DETERMINING THE IMPACTS OF STONE QUARRYING ON RIPARIAN VEGETATION OF RIVER MOLO IN RONGAI SUB-COUNTY, NAKURU COUNTY, KENYA

KIPYATOR K. DENNIS

A Thesis Submitted to the Institute of Postgraduate Studies of Kabarak University in Partial Fulfillment of the Requirements for the Award of Master of Science in Environmental Science Degree

KABARAK UNIVERSITY

NOVEMBER, 2025

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Signed: _____ Date: _____

Dr. Eliud Garry Michura

Department of Physical and Biological Sciences

Kabarak University

Signed: _____ Date: _____

Dr. Edna Koskei

Department of Physical and Biological Sciences

Kabarak University

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ACKNOWLEDGMENT

My profound gratitude goes to my supervisors, Dr. Eliud Michura and Dr. Edna Koskei for their unrelenting guidance and support throughout the development of this research project. I would wish to thank the Higher Education Loans Board for granting me finances to advance my education.

I cannot forget to thank my colleagues and classmates who have played a pivotal role in motivating me throughout this process.

DEDICATION

I dedicate this research project to the Almighty God for the gift of life, wisdom and guidance. I also dedicate this work to my parents Mr and Mrs Willie Chepchieng and my siblings for their emotional, financial and spiritual support.

I especially thank my mother for her daily prayers for my success. I also dedicate to my friends who have been inspirational towards my career development and upward mobility in life.

Lastly, I thank my mentor Dr. Kiplimo Sirma for encouraging me to pursue a master degree and his timely guidance on how to navigate postgraduate studies.

ABSTRACT

The contribution made by stone quarrying to the Gross Domestic Product (GDP) in many countries globally is enormous. Whether small or large-scale, stone quarrying is inherently disruptive and can cause detrimental effects on riparian vegetation which is considered the most vulnerable and fragile ecosystem. This study sought to determine the status of riparian vegetation between 2000- 2023 along river Molo, assess the level of awareness on the impacts of stone quarrying on riparian vegetation, determine the perceived effects of stone quarry works on riparian vegetation of R. Molo and recommend effective measures to curb the negative impacts of stone quarrying activities. A descriptive survey design was adopted where stratified sampling was used to select 404 Visoi, Soin and Mosop wards were 404 head of households were randomly chosen. Fifteen key informants and five quarry sites were purposively sampled for interviews and field visit respectively. Questionnaires, interview schedules and Geographical Information System and Remote Sensing were the main instruments where spatial data obtained were analyzed using ArcMap GIS by employing Normalized Difference Vegetation Index (NDVI) and time series analysis. The data from questionnaires and interviews schedules were analyzed using Ms. Excel and Statistical Package for the Social Sciences (SPSS version 27) employing descriptive statistics and correlation. The findings revealed a significant decline in riparian vegetation attributed to land use changes linked with quarrying activities. The land use analysis showed barren lands along the riparian areas indicating the ongoing quarrying activities, with grasslands and shrub lands dominating the landscape. Notably, (90%) of respondents were unaware of the impacts of stone quarrying on the riparian vegetation implying the need for more public participation. There was a significant negative correlation between public participation and stone quarrying impacts at p= -0.412 implying that low level of public participation on stone quarrying led to increased destruction of riparian vegetation. The study found a strong perception among respondents that quarrying led to changes in riparian vegetation cover, felling of trees and grasses, reduced natural regeneration and increased soil erosion. The likert type scale demonstrated a higher mean score for rehabilitation and reclamation of quarry sites, planting of trees and grass, promotion of public participation, proper disposal of quarry overburden and enactment of laws to govern quarrying in Nakuru County. According to the study these approaches can be regarded as best practices for mitigating the negative impacts of stone quarrying on riparian vegetation.

Keywords*:* *Geographical Information System, Normalized Difference Vegetation Index, Riparian vegetation, Quarrying*

TABLE OF CONTENTS

TABLE OF FIGURES

LIST OF TABLES

ABBREVIATION AND ACRONYMS

CBD	Central Business District
CIPD	County Integrated Development Plan
CPCB	Central Pollution Control Board
dBA	Decibels
EA	Environmental Audit
EIA	Environmental Impact Assessment
EMCA	Environmental Management and Coordination Act
GIS	Geographical Information System
KFS	Kenya Forest Service
KNBS	Kenya National Bureau of Statistics
Km	Kilometer
NECOFA	Network of Eco farming in Africa
NEMA	National Environment Management Authority
NDVI	Nominalized Difference Vegetation Index
NLC	National Land Commission
PPE	Personal Protective Equipment
R	River
RS	Remote Sensing
SD	Standard Deviation
SDG	Sustainable Development Goals
SPSS	Statistical Packages for Social Sciences

CONCEPTUAL AND OPERATIONAL DEFINITION OF TERMS

Anthropogenic Factors-refers to human-induced activities that significantly alter the natural environment leading to ecological and health issues.

Environment- refers to the natural surroundings that are affected by quarrying activities, including ecosystems, air and water quality, soil health, and biodiversity.

Vegetation Cover Change- this is the alteration of vegetation structure, composition, coverage and functionality as a result of quarrying activities (Ozcan & Musaoglu, 2012).

Quarrying- this is act of extracting stones and other materials from the surface of the earth which may cause habitat destruction, pollution, and landscape alteration.

Geographical Information System- this a tool used in analyzing spatial data by managing, analyzing, manipulating and visualizing the data in form of an image.

Land use- refers to the designation, utilization and management of land areas for the extraction of rock, sand, and gravel, agriculture, settlement and forestry**.**

Normalized Difference Vegetation Index- is a technique used to analyze vegetation cover by measuring the differences between Near Infrared radiation reflected by plants and Red light absorbed by plants.

Remote Sensing- This is the art and science of obtaining information about an area under study using radiation and remote sensors.

Riparian Zone- is a transition between a river and the terrestrial environments in an ecosystem which plays crucial roles in buffering against floods, carbon sequestration, purification of water and provision of food, fodder and raw materials.

Riparian Vegetation- These are specific plants adapted to areas between water systems and terrestrial lands.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Quarrying is a form of land use that involves the extraction of building stones, sand, gravel and aggregate from the earth's surface. Substantial increase in natural stone extraction has been witnessed over the last decade owing to the increased construction activities worldwide (Awoke, 2019). However, stone quarrying whether small or large-scale is inherently disruptive and can cause detrimental effects on the environment such as habitat destruction, water pollution and soil erosion (Mahapatra, 2023), hence need for holistic approaches in management of such activities (Vandana et al., 2020). The common extracted natural stones for construction include Limestone, sandstone, granite, marble, slate and serpentine. These stones exhibit good appearance with great strength to withstand stress (Basu, 2020).

Globally, most established quarries produce either dimension stones or aggregate (Umar, 2022). Dimension stones are natural, structural and decorative building blocks used in the construction industry (Gonçalves & Margarido, 2015). They exhibit different colours, textures and patterns depending on materials and nature of formation. Some stones such as granite are polished and utilized for decoration and establishment of monuments. However, aggregate are crushed stones which are commonly mixed with cement during construction to form concrete for purposes of stable foundation (Qasrawi, 2014). Traditional architecture(the use of mud and wood to stone -built houses) is fast disappearing due to neglect of culture and increased urbanization where most people in both rural and urban setups are now embracing stone-built houses (Ikudayisi & Odeyale, 2021).

Stone quarrying is associated with both positive and negative effects on social and environmental well-being (Endalew et al., 2019). Quarrying plays a very important role in providing essential income for many rural residents in the world for instance, in Balasore district, 53% of local tribal people depend on stone quarrying for their livelihood (Mahaptra, 2023). Furthermore, Sayara (2016) found that quarrying of stones contributed to 5.5 % gross domestic product (GDP) in Palestine.

Contrary, stone quarrying has led to significant impacts on the environment especially, riparian areas which as regarded as the most delicate ecosystems (Vandana et al., 2020). Additionally, ecosystems such as riparian areas are more vulnerable to extractive operations since it involves clearing of existing vegetation and stripping of the topsoil.

In Sub-Saharan Africa, quarrying activities have expanded without adequate regulatory frameworks, leading to severe degradation of riparian ecosystems including destruction of habitats, biodiversity loss and water pollution (Nartey et al., 2012). This is primarily due to rapid urbanization, which has increased the demand for construction materials and intensified the environmental impacts associated with quarrying.

In areas such as East Africa, riparian zones have been significantly altered due to extensive quarrying, threatening the livelihood of communities dependent on these ecosystems for water and agriculture (Lameed & Ayodele, 2010). Land degradation aggravated by quarrying activities have rendered relatively large land on earth as derelict (Omondi et al., 2021). Similarly, quarrying negatively affects riparian vegetation and results to decline in riparian vegetation species diversity and health (Koskey et al., 2021).

Riparian zones are dynamic ecosystems where aquatic and terrestrial landscape meet. These zones are shaped by interaction of biophysical components such as hydrology, geomorphology, and vegetation (Rusnák et al., 2022). Huge vegetal losses caused by

unsustainable quarrying practices have limited the role played by riparian vegetation in mitigating the global impact of climate change (Akanwa, 2017). Additionally, Healthy riparian forests are essential to the maintenance of water quality and biological integrity in surface water systems and their destruction often leads to subsequent degradation of adjoining aquatic ecosystems (Elbrecht et al., 2022).

According to Statista (2022) quarrying contributed 91.8 billion to the Kenya's economy in 2021 which is a substantial increase from 68.9 billion in 2018. Additionally, Quarrying activities were shown to facilitate infrastructure growth in Kilifi County by providing raw materials for construction, leading to improved local amenities and economic development (Wambua et al., 2021). Conversely, Eshiwani (2007) noted that most quarrying activities in Kenya are carried out unsustainably, indiscriminately and uncontrollably escalating more negative impacts on riparian systems and the total environment.

Nakuru County is endowed with a variety of mineral resources including; kaolin, diatomite, sand and building stones, trona (soda ash) and natural carbon dioxide) with 15 stone quarries, 13 sand harvesting and 2 murram quarries in Bahati, Gilgil and Naivasha sub-counties. CIDP, (2018-2023).

However, stone quarrying particularly along riparian areas like the Ndarugu and Malewa rivers have been alarming leading to riparian vegetation stress and increased sedimentation in Lake Naivasha, Lake Nakuru and other local water bodies (Mwaura, 2015). This has degraded water quality and affected aquatic life, which is a critical concern for local communities that rely on these resources for fishing and agriculture.

Moreover, public participation on the environmental impacts of quarrying in Nakuru County has been limited and not well coordinated hence exacerbated the environmental

degradation on very fragile ecosystems (Mwangi et al., 2020). The quarrying activities have also led to the destruction of habitats that support biodiversity, such as wetland areas and forests near riparian zones, threatening endemic species such as reeds, *Acacia spp, Syzygium guineense, Ficus spp* among other species and shrubs.

Rongai Sub- County is tapping employment opportunities in the quarry sector where a larger population in the informal settlements depend on quarries for their daily income to sustain their families. Thus far, there is need to strike a balance between enhancing quarry activities to improve people's livelihoods and improving the environment through better management approaches. Dar et al., (2023).

River Molo is a perennial river emanating from the Mau complex traversing through Kuresoi, Molo, Rongai, Mogotio and Baringo South Sub-Counties covering about 100 kilometers stretch. It is one of the major rivers feeding Lake Baringo and a source of water for domestic and agricultural use (NECOFA, 2008). However, according to Chebet et al. (2020), elemental pollution from surface run off during rainy season was a serious concern in Molo river indicating human interference. Similarly, water turbidity in the river was high with declining water flow and volumes (Kipsang et al., 2022).This therefore, underscores the need for sustainable management of quarrying activities in the area as well as development of policies and laws to govern quarrying.

1.2 Statement of the Problem

The contribution made by stone quarrying activities to the improvement of livelihoods is enormous where many residents of Rongai Sub- County rely to earn a living. However, these quarrying activities are unregulated and, in most cases, carried out to maximize monetary benefits posing devastating impacts on the vegetation, especially along riparian zones.

The impact of quarrying on riparian vegetation poses a significant threat to ecological integrity and water quality, yet the extent of this danger is often overlooked. This study sought to show the critical relationship between quarrying activities and the degradation of riparian ecosystems. Although mechanization in quarrying enhances efficiency and increases output, it also accelerates the degradation of vegetation, which is concerning. If not properly regulated, such mechanization could undermine the functionality of riparian ecosystems.

Therefore, there is need for extensive research on the impacts of stone quarrying on riparian vegetation owing to the limited research work done in the sector, this study being among the first. Riparian vegetation is a key player in balancing biogeochemical cycles and sustaining rivers in the long run. Thus, this research seeks to ascertain specific impacts of stone quarrying activities on the riverine vegetation cover of river Molo and come up with mitigation measures.

1.3 Objectives of the Study

The research objectives encompass the broad objective of the study and the specific objectives of the research.

1.3.1 General Objective of the Study

To determine the impacts of stone quarry works on the riparian vegetation of River Molo in Rongai Sub-County in Nakuru County.

1.3.2 Specific Objectives of the Study

i. To determine River Molo riparian vegetation status between 2000- 2023 in Rongai Sub- County, Nakuru County.
ii. To assess the community's level of awareness on the impacts of stone quarrying on riparian vegetation in Rongai Sub-County, Nakuru County.

iii. To determine the perceived effects of stone quarry works on R. Molo riparian vegetation in Rongai Sub- County, Nakuru County.
iv. To recommend effective measures to curb the negative impacts of quarrying on riparian vegetation along R. Molo in Rongai Sub-County, Nakuru County.

1.4 Research Questions

i. What is the vegetation status along River Molo in Rongai Sub- County between 2000-2023?
ii. How aware is the community on the environmental impacts of stone quarrying on riparian vegetation in Rongai Sub-County?
iii. What are some of the perceived effects of stone quarry works on the riparian plants along River Molo in Rongai Sub- County?
iv. Which measure can be put in place to curb the negative effects of stone quarrying activities on the riparian plants along River Molo in Rongai Sub-County?

1.5 Justification of the Study

This research will contribute to SDG 1 – No poverty, 6- Clean water and sanitation, 8- Decent work and economic growth, 13-Climate action and 15- Life on land. Attaining these goals requires holistic approached in promoting conservation of biodiversity, human health and cultural considerations which this study is going to focused on.

The study will contribute to better regulation and management of quarrying in Rongai sub-county and development of Nakuru county quarrying laws. The findings will also be instrumental to the Molo river water resources user's association and Water Resource Authority in development of Integrated Water Management Guidelines. The findings from this study are expected to enrich the Nakuru County Integrated Development Plan in future on the ongoing quarrying in Rongai Sub-County and best sustainable practices

to be employ in order to strike a balance between environmental protection and improvement of livelihoods through stone quarrying.

The ecological benefits provided by riparian plants are crucial and intrinsic. These include; carbon sequestration, purification of water, preventing soil erosion, acting as buffer zones, habitats, and source of food and materials for making a myriad of products. Identifying the major stressors of these resources and developing mechanisms to prevent and solve them will improve social, economic, and environmental benefits.

This study will also enhance compliance to national and international environmental laws through incorporation of environmental issues during planning of quarry activities, best stone extraction methods and protection of 30 meters diameter of riparian areas.

1.6 Scope of the Study

The study was conducted in Rongai Sub-County in Nakuru County between June to August, 2024. The study focused on determining the impacts of stone quarrying on riparian vegetation of river Molo.

1.7 Limitations of the Study

Underscoring the specific impacts attributed to quarrying activities in Rongai Sub-County was an uphill task since there are other factors resulting to degradation of riparian vegetation such as agriculture, industries and deforestation. Additionally, acquisition of high-resolution GIS software was a major challenge because of the budget constraints. However, the study adopted time series analysis and NDVI to determine the effects of quarry on riparian vegetation.

1.8 Assumptions of the Study

The assumption of the study includes:

i. Determining the status of R. Molo riparian vegetation result to better management of riparian vegetation.
ii. Establishing the level of awareness of stone quarrying informs better mechanism to curb negative impacts.
iii. Stone quarrying activities leads to the degradation of riparian vegetation.
iv. Determining the effective measures leads to improved vegetation cover which in turn sustains the river flow and water quality standards.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter analyses the previous research work done by several scholars related to the topic of the study on a global, regional and local scale. It outlines the literature review of the study variables which encompasses the history of quarry activities, level of awareness of stone quarrying on riparian vegetation, stone quarrying effects on the environment and riparian vegetation, application of remote sensing and existing legal frameworks and regulations. The chapter also captures the theoretical and conceptual framework of the study.

2.2 Theoretical Framework

The modified Bertalanffy model (1950) from the General System Theory forms the basis of this research. The model postulates that a system is a complex arrangement that is made up of elements that interact amongst themselves. Interfering with one element will impose a substantial effect on the functioning of the entire system. In connection to this, the environment is referred to a system which is dynamic with living and non-living things which interact with each other.

