LANDSLIDE DISASTER RISKS MANAGEMENT IN MURANG'A COUNTY, KENYA: SCIENTIFIC AND INDIGENOUS KNOWLEDGE NEXUS

BY

JOHN MAINA NJIRAINI

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF DOCTOR OF PHILOSOPHY IN GEOGRAPHY, DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES

SCHOOL OF ARTS AND SOCIAL SCIENCES

MOI UNIVERSITY

ELDORET

2023

DECLARATION

Declaration by the candidate

I declare that this thesis is my original work and has not been presented for a degree in any other university. No part of this thesis may be reproduced without prior written permission of the author and/or Moi University.

John Maina Njiraini …………………………….. Date …………………………

SAS/DG/01/18

Declaration by the Supervisors

This thesis has been submitted with our approval as the university supervisors

Professor Paul Omondi………………………… Date……….……………

Geography & Environmental Studies,

School of Arts and Social Sciences,

Moi University,

Eldoret, Kenya.

Dr. Fredrick O. Okaka………………………… Date………………………

Geography & Environmental Studies,

School of Arts and Social Sciences

Moi University

Eldoret, Kenya.

DEDICATION

The research work is dedicated to my family for their immense support and encouragement during the study. Special and express dedication to: my dear wife, Mary Wanjiru Marubu; our dear children: Gabriel Njiraini, Davis Marubu and Ethan Boutros Kinuthia; Parents: Gabriel Njiraini, David Marubu and Jecinta Nyambura, Elizabeth Wanjiku and finally siblings: Julius, Richard, Joyce, Evelyn, Edith, Eunice, Stephen, Hellen, Samson, Emily, Simon, Joseph and Pauline.

ACKNOWLEDGEMENT

I sincerely thank my able supervisors: Professor Paul A. Omondi (Ph.D) and Dr. Fredrick O. Okaka (Ph.D) for their unwavering guidance and encouragements throughout my research doctorate journey. Special thanks to my main mentor, Dr. Janet Korir (Ph.D) critical advices throughout my work. Many thanks to the leadership of Moi University's department of Geography and Environmental Studies through Chairs of Department (CoDs) Mr. William Kiplagat and Dr. Raphael Wamithi Kareri (Ph.D), the School of Arts and Social Sciences through deans Prof. Peter Simatei (Ph.D) and Prof. Mary Wahome (Ph.D), for making sure that the research journey was not derailed but had a sustained progress. Special thanks also to the CoD-Earth Science Department of Laikipia University's School of Science and Applied Technology, Dr. Barnabas Kurgat (Ph.D), for the constant words of encouragement and support during my regular work assignments. Many thanks also to my research assistants: Titus Manyeki, Simon Kamau, Paul Murage, Susan Mwangi, Peter Muchiri, Julius Kinuthia, Alex Rurira, and Titus Kimani for their dedicated time which without the field data collection exercise would have been impossible. I also do appreciate the following data providers: United States Geological Survey (USGS) for the SRTM; Kenya National Bureau of Statistics (KNBS) for the Kenya Population and Housing Census (KPHC, 2019) data; Food and Agriculture Organization (FAO), Soil Terrain (SOTER) and International Soil Reference Information Centre (ISRIC) World for soil data; SERVIR/Climate SERV for the periodic rainfall dataset, WorldClim for the Very High Resolution Interpolated Climate surface for global land areas; Murang'a County administrative leaders at sub-county and location levels through the County Commissioner, Mr. F.A.D. Ndunga, for smooth cascaded coordination and organizing of the field visits up to the household levels; County Director of meteorological services and Kangema-RANET 106.5 FM, Mr. Paul Murage and the County Disaster Management Directorate through manager Bilhah Wanjiku for landslides and weather data; Google Engine Engine and Murang'a County Government for the boundary and administrative data. Thanks to colleagues at Moi University: Luka C. Kanda, Barnabas Koros and Abu for cooperating and according me the necessary support and thanks to fellow doctoral programme participants: Martin Evans Ogoti, John Aseta, Japhet Kipngeno, Edwin Sang and Juma Edwin for the companionship during the journey. Finally and above all I thank the Almighty God for giving me sober minds and good health.

ABSTRACT

Murang'a County has recently experienced serious, deadly and recurrent landslides but not much research has been done about the disasters. The integration of scientific and indigenous knowledge is rare study option despite the indigenous people being among the key players in disaster management cycle. The general objective of the study is seeking an understanding of landslide disaster risks through scientific and indigenous knowledge. The specific objectives are mapping and delineating landslide disaster risk zones based on the two levels of knowledge, assessing their nexus, comparing the risk zones with landslide inventories, assessing landslides effects and finally studying the prevailing Early Warning Systems (EWS) in both contexts. The study is anchored on the Systems Theory and the Concept of Integration. The study adopted mixed methods sequential explanatory research design. Primary data were collected through proportionate household questionnaires administered to a total of 336 household heads who were selected through systematic random sampling from nine purposively selected study locations spread across six sub-counties. Complementing the questionnaires' data were eight Key Informants Interviews (KIIs) and six Focus Group Discussions (FGDs) for participants who were purposively and randomly selected respectively. Quantitative data were analyzed using IBM-SPSS package for descriptive statistics through percentages and frequencies and further inferential statistics analyzed through correlation analysis. Primary qualitative data obtained through KIIs and FGDs were analyzed through content analysis. Secondary data obtained from remote sensing were quantitatively analyzed in ArcGIS software through overlay analysis of the GRID factors in Simple Linear and Weighted-Linear Combination (WLC) in Multi-Criteria Evaluation (MCE). The study showed that a significant number of respondents ($r=0.862$) reported to have experienced a landslide at least once in their lifetime. Also, a significant number ($r=0.806$) described rainfall and slope/gradient as major landslide causal/trigger factors. The research further established that there existed nexus between scientific and indigenous knowledge due to convergence in the considered 'most influential and prominent' landslide causal/trigger factors identified as rainfall, elevation, slope, soils and land-use land-cover; landslide disaster risk zones which mapped the northern parts of the county, towards the Aberdares Ranges, as being the 'high landslide risks areas' while the southern parts as being the 'low landslide risk areas' zones; conformity of the landslide zones with the March-April-May (MAM) 2018 landslide inventories; regarding the Early Warnings Systems (EWS), some of the locally upheld systems mentioned by the indigenous people over the years had basis in science. The research is key in advancing the knowledge in the following ways: better understanding of the spatial distribution of landslide risk zones in Murang'a County, the linkage and possible integration of the contemporary and indigenous methods in landslide management, the effects of landslides and landslide disasters' EWS. In conclusion, both scientific and indigenous knowledge of landslide disasters should be mainstreamed in an inclusive landslide disaster risk management. Landslides being highly localized, the study recommends further localized research targeting only the households affected by the disasters to gain closer understanding according to their knowledge and experiences.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES AND PHOTOGRAPHS

ACRONYMS AND ABBREVIATIONS

CC	County Commissioner
CIDP	County Integrated Development Plan
DCC	Deputy County Commissioner
DEM	Digital Elevation Model
DR/DRM	Disaster Risk/Disaster Risk Management
EM-DAT	Emergency Events Database
ESRI	Environmental Study Research Institute
EWS	Early Warning System
FAO	Food and Agriculture Organization
FGD	Focused Group Discussion
FM	Frequency Modulation
GE	Google Earth
GEE	Google Earth Engine
GEOTIFF	Georeferenced Tagged Image File Format
GES	Geography and Environmental Studies
GIS	Geographical Information System
GoK	Government of Kenya
GPS	Global Positioning System
HH	Household
HND	Higher National Diploma
IBM	International Business Machines Corporation
ID No	Identification Number

IK	Indigenous Knowledge
KI	Key Informant
KII	Key Informant Interview
Km	Kilometer
KMD	Kenya Meteorological Department
KNBS	Kenya National Bureau of Statistics
KPHC	Kenya Population and Housing Census
Ksh	Kenya Shilling
LDR	Landslide Disaster Risk
LDRM	Landslide Disaster Risk Management
LULC	Land-Use Land-Cover
MAM	March-April-May
MCE	Multi-criteria Evaluation
MD	Meteorological Department
NACOSTI	National Commission for Science, Technology and Innovation
NASA	National Aeronautics and Space Administration
P.	Page
Ph.D	Doctor of Philosophy
RANET	RAdio and InterNET
SASS	School of Arts and Social Sciences
SD	Sustainable Development
SDGs	Sustainable Development Goals

SMCE	Spatial Multi-Criteria Evaluation
SOTER	Soil Terrain
SPSS	Statistical Package for Social Sciences
SRTM	Survey Shuttle Radar Topographical Mission
UN	United Nations
UNISDR	United Nations International Strategy for Disaster Reduction
URL	universal Resource Locator
USAID	The US Agency for International Development
USGS	United States Geological Survey
Vol.	Volume
WLC	Weighted Linear Combination

OPERATIONAL DEFINITION OF SIGNIFICANT TERMS

Landslide: Any form of downward movement (fall, slide, creep, topple, flow, spread) of soils, snow (avalanche), rocks, debris and any attachment on the Earth's surface. It refers to mass wasting and is synonymous to slope failure through among other dynamics rock falls, debris flows as well as soil and other movement of Earth's materials and the attachments thereof downslope in either fast or slow motion.

Disaster: An occurrence which brings about serious disruption of the operations of a society or a people as a result of its widespread losses and repercussions. The affected community is said not to be in a position to cope with such an event hence vulnerable to it.

Disaster Causal/trigger factors: These are the factors which contribute to the occurrence of a disaster by causing of triggering it to happen in a specific area. In the context of the study, causal/trigger factors are synonymous to the pre-disposing factors, sub-elements and sub-systems. Also referred to as 'the factors'

Disaster risk: Refers to the **e**minent losses of among others life, livelihoods, health, properties, which could occur to a person, society or community due to occurrence of a disaster.

Disaster risk management: Is a **c**oordinated and systematic process and efforts towards enhancing the coping capacities and lowering the negative effects of landslide disasters by different players and agencies among them the local people through well formulated strategies and policies.

Local people: Refers to the people living in a certain locality. In the context of the study, local people refer to the inhabitants of the study area regardless of their origin or length of stay. They are also referred to as residents, inhabitants or simply the locals.

Local peoples' knowledge/Indigenous knowledge: Refers to the general and diverse understanding of a phenomena by the inhabitants or residents of a certain area and which is passed through generations through information sharing and dissemination aimed at making the locals cope with challenges in their locality. It is informally passed regardless of their socio-economic, cultural, political or otherwise status. It refers to the information held by the residents over time, also referred to as citizen science or local technical knowledge.

Scientific knowledge: Refers to the formal systematic body of knowledge generated by experts and which has been proven to be supported by scientific underpinnings over time. Science is a systematic body of knowledge generated by experts in a certain field through rigorous observations and experiments and has three tenets: systematic in nature, answers/tests empirical questions/hypothesis and is public knowledge.

Household (HH): Refers to a person or group of persons who reside in the same homestead or compound headed by a household head who is a person above the age of 18 years regardless of the sex.

Spatial Multi-Criteria Evaluation (SMCE): Is a technique used for spatial decision making together with Geographical Information Systems (GIS). In the study SMEC is the same as Multi-Criteria Evaluation (MCE).

