2003). Pesticides and other micro-organic contaminants in freshwater sedimentary environments – a review. *Applied Geochemistry,* **18**, 159-194.

Webb, A. A. and Erkine, W. D. (2003). A practical scientific approach to riparian vegetation rehabilitation in Australia. *Journal of environmtal management,* **68**, 329-341.

Welch, E. B., Jacoby, J. M., Horner, R. R. and Seeley, M. R. (1998). Nuisance biomass levels of periphytic algae in streams. *Hydrobiologia,* **157**, 161–168.

Wetzel, R. (2001). Limnology : Lake and river ecosystems. Academic press, San Diego. 1006

Wohl, E., Lane, S. N. and Wilcox, A. C. (2015). The science and practice of river restoration. *Water Resources Research,* **51**, 5974-5997.

World Health Organization. (2016). Protecting surface water for health. Identifying, assessing and managing drinking-water quality risks in surface-water catchments.

World Health Organization (2002). *Anonym World health report: reducing risks, promoting healthy life. World Health Organization.* France.

Wu, Y. (2016). *Periphyton: Functions and Application in Environmental Remediation*. Elsevier.

Zamxaka, M., Pironcheva, G. and Muyima, N.Y.O. (2004). The status quo with regard to the quality of domestic water sources in selected rural communities of the Eastern Cape Province, South Africa. *Water SA,* **30**, 333-340.

Zhao, G., Mu, X., Wen, Z., Wang, F. and Gao, P. (2013). Soil erosion, conservation, and eco-environment changes in the loess plateau of China. *Land Degradation & Development*, ***24***, 499-510.

Zhao, Y., Xiong, X., Wu, C., Xia, Y., Li, J. and Wu, Y. (2018). Influence of light and temperature on the development and denitrification potential of periphytic biofilms. *Science of the Total Environment*, **613**, 1430-1437.

Zhang, J. (2016). *Forestry Measures for Ecologically Controlling Non-point Source Pollution in Taihu Lake Watershed, China*. Springer Singapore.

APPENDICES

APPENDIX 1: The percentage contribution of each periphyton species among the three study sites of Chepkoo River

TAXA	Abundance	%
Fragillaria ulna	138000	**28.1**
Navicula spp.	95250	**19.4**
Oedogonium spp.	37500	**7.6**
Cladophora spp.	34750	**7.1**
Diatoma spp.	34750	**7.1**
Anabaena spp.	23500	**4.8**
Gomphonema minutum	21500	**4.4**
Microspora spp.	18250	**3.7**
Clasterium	17000	**3.5**
Cocconeis placentula	8750	**1.8**
Gomphonema punilum	7250	**1.5**
Pinnularia gibbu	7250	**1.5**
Gomphonema truncatum	6500	**1.3**
Gomphonema augur	5500	**1.1**
Achnanthidium linearis	3000	**0.6**
Chaetophorus spp.	2250	**0.5**
Gomphonema spp	2000	**0.4**
Botrycoccus spp.	1750	**0.4**
Cymbella spp.	1750	**0.4**
Gomphonema purvulum	1500	**0.3**
Diatomella balforiana	1000	**0.2**
Netrium digitus	1000	**0.2**
Pinnularia spp.	1000	**0.2**
Achnantes inflata	500	**0.1**
Encyonema minutum	500	**0.1**
Gomphonema clavatum	500	**0.1**
Surrella spp.	500	**0.1**
Synedra ulna	500	**0.1**
Other	17000	**3.5**
SUM	**490500**	**100**

APPENDIX 2: The relative abundance of trees in the three study sites

TREES	Upstream		Midstream		Downstream	
Species	% LEFT	% RIGHT	% LEFT	% RIGHT	% LEFT	% RIGHT
Acacia tortilis	1.1	0	5	15	0	0
Caleospina spinosa	0	0	0	0	0	8
Croton macrostachyus	43.3	13.3	0	15	16	12
Croton megalocarpus	0	0	0	5	0	0
Cupressus lusitanica	0	0	0	40	28	36
Eucalyptus saligna	0	7.8	0	20	0	0
Oleawel wischii	2.2	0	0	0	0	0
Pandanus kirki	13.3	18.9	0	0	0	0