Human reasoning to a greater extent affects the integrity of the environment through anthropogenic activities. Technological advancement and increased population overstretch the existing natural resources. Stone quarrying which is the focus of this research imposes significant impacts on the environment and hence the need for a proper management approach.

In the case of stone quarrying, the disruption of riparian vegetation exemplifies the principles outlined in Bertalanffy's model. Extractive processes such as stone quarrying

generate rapid, multidimensional ecological disruptions characterized by synchronous and measurable transformations across physical, hydrological, and biological systems. These often lead to the removal of vegetation along riverbanks, which plays a crucial role in maintaining water quality and stabilizing soil. The destruction of these riparian zones not only affects the immediate area but also has cascading effects on the entire aquatic ecosystem. For instance, increased sedimentation from eroded soils can cloud water, reducing light penetration and affecting aquatic plant growth. This degradation can further disrupt food webs and diminish biodiversity within these ecosystems.

2.3 Literature Review of the Study Variables

2.3.1 History of Stone Quarrying

Quarrying is a form of land use that involves the extraction of building stones, sand, gravel and aggregate from the earth's surface (Banez et al., 2010). The common extracted natural stones for construction include Limestone, sandstone, granite, marble, slate and serpentine. These stones exhibit good appearance with great strength to withstand stress (Basu, 2020). Quarry is a small-scale industry generating materials used for construction, thus contributing to the Gross Domestic Product (GDP) of any country. Increased population rates have overwhelmed the quarrying industry where massive extractions to obtain building rocks is carried out.

In ancient times, traditional methods were used to prospect and extract stones from the ground. Miners used geophysical components to indicate the existence of a particular mineral in an area. Hard rocks were heated to undergo thermal expansion which created cracks. Hand-on tools such as hammers and chisels were employed to remove useful rocks from the earth surface. The Egyptians built the Great Pyramids using extracted limestone and granite blocks from the Aswan quarry in 2600 BCE (Harrel &Storemyr

2009). The Pyramids exist to date and are prominent historical and touristic sites globally.

However, Lakota culture in the U.S, state of Minnesota carried out stone quarrying over many years to make ceremonial smoking pipes. The abandoned quarries now act as historical and cultural sites. Pipestone National Monument was established for remembrance (Southwick, 2005). Miami mines in Florida in the United State is one of the largest quarries in the world and is owned by Rinker Materials Corporation where they have been mining limestone for construction and cement for a very long period (Antunes, 2018). Since the Industrial revolution, stone extraction methods have gradually changed due to technological advancement. Technology has been applied in the entire stages of stone extraction and the output has increased not forgetting the waste generation and dust emission.

Mechanized quarrying employs heavy machinery such as excavators, bulldozers and explosives with larger ecological destruction such as creation of large pits that can alter local hydrology, alteration of vegetation density and increased sedimentation in rivers and stream (Mahaptra, 2023).

Mwanza area, in Tanzania is also characterized by rocks that are used for building and construction purposes. The availability of these building materials has led to the emergence of two methods of excavation as per level of science and capital used (Mshana, 2022). The first being the traditional methods of extraction (the use of hand-based tools such as pickaxes, hammers, charcoal, spade and iron bar to excavate and segment building materials from the ground). The second are modern methods of extraction (the use of technological tools such as machines). The latter method is used by mining companies such as Nyanza Construction Company. The sites where modern methods of extraction are applied are far from residential areas compared to the

traditional methods of extraction that are conducted illegally and carried out in the residential areas (Joseph, 2022).

The quarry operation begins with excavation (stripping) which is the removal of topsoil and sub-soil commonly known as overburden. Graders, bulldozers and excavators are used in this process where a lot of dust emissions and noise and vibration which is a big issue for humans and biodiversity. In addition, massive destructions of vegetation and soil structure are eminent and hence need proper mitigation measures.

Digging is another process of extraction where rocks are manually removed using traditional tools, this method of extracting is done on small scale and mostly stones extracted are used within the locality. Blasting is the use of explosives to break the bedrock. Dynamite, a nitroglycerin-based explosive, is used in most cases to fracture rocks in quarries but is associated with the most adverse impacts on building and human health. Kibii (2020) & Eshiwani (2014) observed that blasting caused cracks on building walls within a given proximity to the quarry site. According to Matheus (2016) blasting involves drilling a hole in the quarry site, placing a charge detonator inside the drilled hole of a target rock bed, denoting the charge for the explosion to happen and break huge rocks into the required size.

Additionally, Stone cutting is undertaken to trim construction rocks into the required shape and size. Several types of stone cutting machines have been developed in different designs depending on size and the desired shape and finally, Loading and transportation to the construction sites. Commercialization of quarried stones has brought improvements in loading from hand loading to mechanization where shovels and other machines are used (Waqas, 2015). Heavy trunks and Lorries are then used to transport stones to the construction sites.

2.3.2 Riparian Lands and Vegetation

Riparian lands are the transition zones between land and water bodies such as streams, rivers, and lakes (Clare &Sass, 2012). These areas are productive and valuable resources, providing numerous social, economic and environmental benefits including reduced erosion, act as animal habitat, source of food and water, serenity, good climate, recreational sites, cultural sites and source of livelihoods among others (Hawe, 2005). Riparian lands are considered a public area that ought not to belong to any party in exclusivity and therefore need protection and proper management (Matunda, 2015). In Kenya several laws have varying riparian width from the river bed as indicated by Karisa (2010).

Table 1

Kenyan Laws on Riparian Area Width

National statutes	Recommended riparian width in metres
EMCA (1999)	Minimum 6m and max. 30m from edge of river (highest ever recorded flood level, on either side)
Water Act (2002)	Minimum 6m and max. 30m from edge of river
Physical Planning Act 2019	Minimum 2m in height and max. 30m horizontal from edge of river
Survey Act (2012)	Minimum 30m for tidal rivers only. No mention of other smaller rivers. Measurement from high water mark

In severely fragmented landscapes, riparian zones are commonly thought to be good nutrient filters and even habitat for species, but their survival is reliant on a variety of factors. Buffer zones have been used to reduce Nitrogen , Phosphorous and pesticide leaks to provide flood protection and habitat for animals and plants, to encourage

biological linkage, to reduce erosion problems, and to provide recreational spaces (Arora et al., 1996; Décamps et al., 2004; Mankin et al., 2007).

Nairobi's riparian zones have been subjected to tremendous pressure from a variety of causes, including human settlements, industrial activities, and urban agriculture. The main causes of riparian degradation in Nairobi have been identified as habitat loss, solid waste, and pollution. Waste, liquid waste, and raw sewage are all examples of waste (Muketha, 2014). The riparian reserves of the three Nairobi Rivers (Mathare, Ngong, and Nairobi) have a large number of informal settlements that lack proper drainage and sanitation facilities. Most of the time, waterways are used to discharge untreated sewage. In addition to raw sewage contributions from informal settlements, most enterprises find it cheaper to discharge their effluent into rivers without adequate treatment (Karisa, 2010).

National Land Commission report on Riparian Lands Conservation and Management Policy Framework highlighted several significant effects on riparian lands as a result of developmental projects and other anthropogenic activities. These included the following but are not limited to destruction of vegetation and soil during stripping, degradation of soil habitat through stripping, land and dereliction and alteration of the landscape and alteration of biogeochemical processes.

2.3.3 Literature on the Status of Riparian Areas of River Molo

River Molo is a permanent river emanating from the Mau Complex. The river stretches about 100 Km from the primary source to Lake Baringo and traverses through five Sub-Counties namely; Kuresoi, Molo, Rongai, Mogotio and Baringo South. According to the information and observations gathered by NECOFA (2008), River Molo has been negatively degraded as a result of massive deforestation, particularly in the Mau forest,

extensive farm practices along the riparian, plantation of inappropriate species, primarily Eucalyptus species, next to water ways whose water consumption rate is very high, a poor land allotment system driven by community resettlement and urban construction on the river bank, and water poisoning from farm chemicals and industrial chemicals

As a result, there has been a general decline in water levels, greater soil erosion, increasing encroachment into forest territory, and widespread pollution. Until 1985, the water in Molo River was pure, secure, and abundant, meeting the needs of the local communities in the area. However, in recent times, the water has become contaminated and significantly reduced in quantity, causing distress to the people residing throughout the region (Kipsang et al., 2022).

2.3.4 Awareness of the Effects of Stone Quarrying on Riparian Vegetation

According to Hamza &Kanyama (2016), the landowners and quarry owners are not effectively carrying out the restoration of quarry areas because they have insufficient knowledge about the impact of stone quarrying on the environment and are unaware of the appropriate measures to mitigate these effects. As a result, progress in the restoration efforts is significantly delayed.

The understanding of quarrying regulations among individuals living near quarries plays a crucial role in ensuring quarry owners comply with the law (Twerefou et al., 2015). Promoting environmental education is crucial in enhancing public awareness about the impact of stone quarrying on riparian vegetation hence leading to sustainable development.

Research by Kibii (2020) found that less than half of the respondents of Tuluongoi were aware of the laws and regulations that govern quarry operations. Generally, this implies

that the level of awareness of the impacts of stone quarrying on the environment and more specifically on natural vegetation is low even among the quarry workers.

2.3.5 Perceived Effects of Stone Quarrying on Riparian Vegetation

These are already existing information on the perceived impacts of stone quarrying encompassing both positive and negative impacts. Quarrying industry is extremely important sector because it contributes to the GDP of every country on earth. Quarrying of gravel, sand and crushed stones generated up to 245,000,000 USD globally. Similarly, quarrying contributes a higher percentage of national income in Pakistan annually and employs over 500, 000 skilled and non-skilled personnel (Ilyas, 2010).

In Malaysia, it is estimated that informal employs over 70% of the population. Stone quarrying creates job opportunities for over 30% of the population (Ibrahim, 2007). According to Sayara (2016), Palestine produces around 25 million square meters of stone every year which accounts to about 4% of the world's stone and marble production and about 5.5% of Palestine's GDP is from quarrying activities (Sayara, 2016).

Walser (2002) asserts that quarrying plays a vital role in the economic development of many countries in the World and there is need for a proper land use management to improve the livelihoods of the people and encourage diversification of economic activities. A livelihood is considered to be sustainable when it can cope and recover from emerging stress through constant income, reduced vulnerability and improved food security (Jiao, 2017). The same has been noted here in Kenya where quarrying and mining industry contributed 91.8 billion to the Kenya's economy in 2021 a noted increase from 68.9 billion in 2018 (Statista, 2022). Wangela (2019) further indicates that stone quarrying in Kiambu County contributed much material to the built environment.

In addition, the county has benefited enormously from the revenue generated from this sector not forgetting the job opportunities for the locals.

(Waweru et al., 2018) identified a total of 60 quarry sections in Ndarugu, Kiambu County. Ndarugu quarry is located 35 Km north of Nairobi CDB and is amongst the leading sources of building stones in Kenya. Mingate & Mohammed (2016) demonstrated that stone quarrying had significantly contributed to physical assets for instance the development of roads, schools and health centres and social capital in Mandera. Careddu (2019) indicates that quarrying stone industry globally has strongly increased and the amount of stone residues generated from quarries amounts to over 71% of the gross quarry production. Hassan (2022) finding revealed that about 40% of vegetation cover and 46.7% of animal were into extinction and threatened by extraction activities in Ogun state, Nigeria. It was also noted that dust covered about 30% of food or cash crops fields.

According to Şirin (2021) dust emission, energy consumption and carbon footprint levels differ when different cutting machines are applied. For example, a diamond wire cutter produces low above-mentioned impacts compared to a chain saw cutter.(Kigomo et al.,2018) indicate that human development has reduced vegetation cover by 75 per cent, soil fertility by 70 per cent, and stream water discharge by 53 per cent in Mbeere North. Wangela (2019) indicated significant negative impacts on plants within the surrounding areas of quarry sites. He observed plants' leaves turning yellow which evident chlorosis as well as necrosis (leaves developing dark and brown spots) all because of dust and disturbances from machinery.

Densely forested areas dominated by shrubs and trees along River Njoro experienced anthropogenic disturbances (Kosgey et al., 2021). Several studies have also shown

significant negative impacts of quarrying on the environment. Anand (2006) opines biodiversity loss as one of the biggest negative impacts of quarrying on the environment. Biodiversity refers to all life forms on earth including flora, fauna, microorganisms and fungi. Tanko (2007) suggested that with careful planning and management biodiversity loss can be minimized. Malashi (2007) established that quarrying affects drainage systems in rivers in the Barut location due to massive soil erosion from excavated soil.

Water catchment areas constitute the forest biodiversity and are water sources to streams and rivers. Deforestation as a result of quarrying substantially affects water recharge and quality (Asaad & Jordan, 1994). The researchers further stated that proper measures must be put in place to curb deforestation and other impacts on riparian systems.

2.3.6 Remote Sensing and GIS in Riparian Vegetation Assessment

Field studies analysis methods are mostly used to determine the level of degradation within ecotones (Wang et al., 2022). However, Remote sensing (RS) technology have become powerful tools to synergize vegetation management through monitoring of vegetation cover change by providing geospatial data over period of time on a large geographical area.

The introduction of the Normalized Difference Vegetation Index (NDVI) technique has enabled the detection of vegetation cover change, soil degradation and change in land use in a heterogenous topographic area (Yengoh et al., 2015). NDVI employs the Multi-Spectral Remote Sensing data technique to find Vegetation Index, land cover classification, vegetation, water bodies, open area, shrub area, hilly areas, agricultural area, thick forest, thin forest with few band combinations of the remote sensed data (Gandhi et al., 2015). It quantifies vegetation cover by measuring the differences

between Near Infrared radiation reflected by plants and Red (visible) light absorbed by plants (El-Gammal, 2014).

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

Densely populated and healthy vegetation with high chlorophyll pigments absorbs more visible light which is used in photosynthesis. Canopies of vegetation within riparian areas can be analyzed and managed using airborne laser and photogrammetry enabling the assessment of vegetation over vast regions on earth.

During monitoring of vegetation using NDVI, satellite imagery is obtained from Landsat, MODIS, Sentinel, or drones with multispectral cameras. The pixel values for the red and near- infrared spectral bands are extracted where the NDVI formula indicated above is applied. The NDVI values are then interpreted within a range of -1 to +1. The negative values represent non- vegetative surface such as water, rocks and clouds, 0 represents bare or urban areas,0.1 to 0.2- indicate barren or rocky areas, 0.2 to 0.5- represents sparse vegetation and shrub and above 0.5- Represents dense and healthy vegetation (Cai et al., 2019). The NDVI results are visualized using GIS software such ArcGIS, or Google Earth Engine.

Remote sensing techniques involve acquiring information about a remote object using radiation and remote sensors. RS is cheaper, time-saving and provides accurate information (Ventura, 2018). Aerial and oblique photography is used in analyses of vegetation cover. The commonly used type of photography to determine the status of vegetation in a large area is satellite imagery which provides a view of the structure and processes of a forest ecosystem. More importantly, Time series analysis is useful to

provide an insightful chronological change of a given forest or riparian ecosystem by using google earth maps.

2.3.7 Measures to Curb Effects of Quarrying on Riparian Plants

Karisa (2010) recommends integrated planning linkage between environmental (riparian) and land use, including human settlements, Institutional capacity building, including operational and financial strengthening and Partnerships bringing together the public, private, and civil society. It also suggests public awareness and participation of communities and civil society organizations in riparian Management to enhance social responsibility.

Several researchers have suggested best practices in quarries to reduce impacts on the environment and riparian plants to be specific. Kindiga (2017) suggested that the soil void areas along the riparian zone of Ngong river be utilized for flood prevention. A rehabilitation plan is needed that considers gradual recovery throughout the entire duration of quarrying activities. The Forest Act suggests reforestation as the most effective method for rehabilitation, particularly for degraded lands. It is crucial to collaborate with a forest officer to choose appropriate riparian plants like reeds and other native species (Warhust, 1999).

In response to the need for area-specific solutions addressing the negative impacts of stone quarry activities on riparian vegetation, it was essential to determine specific measures which can effectively minimize the negative impacts on the riparian vegetation.

Ramsar Convention (1971) on Conservation and sustainable utilization of wetland recognize the fundamental ecological functions of wetlands and their economic, cultural, scientific and recreational value. The agreement constituted all designated areas within

rivers, lakes and oceans and agitates for proper conservation and management strategies for wetlands through ratification by member states. The major contributors to the degradation of this resource include mining activities, agriculture and industrialization among others.

In Kenya, Environmental Management and Coordination Act (EMCA,1999) was established by an act of parliament to provide an appropriate legal and institutional framework for the management of the environment and was later revised in 2016. The act establishes the National Environment Management Authority (NEMA) to supervise and coordinate all environmental management and conservation, undertake research and survey on environmental issues, advice the government on environmental management and land use and regulates the impacts of developmental projects on the environment through Environmental and Social Impact Assessment (ESIA) and Environmental Audits (EA).