'Mzee wa mtaa'- 'wazee wa mitaa' (plural)**:** Swahili for '*village elder'*, a person appointed to lead and link the people in his or her village with government administrators as part of community policing. Also called '*mzee wa nyumba kumi'*- *'wazee wa nyumba kumi'* (plural). He/she must be a senior resident of the village hence knowledgeable about the area and is usually of age. '*Mzee wa mtaa'* is the first line of contact in case of any incidence such as a hazard or disaster in her/his jurisdiction hence provides a very crucial link between people at grassroots and both county and national governments. Some of the consulted wazee wa mitaa were retired teacher and civil servants with proper formal training and education on among other areas disaster management, the reason why they were consulted as key informants

Early Warning Systems (EWS): Early Warning Systems refer to the timely and effective provision of information by concerned institutions and bodies on precursor to a landslide aimed at enhancing the risk knowledge, monitoring and warning those who are at risk and to build better response to a disaster. Timely and effective provision of information by concerned institutions and bodies on precursor to a landslide aimed at enhancing the risk knowledge, monitoring and warning those who are at risk and to build better response to a landslide disaster.

Nexus: A connection or linkage between two or more things. The study focuses on and explores connections between scientific and indigenous knowledge in landslide disaster risk management continuum.

CHAPTER ONE

INTRODUCTION

1.1 Introduction

This first chapter of the thesis which introduces the study ‘story-line’ by generally describing the study problem, which revolves around landslide disasters risk management in Murang’a County. It begins by giving a background of the study and statement of the problem, both of which are key in qualifying the study problem as being worth of study. The study is justified by the outlining ways in which it will contribute to the advancement of knowledge about landslide disasters while the study significance is viewed through how the study will be relevant in mainstreaming the voices of the indigenous people at local, national and global fronts in disaster risk management continuum. The general objective of the research is to study landslides disaster risks in Murang’a County as viewed through both scientific and indigenous peoples’ knowledge, study the nexus between the two levels of knowledge and the possible integration of knowledge in an inclusive disaster risk management. The chapter also outlines the specific objectives of the study and the questions which arise and beg answers. To focus the research work, the delimitation and assumptions the study are explained. The chapter ends by explaining and showing the geographic location and characteristics of Murang’a County, which is the study area.

1.2 Background to the study

Global inventories of natural hazards which extends over a large geographical space such as hurricanes and earthquakes can be cited, contrary to the cases of hazards of small spatial extents such as landslides (Kirschbaum, *et al.*, 2010). Landslide disasters are climate-related extreme events which are recognized (Ngecu & Ichang'i, 1999) but are poorly documented and characterized in East Africa Highlands (Jacobs *et al.,* 2016) and the world (Schuster, 1996, Monsieurs, *et al.,* 2018). Landslides cause huge losses globally but the study on causalities and other effects are 'hugely under-estimated and not complete' (Haque, *et al.,* 2016) and more so in Africa, a continent which is 'under-represented in landslide research' (Broeckx, *et al.,* 2018). Such is against the fact that landslides are projected to increase in future due to population pressure and associated land-use changes exacerbated by climate change in the tropics (Monsieurs, *et al.*, 2018). In a cited case, though debatable, it was contended that landslide studies are available only in areas where development projects are to be initiated (Crozier, & Glade, 2005). A noticeable geographical bias against, Africa South, America and Oceania in landslides vulnerability research where the disasters are poorly studied as opposed to regions such as China, Italy, Turkey and India (Reichenbach, *et al.*, 2018).

Regionally, the East African region has reported major landslides (Ngecu *et al.,* 2004) and Kenya is indeed characterized as a disaster prone country (Republic of Kenya, 2010). Of these, over 70% are hydro-meteorological in nature (Huho *et al.*, 2016). Like many areas of the world, particularly in the tropical developing countries, Kenya is at risk of landslides and their associated effects (Anderson, & Holcombe, 2013) which leads to hundreds billions of dollars loss (Wannous & Velasquez, 2017). Landslide disasters are not new phenomena in Kenya (Davies, 1996; Salome *et al*., 2004; Wahlstrand, 2015), they have been reported to occur in the central highlands, eastern and rift valley with specific cases in among other areas Elgeyo Marakwet County (Aseta, 2018 Loice, *et al.,* 2021), Mount Elgon and Nandi (Maina-Gichaba, *et al.*, 2013), slopes of Mount Kenya, Kisii, Kibwezi (Ngecu & Mathu, 1999) and Central Highlands (Mwaniki, *et., al* 2017). Yet according to Davies (1996), Wahlstrand (2015) and Zhou, *et al.* (2020) there is a dearth of information about landslide disaster in Kenya. Landslide studies in Kenya have received less interest as opposed to other regions of the world (Maina-Gichaba *et al.,* 2013).

Nationally, Murang'a County presents a unique case due to its geographical location within the Aberdare Ranges, which runs across other counties such as Nyeri, Nyandarua and Kiambu, but with Murang'a landslides being recurrent in the recent past (Salome *et al.,* 2004) and deadly (Ngecu *et al.,* 2004). The study area has unique, favourable characteristics for landslide disaster occurrences (Kimani, 2020). The growing population and expansion of settlement has led to increased impacts of disasters such as landslides (Othman *et al*., 2012). The landslides have previously caused injuries, deaths, disruption and displacement of people's lives and property (Mwaniki *et al.,* 2011). Such unfortunate cases happen against the backdrop of the fact that landslide-prone areas are agriculturally very productive (Ngecu *et al.,* 2004) and farmers living in Kenyan highlands such as the upper Murang'a are said to be at risk of landslide disasters due to lack of resources and information (Davies, 1996; Wahlstrand, 2015). Landslides are poorly studied phenomena in the Eastern foot-slopes of the Aberdare Ranges in Central Kenya (Ngecu & Ichang'i, 1999). The disasters occur especially during the two rainy seasons, (Wahlstrand, 2015) and has been recurring in recent past (Salome *et al.*, 2004). Some of the major reported landslides in Murang'a include: On 15th May 1991 in Gacharage Village, a landslide buried a house near a cliff toe, killing all eight residents in their sleep and destroying an estimated 10, 000 US dollars' worth of property (Davies and Nyambok, 1992). On 30th April 1997 in Maringa Village, a landslide buried three houses and killed eleven occupants and destroyed their three semi-permanent houses leading to a loss of property worth thousands of US dollars

(Ngecu, & Ichang'i, 1999). Also, on 26th November 1997, a deadly landslide occurred in Gatara Village and caused deaths of three people and destruction of tea plantations (Ngecu et al., 2004). In the same year (on 10th November 1997), a landslide occurred along Murang'a-Thika highway at Karugia and swept 1km section of the highway while also affecting 25 hectares of agricultural land and disrupting the telecommunication network (Ngecu & Mathu, 1999). According to KMD, Murang'a County, in the year 2013, on date 1/2/2013, Kiriko-ini village, in Gatuya location, Murarandia Division, huge cracks appeared on most farm lands, and also on homesteads. Houses were damaged and others rendered inhabitable as huge cracks appeared on the walls and the floor of the affected houses. Some portions of farmlands appeared to have sunk or shifted downslope. In the same year, on 1/4/2013, a landslide occurred in Gitiri Village, Kahuro, Division where a household was affected when iron sheet to their houses were destroyed during the slide. Luckily, no one was injured but a bigger landslide loomed and the families were advised to plant trees and grass on the landslide slope so as to prevent any further soil movement down wards. The two most recent landslide cases were reported by The Star Newspaper (unpublished-April 28, 2018). One occurred at Inooi Kianda gia Ithanwa Village in Kahuro Sub-County in Kiharu, in which three people were killed and a house swept away while the second one was at Kahwai Village within Gitugi Ward in Mathioya Sub-County in which three farms were swept away.

The First United Nations (UN) Sustainable Development Goal (SDG) seeks to end poverty in all its forms everywhere in the world. Its target number Five (1.5) aims to build resilience of the poor and those in vulnerable situations and reduce their exposure and susceptibility to, among others, climate-related extreme events, environmental shocks and disasters by the year 2030. Building resilience of the poor and strengthening disaster risk reduction is a core development strategy for ending extreme poverty in the most afflicted countries (UN, 2018). On the same strength, the social pillar of Kenya's Vision 2030 seeks to have *'a just and cohesive society enjoying equitable social development in a clean and secure environment'* (GoK, 2007, P. 2). The pillar emphasizes on 'investing in people of Kenya' and with respect to the environment, it seeks to enhance disaster preparedness in prone areas and improve adaptation capacity of the people (GoK, 2007).

Generally, landslide disaster research has concentrated on the scientific understanding of landslides and their effects. Indigenous people (people living in a certain locality or the inhabitants/ residents/locals regardless of their origin or length of stay) are some of the main players in disaster risk management continuum and are affected in one way or another (Salome *et al.,* 2004). People living in landslides prone areas have rich experiences about landslides but have remained hugely unexploited. Such a contention is supported by other studies on natural disasters in various parts of the world. For instance in a pilot study about potential application of indigenous knowledge in the understanding of cyclones in Bangladesh, older people were said to have demonstrable early warning indicators, some of which were recommended for integration with the existing scientific systems (Howell, 2003) generally, indigenous knowledge have been used in solving societal problems, including those related to climate change and variability (Gyampoh, *et al.*, 2009).

Landslides are highly localized as they occur in small geographical extents and viewed as system comprising of sub-systems characterized by causal/trigger factors (Shi, *et al.*, 2020; Khasanov, *et al.*, 2021). The scientific and indigenous peoples' understanding of these factors gives an indication of the nexus between the two levels of knowledge and whether to incorporate the same in the local and national disaster management strategies and policies. Iloka (2016), states that there is lack of proper documentation of local indigenous knowledge of landslide disaster in Africa. Yet the integration of the scientific and indigenous peoples' understanding of landslide causal factors and risk management in the local and national disaster management strategies and policies can play a big role in improving landslide disaster preparedness and reducing its impacts. The study would contribute knowledge on mainstreaming of IK in the disaster management continuum hence community-inclusion, lack of which has been cited to be a contributor to the problem of implementing the Kenya's Vision 2030 (Korir, 2019).

However not much research has been carried out about the hazards in Murang'a County (see Davies & Nyambok, 1993) yet the county in central part of the Kenya, presents a unique case of geographical interest. This is because, of all the counties traversed by the Aberdare Ranges, the county has had the most serious, deadliest and recurrent landslide disasters in the recent past, (Salome *et al.*, 2004, KMD, 2022). These landslides are termed as deadly (Ngecu *et al.*, 2004).

Although Kenya's disaster management policy provides a general architectural guidance on the country's disaster management, the framework only outlines how the disaster actors and sectors should coordinate and act but not specific on any one given disaster. It stipulates that research investments should include best practices based on indigenous knowledge and traditional technologies which have helped a given community to sustainably be resilient to disasters in the past. It further advocates for the local community to be viewed as not only vulnerable but as having potential and strength in disaster management. The contention is in line with the current approach in disasters risks management approaches in the world advocating for local participation and a people-centered approach (Scolobig *et al*., 2015). However, the policy is an abstract and a general framework for any disaster and fails to show how indigenous knowledge can be mainstreamed. The non-recognition of knowledge adaptation in disaster management continuum is clearly visible in the organizational structure of country’s Disaster Risk Reduction/Disaster Risk Management (DR/DRM) in which indigenous knowledge is not featured in its bottom hierarchy. Lack of local peoples’ awareness has been cited as one of the reasons for the failure of implementation of Kenya’s Vision 2030 (Korir, 2019). In building strategies and policies, the many stakeholders who are directly or indirectly involved in the risk identification and promulgation of steps to reduce and manage them should be consulted. Balancing the inputs of parties of interest is key in the disaster risk management cycle (Crozier & Glade, 2005). The stakeholders include among others: property owners, financial institutions, insurance companies, politicians, media, Non-Governmental Organizations, farmers, regulatory and other government organizations, humanitarian organizations, media, residence, decision makers and managers. Some of the represented actors are line ministries, universities/scientific institutions, civil societies, private sectors/companies, Kenya Red Cross and international/regional offices. The study focuses on the local people, who are the most vulnerable in case of a landslide disaster in their localities.