APPENDIX 3: The relative abundance of shrubs in the three study sites

SHRUBS	Upstream		Midstream		Downstream	
Species	% LEFT	% RIGHT	% LEFT	% RIGHT	% LEFT	% RIGHT
Acanthes eminens	0	0.8	0	1.61	0	19
Fern	21.2	9.8	0	0	10.1	15.2
Lantana camara	0	0	21	3.23	12.7	12.7
Oplismenus burmanii	1.5	27.3	66.1	3.23	0	0
Plectrathes spp.	8.3	9.8	0	0	12.7	13.9
Solanum nigrun	0	0.8	0	0	0	0
Verbena lasiopus	0	20.5	1.6	3.23	3.8	0

APPENDIX 4: The relative abundance of grass in the three study sites

GRASS	Upstream		Midstream		Downstream	
Species	% LEFT	RIGHT	% LEFT	RIGHT	% LEFT	RIGHT
Arundinaria alpine	0	4.5	0	0	0	0
Cynadoh dactilon	0	18.2	0	0	0	0
Pennisetum clandestinum	21.2	56.1	54	46	0	100

APPENDIX 5: The relative abundance of forbs and climbers in the three study sites

FORBS and climbers	**Upstream**		**Midstream**		**Downstream**	
Species	% LEFT	% RIGHT	% LEFT	% RIGHT	% LEFT	% RIGHT
Sadge	55	45	51.3	48.7	0	100
Stephania abyssinica	100	0	0	0	0	0

APPENDIX 6: The correlation of all the studied parameters in Chepkoo River

Correlations

	Temp	EC	DO	NO3	SRP	TP	NH4	NO2	pH	Periphyton	CPOM
Pearson Correlation	1	-.017	-.337	-.323	-.152	-.139	-.317	-.350	.456*	-.589**	.047
Sig. (2-tailed)		.936	.092	.107	.459	.498	.114	.080	.019	.002	.819
N		26	26	26	26	26	26	26	26	26	26
Pearson Correlation		1	.624**	.232	.901**	.789**	.083	.225	-.722**	.282	.272
Sig. (2-tailed)			.001	.254	.000	.000	.688	.270	.000	.162	.179
N			26	26	26	26	26	26	26	26	26
Pearson Correlation			1	.154	.750**	.712**	.395*	.496**	-.783**	.453*	-.040
Sig. (2-tailed)				.454	.000	.000	.046	.010	.000	.020	.848
N				26	26	26	26	26	26	26	26
Pearson Correlation				1	.248	.342	.417*	.474*	-.566**	.739**	-.109
Sig. (2-tailed)					.223	.087	.034	.014	.003	.000	.596
N					26	26	26	26	26	26	26
Pearson Correlation					1	.843**	.103	.302	-.845**	.352	.184
Sig. (2-tailed)						.000	.618	.134	.000	.078	.368
N						26	26	26	26	26	26
Pearson Correlation						1	.472*	.605**	-.848**	.496*	.113
Sig. (2-tailed)							.015	.001	.000	.010	.582
N							26	26	26	26	26
Pearson Correlation							1	.959**	-.454*	.664**	.011
Sig. (2-tailed)								.000	.020	.000	.958
N								26	26	26	26

Pearson Correlation								1	-.605**	.716**	.021
Sig. (2-tailed)									.001	.000	.920
N									26	26	26
Pearson Correlation									1	-.754**	-.079
Sig. (2-tailed)										.000	.703
N										26	26
Pearson Correlation										1	.070
Sig. (2-tailed)											.732
N											26
Pearson Correlation											1
Sig. (2-tailed)											
N											

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

APPENDIX 7: Water Quality Regulations for Domestic use (NEMA, 2006)

NO.	Parameter	Maximum allowable value for domestic use
1	Ph	6.5-8.5
2	Temperature	30˚C
3	Total suspended sediments	30mg/l
4	Nitrate (NO3)	10mg/l
5	Ammonium (NH4)	0.5mg/l
6	Nitrite	3mg/l
7	Phosphate	2mg/l

APPENDIX 8: Research Authorization

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

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Ref: No. **NACOSTI/P/18/48583/26326**

Date: **26th October, 2018**

Chepsoo Jemutai Elizabeth
Egerton University
P.O. Box 536-20115
NJORO

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Effects of vegetation composition on water quality coarse particulate organic matter and periphyton in Chepkoo River Elgeyo Marakwet Kenya"*** I am pleased to inform you that you have been authorized to undertake research in **Elgeyo Marakwet County** for the period ending **24th October, 2019.**

You are advised to report to **the County Commissioner and the County Director of Education, Elgeyo Marakwet County** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

BONIFACE WANYAMA
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Elgeyo Marakwet County.

The County Director of Education
Elgeyo Marakwet County.