The second schedule of the act highlights mining activities quarrying included; as a first-rate project which poses significant environmental impacts. It is therefore a requirement by law for EIA and EA be undertaken to mitigate negative environmental outcomes and ensure sustainability.

Additionally, Forest act of 2005 establishes Kenya Forest Service (KFS) mandated to manage, conserve and protect the forest resources in Kenya. Forest management does not exempt developmental activities such as mining which in the long run affects the environment and forest resources to be specific. In a nutshell, mining and quarrying may be carried out in the forest following the acquisition of requisite licenses and permits. The license can only be issued under the following conditions; development of all safety measures to prevent injury to human beings, livestock and wildlife traversing the forest

and compulsory re-vegetation immediately upon the completion of the activity in case the conditions provided in this act concerning mining and quarrying in forest areas are contravened, the individual or institution will have committed an offence and shall be liable on conviction.

Part six of Mining Act, 2016 concentrates on health, safety and environmental issues attributed to mining activities. The act requires an EIA study to be undertaken before the commencement of any mining and quarrying activity in Kenya. The act prescribes various measures to curb health, safety and environment-related issues which include and are not limited to the development of rehabilitation plans, proper blasting procedures and engagement of the public.

The Technical Advisory Committee of Kenya formed in 2011 on riparian lands along rivers recommended "a minimum riparian reserve of 6m or equal to the average full width of the river measured from the highest watermark, whichever is higher, up to a maximum of 30m shall be maintained. However, for rivers with an average full width of up to 2m, measured from the highest watermark, a riparian reserve equal to double the average full width of the river shall be maintained. This shall apply to both seasonal and perennial rivers."

Kenya has enormous mineral resource development and exploitation potential. Over 200 local and foreign companies and individuals are engaged in mineral exploitation and exploration. Because of the nature and occurrence of the minerals, the mining method is primarily open cast. Environmental impacts of quarrying and mining activities include flora and fauna disturbances, visual squalor, noise pollution, dust and vibrations causing negative human health impacts and property destruction. Furthermore, mining operations generally have an impact on hydrological functions and compete with ecologically protected areas such as national reserves, game parks, and gazetted forests.

The best practices prescribed under this guideline in regards to quarrying activities includes; extraction of soft rocks, gravel, sand and soil in benches with no vertical cliff exceeding 2.5 meters, fencing of quarry site with a buffer zone of at least 3 meters using chain link of not less than 1.5 m in height. Additionally, providing adequate signages, minimize cutting of trees and should not be undertaken within designated wetland zone, aftermath rehabilitation measures such as levelling and re-vegetation, adoption of proper blasting procedures and issuance of personal protective equipment to all quarry workers.

The Climate Change Act of 2016 in Kenya addresses various aspects related to climate change mitigation and adaptation. It incorporates provisions that aim to regulate and manage activities that contribute to environmental degradation, including quarrying operations. These provisions emphasize the need to reduce greenhouse gas emissions, promote sustainable land use, and protect natural resources. The act it underscores the broader objective of promoting sustainable development and safeguarding the environment. It aims at minimizing the carbon footprint associated with quarrying activities, such as reducing energy consumption and employing efficient extraction techniques. Furthermore, the Act promotes the rehabilitation and restoration of quarry sites to mitigate the negative impacts on the environment and ecosystems.

Water Act of 2016 establishes a comprehensive framework for managing Kenya's water resources through decentralized governance involving both Water Resource Authority, County Government and local community water users' associations. This collaborative approach is crucial to enhance sustainability, ensure equitable access to water, and promote active participation from all stakeholders in managing this vital resource effectively.

According to the Constitution of Kenya, 2010, chapter five, the state is mandated to ensure sustainable exploitation, utilization, conservation and management of the environment and natural resources, and ensure the equitable sharing of the accruing benefits, encourage public participation in the management, protection and conservation of the environment, eliminate processes and activities that are likely to endanger the environment and utilize the environment and natural resources for the benefit of the people of Kenya.

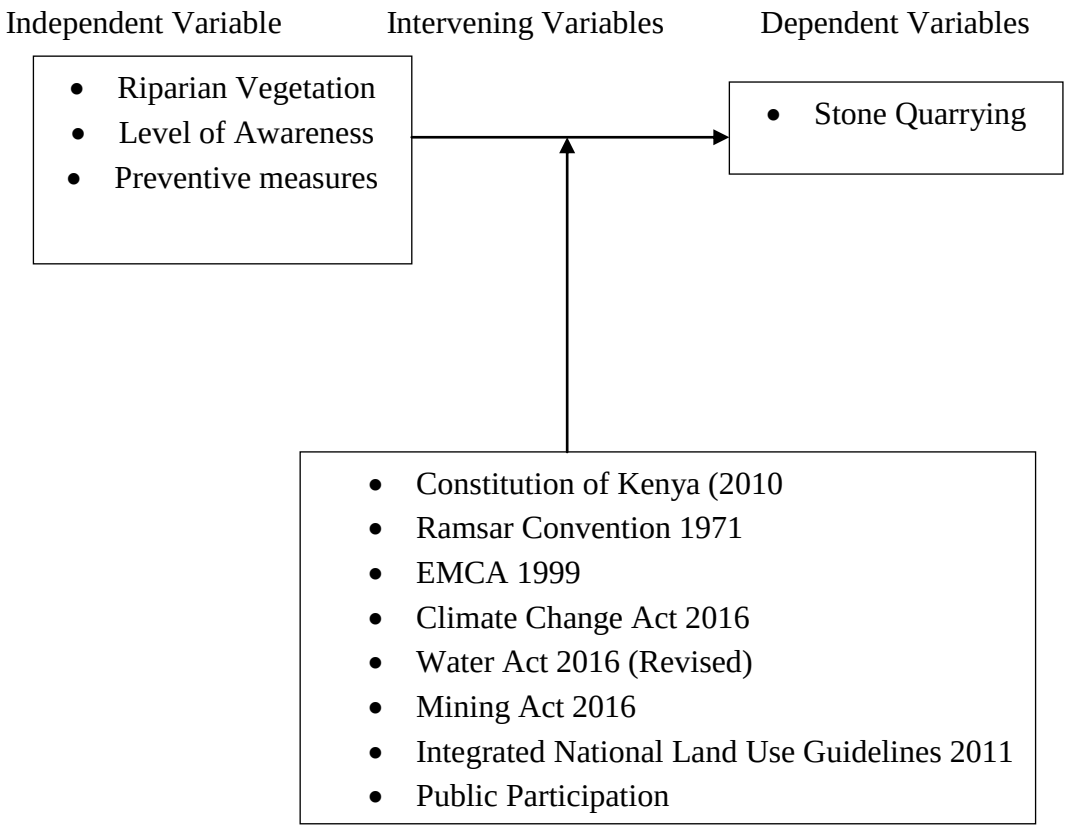
Article 42 provides that every citizen is entitled to an environment that is both clean and healthy. This encompasses the entitlement to safeguard the environment for the welfare of current and future generations, using legal and other means outlined in Article 69. Additionally, individuals have the right to ensure that responsibilities concerning the environment are met as specified in Article 70.

2.4 Conceptual Framework

The nexus between quarrying activities and biophysical components in the environment are the implication caused which can either be positive or negative as presented by Figure 1.

Figure 1

Conceptual Framework



Source: Author, (2025)

The independent variables for this research included vegetation cover, level of awareness on impacts of quarrying on riparian vegetation and measures put in place to curb negative impacts of quarrying on riparian vegetation of river Molo.

The dependent variable was mainly stone quarrying which differ in scope, extraction methods and capacity. The intervening variables influenced the extend and manner of extraction and environmental degradation particularly, on riparian vegetation. These comprised of the existing laws and regulations governing operations in quarries and public education and participation. These laws and regulations range from Ramsar Convention 1971, Constitution of Kenya 2010, EMCA 1999, Mining Act of 2016, Forest

Act 2005, Water Act 2005, Climate Change Act of 2016 and Integrated National Land Use Guidelines 2011.

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2.5 Summary of Literature and Research Gaps

Substantive research work has been conducted on the impacts of agricultural development and Mau complex deforestation on water quality and quantity. Despite of the vital role played by the riparian vegetation along river Molo, little has been done on how quarrying activities affects riparian vegetation.

In areas where quarrying activities are taking place, Location -specific research are needed to determine the extent of destruction caused on riparian vegetation in order to inform on the measures to put in place. Essentially, this research provided insights on the current situation of riparian vegetation along river Molo.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

The chapter entails research design, study area, target population, sampling procedures and sample size, research instruments, pilot study, validity and reliability of instruments, data collection, data analysis and ethical consideration.

3.2 Research Design

The study adopted a descriptive survey design that portrayed peoples' opinions and the researcher's observations. This approach was therefore relevant in this study on the impacts of stone quarry works on riparian vegetation in Rongai Sub-County, Nakuru County.

3.2 Location of the Study

The study area for this research was Rongai Sub-County, located in Nakuru County, Kenya. It is situated along the A104 road and the railway line connecting Nakuru to Uganda with a geographical area of 988 km^2. The Geographical Positioning System (GPS) of the study area are between 0° 3'0.41"S, 35°57'16.17"E and 0°11'50.04"S, 35°50'1.60". The sub-county has an elevation of about 1,912 meters characterized by favorable climate with varied topographical elevations.

Rongai is endowed with an elaborate drainage system consisting of a number of surface and underground water sources including, river Molo, river Rongai, Maji Matamu River, Olbanita and several streams. The rainfall pattern is bi-modal with the short rains falling between October and December and the long rains falling between March and May with an average temperature 29.3^oC. Rongai also falls under AEZ Lower Highlands (LH)

zone with a range of agro-economic activities such as crop farming (wheat, maize, pyrethrum) and ranching (CIDP, 2023-2027).

3.3 Target Household Population and Key informants

Rongai Sub- County is comprised of five wards namely: Mosop, Soin, Menengai West, Solai, and Visoi. According to KNBS (2019), Rongai Sub- County had a total population of 199, 906 people where 99,976 were males and 99, 922 females with a total number of 52,348 households. The study targeted 35,545 head of households in Visoi, Soin and Mosop wards.

These wards were selected using stratified sampling because River Molo flows through them and the primary quarries of interest were situated within their boundaries. Household heads were randomly selected from the three wards to avoid biasness in data collection.

Table 2

Distribution of Population in the Study Area

Ward	Household Heads
Visoi	14,904
Soin	10, 184
Mosop	10,457
Total	35,545

The study also targeted chiefs, NEMA official, Rongai sub-county public health officer and environment officer who were key informants as shown in Table 3.

Table 3

Key Informants

Ward	Category	Number
Mosop (4 locations)	Chiefs	4
Visoi (4 locations)	Chiefs	4
Soin (4 locations)	Chiefs	4
NEMA Official	Sub-county level	1
Public Health Officer	Sub-county level	1
Environment Officer	Sub-county level	1
Total		15

The researcher purposively selected these categories of individuals as key informants because their responsibilities related to the subject of the study and that they possessed rich information and knowledge on the impacts of quarrying on riparian vegetation, level of compliance to existing legislations and possible mechanisms to minimize negative impacts on riparian vegetation.

3.4 Sampling Procedures and Sample Size

The researcher used stratified sampling to select three wards and random sampling technique to select head of households who were engaged during questionnaire survey process. Additionally, purposive sampling was used in identifying key informants for interviews. This technique was appropriate since government officials were targeted to give more insights on the quarrying activities in the area. Proportionate sampling method was employed to determine the head of households' sample for each ward.

3.4.1 Sample size

The study adopted the Yamane formula (1967) to determine its sample size.

$$n = \frac{N}{1+N\,(e\text{^}2)}$$

= 35,545

1+35,545(0.05) ^2

n= 404

Where;

n- Sample size

N- Target population

e- Confidence level (0.05)

Proportionate sampling for each ward

Visoi -14904/35545*100=169

Soin- 10184/35545*100=116

Mosop- 10457/35545*100=119

Table 4

Distribution of Sample Population

Ward	Households	Sample Population
Visoi	14,904	169
Soin	10, 184	116
Mosop	10,457	119
Total	35,545	404
Key Informants		
Chiefs		12
NEMA Official		1
Public health officer		1
Environment Officer		1
Total		15
Sample Population		419

Four hundred and four (404) household heads were randomly selected from Visoi, Soin and Mosop wards where questionnaires were administered to them to gather their views.

Household heads were proportionately distributed between the three wards using proportionate sampling method based on the total number of households for each ward as per the 2019 census. The researcher also considered those not directly involved during data collection process. Fifteen (15) Key informants were purposively selected for interviews from the three wards as shown in Table 4. Five (5) quarrying sites namely chepkeres, Athinai, Olepolos, Kwa Gidy and Mauande were sampled to minimize the cost.

3.5 Instrumentation

Structured questionnaires were administered to 404 head of households in Visoi, Soin and Mosop wards to capture their views. These questionnaires were prepared according to the four objectives of the study with five sections. The researcher and the research assistant at first briefed respondents on the purpose of the study and sought permission before filling the questionnaires. Depending on the need, the researcher and the research assistant also helped respondents in filling the questionnaires based on their responses. The questionnaire was used to collect qualitative data relating to the quarrying activities and their impacts on riparian vegetation.

The identified fifteen key informants including chiefs, NEMA official, Rongai sub-county public health officer and environment officer were interviewed to obtain valuable information for the study. These individuals were involved in overseeing all activities at location and ward level including quarrying. The researcher booked appointment from each individual selected where they were inducted first on the purpose of study and the key areas which were interviewed (when the quarries were established, method of extraction, impacts of quarry operation on riparian vegetation and mechanism taken or to be taken to minimize the impacts).

ArcMap and google earth pro software were used to obtain spatial data through Time series analysis and NDVI to determine the extent of riparian plants and the land-use changes as a result of stone quarrying in the area. Spatial data was obtained from the United States Geographical Survey Earth Explorer where shape files were downloaded. Landsat and Sentinel images were mainly used between 2000- 2023. Using ArcMap GIS software, unsupervised image classification map was generated showing the land use and land cover trends during the research period. The NDVI values were then subjected to hyper spectral analysis to generate NDVI trend curve between 2000-2023.

The information was also sourced from Kenya National Bureau of Statistics and Kenya Meteorological department majorly on Rongai sub-county occupation trends and climatic conditions respectively. During data collection, the research took ground photographs to show the state of quarrying activities and their impacts on adjacent riparian vegetation. Additionally, observation checklist was utilized to inform on the specific impacts of quarrying. This was also useful in ensuring that adequate data was acquired for each objective.

3.5.1 Pilot Study

A pilot study was conducted in Kampi ya Moto location where 15 number of household heads were randomly selected for the small-scale preliminary study. Kampi ya Moto was purposely selected for the pilot study because it had high number of households and river Molo traverses the area. Out of several quarries located in Kampi ya Moto were Junction quarry was selected for the pilot study. The head of household selected as respondents during the pilot study were identified to ensure that they were not selected during the actual study period.

3.5.2 Validity and Reliability of Instrument

According to Mugenda & Mugenda (2003) accuracy and meaningfulness of research instruments must be determined to ensure consistency and reduced errors and ambiguity during data collection, coding and analysis. Validation was achieved by developing well-structured instrumentation designs aligned with the objectives of the study and thorough consultation with the supervisors and statistician to access relevance of the research instruments to avoid errors and inconsistencies.

The data obtained during the pilot study was subjected to a reliability test using Cronbach's alpha coefficient (Kothari, 2004). The test yielded an alpha coefficient of 0.7, indicating an acceptable level of internal consistency for the research instrument. Cronbach's alpha is a measure of the internal consistency or reliability of a set of items or questions in a survey or test. It ranges from 0 to 1, with higher values indicating greater internal consistency.

3.6 Data Collection Procedures

The researcher visited the chiefs in their respective offices within the study area to present introductory letter from the university and research permit from National Commission for Science, Technology and Innovation (NACOSTI). The researcher and the research assistant sought the consent of respondents before administering questionnaires by briefing them on the purpose of the study, seeking their permission to participate. Using random sampling, 404 head of households were approached and questionnaires administered to those who voluntarily agree to participate.

Some respondents (head of households) were assisted by the researcher and the research assistant in filling the questionnaires while others were allowed to fill on their own. To ensure good percentage of returned filled questionnaires, the researcher monitored

questionnaires by keeping records of every administered questionnaire and giving prior instruction on how to return questionnaires after filling.