Generally, the research seeks to study landslides disaster risks in Murang’a County as viewed through both scientific and indigenous peoples’ knowledge, study the nexus between the two levels of knowledge and their possible integration in an inclusive disaster risk management, as advocated for by the contemporary disaster risk management strategies.

1.3 Statement of the problem

Kenya is a disaster-prone country and landslides are among the deadliest and recently recurrent disasters in Murang'a County (Salome *et al.*, 2004) courtesy of the favourable causal/trigger factors. Landslides are recognized disasters but poorly studied and managed in Kenya and the Eastern slopes of Central Kenyan Highlands is not an exception (Jacobs *et al.,* 2016). In Murang'a, the recurrent landslides have caused injuries, deaths, disruptions of livelihoods, displacements of people and property in the area.

Generally, information about landslides are scanty and most studies are limited to the scientific understanding through modeling the risks. The integration of scientific and the local peoples' knowledge is a rare research option for the disaster management albeit the indigenous people being one of the key players in the disaster management continuum and who are affected in one way or another (Salome *et al.*, 2004).

Indigenous knowledge is globally recognized in disaster management cycle but has not been entrenched in Kenyan's practice and policy. The country's disaster management policy is silent on the indigenous knowledge, one of the possible reasons for the exclusion being the fact that the knowledge is not documented/ oral and is characterized as informal and subjective (Warren, & Rajasekaran, 1993, Antweiler, 1998).

No comprehensive landside disaster study has been done in Murang'a County and specifically around the geographical feature and area, the Aberdare Ranges, which has unique characteristics of interest when it comes to causing and/or triggering landslides. Such characteristics are embedded in the regions climatic, geological, topographical, pedological and vegetation formations. Further to that, in Kenya, no study has attempted to assess the landslide causal/trigger factors in light of both scientific and indigenous knowledge.

1.4 General objective

The main aim of the research is to study landslides disaster risks in Murang'a County as viewed through both scientific and indigenous peoples' knowledge, study the nexus between the two levels of knowledge and the possible integration in an inclusive disaster risk management. The research will therefore be useful in gaining further insight of issues of disaster risk management through both indigenous knowledge and modern science understanding.

1.5 . Specific objectives

The general objective of the study is achieved through the following specific objectives:

1. Mapping and delineating landslide disaster risk zones based on scientific knowledge.
2. Mapping and delineating landslide disaster risk zones based on indigenous knowledge.
3. Assessing the nexus between the scientific and indigenous knowledge landslide disaster risks understanding in comparison with March-April-May (MAM) 2018 landslide inventories for Murang'a County.
4. Assessing the landslide disasters effects in Murang'a County.

5. Assessing the local peoples’ Early Warning Systems (EWS) through the use of indigenous knowledge and the nexus with the scientific systems.

1.6 Research questions

The guiding research questions are:

1. Which zones are at risk of landslides based on scientific understanding of the causal/trigger factors?
2. Which zones are at risk of landslides based on indigenous knowledge understanding of the causal/trigger factors?
3. Is there a nexus between the scientific and indigenous-knowledge-based landslide disasters risks and how does each with to the documented landslide inventories for MAM 2018 for Murang’a County?
4. What are the effects of landslide disasters in Murang’a County.?
5. Through the application of indigenous knowledge, which Early Warning Systems (EWS) are used by the local people and how are they related to the scientific systems?

1.7 Justification and significance of the study

Generally, the primary significance of the study is to fill the existing research gap in understanding of the recurrent landslide disaster risks in Murang’a County through an investigation of the landslide system’s causal/trigger factors, landslide effects and landslides’ Early warning Systems (EWS) as viewed through the lenses of both scientific and indigenous knowledge.

The specific importance of the study are as discussed below:

Firstly, through mapping and delineation of the landslide disaster risk zones, the research will contribute to better understanding and awareness of the spatial distribution of landslide disasters prone zones in Murang'a County. This will advance knowledge and fill the missing gaps in research as dearth of information about landslides has been cited in East Africa Highlands (Jacobs *et al.,* 2016) and Kenya (Davies, 1996; Wahlstrand, 2015, Zhou, *et al.,* 2020).

Iloka (2016) states that there is lack of proper documentation of indigenous knowledge in Africa and by engaging the locals, the study will also contribute to new knowledge about the indigenous peoples, knowledge and how it connects with the often researched scientific understanding of landslide disasters.

Thirdly, the study will contribute in filling the research gap on both negative and positive effects of landslides hence adding to the general information about landslide effects in Murang'a County. The information about landslides and the resultant effects at a global regional and local scales are said to be scanty, probably due to the fact that damages emanating from landslides are perceived to be relatively fewer compared to other disasters. Another possible reason is the fact that in most cases, damages from landslides are 'opaque' as landslides are normally triggered by or occur in combination with other disasters such as earthquakes and floods (Ciurean *et al.*, 2013), which makes it difficult to isolate the specific disasters from the landslides. The study will contribute to the understanding of the not much researched or neglected positive effects of landslide disasters. Available literature shows that studies about landslide effects pay much attention to the negative effects at the expense of any positive contributions of the occurrences in an area. This study sees to fill the gap in literature on the positive contribution of landslide disasters by also discussing and highlighting the eminent benefits from a landslide disaster.

Fourthly, the study will be significant in filling the gap about the use of EWS by the indigenous people and how the systems link with science as landslides' EWS are among the many interventions known to reduce hazard risks (Macherera *et al.*, 2016, Adams, *et al.*, 2022) and specifically the risks caused by a landslide disaster (Piciullo, *et al.*, 2018). Such is crucial because historically, EWS have been linked to the scientific understanding hence ignoring the traditional systems held by the local people (Sufri, *et al.,* 2020). The integration would make real the opportunity to have robust and more people-oriented approaches to reduce the effects of disasters through multi-sectoral and all-inclusive engagement as prescribed by the Sendai Disaster Risk Reduction Convention.

The justification of the study is viewed in terms of how the research would positively contribute to the community or society at different levels summarized as follows:
At the grassroots and local community level, the study is key in raising and mainstreaming the voice of the indigenous people in landslide disaster management continuum. The locals are usually affected by the disasters when they occur but are often ignored. The overall knowledge from the study would lead to the formulation of better disaster management strategies and policies in Murang'a, where no existing polices on disaster management exist. Such can set a precedent in Kenya and contribute in the realization of the Kenya's Vision 2030 social agenda, aimed at having a just and cohesive society enjoying development in a clean and secure environment. On the same breath but on the global scale, the study would contribute to the realization of

Sustainable Development Goal (SDG), in helping the locals who reside in vulnerable situations to build resilience and reduce their exposure and susceptibility to, among others, climate-related extreme events, environmental shocks and disasters as prescribed by Kenya's Vision 2030.

1.8 Scope of the study

The study made the following considerations: Firstly, the study is about the landslide disasters as a general mass movement type without differentiating among the various types and forms of landslides within the study area. The study is also not framed on any specific season and reference is made to spatial data's year of acquisition where applicable and a justification is given. For example the study focuses on March-April-May (MAM) 2018 historical landslide cases because it represents the period with the highest number of reported landslide cases within a single rainy season (March-April-May) in the history of the recurrent landslides in Murang'a County (KMD, 2021). The study focuses on instances where landslide disasters have occurred and had reported cases of deaths, displacements of people and animals, destruction of goods and properties.

1.9 Weaknesses and assumptions of the study

Many natural hazards occurrences are difficult to predict in terms of place and time (Othman *et al*., 2012). Landslides are highly localized and might have been differently characterized from one place to another (Van Westen, 2006). Such may call for localized and separate landslide event analysis for different zones for different causal/trigger factors (Barredo, *et al.*, 2000). This points out to the fact that the study cannot be directly replicated in a different locality with different characteristics.

Nevertheless and to address such a limitation, a study assumption is made that landslides will occur under similar prevailing conditions.

Secondly and closely connected to the above point, is that a landslide event causes modification of the landscape in an area, meaning that even if a landslide was to occur in the same area and under the same conditions, it would most likely not occur in the same modified zones (Van Westen, 2006). This raises the limitation of the study results not being replicated and recommended for future risks mitigation in extensively modified landscape previously affected by a landslide. Assumption is made that no major modification would occur in an area to affect landslides recurrence in future as for the cases of Murang'a County. Nevertheless, the study is important as the analysis results provide an opportunity of pointing out susceptible areas through an assumption that landslides will occur under similar conditions in the future.

Thirdly, disaster risks are multi-faceted and touch on both human and natural factors (Johnson & Tversky, 1984). This brings a contention of how to properly interpret, manage and integrate in the policy the diverse views (Eiser *et al*., 2012). Local people are some of the key players in a disaster event and are equipped with indigenous knowledge gained over years of experiences. The knowledge is cultura-specific (Shaw, *et al.,* 2008) and location specific (Barker, 2017), facts which make the study to have some degree of subjectivity (Van Westen, *et al.*, 2006) varying from one community to another. I therefore, mean that the results may be influenced by the indigenous peoples' understanding of landslide causal/trigger factors under consideration. It further means that different factors combinations might yield different results. To mitigate against it, the study carefully selects and analyses only the most significant factors (Barredo, *et al.*,

2000) as guided by local people's knowledge as well as the scientific information obtained through experts knowledge and the available scientific literature.

Finally, landslide are usually of small spatial extents, which for instance, would require high resolution images (Kirschbaum, *et al.*, 2010) for a localized study. Such data were not easy to obtain for the study area for all the factors. Assumption is made that a mixture of high and low resolution remote sensing grid data would yield acceptable results.

1.10 The study area

1.10.1 Geographical Position, size, administrative units and physical conditions

The study area, Murang'a County, is located in Kenya, a country which is in the East Africa and lies approximately between Eastings 34^{o} and 42^{o} and Northings 4^{o} 22' and -4^{0} 28'. The country is divided into almost two equal parts by the equator and borders Uganda to the West, Ethiopia and Southern Sudan to the North, Tanzania to the South-West, Somalia to the East and the Indian Ocean to the South East. The country's area coverage is approximately 587,000 km^{2} of which 11,000 km^{2} consists of water bodies. The country is under a new constitution which was promulgated on 27th August 2010 and which provides for a two-tier government structure. These are one (1) national government and forty-seven (47) devolved county governments.

Murang'a County is one of the five counties of the former Central Province and is county number 21 according to the First Schedule of the Kenyan Constitution (Constitution, 2010). The county borders the following counties: Nyeri (North), Kiambu (South) and finally Nyandarua (West) and Kirinyaga, Embu and Machakos counties to the east as shown in Figure 1.1. Murang'a County lies between latitudes 0^{o} 34' South and 1^0 7' South and longitudes 36^o East and 37^o 27' East and has seven sub-counties namely: Kiharu, Gatanga, Kigumo, Kandara, Mathioya, Kangema and Maragwa. The administrative units of are: Murang'a East, Kahuro, Murang'a South, Gatanga, Kigumo, Kandara, Mathioya, Kangema (KNBS, Volume I, 2019). Three administrative units named Murang'a East, Kahuro and Kiharu are in Kiharu Sub-county while Maragwa Sub-county is made up of Maragwa and Murang'a South administrative units.

The county is spatially expansive, spanning from an alpine zone defined by a tropical forest called the Aberdare Forest to semi-arid zones bordering Machakos and Embu Counties. The altitude ranges from 914 meters ASL in the lowlands East and 3,354 meters ASL in the highlands west along the slopes of the Aberdare Ranges. The highlands consists of volcanic rocks of the Pleistocene age containing porous beds and disconformities which acts as important aquifers and is origin of many streams while the lowlands has basement rocks of Achaean type. The latter has dissected terrain characterized by valleys and ridges which makes the zones prone to landslides and erosions (CIDP, 2018).