The 15 key informant who were purposively selected were informed prior to the interview dates and appointments acquired. Areas of concern including when the quarries were established, method of extraction, impacts of quarry operation on riparian vegetation and mechanism taken or to be taken to minimize the impacts were communicated to all key informants on time. The researcher briefed the key informants before undertaking interviews and adequately assured them their data protection and privacy. Access to the data was restricted to authorized personnel only (Researcher) and any identifying information were removed before data analysis. Moreover, all data were securely discarded after the completion of the study.

During data collection process, the researcher visited Chepkeres, Athinai, Olepolos, Kwa Gidy and Mauande quarry sites after getting permission from the quarry owners. The researcher requested the quarry owners to use site offices to conduct questionnaire surveys during lunch hours to reduce risks. The research utilized oblique photography and observation checklist to capture the required information during the site visit. The researcher and the research assistant wore helmets and safety boots while in the quarries. Quarry managers gave safety briefs and precautions to ensure safety while in the quarry sites.

3.7 Data Analysis and Presentation

Analysis for objective one (1) was conducted using Geographical Information System., ArcMap software was utilized to calculate the Normalized Difference Vegetation Index (NDVI) from satellite imagery, which assessed vegetation health and cover changes over time. NDVI values, derived from Landsat satellite images, facilitated a time series

analysis to identify trends in vegetation health, capturing seasonal variations and long-term changes.

Additionally, the Statistical Package for Social Sciences (SPSS version 27) was employed to analysis data for objective 2, 3 and 4, where descriptive statistics were used to summarize the characteristics of the collected data and correlation analyses to examine relationships between variables of the study. A Likert-type scale was also used to gauge perceptions of the impacts of stone quarrying on riparian vegetation and the proposed measure to curb negative impacts of stone quarrying on riparian vegetation using means and standard deviation.

3.8 Ethical Considerations

The researcher obtained an ethical clearance from Kabarak University and thereafter sought a research permit from the National Commission of Science, Technology and Innovation. The permit was then presented to the chiefs of the respective areas and the key informants before undertaking the study.

The researcher and the research assistant sought the consent of respondents before administering questionnaires and interviews by briefing them on the purpose of the study and seeking their consent to participate. The researcher adequately assured all respondents of their data protection and privacy by restricting data access to authorized personnel only and ensuring that all the data were securely discarded after the completion of the study.

CHAPTER FOUR

DATA ANALYSIS, PRESENTATION AND DISCUSSION

4.1 Introduction

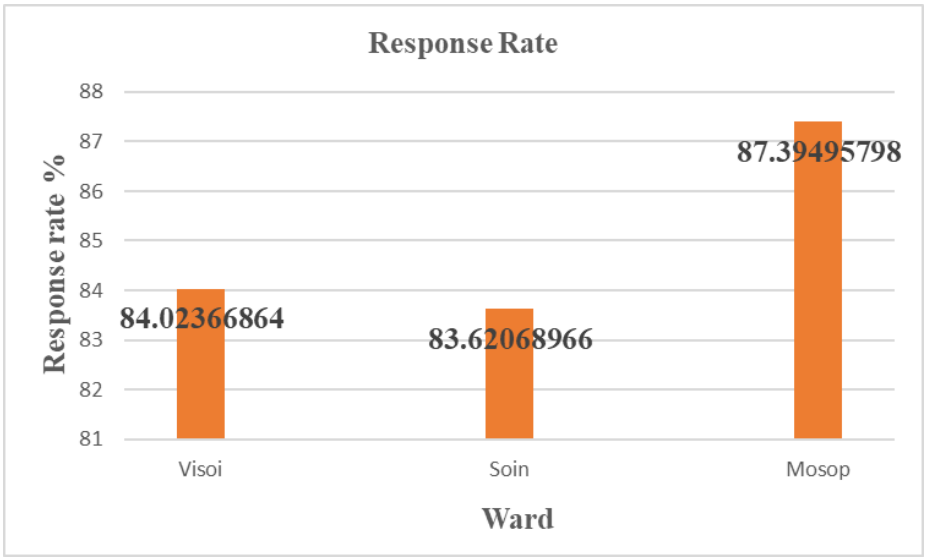
This Chapter encompasses the findings, interpretations and discussion on the effects of stone quarry works on riparian vegetation along River Molo in Rongai Sub- County. The discussions revolve around the four objectives of this study.

4.2 Response Rate

The researcher administered questionnaires during data collection and an average of 85% response rate was recorded. Mosop ward was leading with a response rate of 87%, followed by Visoi with 84% and lastly, Soin with 83% as shown in Figure 2 below. Based on Mugenda and Mugenda (2003) findings, a response rate of above 70% is considered as very good. The slight lower rates recorded for Soin ward was attributed to the vastness of the ward with major challenges in road accessibility and hot temperatures. All 15 key informants were also interviewed with 100% success. This was achieved because all selected key informants were contacted prior to the data collection were the researcher sought appointment dates convenient to them.

Figure 2

Response Rate Graph



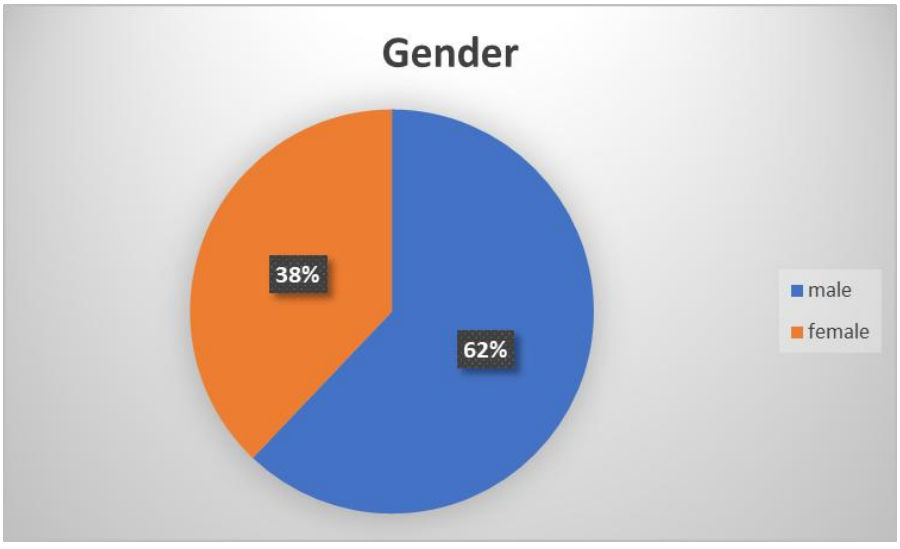
4.3 Demographic Characteristics

Demographic data represented respondents' information on gender, age, educational level and occupation.

4.3.1 Respondents by Gender

Figure 3

Respondents by Gender



As depicted in the Figure 3, male constituted 62% out of the 343 respondents and 38% represented women. This disparity was largely attributed to the fact that most household heads in the study area were male hence affecting decision-making processes regarding land use and environmental management.

The predominance of male household heads often correlates with a higher engagement in quarrying activities, as men are typically more involved in off-farm employment and resource extraction. This is attributed to increased pressure on riparian zones, as male-dominated households may prioritize economic gains from quarrying over the conservation of vegetation.

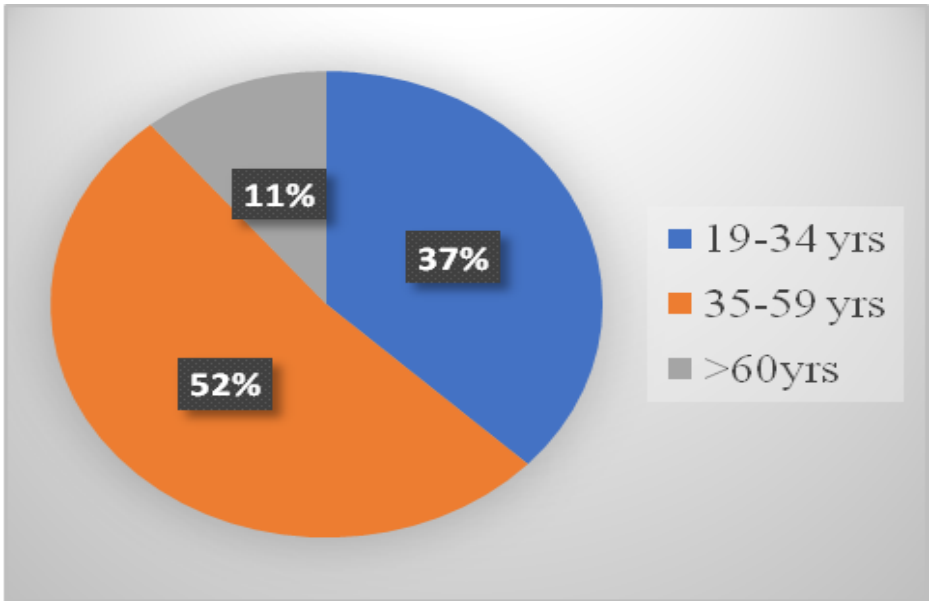
According to Mirzabaev et al. (2019), gender influences land-use decisions, with men more likely to adopt practices that may degrade riparian ecosystems due to their focus on immediate economic benefits. The gender dynamics within households significantly influence the management of riparian vegetation and the impacts of quarrying activities.

4.3.2 Respondents by Age

The research found that 19-34 yrs category constituted 127 (37%) of the respondents, 178 (52%) respondents were aged between 35-59 yrs, and 38 (11%) >60 yrs category as indicated in Figure 4. The age group of 35-59, seemed more involved in economic activities and decision making related to quarrying activities in Rongai especially on land use issues. According to Muhoma (2014), while younger individuals (25-35 years) were actively participating in off – farm activities such as quarrying in Rongai, the older demographic (35-59 years) plays a crucial role in decision-making processes related to land use and agricultural practices.

Figure 4

Representation of Respondents' Age



4.3.3 Educational Level of the Respondents

The research's findings showed that 45% of the respondents attained secondary education. Respondents who were privileged to attain tertiary education were 39% and 16% only got primary level education. The primary level education covered those who finished and got Kenya Primary School Education certificate and those who joined but dropped on the way.

Table 5

Educational Level of Respondents

Educational level	Number of Respondents	Percentage
primary	55	16
secondary	154	45
tertiary	134	39
Total	343	100

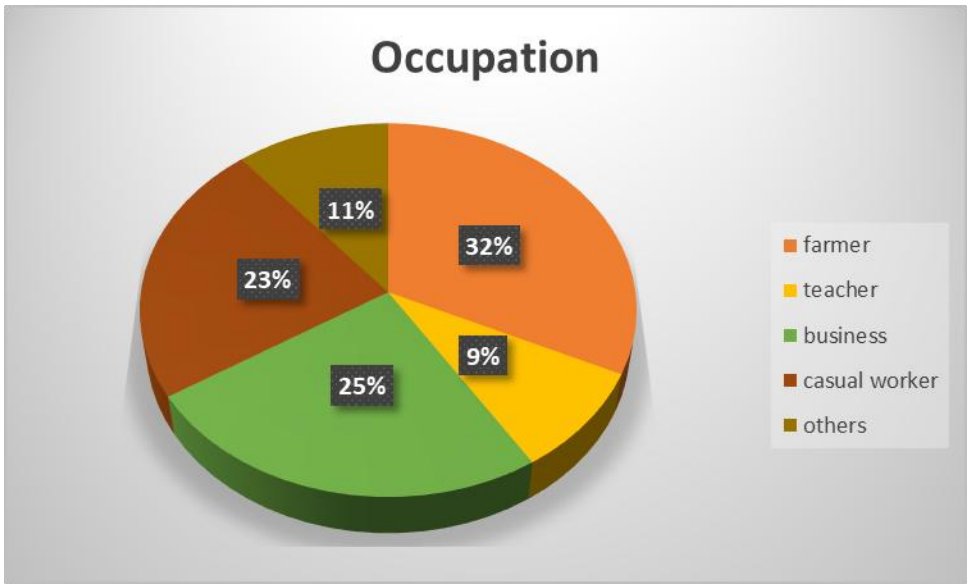
Higher education levels are often associated with greater environmental awareness and advocacy for sustainable practices. Educated individuals are more likely to understand the long-term consequences of quarrying on riparian ecosystems and advocate for measures to protect these vital areas (Xie et al., 2019). Conversely, lower education levels may correlate with a lack of awareness regarding the environmental impacts of quarrying, leading to greater acceptance of practices that degrade riparian vegetation.

4.3.4 Occupation of the Respondents

Respondents were distributed in different occupations where 110 (32%) were farmers, 85 (25%) business people, 79 (23%) casual labourers, 31 (9%) teachers and 38 (11%) in other occupations as shown in Figure 5.

Figure 5

Occupation of the Respondents



Many casual laborers in the area found employment in quarrying sector owing to the many existing quarries. Additionally, a significant portion of business people were engaged in transportation of building stones and others being middle men and women between the quarry owners and the end consumer. While quarry owners may benefit

significantly from profits, local workers often earn low wages, leading to disparities in wealth distribution within communities. (Wambua, 2021).

The dry climatic conditions in the area limited most farmers to engaging in farming activities only during the rainy seasons, prompting them to seek alternative sources of income in quarrying sector to support their families. This implied that the many people from within and outside the study area depended on quarrying sector as a source of income hence accelerating the destruction of riparian vegetation.

4.4 Findings on River Molo Riparian Vegetation Status between 2000- 2023

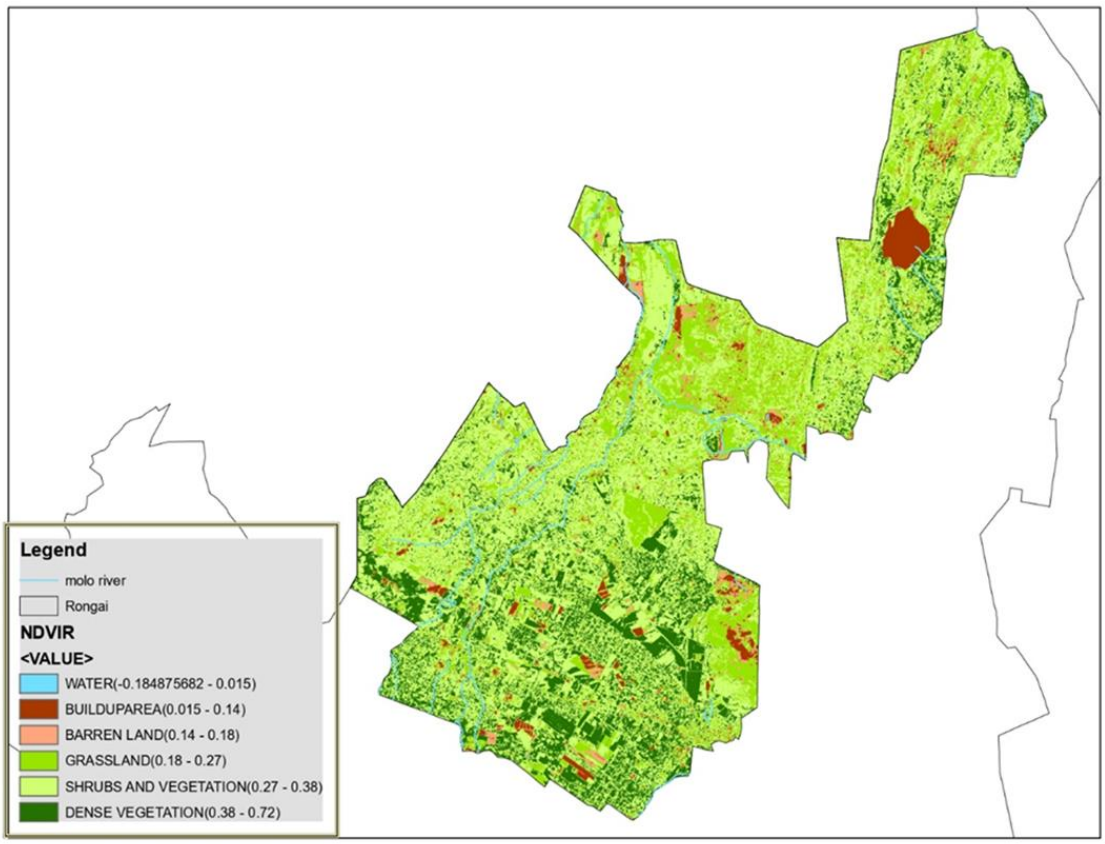
The spatial data used in the study were obtained from the United States Geological Survey (USGS) Earth Explorer platform accessed through (https:// earth explorer. usgs. gov/.). The satellite images covered between 2000 and 2023 were acquired from Landsat 8 and sentinel 2 with high resolution and multispectral capabilities suitable for environmental and vegetation studies.

Bands 4 (Red) and 5 (Near Infrared) were used to calculate NDVI values, which measure vegetation health and density. Unsupervised map Classification was performed because of time limitation and the high capability of algorithm to classify bands based on the satellite imagery especially in areas with lower land use land cover classification

This is shown in Figure 6.