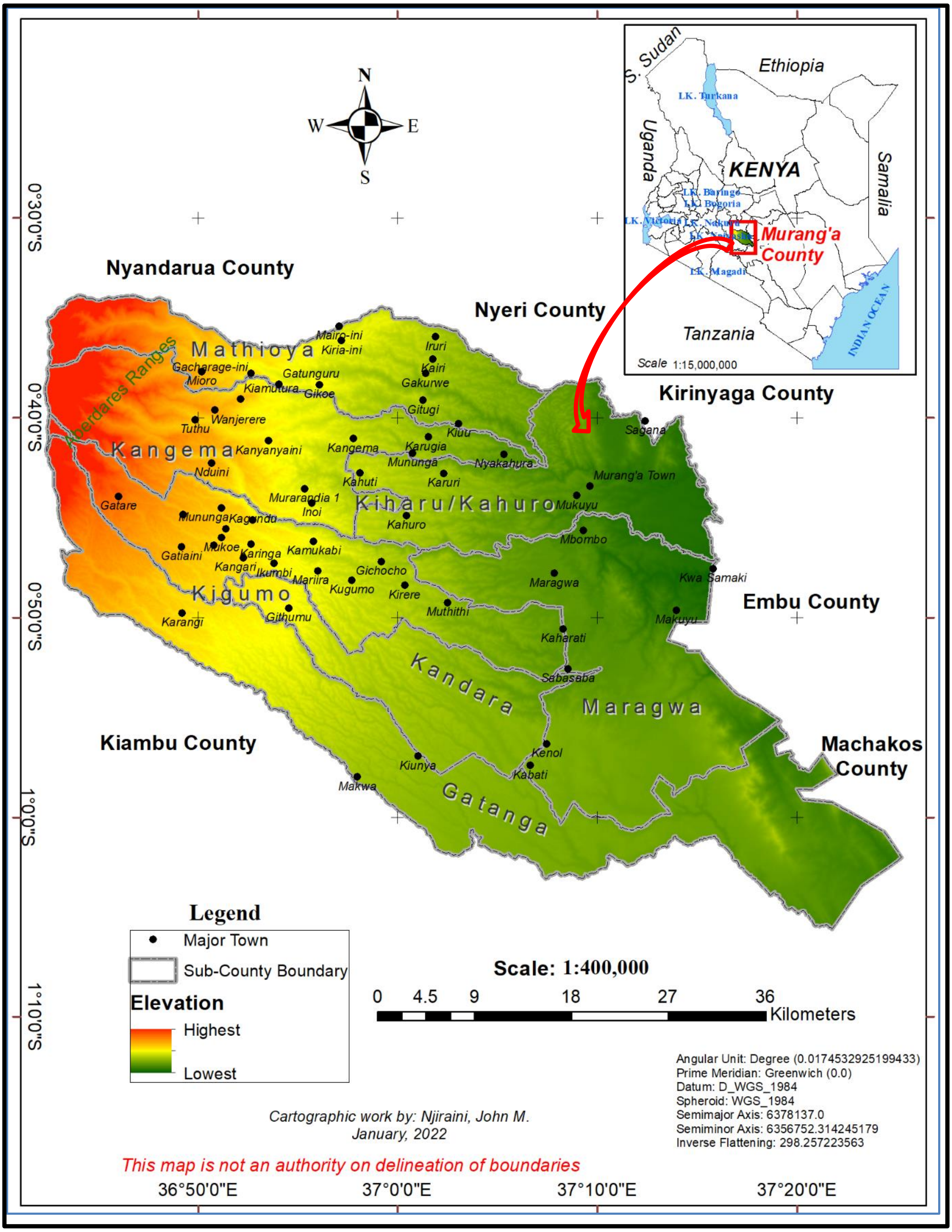


Figure 1.1: ***The study area in Murang'a County, Kenya***

Data from USGS (2015) and Google Earth (2021)

1.10.2 Climatic and ecological conditions

Murang'a County is divided into six agro-ecological zones with zone 1 having the highest potential and is covered by forests and tea bushes. Zones 2 and 3 are the lowlands east of the Aberdares Ranges and are generally suitable for coffee and dairy farming. The third ecological cohort is made up of zones 4, 5 and 6 comprising of the arid and semi-arid conditions suitable for irrigated agriculture. There are three climatic regions namely: equatorial in the west, sub-tropical in the central and semi-arid in the eastern end of the county. Kangema, Gatanga, Mathioya, and upper parts of Kigumo and Kandara are in the western region and are characterized by wet and humid climate due to their close proximity to the Aberdare Ranges. According to the Murang'a County Integrated Development Plan (CIDP, 2018), annual average temperatures are between 9^0 C (lowest) and 38^0 C (highest). Long rains (highest amounts) are normally experienced annually between the months of March and May while the short rains (lowest amounts) are between the months of October and November/December. The western region, Kangema, Gatanga, and higher parts of Kigumo and Kandara, is generally wet and humid due to the influence of the Aberdares and Mt. Kenya. The eastern region, lower parts of Kigumo, Kandara, Kiharu and Maragwa receive less rain and crop production requires irrigation. Proximity to Mount Kenya and Aberdares Ranges makes the uplands wet and tributaries of major rivers in Kenya originates from the area (Mwaniki *et al.*, 2011).

1.10.3 Population: size, density, composition and distribution

The Kenyan Central Highlands are densely populated courtesy of fertile soils and favourable climatic conditions for farming (Westerberg & Christiansson, 1999). According to the 2019 Kenya Population and Housing Census (KPHC) by the Kenya

National Bureau of Statistics (KNBS), the county has a total land area of 2,524.2 Km^2 with a total population of 1,056,640 and a population density of 419. Total males, females and intersex are 523,940, 532,669 and 31 respectively. The county has a total of 318,105 House-Holds (HH) with an average of 3.3 persons per HH (KNBS, Volume I, 2019). In terms of the population distribution, Gatang'a and Kiharu Sub-counties (Murang'a East and Kahuro) have the largest total number of people compared to special demarcated zone of Aberdare Forest as shown in Table 1.1 below:

Table 1.1: ***Population distribution in Murang'a County***

Sub-county/Zones	***Male***	***Female***	***Intersex***	***Total***
Murang'a East	54,665	55,645	1	110,311
Kangema	39,582	40,862	3	80,447
Mathioya	45,454	47,359	1	92,814
Kahuro	43,352	44,834	7	88,193
Murang'a South	91,732	93,087	5	184,824
Gatanga	94,437	93,548	4	187,989
Kigumo	67,989	68,929	3	136,921
Kandara	86,698	88,393	7	175,098
Aberdare Forest*	31	12	-	43

**Special census zone*

Source: (KNBS, Volume I, 2019).

1.10.1 Economic activities

According to the 2019 Kenya Population and Housing Census (KPHC), 73% of the population practice agriculture (KNBS, Volume IV, 2019) courtesy of fact that there are volcanic soils in uplands which are generally fertile and rich for crop growing. Major cash crops include tea, coffee (Wahlstrand, 2015), avocado, mangoes and macadamia. Tomatoes, French beans, kales, cabbages, watermelons, pineapples and spinach are the main horticultural crops grown in the area. Many of the locals have formed community self-help groups and Savings and Credit Cooperatives (SACCOs) for their activities such as marketing and selling of their produce. The main industrial activities in the county entails coffee and tea processing.

1.11 The structure of the thesis

The thesis is organized in chapters, each with sections and sub-sections. Chapter one is the introduction and gives a background of the study, statement of the problem, objectives, justification, scope, limitations and description of the study area. Literature review is in chapter two detailing and in-depth and critical review of related studies. In the chapter, the main research items are elaborated and contextualized in the scholarly world with the applicable theory and concept; systems theory and the concept of integration being explained in the context of the research. Chapter three, the research methodology, explains the research design and approach, study population, sampling; sampling frame, sampling design and techniques, sample size calculation, data types and sources as well as the data treatment and processing. The next chapter, data analysis, results and discussions, is core for the research and explains how the study data are analyzed and results presented to position the empirical results in the scholarly world. The chapter is organized in objective-by-objective basis and study assumptions are well explained. Chapter five is the research summary, conclusions and recommendations based on the findings.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter gives an in-depth and critical discussion on the core components of the research as well as the theory and concept underpinning the study through a review of relevant literatures. The debate in the review of literature yields the identification of the research gap.

2.1 Landslide disasters

2.2.1 Definition, types and forms of landslides

A landslide is defined differently by different professionals as a result of diversity in disciplines which study the disasters (Highland *et al*., 2008). According to a book titled '*The landslide handbook-A Guide to Understanding Landslides'* by Highland and others, a landslide is any form of downward movement (fall, slide, creep, topple, flow, spread) of soils, snow, rocks, debris and any attachment on the Earth's surface. It refers to mass wasting and is synonymous to slope failure through among other dynamics rock falls, debris flows as well as soil and other movement of Earth's materials and the attachments thereof downslope in either fast or slow motion. Generally, the term landslide refers to the various types of downward and outward movements of slope materials such as soils/earth, rocks, debris and other ground materials either in fast or slow motion. The earth's materials may flow, fall, creep, topple, slide, spread or undergo a combination of these processes Highland, (2006). The occurrence of a landslide is subject to the energy from the environment and the state of causal/trigger factors (Yufeng & Fengxiang, 2009). Landslide events are subject to a variety of such factors which in turn results to different types of landslides in terms of slope failure type, magnitude and spread (Glade, 2003; Glade *et al.,* 2006*;* Uzielli *et al.,* 2008; Fell, 1994*).*

Types of landslides may be characterized and categorized according to the type of materials in question and how they are moved (Maina-Gichaba *et al.,* 2013), dynamics and types of the slope failure (Highland *et al*., 2008). Landslide is a type of mass movement or mass failure (Gorsevski,et al., 2005), a geomorphic process which affects steep slopes world-wide (Westerberg & Christiansson, 1999) and which may have different characteristics from place to place (Van Westen, 2006). They are landforms-associated processes linked majorly to geomorphological, hydrological/climatic, geological and anthropogenic conditions in an area (Crozier & Glade, 2005).

Landslides accounts for a significant part of major natural disasters and usually occur in mountainous regions, but can also happen in low elevation areas for instance slope failures in cliffs or cut and fill materials (Maina-Gichaba *et al.,* 2013). Whichever the case, they are usually within a small spatial extent (Kirschbaum, et al., 2010). Landslides are known to be hazards of small spatial extents which are poorly inventoried (Crozier, & Glade, 2005). The hazards affect a ‘point’ rather than an ‘area’ as the case with other disasters of larger territorial extent like earthquakes and floods (Van Westen, 2006).

2.2.2 Landslides’ causal/trigger factors

Landslide causal/trigger factors are the factors which contributes to the occurrence of a landslide by causing and/or triggering the landslide event in an area. In the context of the study, causal/trigger factors are synonymous to the pre-disposing factors, sub-elements and sub-systems of a landslide system.

Landslides are caused or triggered by multiple factors (Shi, *et al.,* 2020; Khasanov, *et al.,* 2021) which can be grouped into inherent and trigger factors. Inherent causes may be natural or human-induced and includes geological causes (such as weak, disjointed, sheared, fissured, weathered materials etc.), morphological causes (such as tectonic and volcanic uplift, freeze and thaw, slope-loading etc.) and anthropogenic causes (slope-loading, excavations, deforestation, mining, water-leakages etc.). Some of the prominent causal/trigger factors are as discussed below:

Rainfall

It is documented that more than 70 percent of natural disasters in Kenya are related to extreme climate events (Republic of Kenya, 2010). Climate variability can be linked to increased cases of landslides where increased rainfall is the main trigger factor for landslides in Kenya (Maina-Gichaba *et al.,* 2013), just as is the case for other recorded global cases (Froude & Petley, 2018). Such a contention is also in line with other studies which indicate that rainfall is a trigger factors for landslides occurrence (Ngecu *et al.,* 2004; Othman *et al*., 2012; Wahlstrand, 2015; Mwaniki *et al.,* 2015; Huho *et al*., 2016). Rainfall as a landslide causal/trigger factor is common in Central Kenya. This is evident judging from the reported landslide cases, especially during the *El nino* rains (Mwaniki *et al.,* 2011). During that period, the country experienced a ten months period of heavy rains (May, 1997 and February, 1998) which caused widespread landslides and floods (Ngecu & Mathu, 1999).

Slopes and gradient

Naturally, Earth movements such as tremors, earthquake, thunder, volcanic activities and faulting may trigger landslides due to the destabilization of the slope formations (Gorsevski *et al*., 2005; Kipseba *et al*., 2013). In a book titled by Paron *et al*., (2013) "*Kenya: A natural outlook. Geo-Environmental Resources and Hazards*" steep slopes, among others factors, have been cited as landslide causal factors in Kenya. Existence of slopes is one of the main causal factor for landslide occurrence in many parts of the world (Othman *et al*., 2012; Van Westen, 2006). For instance, slope as a key factor has been cited in a study which analyzed fifty-six landslide research publications (between the years 2000 and 2020) in Central Asia and found out that fourty two (42) out of seventy nine (79) Scopus peer-reviewed and published papers, accounting for 53%, cited slope as being a main cause/trigger factor for landslide occurrences (Khasanov *et al.,* 2021). Nevertheless, slope factor works alongside other favourable factors for the occurrence of a landslide. For instance, one of the main landslides' causal/trigger factors in Kenya are the actions of water and human activities on sloping grounds as has been reported in Kenyan Highlands where landslides occur in slopes with a gradient of 25^{o} or above (Wahlstrand, 2015). In another publication by Thomas (1974), mass movements in tropical areas are generally confined to slopes of between 30^{0} and 60^{0}.

Elevation and soils

Most of the El-nino rains-induced landslides occurred due to high relief in the affected regions (Ngecu & Mathu, 1999) as heavy rainfall weakened the slope stability hence resulting to slope failures. Due to increased soil moisture and saturation in the hilly areas as a result of heavy rainfall, slope failures occurs due to the weakening of the slope stability courtesy of increased soil wetness (Huho *et al.,* 2016). Rapid saturation of soils due to heavy rains makes the soil to be saturated hence losing the cohesiveness of its particles and makes it susceptible to slides (Mwaniki *et al.,* 2011). Nitsols which have undergone intense weathering and Andosls are cited to be prone to landslides (Westerberg & Christiansson, 1999). Nitsols are found in Kenya Highlands and has a clay content of 50-60% in the deep solum but with loam characteristics (Keter & AHN, 1986).

Anthropogenic activities

Apart from the natural instability in landslide-prone areas, various human activities are cited to contribute to the occurrence of the disasters Paron *et al*., (2013). For instance it has been reported that landslide risks in the Kenyan Highlands occur within a distance of 80m from the roads (Othman *et al*., 2012). Increasing population and development in Kenya has led to human settlement and encroachment into landside risk areas (Maina-Gichaba *et al*., 2013). In such areas, the clearing of vegetation cover, including the forests is evident, an action has led to exposure of unstable soils and regolith due to removal of the anchor roots and foliage cover from the vegetation (Ngecu *et al.,* 2004).

2.2.3 Spatio-temporal distribution of landslide occurrences in the world, East Africa, Kenya and Murang'a County

According to Froude & Petley (2018), landslides are a significant global disasters of heterogeneous spatio-temporal distribution and is said that a landslide may occur anywhere in the world depending on the varying causal/trigger factors (Highland *et al*., 2008). In Europe for twenty years period between 1995 and 2017, twenty seven countries were reported to have diverse degree of four hundred and seventy six reported landslides which occurred in alpine regions and caused one thousand, three hundred and seventy deaths and seventy eighty-four injuries, with Italy being the most affected (Cardinali *et al.,* 2006, Haque *et al.,* 2016). Italy has many landslide cases due to its unique landscape and active geomorphic and geomorphological processes (Esposito, *et al.,* 2021) as well as intense human activities (Fiorucci, *et al.,* 2022). In America, countries such as Costa Rica, Panama, El Salvandor and Guatemala, landslides have been reported as triggered by the active seismic actions (Bommer & Rodríguez, 2002; Reyes-Chaves & Fernández-Arce, 2014; Reyes-Chaves *et al.,* 2014). In Washington, United States of America, a deadly flash landslide ever was reported in the years 2014 where two hundred acres of land were destroyed and forty three deadly injuries reported within seconds (Tart, 2016). Also, Latin America and Caribbean is not exceptional to landslide cases. For instance within a span of ten years, between 2004 and 2013, a total of eleven thousand six hundred and thirty one people died from the six hundred and eleven experienced landslides distributed in countries such as Haiti, Columbia and Brazil (Sepúlveda & Petley, 2015; Garcia-Delgado *et al*., 2022). Other notable landslide prone areas in America include Mexico (Diaz et al., 2020) and Canada (Evan, 2018) in Central and Northern America respectively.

In Asia Continent, regarded as the 'epitome of landslides', landslides are reported to cause huge losses in along the Himalayan Arc which runs across Asia, Pakistan, Bangladesh, Bhutan, India, Nepal, Philippines, Taiwan, Indonesia and Japan (Petley, 2012). The underlying cause of landslides in Asia is the active geologic and tectonic structure (Gupta *et al.,* 2022; Fayaz, *et al.,* 2022; Singh, *et al.,* 2022). For instance the hilly coastal of South-East Asia have experienced typhoon characterized by heavy rainfall and winds and which have triggered landslides with incredible adverse effects (Zhuang, Yu, *et al.,* 2022).

Africa is a continent which is 'under-represented in landslide research' (Broeckx *et al.,* 2018). The East African highlands, which are the most agriculturally productive due to rich soils and high rainfalls and also characterized by high population densities, have experienced major landslides with devastating effects on lives and properties (Westerberg and Christiansson, 1999) and the area is termed as 'landslide prone' but poor on landslide data inventory (Jacobs *et al.,* 2016). Nevertheless, Eastern Africa countries with prominent landslide are: Tanzania, Rwanda, Burundi, Kenya, Uganda and Democratic Republic of Congo. The Great Rift Valley and highlands of tropical Africa regions are termed as 'landslides-prone areas' (Kubwimana *et al.,* 2021). Such areas include: the hilly parts of Burundi and Tanganyika in Tanzania (Kubwimana *et al.,* 2021, Dewitte, *et al.,* 2021, Depicker, *et al.,* 2021, Vodacek, 2021), Tanzania's Rwenzori Mountains (Jacobs *et al.,* 2016) and Mgeta Valley (Lundgren, 1978), the mountainous regions near Lake Kivu in the Democratic Republic of Congo (Maki Mateso *et al.,* 2021, the Ethiopian Highlands (Mebrahtu, *et al.,* 2021), the Ugandan Highlands particularly the South Western Uganda (Nseka *et al.,* 2021, Mugume *et al.,* 2021), Eastern Uganda (Lunyolo *et al.,* 2021), Mount Elgon regions (Namono *et al.,* 2019, Nakileza & Nedala, 2020, Kibet, 2021, Ssennoga *et al.,* 2022,), Rwanda- (Kuradusenge *et al.,* 2020).

Landslides in Kenya are mostly recorded in central highlands, rift-valley and western parts (Nyaoro, *et al.,* 2016) characterized by high rainfall regimes, mountainous terrains, deep volcanic soils and high population densities (Mines and Geology Department, 2012). In a profile of prominent disaster occurrences in Kenya between the years 1974 and 2009, the year 2002 landslides which affected 2,000 people were reported in Meru Central, Murang'a and Nandi (Gok, 2009). Recently, Sigor and Pokot South Sub-counties of the West Pokot County in Kenya recorded deadly landslides in 2019 as a result of 'extremely' heavy rainfall causing deaths and destruction in the region (Schlögel, *et al.,* 2020). Landslide have also been reported in Yatta in Machakos County (Ogora & Kotut, 2013). Occurrence of landslides is linked to steep landscapes and destructive human activities. Examples are the several landslides which were reported in Mount Kenya areas of Meru and Embu in 1997 and 1998 (Ngecu *et al.,* 2004).

Other than in Murang’a County, other parts of Kenya with reported landslide events are: Meru and Embu, having reported cases due to highly water-saturated andosols sliding-over under heavy rainfall (Ngecu & Ichang'i, 1999). According to Maina-Gichaba *et al.*, 2013, the main landslide disaster prone areas in Kenya are also found around Mount Elgon, Nandi Escarpment, Tugen Hills, Cherangany Hills, Nyambebe Hills, Taita Hills and Rift valley Escarpments. Emergency Events Database (EM-DAT) shows that the western Kenya and specifically Kakamega is also a landslides prone area with reported cases between the years 2002 and 2008. For Kakamega in the year 2007, five people were killed, 67 injured and 13 families had to be evacuated (Rop, 2011).

In Murang’a County, landslides are said to be on the increase and recurrent in the recent past (Salome *et al.*, 2004). A comprehensive study done in the case of the 1997’s Muringa village landslide showed that other than the heavy rainfall in the year, geology, climate and soils were other major contributing factors. The landslides occurred in the heavily weathered pyroclastic regolith and deep red andosols found on highly unstable slopes slide over the stable agglomerate under the trigger of heavy rains (Ngecu *et al.*, 2004). Geological formation of an area is another causal factor with landslides being associated with deeply weathered rocks with reduced shear strength (Ngecu & Mathu, 1999). For instance the Gatara Village landslide was due to highly permeable pyroclastic rocks which rested on impervious agglomerates became saturated and resulted to sliding of the detached pyroclastic material after prolonged heavy rainfall. Land-use associated to human activities and which leads to slope failure as reported in Kangema, Murang’a County and include the construction of roads, digging of ponds and building of structure (Davies, 1996; Westerberg and Christiansson, 1999). Land cover change from mixed forests to single stands eucalyptus plantations has been reported in the Kenyan highlands (Wahlstrand, 2015) as a significant contributor to the occurrence of landslides (Mwaniki *et al.,* 2011). Prevailing soil characteristics is also an important factor like in Kenya, landslide prone areas are characterized as having red-brown nitosols derived from volcanic rocks (Ngecu *et al.,* 2004).

2.2.4 Research gap in landslide studies in Murang'a County

Murang'a County, in central part of Kenya, presents a unique case of geographical interest because it has had the most serious, deadliest and recurrent landslide disasters in the recent past of all the counties traversed by the Aberdare Range (Salome *et al.,* 2004). The landslides are termed as deadly (Ngecu *et al.,* 2004). A dearth of information about landslides has been cited in East Africa Highlands (Jacobs *et al.,* 2016) and Kenya (Davies, 1996; Wahlstrand, 2015, Zhou, *et al.,* 2020). A good example of it is the undocumented statistical data about the 1997/98 El-Nino landslide destruction which led to massive destructions of agriculturally-rich farmlands, transport and telecommunication facilities were disrupted and destroyed. River sedimentation also increased choking the river channels and adversely affecting the hydro-electric dams (Ngecu & Mathu, 1999).