Figure 6

Rongai Land use Map 2024



From the map, vegetation is denser in the northern and central areas (dark green), highlighting areas with healthy riparian zones and forested regions. Grassland and shrub lands dominate the landscape, indicating semi-arid conditions. Built-up areas are scattered, suggesting localized human settlement and infrastructure.

This map categorized the land uses into different types based on their NDVI values, which reflect the density and health of vegetation. The categories included water, built-up areas, barren land, grassland and agriculture, shrubs and sparse vegetation and dense vegetation. From the map, it is also evident that there were barren areas along the riparian zone of River Molo indicating human interference including farming and quarrying activities.

In a similar research conducted by Barchok et al. (2024) revealed an increase in non-vegetation cover class by 18.70% between the years 1985 and 1995 and reduced vegetation cover by 18.24% between 2010 and 2022, leading to land degradation and reduced aesthetic value in Narok.

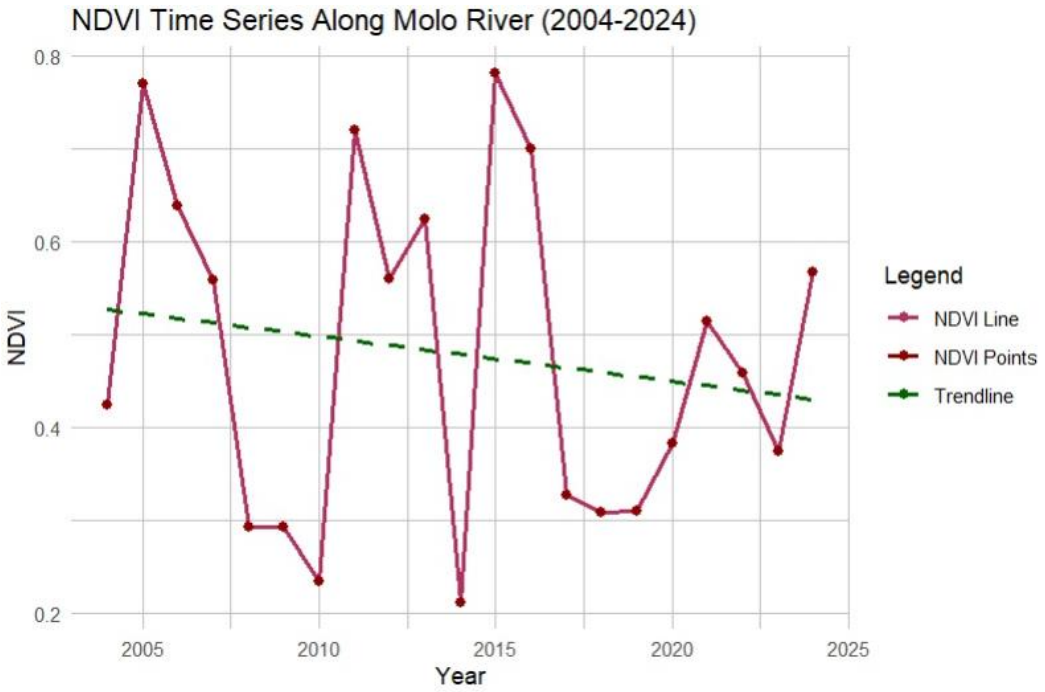
Ren et al. (2019) study also emphasized that human activities, such quarrying, significantly affect the structure and function of riparian ecosystems leaving the land exposed, hence corroborating with the results above.

4.4.1 Normalized Difference Vegetation Index Time Series along River Molo

The NDVI data shown in Figure 7 was obtained through time series analysis of satellite imagery between 2000-2023.

Figure 7

Normalized Difference Vegetation Index



The imagery was subjected to hyperspectral analysis using ArcMap with huge focus on variation in reflectance, topography and vegetation along River Molo. Figure 8 shows

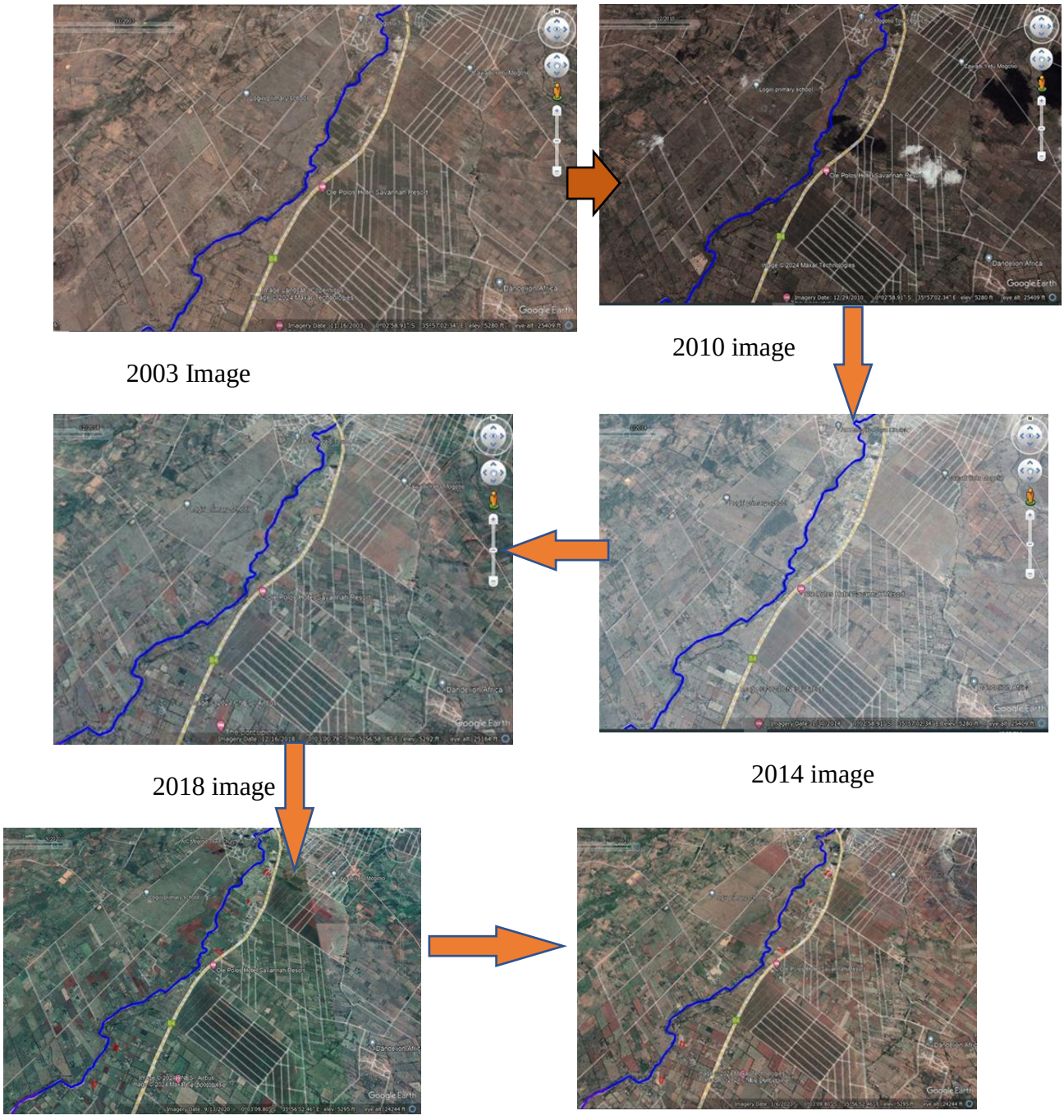
the down sloping trendline suggesting a decline in NDVI between the timeframe. The decline is largely attributed to stone quarrying activities along the riparian areas of River Molo. The NDVI curve finding is consistent with the findings by Ruto et al. (2023) which indicated that anthropogenic activities (grazing, crop farming and quarrying) fragmented riparian forests, resulting in reduced NDVI values.

4.4.2 Satellite Images of Athinai Area between 2000-2023

Figure 8 shows the satellite images for 2003, 2010, 2014 and 2018. The images were retrieved from Google earth pro software. The four years were chosen based on the existing Landsat and sentinel images. The images depict the gradual transformation of the vegetation over time, which can be attributed to human-induced activities in the region. However, quarrying operations were not extensive during this period, as manual labor was the sole method employed for extraction purposes.

Figure 8

Satellite images of Athinai Area between 2000-2023



The mechanization of quarrying activities in the region commenced between 2019 and 2020, marking a significant shift in the scale and intensity of operations. This transition to mechanized methods has led to observable changes in the landscape, particularly

evident through the excavation of topsoil. The removal of topsoil not only disrupts the natural habitat but also exposes underlying soil layers, which can alter local ecosystems.

In 2023, it is also evident that quarrying activities expanded due to change in soil color from dark to pale yellow indicating deeper extraction processes. This suggests that the extraction is penetrating beyond the surface layer potentially reaching subsoil or bedrock. Such deep excavation can have profound implications for the environment, including increased erosion, sedimentation in nearby water bodies, and disruption of groundwater recharge processes.

4.4.3 Tree/Shrub Species along the Riparian Areas of River Molo

During field visits the researcher observed several tree species along River Molo which were scattered in some areas and densely populated in other areas. The few sampled common tree species noted were as shown in the Table 6.

Table 6

Tree Species along River Molo

Scientific Name	Local Name	Pictorial
Euphorbia candelabrum	Kuresye	
Markemia lutea	Nile tulip	
Vangueria madagascariensis	Komolwee	

Ficus spp	Lokoiyee	
Vachelia xanthphloea	Acacia (Sesye)	
Terminalia brownii	Koloswee	

4.5 Findings on Awareness on Impacts of Stone Quarrying on Riparian Vegetation

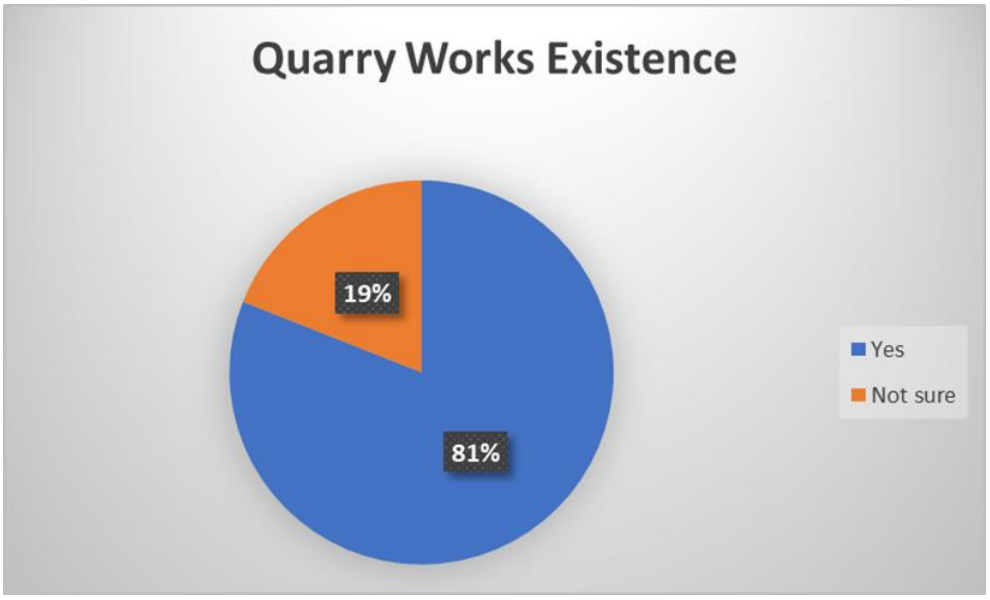
This sub section covers the level of awareness of stone quarrying on riparian vegetation among respondents and key informants.

4.5.1 Level of Awareness of Quarry Works Existence

Respondents were asked whether they were aware of the existing quarrying activities in their locality where 81% agreed that quarrying activities were going on whereas 19 % were not sure whether there were quarries in their area as shown in Figure 9.

Figure 9

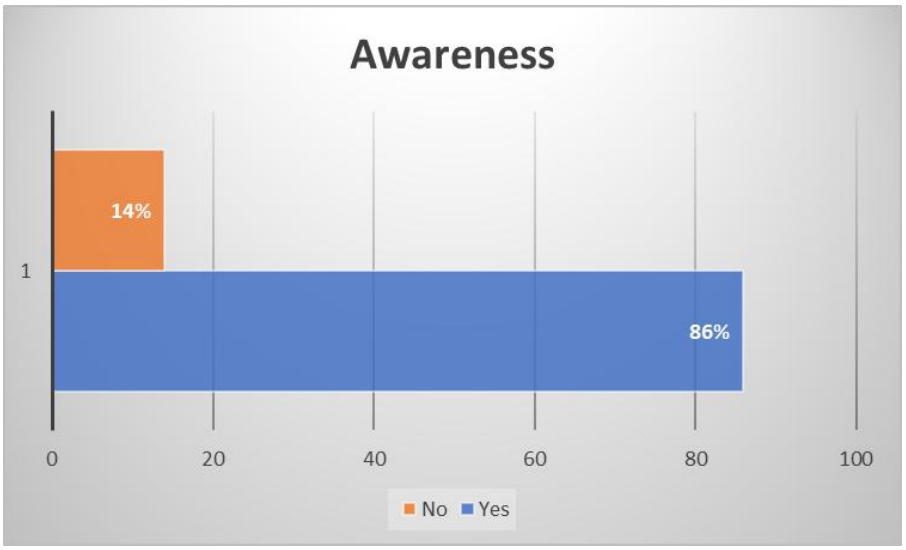
Quarry Works Existence



As indicated in Figure 10 majority (86%) of respondents were aware of the impacts caused by the ongoing quarry activities on R. Molo riparian vegetation. A smaller proportion (14%) of respondents were not aware of the impacts caused by the quarry works on riparian vegetation in R. Molo.

Figure 10

Level of Awareness on Impacts of Stone Quarrying on Riparian Vegetation



All key informants indicated that they were aware of the ongoing quarrying activities in the area. Two out of fifteen revealed that they had visited the quarry sites for inspection. However, they all acknowledged that it was difficult to keep track on the daily activities happening in the quarries due to the vastness and the limited transportation means.

It was noted that most respondent got the information of the ongoing quarrying activities in the area from observation not formal information that emanated from the chief and other community leaders through public forum such as barazas.

These finding was against Eshiwani (2014) and Nyakeniga (2009), where they suggested that communities with higher levels of awareness regarding the environmental impacts of quarrying were more proactive in monitoring quarrying activities, advocating for better environmental practices as well as seeking alternative livelihoods and sustainable practices.

4.5.2 Correlation between Education Level of Respondents and Level of Awareness

Correlation was used to establish whether there was any relationship between the level of education of respondents and the level of awareness on impacts of stone quarrying on riparian vegetation as presented in Table 7.

Table 7

Correlation between Education of Respondents and Level of Awareness on stone Quarrying

		Education	Awareness
Education	Pearson Correlation		.073
	Sig. (2-tailed)		.472
	N		343
Awareness	Pearson Correlation	.073	
	Sig. (2-tailed)	.472	
	N	343	

The Pearson correlation coefficient between education and awareness was p= .073. This indicated that there was no significant linear relationship between education of respondents and level of awareness on stone quarry effects on riparian vegetation.

Contrary, research conducted by Onyango & Opiyo (2021) in the Lake Victoria Basin found that community perceptions of watershed degradation were significantly influenced by educational levels, with more educated individuals demonstrating a better understanding of the impacts of activities like quarrying on riparian ecosystems.

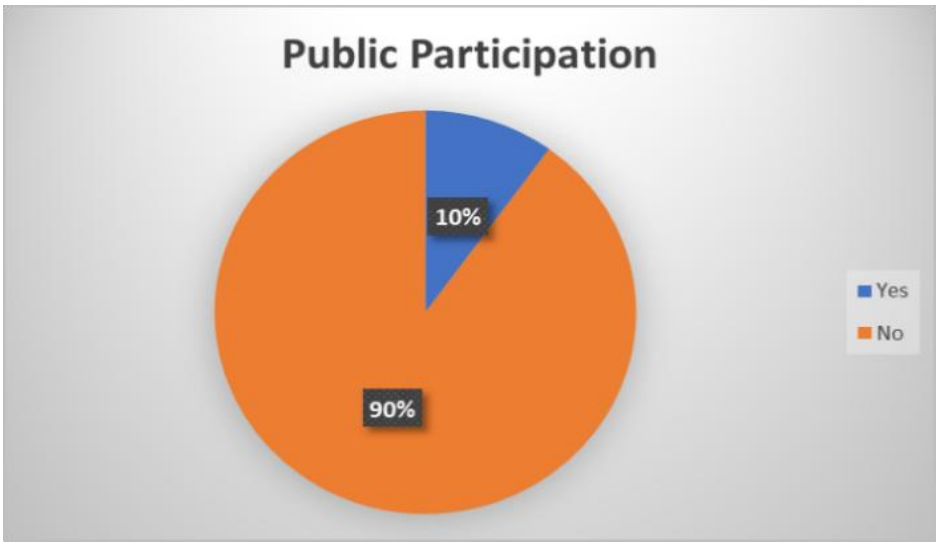
4.5.3 Public Participation

From the Figure 11, 10% of the total respondents agreed that they had received public education on the impacts of stone quarrying on vegetation and the entire environment. On the other, 90% responded that they had not received any form of public education regarding impacts of quarrying on vegetation and the entire environment. The researcher

found that respondents who had received public education were facilitated through workshops organized by NGOs, such as World Vision.