Generally, Kenya is a disaster prone country (Republic of Kenya, 2010) of which over 70%, are hydro-meteorological in nature. Examples of such disasters are landslides which are triggered by heavy rainfall in mountainous parts of the country (Huho *et al.,* 2016). That notwithstanding, there is still a dearth of information about landslides in Kenya (Davies, 1996; Wahlstrand, 2015, Zhou, *et al.,* 2020) despite the reported negative effects caused by the disaster (Davies, 1996; Wahlstrand, 2015). The pioneer study of landslides in Kenya can be traced to Kamau (1981) on a study about Kangema in the highlands. Others include Rowntree (1989), Davies and Nyambok (1992) in Nyandarua Range and more recently continuous study by Stockholm University physical geographers conducted on the eastern slopes of Nyandarua Range since 1991 (Westerberg & Christiansson, 1999).

In conclusion, no comprehensive landside disaster study has been done in Murang'a County and specifically around the geographical feature and area, the Aberdare Ranges, which has unique characteristics of interest when it comes to causing and/or triggering landslides. Such characteristics are embedded in the regions climatic, geological, topographical, pedological and vegetation formations. Further to that, in Kenya, no study has attempted to assess the landslide causal/trigger factors in light of both scientific and indigenous knowledge.

2.3 Tenets of knowledge and ways of acquiring it

The epistemological question of what knowledge has been and still complex and debatable. According to Truncellit, (2007), knowledge can be used to mean a number of things, such as familiarity with people, places, persons, skills, and competences of performing various tasks, beliefs, faiths and everyday experiences. Knowledge is a result of many processes like knowing, perceiving, thinking, remembering, reflecting, observing, finding out, inferring, proving and so on. There are various tenets of knowledge. According to Russell (1992), knowledge should be based on facts. Fact constitutes what must be known so that truth and falsehood of any assertion may be substantiated. Secondly, knowledge is based on beliefs, which is a mental state of mind. According to Hetherington (2012), many people have beliefs hence are knowledgeable but only a small amount of such acknowledge is used at any instance. Facts and beliefs must however be based on objective truth, the third tenet of knowledge. It is assumed that as one acquires knowledge, one is increasing the body of true beliefs and simultaneously minimizing falsehood in an objective manner. Nevertheless, knowledge must be based on procedural evidence. Evidence or reason is necessary for a proposition to be true and hence to termed as knowledge. The key point in understanding how a people or a society get and use knowledge is crucial for improving their lives and more so for the poorest among them. Knowledge is paramount to human beings for their survival and development against the physical threats (World Bank, 1998).

According to Price, *et al*., (2015), knowledge can be acquired through: intuition, authority, rationalism, empiricism, scientific method. Sources of knowledge include: life experiences, social customs and traditions, authority, scientific investigations (deductive and intuitive reasoning) and last but not least social inquiry. There is no clear-cut boundary of where one source of knowledge starts and ends and in most cases, knowledge is an integration of various sources. Depending on the dominant source, the acquired knowledge may then be loosely termed as scientific or indigenous knowledge.

2.3.1 Scientific versus Indigenous knowledge and the understanding of landslide disasters

The terms *'scientific'* and '*indigenous*' *('traditional', 'local knowledge')*, have remained contentious and many authors have debated it (Antweiler, 1998). Nevertheless, it is not of interest in this study to dwell on the debate but just to appreciate the fact that that both are phenomenal in disaster risks reduction (Mcwilliam *et al*., 2020), though each has limitations (Gyampoh, *et al.*, 2009). 'Scientific' refers to the systematic body of knowledge generated by experts in a certain field through rigorous observations and experiments. Science is a systematic body of knowledge generated by experts in a certain field through rigorous observations and experiments (Roncoli, *et al.*, 2002) and has three tenets: systematic in nature, answers/tests empirical questions/hypothesis and is public knowledge (Price, *et al*., 2015).

On the other hand, the term "*Indigenous"* defined according to UN refers to groups of people whose social, cultural and economic conditions differentiate them from other people or communities and whose status is regulated wholly or partially by their own customs or traditions or by special laws or regulations. However, the United Nations takes cognizance of the fact that no formal definition of who indigenous people or local communities are (Hill *et al.,* 2020).

Considering the diversity of the indigenous people, the basic tenets for identifying such a group include:

i) Strong linkage with their environment which include the natural resources
ii) Unique social, political and economic systems
iii) Unique language, beliefs and cultures.
iv) Historical continuity and resolve to maintain and reproduce their ancestral environments and systems.

Indigenous knowledge, also called local knowledge (Antweiler, 1998), is a dynamic and complex body of understanding, skills and way of doing things maintained and practiced by people or community with a common understanding and experiences in a given locality (Castree, 2017). It is sometimes referred to as ‘citizen science’ (Cieslik, *et al*., 2019) and is an adaptive management strategy developed within a community over time (Berkes, *et al.,* 2000). The knowledge is abundant but have been ignored for long in Africa (Lunga & Musarurwa, 2016) and referred to as ‘primitive’ (Berkes, 2010). The knowledge is a response to livelihood challenges and issues, particularly threats, in a given community (Walshe, & Nunn, 2012). IK existed long before the modern science and enabled the locals not only to survive but also develop amidst the environmental and physical threats in their localities (World Bank, 1998). It is important to note that indigenous people are amongst the key stakeholders and informants at the grass-root level in case of a landslide occurrence and they have experience and traditional knowledge. It is believed that older people in the community hold years of knowledge, skills and wisdom, all which are key to reducing disaster risks and should be part and parcel of disaster risk reduction plans and policies (UNISDR, 2015). Communities have diverse and rich knowledge (Thapa, *et al.,* 2009) and every generation has a contribution in improvising and adapting indigenous knowledge according to changing circumstances (Lunga & Musarurwa, 2016). The knowledge emanates from the interaction between the local community and the environment in which they live in and helps them survive over generations (Iloka, 2016). It is acknowledged that the knowledge can make vital understanding of environmental change in developing countries (Agrawal, 1995; Mercer, 2010; Shaw *et al.*, 2009). Some proponents indicate that the knowledge has been tested over time and found to be sustainably effective in the reduction and management of unavoidable hazards and disasters (Shaw *et al*., 2009). It has impressively been applied to design critical livelihood strategies and has the potential in making the local communities less vulnerable to adverse occurrences (Barker, 2017). For instance to mitigate against disasters such as food security and forest preservation of forest resources (Lunga & Musarurwa, 2016).

2.3.2 The integrating scientific and indigenous knowledge in the understanding of landslide disasters

Without taking sides, the author is of the opinion that it is important to have both understanding as it would contribute to better knowledge about landslide disasters. With the understanding of existence of the two sets knowledge, a critical review of literature is done focusing on the integration of both and cases where it has been applied in studies. Table 2.2 highlights a summary of related studies in terms of the approaches, areas, author and year of study with an aim of pointing out the gaps, which this study is set to fill.

Table 2.2: ***Integrating scientific and indigenous knowledge study approaches***

Study Approach, Area, Author and Years	Research Gap
Strengthening rural community bonds in reducing landslide disaster risks susceptibility in Murang'a and Meru, Kenya (Salome *et al*., 2004)	Did not make an attempt to link the scientific and IK and no in-depth study about the local community's knowledge was done. The study area is also quite diverse.
Integrating traditional knowledge in botanical sustainable land Management- Western Kenya (Shisanya, 2017)	Not focusing on landslide disasters.
Indigenous knowledge on disaster mitigation: Towards creating complementarity between communities' and Scientists' knowledge- Nepal (Thapa, *et al.*, 2009)	Focused on general disaster preparedness and mitigation and not specifically on landslide disasters

Source: *Salome et al., (2004), Shisanya, (2017) and Thapa, et al., (2009*)

2.4 Effects of landslide disasters

Landslide economic losses have been characterized as direct or indirect (Ngecu & Ichang'i, 1999; Ngecu & Mathu, 1999; Schuster & Highland, 2001). The direct losses are the immediate destructions and damages on the property, land and other developments while the indirect are the resultant losses from the direct losses which include among others depreciation of land, loss of tax, reduced agricultural productivity, traffic/rivers interruptions and psychological trauma on those affected (Knapen *et al.*, 2006; Kitutu *et al.*, 2009). Information about landslides and the resultant effects at a global, regional and local scales are scanty but one of the important indicators are the elements at risk such as among others the people, civil and structural engineering establishments, economic activities and utilities (Van Westen, 2006). The perception might be so because damages emanating from landslides are perceived to be relatively fewer compared to other disasters. Another possible reason is the fact that in most cases, damages from landslides are opaque as landslides are normally triggered by or occur in combination with other disasters such as earthquakes and floods (Ciurean *et al.,* 2013), which makes it difficult to isolate the specific disasters from the landslides.

2.4.1 Murang'a County Geo-meteorological hazards profile

Murang'a County has had many reported disasters over time as shown in landslide are unique and noticeable because they are recurrent and affect all the seven sub-counties of Murang'a as a result of excessive rainfall, dissected topography, favourable soil types and anthropogenic activities on land courtesy of increasing population. The landslides have caused many losses as outlined on Table 2.3.

Table 2.3: ***Murang'a County geo-meteorological hazards profile and their associated effects***

Risk Type	Potential place of occurrence	Causes of threat	Brief information of degree of severity and history of the hazard
Landslides and mudslides	Kigumo, Kahuro, Gatanga, Kiharu, Mathioya, Kangema Kandara	-Excessive rainfall -Dissected topography, -Soil erosion, -Human activity	The county has a history of landslides/mudslides but due to climate change, increase in population, from year 2016, each rainfall season, the county reports numerous landslide leading to loss of lives, destruction of property, displacement of people, among others.
Drought	Lower zone of Murang'a	Due to erratic and unpredictable rainfall	Due to climate change and variability, farmers have incurred loss leading to loss of crops and pasture
Food insecurity	Lower Gatanga,	-Pests and diseases, Fall army worm -Drought and other	Due to effects of climate change, poor attitude towards

	Maragua and Kiharu	extreme weather conditions -Climate change and variability, -Poor Post-Harvest management practices, -Change of agricultural land to residential due to increase in urbanization and industrialization, -Lack of legal framework and implementation	farming, the geographical features of the county.
Flash/ flooding	Urban centres due to poor planning River flooding due to excess rainfall in Lower Kiharu, Mathioya, Gatanga and Maragua	-Poor planning in urban centres and River flooding due to high rainfall and farming in riparian areas	There has been an increase flooding leading to displacement of people, loss of crops and livelihood
Drowning	County wide	-Natural causes -Technical errors -Human errors	Cases rise during the rainy season and also as a result of mental health issues.
Fire hazard (both structural and wild fires)	County wide	-Arson -Human error -Technical error -Non-compliance -Natural causes -International situation -Lack of legal basis and supervision	Unkempt forests and poaching are posing a threat to our indigenous forests from a recent survey of forest fires. School fires are on a new surge due to students' unrest. Urbanization.
Road Traffic Accidents	County wide	-Human error -Technical errors -Non-compliance -Natural causes -Topography	The topography our county causes contributes to high cases of this hazard. Most roads have inadequate traffic signage. Road users' attitude.

Source: *Murang'a County Disaster Management Directorate (2021)*

2.4.2 Challenges of establishing landslide effects and relating landslide sizes with effects in different geographies

Landslide events are highly localized leading to a difficulty in compiling a complete vulnerability information for mitigation purposes (Van Westen, 2006). Assessing the susceptibility of elements at risk in the case of a landslide event is challenging as it depends on many factors such as volume and velocity of the slides and the nature and distances of the said elements (Finlay and Fell, 1997). In different areas, there are different types and forms of elements at risks and the landslides being 'highly localized' it becomes challenging to establish the effects for different localities with different characteristics and which faces different magnitude of landslides. For instance due to intensive agricultural activities on small pieces of land occasioned by high population densities in landslide prone areas, a minor landslide causes huge losses as it affect many people when it occurs (Westerberg and Christiansson, 1999).