Figure 11

Public Participation



4.5.4 Correlation Between Public Participation and Stone Quarry Impacts

A Pearson correlation was performed to examine the relationship between public participation and impacts of stone quarrying on riparian vegetation as shown in Table 8.

Table 8

Correlation between Public Participation and Stone Quarry Impacts

		Education	Awareness
Public Participation	Pearson Correlation		-412
	Sig. (2-tailed)		.000
	N		343
Impacts	Pearson Correlation	.-412	
	Sig. (2-tailed)	..000	
	N	343	

There was a significant negative correlation between public participation on impacts of stone quarry works on riparian vegetation and the impacts of stone quarry works on riparian vegetation in the study area. From the table 10 above $p=-0.412$ which implied that the low level of public education resulted to increased impacts of stone quarrying on riparian vegetation.

These results are supported by findings by Kibii (2020) which highlighted that awareness and public participation of environmental regulations significantly influences community responses to quarrying activities. Additionally, communities with higher awareness levels were more likely to engage in advocacy for environmental protection and compliance with regulations, leading to reduced impacts on the environment.

4.6 Findings on the Perceived Impacts of Stone Quarry Work on River Molo Riparian Vegetation

As depicted In Table 9 and Figure 12, the researcher used Remote sensing (Google earth pro) to determine the Geographical Positioning System of the five quarries in the study area.

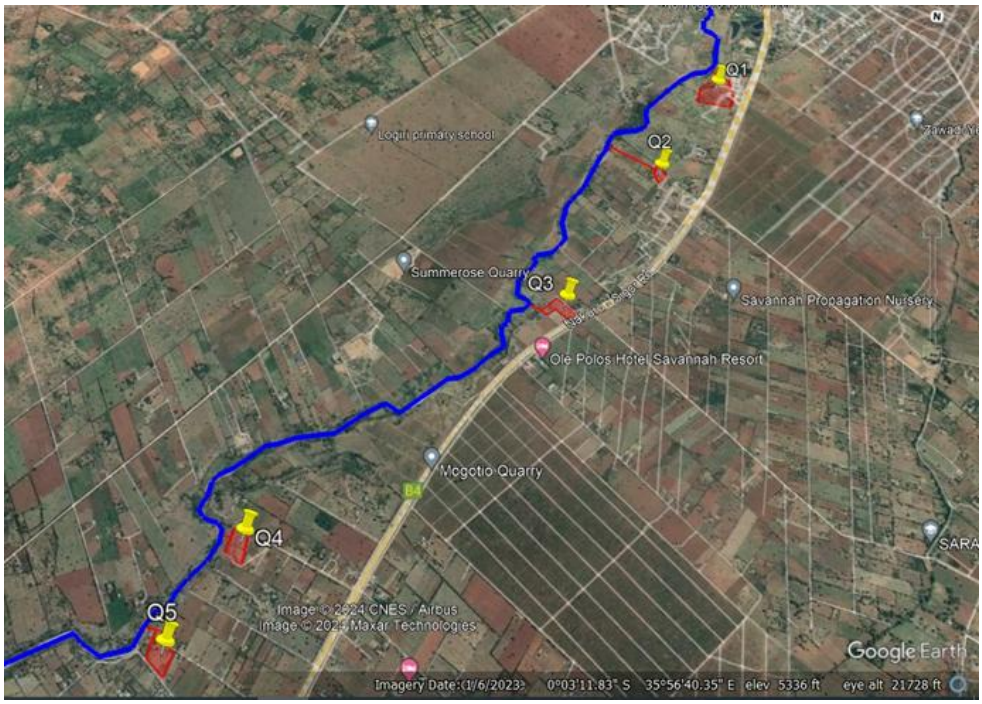
Table 9

Details of the Quarries

S/No	Name	GPS Coordinates	Area coverage (ha)	Proximity to the River(meters)	Status
1.	Chepkeres	0°2'3.56"S 35°57'43.73"E	3.74	91.92	Inactive
2.	Athinai	0° 2'26.96"S 35°57'31.81"E	0.48	323.42	Active
3.	Olepolos	0° 2'59.24"S 35°57'14.27"E	1.10	78.73	Active
4.	Kwa Gidy	0° 3'49.32"S 35°56'24.53"E	1.32	49.99	Active
5.	Mauande	0° 4'7.96"S 35°56'15.66"E	1.49	49.48	Active

Figure 12

Satellite Imagery Showing the Location of the Quarries



The distance between R. Molo and the quarries and the area of coverage in hectares for each quarry was also established as shown in table 9. It was established that Chepkeres quarry was the leading in area of coverage with a total of 3.74 Ha and Athinai being the least with 0.48 Ha. Moreover, Mauande recorded the lowest proximal distance to the river with 49.48 meters whereas Athinai was the furthest with proximal distance of 324.42 meters. During field visit and observation, the researcher also established that all the five quarries were active except Chepkeres quarry which had been abandoned. However, the researcher did not establish as to why the quarry was abandoned.

According to Environmental Management and Coordination Act (2015 amended) and Water Act (2016) the riparian buffer zone should be a minimum of six meters and a maximum of 30 meters from the highest recorded flood level. For the case of highly impactful activities such as quarrying (as stipulated in EMCA, 2015 Schedule two), proponent should initiate a comprehensive environmental Impact Assessment study

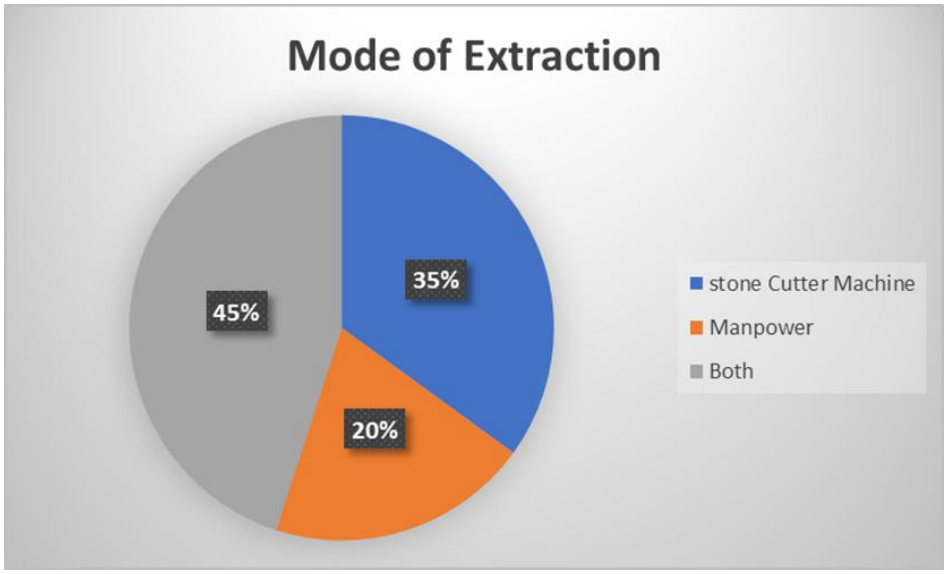
before commencing any quarrying activities. EIA expert should undertake a comprehensive screening process to establish the proximity of the proposed quarry to the riparian areas and recommend whether to proceed or look for an alternative site.

4.6.1 Mode of Extraction

Figure 13 shows the different methods used in extraction of building stones in the study area where 20% of the sampled household heads indicated that manpower was used to extract stones, 35% stone cutting machines and 45% both methods were used.

Figure 13

Mode of Extraction



These findings were in concurrence with the information obtained from the key informants. The key informants indicated that quarrying activities began early 1980s where manpower was used. However, towards 2018 the quarry owners introduced stone cutting machines which accelerated processes of extraction to meet the demand. During field visits, the researcher established that stone cutting machines were used to cut the rocks and other remaining processed were done by the quarry workers as shown in Figure 14.

Figure 14

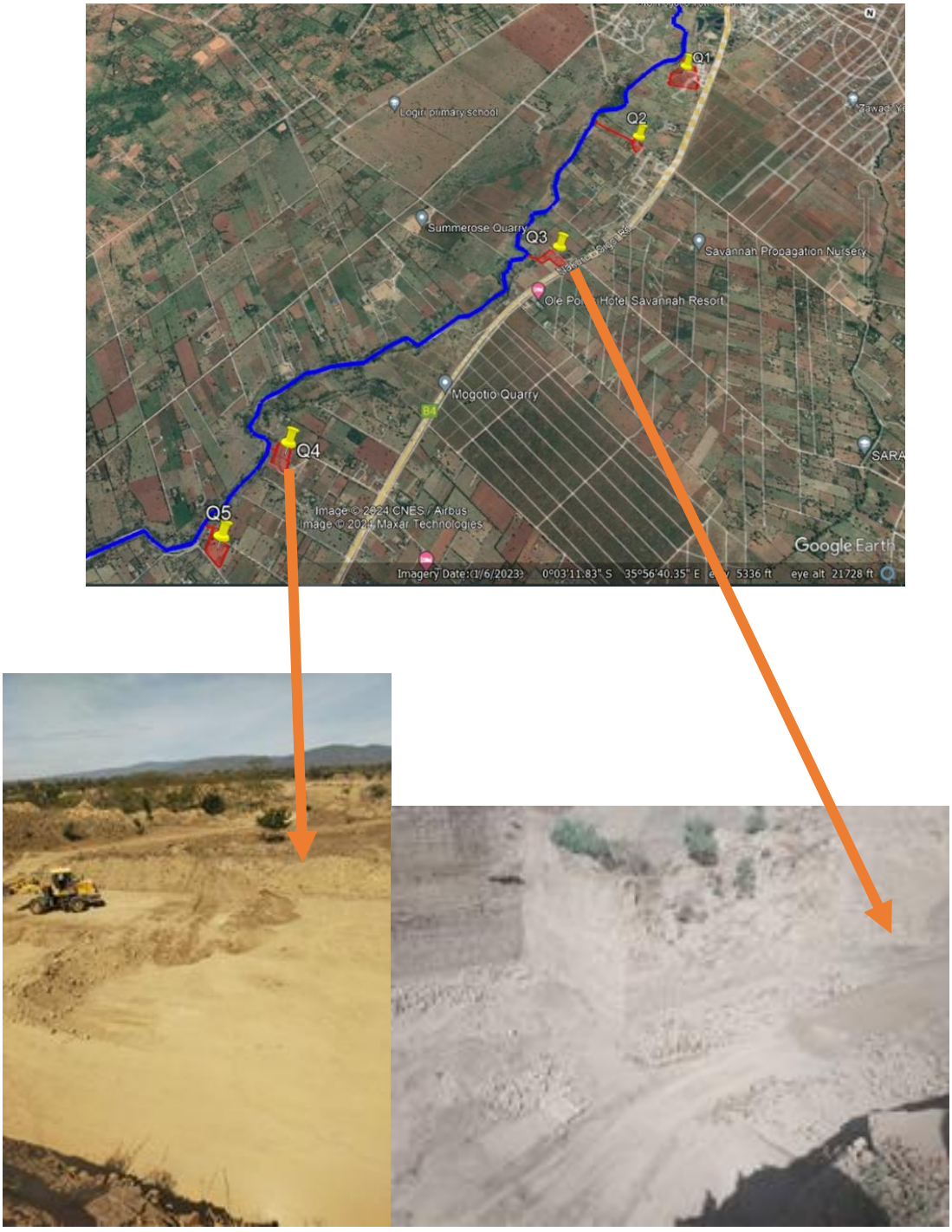
Stone Cutting by Machine and Quarry Workers

The Figure 14 shows the extent of stone extraction in Q3 and Q4 where existing trees and shrubs were uprooted to pave way for extraction processes. It was also noted that deep cuts were existing showing no adherence to sustainable extraction methods as prescribed by NEMA. The researcher also observed a lot of dust emissions emanating from quarry operation which significantly affected photosynthesis by blocking stomata in plant leaves.

The extend of stone extraction in the quarries has been shown in Figure 15.

Figure 15

Pictorial Presentation of the Quarries and Mode of Extraction

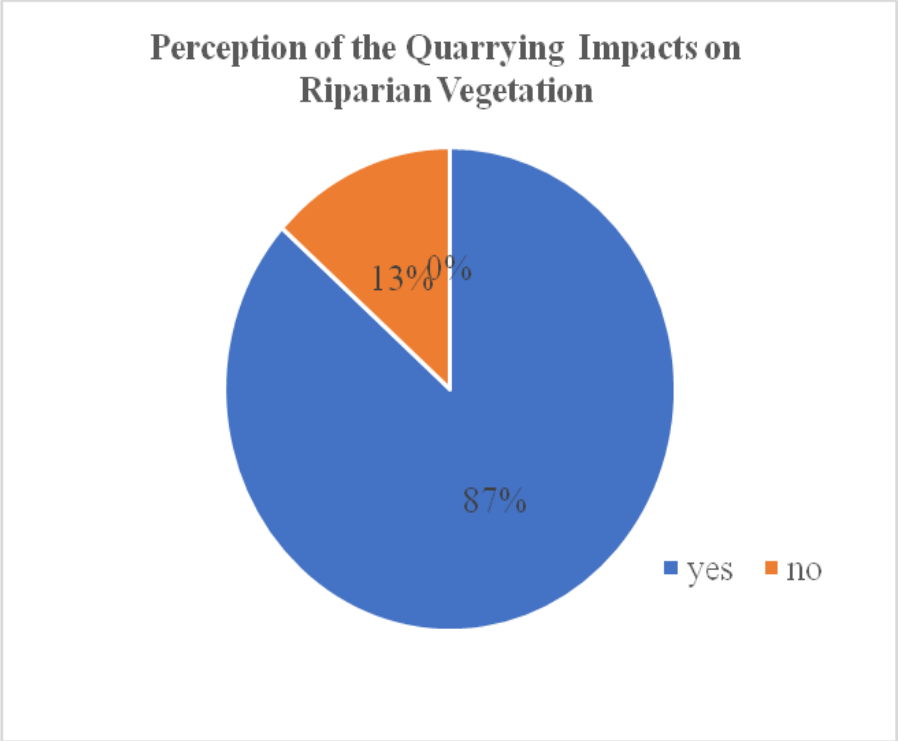


4.6.2 Perception of Stone Quarrying on Riparian Vegetation

Figure 16 indicated a strong majority of 87% of respondents perceiving stone quarrying as having a negative impact on riparian vegetation of River Molo. Additionally, 13% of respondents did not see stone quarrying as detrimental to the riparian vegetation in the study area.

Figure 16

Perceived Impacts of Stone Quarrying on Riparian Vegetation



The survey results showed a strong consensus among respondents regarding the environmental impacts of stone quarrying on riparian vegetation of River Molo.

Table 10

Household head's Perception towards the Impacts of Stone Quarrying on Riparian Vegetation

Statement	Strongly Disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly Agree (%)	Mean	Standard Deviation	Perception
Quarrying leads to changes in riparian vegetation cover and creation of barren land.	0.58	2.04	0	13.12	84.26	4.78	0.6	Very High
Quarrying reduces natural regeneration of vegetation.	4.37	9.33	2.92	29.15	54.23	4.2	1.14	High
Quarrying results in the felling of riparian trees.	0	0.58	0	5.83	93.59	4.92	0.32	Very High
Quarrying contributes to soil erosion.	0.29	1.46	2.92	32.94	62.39	4.56	0.65	High
Average								4.165

Table 10 indicated a weighted average = 4.615 for all the four statements. Statement one on changes on riparian vegetation cover recorded a mean of 4.78 and a standard deviation (SD) of 0.60 suggesting a very high perception that quarrying significantly changes vegetation cover along the river.

Statement two on reduction in natural regeneration of riparian vegetation scored a mean of 4.20 and SD of 1.14 hence falling below the weighed mean. This therefore implied a high perception on reduced natural regeneration of riparian vegetation as a result of stone quarrying.

The third statement on felling of riparian trees recorded a mean of 4.92 and a SD of 0.32 indicating a very high perception that quarrying leads to the removal of trees near the riparian areas. Lastly, the fourth statement on soil erosion scored a mean of 4.56 and a SD of 0.65 showing high perception that quarrying resulted to soil erosion which greatly affected riparian vegetation health and growth.

Additionally, all fifteen (15) key informants confirmed that most of the quarries fell trees to allow space for expansion and the overburden generated were heaped unsustainably affecting the rate of natural regeneration of trees particularly grasses and low-lying herbaceous plants. Similarly, quarrying activities led to chlorosis (loss or reduction of chlorophyll leading to yellowing of leaf) in plants corroborating to the findings by Moilinga & Athian, (2023) which concluded that quarrying activities led to the destruction and removal of local vegetation, particularly grasses and low-lying herbaceous plantsin Mount Korok in South Sudan. Furthermore, Omondi *et al.,* (2020) documented how the extraction of materials led to the creation of deep gullies and barren landscapes, which negatively impacted local ecosystems and biodiversity in Lake Victoria Basin. Another study by Muthee (2017) in Kenya's central highlands indicated disruption of key riparian species through soil erosion as a result of stone quarrying.

The findings are also supported by Kamran & Siddique (2020); Shah &Sah (2018 who found that quarrying activities led to reduced vegetation, soil erosion and felling of trees which appeared to be the immediate repercussions of quarrying. In the contrary, Ogunbode & Ifatimehin (2013) in Nigeria suggested that application of stone quarrying best practices could mitigate all related environmental damage especially along riverine areas.

Taken together, these findings suggest that stone quarrying has had detrimental effects on the riparian vegetation, leading to deforestation, disruption of natural ecological processes, soil degradation, and reduced natural regeneration among riparian vegetation communities.

4.7 Findings on Measures to Curb Negative Impacts of Stone Quarrying Activities

Table 11

Perceived Measure to Curb Negative Impacts

Statement	Strongly Disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly Agree (%)	Mean	Std Dev	Decision
Rehabilitation and reclamation of quarries lead to enhanced ecological balance in riparian ecosystems.	0	1.75	7.87	16.33	74.05	4.63	0.7	SA
Proper disposal of quarry overburden leads to increased natural regeneration.	0	4.08	8.75	25.07	62.1	4.45	0.82	Agree
Planting of trees and grasses improves the functionality of riparian vegetation.	0.58	0	3.5	9.33	86.59	4.81	0.54	SA
Public participation leads to reduced impacts of quarrying on riparian vegetation.	0	0.58	0.87	19.83	78.72	4.77	0.48	SA
Enactment of Nakuru County quarrying laws leads to sustainable quarrying practices	0	0	10.2	31.78	58.02	4.48	0.67	Agree
Average								4.628

The first statement on rehabilitation and reclamation of quarries scored a mean of 4.63 and SD of 0.7 indicating a strong agreement among the respondents. This suggests that

environmental restoration in quarry areas is seen as a critical step for conserving riparian ecosystems. This finding is supported by Singh & Anbalagan (2018) where they found that proper rehabilitation through soil stabilization and planting of trees significantly enhances riparian biodiversity and water quality. On the contrary, Koptseva & Egorov (2017) acknowledged the need for a combination of natural recovery and artificial restoration techniques to achieve successful vegetation rehabilitation.

Proper disposal of quarry overburden scored a Mean of 4.45 and SD 0.82 below the weighted average indicating that respondent agreed to the nation that proper disposal of quarry overburden leads to increased natural regeneration. This agrees with Farrant et al. (2017) findings which stated that inappropriate disposal of quarry overburden can lead to habitat loss and water pollution, while responsible disposal helps improve soil quality and promotes plant growth in degraded areas.

The third statement on planting of trees and grasses improves the functionality of riparian vegetation a Strong Agreement (Mean = 4.81, SD = 0.54) which demonstrated that most respondents believed that planting vegetation enhances riparian functionality and supporting ecological services such as water filtration, erosion control, and habitat provision. Comparably, Dosskey et al. (2010) showed that replanting efforts significantly contribute to improving riparian ecosystems by stabilizing soils and reducing nutrient runoff.

The fourth notion on public participation leads to reduced impacts of quarrying on riparian vegetation scored a Mean = 4.77 and SD = 0.48 above the weighted mean which implied that there was a strong agreement that if more public participation were undertaken the effects of stone quarrying on riparian vegetation would reduce significantly. Equally, Reed (2008) found that participatory approaches lead to better

compliance with environmental regulations and stronger local stewardship of ecosystems.

The First statement on the enactment of Nakuru County quarrying laws had a mean = 4.48, SD = 0.67 which implied that respondents agreed to the notion. However, Patel et al. (2016), argued that regulatory gaps and corruption can undermine the effectiveness of well-intentioned policies.

The findings from the 15 key informants revealed a strong consensus on the need for compliance with excavation procedures as outlined by the National Environment Management Authority (NEMA) guidelines on land use management. They emphasized the importance of planting adaptable trees, shrubs, and grasses to protect and enhance the riverine ecosystem. Furthermore, the informants advocated for the reclamation of quarry sites prior to decommissioning to mitigate the environmental impacts associated with quarrying activities.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter encompasses the summary of the findings on the impacts of stone quarrying on riparian vegetation of river Molo in Rongai Sub-County. The section also covers conclusion and the recommendation of the research study.

5.2 Summary of the Findings

The study revealed that most respondents in the study area were males with 62% and females being 38%. The larger proportion of the respondents' age (52%) fall between 35- 59yrs followed by 19-34yrs with (37%) and lastly >60yrs representing (11%). This indicated that most of the household heads in the study area were between 19-59 yrs which is the working age according to KNBS (2019).

The research also indicated that majority of the respondents had obtained a secondary education at 45% followed by tertiary education at 39% and lastly primary education at 16%. In connection to this, 32% of the respondents were farmers, 25% were business people, 23% casual workers including those who worked at the quarry sites, 11% other occupations and 9% were teachers. Correlation analysis also demonstrated no significant linear correlation of p= .073 between level of education of the respondents and the level of awareness on the impacts of stone quarrying on riparian vegetation of River Molo.

5.2.1 Riparian Vegetation Status between 2000-2023

Objective one findings on riparian vegetation status between 2000-2023 indicated that there was a gradual decline in the Nominalized Difference Vegetation Index of the study area within the timeframe. Rongai Sub- County land use classification map categorized land use and land cover into water bodies (rivers, ponds and water pans), built up areas,

barren land, grassland and agriculture, shrubs and sparse vegetation and dense vegetation. It was also evident that there were barren areas along the riparian zones of river Molo which indicated human interference through agriculture and quarrying activities. The results corroborate with findings by Ruto*et al*. (2023) which found that land use changes were decreasing riparian forest species and structure. The satellite images between 2020-2023 indicate clear evidence of ongoing quarrying activities which were accelerated by introduction of stone cutting machines to meet the growing demand of building stones.

The common tree species found during field visits were *Euphorbia candelabrum, Markemia lutea, Vangueria madagascariensis, Ficus species Vachelia xanthphloea* and *Terminalia brownii* among other species. These trees were most adapted to the climatic conditions of the area and they play a pivotal role in ecological health, functioning and integrity.

5.2.2 Level of Awareness on Impacts of Stone Quarrying on Riparian Vegetation

The objective two findings regarding the level of awareness on impacts of stone quarrying on riparian vegetation revealed that majority (81%) of the respondents were aware of the ongoing quarrying in the area whereas 19% were not aware. Moreover, 86% of the respondents were aware that stone quarrying activities had detrimental impacts on the riparian vegetation whereas 14% were not aware at all.

Additionally, 10% of the respondents agreed to have received public education on the impacts of stone quarrying on the riparian vegetation and the entire environment. On the other hand, larger proportion of 90% had no idea about the impacts of stone quarrying on the riparian vegetation. This implied that there was high level of ignorance among the community members with little interventions done by relevant authorities.

The research analysis also pointed out that there was a significant negative correlation *p=-0.412* between public education on the impacts of stone quarrying on riparian vegetation and the impacts of stone quarrying on riparian vegetation. This inferred that low level of public participation on impacts of stone quarrying on riparian vegetation among the community members was the major factor attributing to the increased negative impacts on riparian vegetation. It was also established that all key informants were aware of the ongoing quarrying activities.

5.2.3 Effects of Stone Quarrying on Riparian Vegetation

Research findings concerning objective three on the effects of stone quarrying on riparian vegetation showed that most of the quarries were situated near the riparian zones of River Molo with the closest quarry being 49.48 meters away. The results from observation and key informants' response revealed that out of the five sampled quarries one was inactive and abandoned with no indication of rehabilitation work taking place. However, the key informants indicated that quarrying activities started way back in 1980s where manual labor was only utilized. The study also uncovered that both man power and stone cutting machines were used in extraction process. The quarries were deeply excavated with the overburdens heaped near the sites.

However, the analysis of satellite imagery from 2000 to 2018 did not reveal substantial evidence of quarrying activities. Notable change was observed between 2019 and 2023, coinciding with the introduction of modern stone cutting machines. This suggests that the recent adoption of advanced quarrying technologies has accelerated the pace and scale of stone extraction in the study area during the 2019-2023 period.

The research analysis revealed that 27% of the respondents depended on riparian vegetation for raw materials used in building and other uses, 15% for good air, 12% for

fruits and medicine, 11% for culture (circumcision), 20% for fodder and 15% for firewood and charcoal. This suggests that riparian vegetation of river Molo is a vital resource that immensely contribute to the socio-economic and cultural improvement of the community in the area. Regarding whether the benefits of riparian vegetation were declining as a result of quarrying activities, 78% of the respondents agreed that there was a decline in the benefits, 19% noted that there was no decline and lastly 3% were not sure.

The Likert type scale analysis showed a strong consensus among respondents regarding the environmental impacts of stone quarrying on riparian vegetation of River Molo with a weighted average = 4.615 for all the four statements. Change in riparian vegetation cover and felling of riparian trees to pave for the expansion of quarrying recorded the highest means above the weighted average and reduced natural regeneration as well as increased soil erosion scored 4.2 and 4.56 respectively.

During Field Visits the researcher observed that trees and shrubs were being uprooted to pave way for expansion of quarry operations. The overburden was heaped on shrubs and trees which adversely affected plant biodiversity, natural regeneration and increased soil erosion. Deep cut extraction was observed in merely all the five quarries which indicated no adherence to sustainable extraction methods as prescribed by NEMA. The researcher also observed a lot of dust emissions emanating from the quarry operations which significantly affected photosynthesis by blocking stomata in plant leaves.

5.2.4 Proposed Measures to Curb Negative Impacts on Riparian Vegetation

The statistical analysis revealed a strong consensus among respondents, with reclamation and rehabilitation of quarry sites, planting of trees and grass, and promoting public participation scoring above the weighted mean of 4.628. Additionally, proper disposal of

quarry overburden and enactment of Nakuru quarrying act scored slightly below the weighted value indicating that all the five strategies are crucial in promoting sustainable stone quarrying and improved conservation of riparian vegetation in the area.

5.3 Conclusions

The NDVI analysis targeted along riparian areas of river Molo indicated a decline in vegetation index which was largely attributed to land use changes particularly quarrying activities in the area. The research findings showed that there was minimal public education on the impacts of stone quarrying on riparian vegetation which accelerated the decline in vegetation index.

The study also revealed that all five sampled quarries were very close to the riparian areas of river Molo, with nearest being 49.48m away. This proximity directly contributed to trees being felled down, reduced natural regeneration, altered photosynthesis due to dust emissions, soil erosion and heaping of quarry overburden on already existing trees leading to reduced vegetation richness and abundance.

Rehabilitation and reclamation of quarry site, planting of trees and grasses, public education and sensitization, proper disposal of quarry overburden, and enactment of quarrying law and policy at the county level are the best practices to minimize ongoing degradation of riparian vegetation along River Molo.

5.4 Recommendations

Based on the findings and the conclusions, the following recommendations were made.

5.4.1 Policy Recommendation

The policy recommendation of this study includes:

Ensure rehabilitation and reclamation of quarry sites after decommissioning to promote enhanced landforms and vegetation cover.

Planting of trees and grass to reduce soil erosion and enhance riparian ecosystem functioning Promote public education and sensitization on the impacts of stone quarrying on riparian vegetation. Enactment of Nakuru County quarrying laws to regulate establishment of quarries and mode of extraction and proper disposal of quarry overburden and other wastes. Adoption and development of Integrated Water Resource Management Plan for Molo river ecosystem.

5.4.2 Recommendations for Further Research

The researcher recommends the following areas for further research:

Assessing the compliance level of Environmental Impact Assessment and Audits by quarries in Rongai Sub- County Investigation of Occupational and Health and Safety issues associated to quarrying activities in Rongai Sub- County. Determining the effects of quarrying activities on water turbidity of river Molo.

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APPENDICES

Appendix 1: Questionnaire

Section 1: Introduction

I am Kipyator Dennis, a Kabarak University student pursuing a Master's of Science in Environmental Science. I am Conducting research on "**Determining The Impacts Of Quarry Works On Riparian Vegetation Of River Molo In Rongai Sub-County, Nakuru County**." This questionnaire seeks to capture your views and opinions regarding the study. Kindly note that your name and information herein will only be used for academic purposes.

Section 2: Personal Information

Name: ……. Locality: ……

Occupation: …… Age: …….

Level of education: Primary [ ] Gender: Male [ ] Female: [ ] Other: [ ]

Secondary [ ] Tertiary [ ] None [ ]

Section 3: Stone Quarry Works

i. Are you aware of the stone quarrying activities in your area**?** Yes [ ] No [ ]

If yes, where are they located

_____

_____

ii. When did the quarry operations start?

_____

_____

iii. What methods of extraction have you observed in the quarry sites in your area?

_____

_____

iv. Can a quarry be established next to a river Yes [ ] No [ ]

If No, why? _____

_____

Section 4: Awareness of the Impacts of Stone Quarrying on the Environment (Riparian Plants)

i. Do you know what riparian vegetation is? Yes [ ] No [ ]
ii. Do you think stone quarry operations affect riparian vegetation? Yes [ ] No [ ]
iii. Have you ever received public education on the effects of quarrying on the environment (riparian plants)? Yes [ ] No [ ]

If yes, who organized it? _____
What did you learn? _____
Are you aware of any law or regulation that governs the quarry activities?
_____
_____

Section 5: Impacts of Stone Quarry on the Riparian Vegetation

i. How does the plant vegetation along River molo help you? (*You can select more than one)*

[ ] Firewood [ ] cultural use [ ] Good air
[ ] Fodder for livestock [ ] Fruits [ ] Raw materials (building, crafting)
[ ] other uses Specify……..

ii. Has there been a decline in the benefits of riparian vegetation you have mentioned above after the establishment of the stone quarry in your area? Yes [ ] No [ ]

iii. Do you think stone quarrying affects the plant vegetation along River Molo? Yes [ ] No [ ]

Select the most appropriate response choice for the following statements/questions (1. Strongly disagree, 2. Disagree, 3. Neutral, 4. Agree, 5. strongly agree)

Statement	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
Quarrying leads to changes in riparian vegetation cover.					
Quarrying reduces natural regeneration of vegetation.					
Quarrying results in the felling of riparian trees.					
4Quarrying contributes to soil erosion.					

Section 6: Effective Measures to Curb the Effects of Quarrying on the Riparian Vegetation

ii. Have you noted any measures applied so far to reduce effects on the riparian plant?
Yes [ ] No [ ]

If yes, mention them. _____
_____

Select the most appropriate response choice for the following statements/questions (1. Strongly disagree, 2. Disagree, 3. Neutral, 4. Agree, 5. strongly agree)

Statement	**Strongly Disagree (%)**	**Disagree (%)**	**Neutral (%)**	**Agree (%)**	**Strongly Agree (%)**
Rehabilitation and reclamation of quarries lead to enhanced ecological balance in riparian ecosystems.					
proper disposal of quarry overburden leads to increased natural regeneration.					
Planting of trees and grasses improves the functionality of riparian vegetation					
Public participation leads to reduced impacts of quarrying on riparian vegetation					
Enactment of Nakuru County quarrying laws leads to sustainable quarrying practices					

Section 7: Any other concern/comment

Do you have any other comments or concerns related to quarrying and riparian vegetation in your area? Yes [ ] No [ ]

If yes, which are they? _____

Thank You for participating.

Appendix II: Key Informant Interview Schedule

This schedule has been designed to gather detailed information on the stone quarry works in Rongai Sub-County and its impacts on riparian vegetation along river Molo. I am kindly seeking a little of your time to fill this schedule.

Section A: General information

Location for the interview: …… Date: ……..

Designation: ……. Organization: ……

Section B: Questions

1. When was the stone quarry started?

   _____

   _____

2. What are the methods used in the quarry?

   _____

   _____

3. Are the quarries licensed as per the law? Yes [ ] No [ ]

   If No, why? _____

4. What are the major impacts you have noted on riparian vegetation?

   _____

   _____-

5. Have you conducted public awareness on the impacts of quarries on the riparian systems? Yes [ ] No [ ].

   If yes, when? _____

6. What are some of the mechanisms you have put in place to curb these impacts?

   _____

   _____

7. What are some of the challenges you have encountered in the implementation of these measures?_____

8. What do you think should be done further to curb the impacts of riparian vegetation?

   _____

   _____

Thank you for participating.