True but surprisingly, another big setback of mass-movement mitigation is the myth that some rural populace associate the disasters with. They contend that the disasters are the 'work of God' (Westerberg and Christiansson, 1999). Such a contention make them have less faith in the process of even ascertaining the effects of landslides as they view the whole disasters being supreme and beyond their control.

2.4.3 Positive versus negative landslide effects

Landslides are serious geologic disasters which cause serious damages than is generally recognized (Maina-Gichaba *et al*., 2013) ranging from the destruction of human, property, traffic and structures. In some studies, landslides are defined as a serious geologic disaster that cause destruction to human, property, traffic and structures (Yufeng & Fengxiang, 2009).

According to available literature, studies about landslide effects pay much attention to the negative effects of landslides at the expense of any positive contributions of the occurrences in an area. This is a research gap that this study tends to bridge by also discussing and highlighting the eminent benefits from a landslide disaster. Unfortunately, some of the positive effects are easily turned to be of negative effects by the irrational people in the society through actions such as diversion of funds meant for activities such as relief and reconstruction post a landslide disaster.

2.5 Landslide Disasters' Early Warning Systems (EWS)

According to UNEP, Early Warning Systems refer to the timely and effective provision of information by concerned institutions and bodies on precursor to a landslide aimed at enhancing the risk knowledge, monitoring and warning those who are at risk and to build better response to a landslide disaster. Consequently, it has been reported that the framing, adoption and implementation of landslide disaster EWS is gaining traction among the different stakeholders in the disaster management (Guzzetti, *et al.*, 2020). Landslide EWS are among the many interventions known to reduce hazard risks (Macherera *et al.*, 2016, Adams, *et al.*, 2022) and specifically the risks caused by a landslide disaster (Piciullo, *et al.,* 2018) and should be timely in calling on people to act in a certain direction to avert untold suffering from a disaster and can be done in various ways to avert the disaster of reduce the high prospects of damages (Calvello, 2017).

According to the United Nations, EWS have been in existence for a long time. The UN, through the United Nations Environment Programme (UNEP), 2012, outlines the elements of Early Warning Systems (EWS) as being:

1) Risk knowledge, monitoring and warning,
2) Dissemination and communication
3) Response capacity.

According to the Sendai Disaster Risk Reduction 2015-2030 (Reduction, 2020), which was adopted at the third United Nations World Conference on disasters held in Sendai, Japan, countries of the world were presented with unique opportunities, two of these being that:

i) They should plan and reduce disaster risks as a matter of priority and ensure plans to protect the elements at risk through strengthening their coping mechanisms.
ii) To have a robust and more people-oriented approaches to reduce the effects of disasters through multi-sectoral and all-inclusive engagement.

2.5.1 Application and integration of scientific and traditional EWS

Much attention is given to the scientific EWS in which through enhanced technologies, EWS have been greatly improved and become more accurate. Historically, EWS have been linked to the scientific understanding hence ignoring the traditional systems held by the local people (Sufri, *et al.*, 2020). Nevertheless, the application of traditional knowledge in EWS can be cited in communities in Pacific, America and Africa. According to Sufri and others, generally, lack of or inadequate integration of scientific and indigenous knowledge is a reality. For instance in a pilot study about potential application of indigenous knowledge in the understanding of cyclones in Bangladesh, older people were said to have demonstrable early warning indicators, some of which were recommended for integration with the existing scientific systems (Howell, 2003) generally, indigenous knowledge have been used in solving societal problems, including those related to climate change and variability (Gyampoh, *et al.,* 2009). The integration of scientific and indigenous EWS, each of which has limitations (Gyampoh, *et al.*, 2009), would make real the opportunity to have a robust and more people-oriented approaches to reduce the effects of disasters through multi-sectoral and all-inclusive engagement as prescribed by the Sendai Disaster Risk Reduction Convention. Such an option is a gap in research which this study seeks to fill in assessing EWS as understood in science and by the indigenous people of Murang'a and analyzing the nexus and convergence between the two sets of views.

1.6 Landslide disasters research study approaches

2.6.1 Landslide disasters study designs

Three approaches of landslide risks and vulnerability assessments are broadly categorized into: quantitative, semi-quantitative and qualitative (Zhou, *et al*., 2020), each with merits and demerits. Quantitative approach is best suited where more detailed data for a large scale landslide occurrence is available and results to more objective and explicit outputs as compared to the qualitative studies. Quantitative approach is regarded as deterministic approach and is the most detailed (Barredo, *et al.,* 2000). Qualitative approach is subjective but less data intensive, cost effective and easily understood by non-experts. The semi-quantitative methods, which is a blend between qualitative and quantitative approaches and is adopted in this study, is useful in reducing the generalization and subjectivity posed by the qualitative approach (Ciurean *et al*., 2013). However, the most appropriate approach will depend on many factors such as the problem at hand, data availability among others. It is important to note that here is no pure approach which is preferred or stand-alone for the risks studies (Ho, *et al.*, 2000). A preferred model may integrate different techniques, for example: integrating fuzzy logic and analytical hierarchical process in a heuristic approach (Gorsevski, *et al.*, 2006), Fuzzy k-means and Dempster-Shafer Theory (Gorsevski, *et al.*, 2005),

2.6.2 Geographic Information Systems (GIS) and Multi-Criteria Evaluation (MCE) in landslide disasters study

Understanding landslide disaster risk entails making a correct decision with regards to the occurrence of the hazard and the vulnerability in an area. Geographers usually face the problem of making spatial decisions against multiple alternatives and factors (Malczewski, 1999; Eastman, 2012). A priority in understanding disaster risks at national and regional levels has previously been cited (UNISDR, 2015). Different researchers use different methods in understanding disaster risk zones (Othman *et al.*, 2012).

This research uses GIS in MCE to integrate various landslide causal/trigger factors as understood through scientific and locals' indigenous knowledge. One of the crucial applications of GIS is being a tool for decision support and MCE allows the combination of data from different criteria to yield a single index combination (Eastman, 2012).

The main reason for the integration of the two arguably incompatible schools of thought is the fact that landslides studies are at the nexus of both social and scientific concerns (Crozier & Glade, 2005). The output of indigenous knowledge-based MCE will be compared with that of the scientific knowledge to assess the local's understanding of landslide risks in the prone areas of Murang'a County. The two techniques can benefits from each other (Malczewski, 1999).

According to the Sendai Framework for Disaster Risk Reduction 2015-2030 which was adopted at the Third United Nations World Conference on Disaster Risk Reduction, held from 14 to 18 March 2015 in Sendai, Miyagi, Japan, disaster risk reduction should:

> '*ensure the use of traditional, indigenous and local knowledge and practices, as appropriate, to complement scientific knowledge in disaster risk assessment and the development and implementation of policies, strategies, plans and programmes of specific sectors, with a cross-sectoral approach, which should be tailored to localities and to the context'* -(UNISDR, 2015, *P. 10*).

To implement the Sendai framework, Multi-Criteria Evaluation (MCE) is used to integrate the indigenous knowledge with a scientific analysis of landslides trigger/causal factors in a GIS modeling of scenarios. GIS tools have been noted to be impressive in providing solutions to location-based problems (Articte, 1995). Raster-GIS enables analysts to establish logical and mathematical relationships among data layers to yield derivative decision support maps layers (Articte, 1995). Even though, GIS has been noted to have various inadequacies, which makes it weak to stand alone (Stephen J. Carver, 1991, Honea, R.B., 1990).

A combination of both GIS and MCE gives rise to Spatial Multi-Criteria Evaluation (SMCE), a powerful tool to map and predict landslide hazard zones (Othman *et al*., 2012). SMCE has recently been used to study landslides susceptibility in Rwanda using causal factors such as slope, distance to roads, lithology, precipitation, soil texture, soil depth, altitude and land cover (Nsengiyumva *et al.,* 2018). Exampls of other researchers who have previously used the same approach include Stephen (1991), Piotr Jankowski, (1995), Nsengiyumva *et al.,* (2018). In others studies, Spatial Multi-Criteria Evaluation

(SMCE) have been developed through the use of experts' knowledge in formulating the evaluation criterion (Othman *et al.*, 2012) for studying landslides and other location-based issues (Articte, 1995, Store, & Kangas, 2001, Malczewski, 2004).

This research intends to use the same methodology but with a departure from the previous studies as it will use of local indigenous people's experiences and knowledge to formulate the factors' scores/weights to be applied in the MCE analysis. Such like a study which dealt with local indigenous people at a community level was a study done for a community-based landslide risk reduction where inputs were sought from residents, leaders and contractors and used in formulating the MCE (Anderson, & Holcombe, 2013). However, that study did not emphasis on local indigenous knowledge parse and also missed an opportunity to integrate it with the scientific knowledge. Integration of local indigenous knowledge study was carried out in a case study in Tutkabon, Iran but the applied a different theory, Dempster- Shefar, to mainstream disaster risk factors had noticeable weaknesses (Milaghardan, 2016). There has been an ongoing debate about the link and integration of knowledge contained in the pure and social sciences (represented in this study by indigenous people). The outcomes of this study will contribute to the de-escalation or otherwise of the existing 'conflict' between the two schools of thoughts (Crozier & Glade, 2005; Barker, 2017).

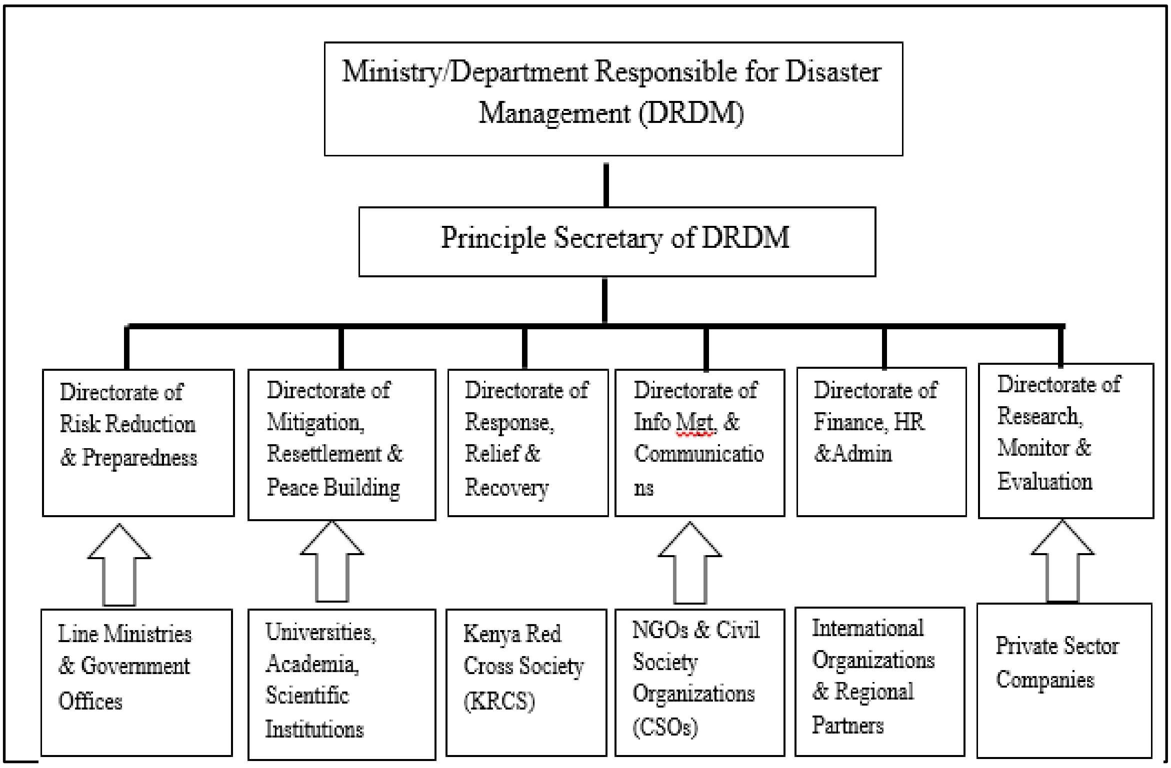
2.7 Disaster management policy in Kenya

Government agencies and those who formulate policy need to develop a better understanding of significance of landslides (Schuster, 1996; Davies, 1996). Kenya has a policy which was enacted in 2010 and which provides a general architectural guidance on disaster management in the country. It outlines an overarching framework for decision making and how disaster actors and sectors should act and coordinate. As currently formulated, the framework has noticeable strengths and weaknesses with respect to mainstreaming the local indigenous knowledge in disaster management continuum.