Appendix III: Observation checklist

Item	**Action**
Quarry sites {methods and proximity to the riparian areas}	Photographs and observation
Riparian vegetation {felled trees, encroached zones riparian vegetation width, stripped land and plant leaves health(colour)}	Photographs and observation

Appendix IV: Informed Consent Tool

KABARAK UNIVERSITY RESEARCH ETHICS COMMITTEE

ADULT INFORMED CONSENT FORM (TEMPLATE)

(The form is written in English language but can be translated to Kiswahili or any other appropriate language)

STUDY TITLE: Determining the Impacts of Stone Quarrying on Riparian Vegetation of River Molo in Rongai Sub-County, Nakuru County, Kenya

PI Kipyator K. Dennis Affiliated Institution Kabarak University

Co-investigator(s) Dr. Eliud Michura & Dr. Edna Koskei

Affiliated Institution(s)_____Kabarak University_____

INTRODUCTION

You are invited to participate in this research study being undertaken by the above listed investigators. This form will help you gather information about the study so that you can voluntarily decide whether you want to participate or not. You are encouraged to ask any questionregarding the research process as well as any benefit or risk that you may accrue by participating. After you have adequately been informed about the study, you will be requested to either agree or decline to participate. Upon agreeing to participate in the study, you will be further requested to affirm that by appending your signature/thumbprint on this form. Accepting or declining to participate in this study does not in any way waive the following rights which you're entitled to:

a) Voluntary participation in the study;

b) Withdrawing from the study at any time without the obligation of having to give anexplanation and;

c) Access to services which you're entitled to

A copy of this form will be provided to you for your own records Should I continue YES/NO _____

This study has been reviewed and approved by Kabarak University Research Ethics Committee (KUREC)

What is the Purpose of the Study?

The main reason(s) for conducting this study is to answer the following questions:

1. To determine River Molo riparian vegetation status between 2000- 2023 in Rongai Sub- County, Nakuru County.…….....……..
.....

2. To assess the community's level of awareness on the impacts of stone quarrying on riparian vegetation in Rongai Sub-County, Nakuru County.....
…….....…..

3. To determine the perceived effects of stone quarry works on R. Molo riparian vegetation in Rongai Sub- County, Nakuru County.....
…….....……..

4.To recommend effective measures to curb the negative impacts of quarrying on riparian vegetation along R. Molo in Rongai Sub-County, Nakuru County.

(In order to answer these research questions, you are requested to voluntarily answer question(s) and/or accept some procedures performed on you)

Who can Take Part in the Study? *Outline the inclusion and exclusion criteria Specify the sample size*

In Case You Agree to Participate in the Study, What Will Happen?

This is what is going to happen once you have agreed to participate in the study:

- *First, include a statement about the time commitments of the research for the participantincluding both the duration of the research and follow-up, if relevant.*

_____
_____
_____

- *Second, a qualified and well-trained interviewer will ask you questions in a private place where you will feel comfortable. In case there is any question you feel uncomfortable responding to, you will not be coerced to respond. The questions will be on the following areas: (list the areas below)*

_____
_____
_____
_____

- *Third, after the interview, the following procedures will be done {detailed*

information on anyprocedures to be undertaken by the investigator(s)}

_____
_____
_____

- *Last, you are requested to provide your contact details (phone number or any other reliable form of contact). This will help reach you in case new information regarding the study emerges. Other reason(s) for requesting your contact details is (are)*

_____
_____
_____

- *The contact details you will provide shall remain confidential to the lead researcher (PI).*

What Potential Risks are Associated with Participation in this Study?

Any research involving human subjects has the potential of imposing a number of risks/harms or discomfort including psychological, physical, emotional, environmental, cultural etc.
{*The risks depend upon the nature and type of study and the interventions. State and explain the risk to the participant. Explain to the participant how this risk will be mitigated*}

_____
_____
_____
_____

There is no potential risk associated to this research.

Privacy & Confidentiality

Privacy is the right of an individual to have some control over how his or her personal information/data is collected, used, and/or disclosed. Confidentiality is the duty to ensure information (data) is kept secret only to the extent possible/reasonable. {*Explain to the participantshow privacy and confidentiality will be upheld. Explain to the participant any extra precautions, you will take to ensure safety and anonymity. How well data will be*

handled and after how long will the data be discarded and how the data will be discarded}

No unauthorized personnel will have access to the data only and that all the data will be securely discarded after the completion of the study.

In case you aren't comfortable answering any of the questions during the interview because of feeling embarrassed or uncomfortable, it will be within your rights to decline. Otherwise every measure has been taken to ensure that the interview is conducted in a private area with minimal to no interference so that you feel comfortable.

In case of clinical procedures: You may experience some discomfort/pain after {*State the procedure*}_____. This may even cause some {*state the effects of the procedure*}

If at all you suffer any injury, illness or complication(s) by participating in this study, kindly contact us immediately using the contact details provided at the bottom of this form. you will be attended to by the study clinician and if there is need for further assessment or treatment you willbe referred accordingly

What Benefits are you Going to Accrue by Participating in the Study

{*Benefits may be divided into benefits to the individual, benefits to the community in which the individual resides, and benefits to society as a whole as a result of finding an answer to the research question. Mention those that will be actual benefits not entitlements*}

{*Highlight the significance of the study*}

No benefit will be accrued to the participate since it will be on voluntary basis

What Will it Cost You to Participate in the Study?

{*Will the participant incur any cost in order to participate in the study? Explain it clearly to theparticipant*}

No cost will be incurred by the participant maybe only his/her time

Will Any Expenditure that You Incur by Participating in the Study be Refunded? Or will you be Paid for Participating in the Study? {*Explain clearly to the participant whether or not they will be reimbursed*}

None

In Case I Have any Further Questions/ Concerns in Future Whom Should I Contact?

In the event that you need further clarification or questions regarding your continued participation in the study feel free to contact the PI {*Provide the contacts of the PI*}. In case of concerns regarding your rights and/or obligations as a research participant do not hesitate to contact the secretary, KUREC on {*KUREC contact*}

What Alternative Options are Available to Me?

The decision on whether to participate or not is absolutely voluntary. You will be free to withdrawfrom the study at any point during the study without providing any explanation.

How Will the Findings of this Study be Communicated or Shared?

{*Provide a detailed plan of how feedback of the study findings will be given*}

The findings will be communicated through the chief. Additionally, the findings will be published in an open access journal for everyone to access and get information

Statement of Consent

I have comprehensively read the consent form or/the information has been comprehensively read to me by the researcher. I have understood what the study is about and all the questions and concerns that I had have been responded to in a clear and concise. The study benefits and foreseeable risks have been explained to me. I totally understand that my decision to participate in this study is voluntary and I have the right to withdraw at any point during the study.

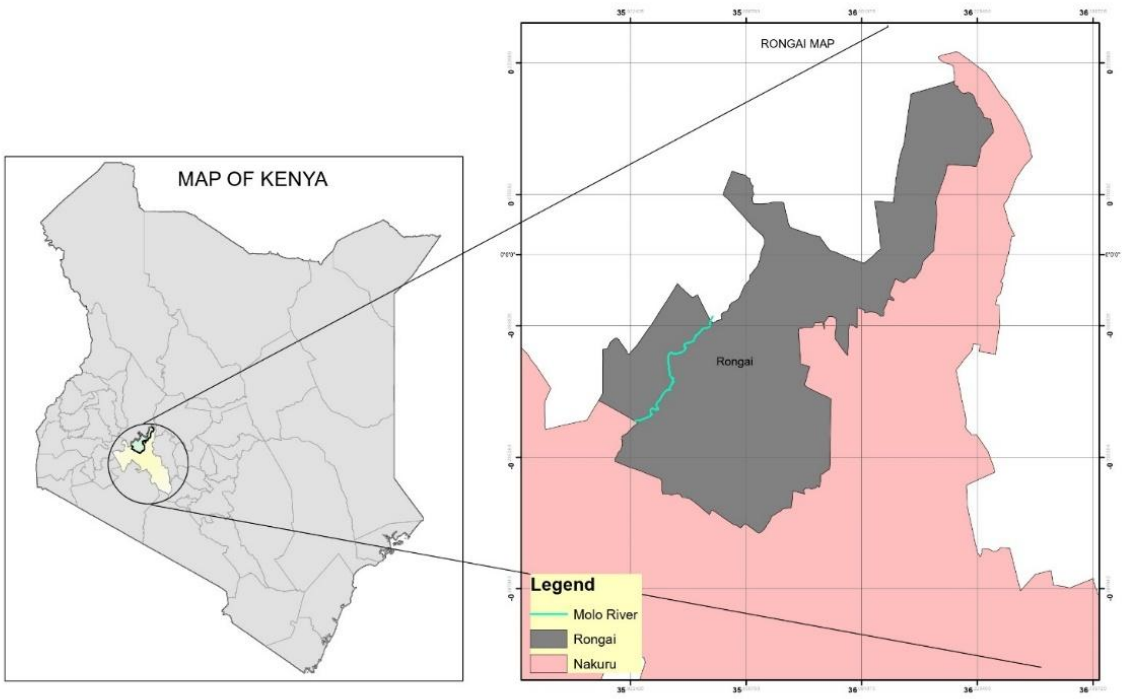
I freely consent to participate in this study

Signing this form does not in any way imply that I have given up the rights am entitled to as a participant

I agree to participate in this research YES_____NO___ I agree to provide my contact details for follow-up YES_____NO___ Participant's Name _____

Participant's Signature/Thumb print_____Date _____

Appendix V: Rongai Sub-County Map



Source: Author (2024)

Appendix VI : Photographs

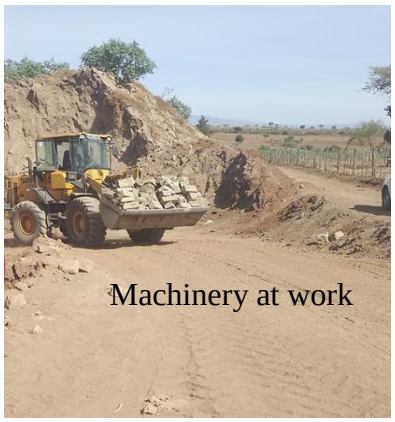
Molo river riparian area before heavy downpour

Molo river riparian area after heavy downpour

Sparsely populated riparian vegetation

A huge heap of quarry overburden

Heaped overburden destructing shrub and tree growth



Machinery at work

Appendix VII: KUREC Clearance Letter

KABARAK UNIVERSITY RESEARCH ETHICS COMMITTEE

Private Bag - 20157
KABARAK, KENYA
Email: kurec@kabarak.ac.ke

Tel: 254-51-343234/5
Fax: 254-051-343529
www.kabarak.ac.ke

OUR REF: KABU01/KUREC/001/04/05/24

Date: 23rd May, 2024

Dennis Kipyator,
Reg No: GMEN/NE/3046/09/19
Kabarak University,

Dear Dennis

RE: DETERMINING THE IMPACTS OF STONE QUARRY WORKS ON RIPARIAN VEGETATION OF RIVER MOLO IN RONGAI SUB-COUNTY, NAKURU COUNTY, KENYA

This is to inform you that ***KUREC*** has reviewed and approved your above research proposal. Your application approval number is ***KUREC-040524.*** The approval period is ***23/05/2024 – 23/05/ 2025.***

This approval is subject to compliance with the following requirements:

i. All researchers shall obtain an introduction letter to NACOSTI from the relevant head of institutions (Institute of postgraduate, School dean or Directorate of research)
ii. The researcher shall further obtain a RESEARCH PERMIT from NACOSTI before commencement of data collection & submit a copy of the permit to **KUREC.**
iii. Only approved documents including (informed consents, study instruments, MTA Material Transfer Agreement) will be used
iv. All changes including (amendments, deviations, and violations) are submitted for review and approval by ***KUREC***:
v. Death and life-threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to ***KUREC*** within 72 hours of notification;
vi. Any changes, anticipated or otherwise that may increase the risk(s) or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to ***KUREC*** within 72 hours;
vii. Clearance for export of biological specimens must be obtained from relevant institutions and submit a copy of the permit to KUREC;
viii. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal and;
ix. Submission of an executive summary report within 90 days upon completion of the study to ***KUREC***

KABARAK UNIVERSITY
INSTITUTIONAL RESEARCH ETHICS COMMITTEE
24 MAY 2024
APPROVED
P. O. PRIVATE BAG - 20157, KABARAK

Sincerely,

Prof. Jackson Kitetu PhD.
KUREC-Chairman

Cc Vice Chancellor
DVC-Academic & Research
Registrar-Academic & Research
Director-Research Innovation & Outreach
Institute of Post Graduate Studies

Appendix VIII: NACOSTI Research Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Ref No: **399315**

Date of Issue: **31/May/2024**

RESEARCH LICENSE

This is to Certify that Mr.. DENNIS K. KIPYATOR of Kabarak University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Nakuru on the topic: DETERMINING THE IMPACTS OF STONE QUARRY WORKS ON RIPARIAN VEGETATION OF RIVER MOLO IN RONGAI SUB-COUNTY, NAKURU COUNTY, KENYA for the period ending : 31/May/2025.

License No: **NACOSTI/P/24/36419**

399315

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

See overleaf for conditions

Appendix VIII: Evidence of Conference Participation

KABARAK UNIVERSITY

Certificate of Participation

Awarded to

Dennis K. Kipyator

For successfully participating in the 14th Annual Kabarak University International Research Conference held from 10th -11th July 2024 and presented a paper entitled ***"Determining the impacts of stone quarry works on riparian vegetation of***

Conference Theme

Climate innovations for environmental, industrial and energy sustainability

Dr. Peter Rugiri
Dean, School of Science Engineering and Technology

Dr. Moses Thiga
Director - Research, Innovation and Outreach

Kabarak University Moral Code

As members of Kabarak University family, we purpose at all times and in all places, to set apart in one's heart, Jesus as Lord.

(1 Peter 3:15)

Kabarak University is ISO 9001:2015 Certified

Appendix IX: List of Publication

MERIT RESEARCH JOURNALS
www.meritresearchjournals.org

Merit Research Journal of Agricultural Science and Soil Sciences (ISSN: 2350-2274) Vol. 12(2) pp. 031-042, October, 2024
Available online http://meritresearchjournals.org/asss/index.htm

doi: 10.5281/zenodo.14055815

Original Research Article

Determining the Impacts of Stone Quarry Works On Riparian Vegetation of River Molo in Rongai Sub-County, Nakuru County, Kenya

Kipyator Dennis*, Eliud Garry Michura, Edna Koskei

Kabarak University

***Corresponding Author's E-mail: kipyatordennis@gmail.com**

Abstract

The contribution made by stone quarrying to the Gross Domestic Product (GDP) in many countries globally is enormous. Whether small or large-scale, stone quarrying is inherently disruptive and can cause detrimental effects on the fragile riparian vegetation. This research therefore, aimed at determining the status of riparian vegetation between 2000- 2023 along river Molo and establishing the effects of stone quarry works on riparian vegetation. A descriptive survey design was adopted where 404 household heads were randomly sampled from a total of 35,545 households in Visoi, Soin and Mosop wards. 15 key informants were purposively sampled for interviews. Questionnaires, interview schedules and Geographical Information System (GIS) and Remote sensing (RS) instruments were used in data collection. The obtained data was analyzed using SPSS (Version 25), ArchMap and remote sensing (time series) to analyze changes in riparian vegetation using the Normalized Difference Vegetation Index (NDVI). The findings revealed a significant decline in riparian vegetation attributed to land use changes driven by poor agricultural practices and quarrying activities. The five purposively selected quarries were found to be located between 49 - 330 meters away from the river, where one was abandoned with no sign of reclamation, thus directly affecting the health and integrity of the riparian vegetation. It was also noted that massive heaping of quarry overburden and deep excavation accelerated felling of trees, reduced natural regeneration and increased soil erosion. These findings will be useful to inform the best quarrying practices to reduce detrimental impacts on riparian vegetation and a foundation for policy development in quarrying sector at county and national level.

Keywords: Geographical Information System, Normalized Difference Vegetation Index, Riparian Vegetation, Quarrying

INTRODUCTION

Quarrying is a common land use activity that involves the extraction of building materials such as stones, sand, and gravel. Globally, most established quarries produce either dimension stones or aggregate (Umar, 2022). Dimension stones are natural, structural and decorative building blocks used in the construction industry (Gonçalves and Margarido, 2015). However, traditional architecture; (the use of mud and wood to build houses) is fast disappearing due to neglect of culture and increased urbanization where most people in both rural and urban