Strengths include the fact that stakeholders in disaster management should uphold certain code of conducts which are deemed to champion the local community's contributions. It is in line with the global approach of reduction and management of unavoidable hazards and disasters (Shaw *et al*., 2009). For instance the policy states that the stakeholders should respect culture and customs of the community and households in a given area. Further, the research investments should include best practices based on indigenous knowledge and traditional technologies which are deemed to have helped the said community be sustainably resilient to disasters in the past. It also states that the stakeholders should reinforce the locals' capacity to manage full disaster cycle and the local community should be viewed to be not only vulnerable but also as having potential and strength in disaster management. The disaster management activities are therefore supposed to reinforce but not suppress community capacities.

The policy is however found have *lacuna* and therefore being an inadequate advocate for mainstreaming indigenous knowledge in disaster risk management. One of its weaknesses is that the policy is not specific to any disaster management but is just a general framework for all disasters hence cannot be considered as an adequate blueprint for landslide disasters. This is against the fact that natural disasters are unique in nature and place. Secondary, the policy does not stipulate how the mainstreaming of community inputs will be achieved. As would be expected, it gives no specific framework on how a particular disaster such as landslides would be appropriately managed through the integration of the local indigenous knowledge and other techniques as may be applicable. Thirdly, the policy talks of embracing community knowledge but with no specific emphasis on traditional, indigenous and local knowledge as recommended by the Sendai framework (UNISDR, 2015). This is against the contention that for proper understanding and prevention of disasters, the crucial role of human agencies and the society must be considered (Mileti, 1999). Recommendations are advanced to the effects that future strategies for reducing disaster risks should mainstream community indigenous knowledge and integrate it with the scientific knowledge (Walshe, & Nunn, 2012). Finally, the disaster management organization structure as stipulated in the policy does not feature the local community yet it claims to be a bottom-up and community-centered (see

Figure *2*.2).



Adapted from: (Republic of Kenya, 2010)

Figure 2.2*: Disaster risk management organization structure of Disaster Management/ Disaster Risk Management (DM/DRM) Directorates in Kenya*

2.8 Theoretical Frameworks of the study

A theory is a set of interrelated propositions that allow for the systematization of knowledge, explanation and prediction of social life and the generation of new research hypotheses (Faia, 1986; Ritzer & Smart, 2000). A theoretical approach is a complex of concepts, suppositions and prepositions which are logically integrated and empirically referenced (Laszlo & Krippner, 1998). The development of a conceptual scheme or paradigm is meant to bring about major changes and advancement in any science discipline. The revolutionary change brought about by a theory should make a discipline stand tall in the eyes of other practitioners (Kuhn, 1962).

Recent years have seen an increasing need for a theory which would be an applicable general framework for discussing the empirical world such as the systems theory (Boulding, 1956). The systems theory and the concept of integration underpin the theoretical framework of this study as discussed below.

2.8.1 The Systems Theory

Ludwig von Bertalanffy is considered to be the father of the general systems theory, an interdisciplinary school of thoughts (Von Bertalanffy, 2010). Systems theory is a science which enables comparative study of a system and its components. As a general theory, it has a wide application in many fields such as biology, chemistry, mathematics, physics and social sciences (Stichweh, 2011). The systems theory is described as ‘basis *for unifying science’* embraced by biologists and social scientists (Kast & Rosenzweig, 1972, *P.* 447). It is a general a framework (Stichweh, 2011) for testing, and validating trans-disciplinary study queries as opposed to being discipline-specific (Laszlo & Krippner, 1998; Lalande & Baumeister, 2014). The theory is said to bring about new paradigm in social sciences studies but just lacks the precision (Kast & Rosenzweig, 1972). Applications in sociology is linked to Talcott Parsons (1980) and Luhmann (1995). Professor Talcott Parsons has a special place in the history of sociological theory with his pioneer social systems works, *The Structure of Social Action* (1937) and later *The Social Systems* being very influential (Parsons, 1980).

The concept of systems

In broader terms, the concept of ‘system’ may be viewed as a complex interaction of related components with identifiable relationships and boundaries but which in total makes an entity or a process (Laszlo & Krippner, 1998). A ‘system’ refers to ‘sets of standing interrelated items’ (Von Bertalanffy, 1968). Ackoff (2000) suggested that the concept of a system should be characterized by a combination of one or two elements that that satisfies the following:

i) The behaviour of each element of the system has an effect on the whole system.

ii) There is interdependency within and between the system’s elements and their behaviours and effects on the whole system. This means that no one single element can be considered to have exclusive effect on the whole system.

iii) Where sub-elements of the elements are formed, each will conform to the above two conditions.

According to Kast & Rosenzweig (1972), systems can loosely be viewed in two dimensions, Open system and closed systems. The former are the biological and social systems characterized by the exchange of energy, materials or information between the system and the environment. Such a system is in a dynamic relationship with its environment from which it gets the inputs. The environment may comprise of among others the complex of climate, resources, population and other physical possibilities (Parsons, 1980). A closed system is considered isolated as there is no interactions with the environment (Von Bertalanffy, 1973).

Components of a system and landslide as an open system

According Von Bertalanffy (1968), a system is defined by the following parameters; inputs, through-puts, environment, feedbacks and outputs. This is as depicted in

Figure 2.3 which shows a hypothetical framework of a landslide disaster as a system. The landslide disaster is considered to be the system operating in an environment characterized by climatic, geological, topographical, geomorphological and anthropogenic activities. Such an environment is in constant interaction through inputs which include among others rainfall, soils, altitude, Land-use land-cover (LULC), vegetation, population and their practices, slope and its derivatives among other factors. The inputs undergo a transformation and are processed within the system to result in a landslide disaster courtesy of prevailing favourable causal/trigger factors status at a point in time. Such favourable status include characteristics such as high rainfall, steep slopes, high altitude, loose soils, loss of land-cover which exposes and disturbs the soils among others. The next stages are the outputs characterized by landslide disaster effects, landslide disasters' management tactics and constraints. A constant communication and feedback will be present between the outputs and the inputs to enable a constant state of equilibrium, meaning no or less cases of landslide event. The scientific and local people's understanding, which are subject to the environment are important in bringing the whole system to stability through constant interaction and feedback on how best to manage the landslides' causal/trigger factors hence lessening the chances of a landslide occurrence at a given time. The two levels of knowledge are important in making the through-put 'opaque' hence less likely to act and collectively contribute to an occurrence of a landslide.

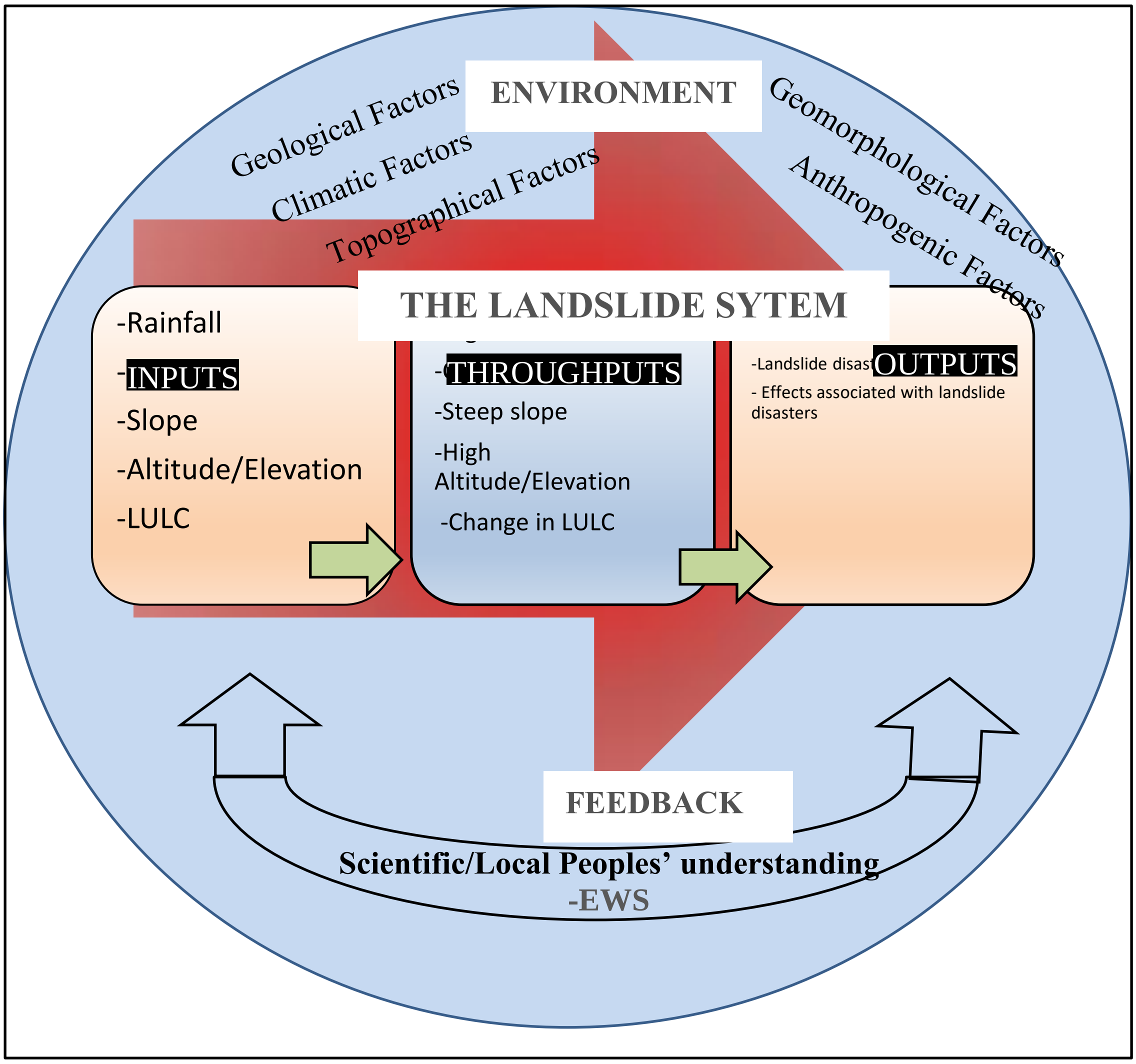


Figure 2.3: ***A hypothetical landslide as a 'system' framework***

The systems theory has been used in studying landslide and other disasters and risks such as environmental and human health risks (Skoko, 2013) as it is powerful in iterating and rigorously integrating both mathematical and intuitive approaches to determine and design preferred plans for a complex phenomenon (Simonovic, 2015). The systems theory is applicable in the study as landslides and the associated stability or instability in a given area has been defined as a system (Shi, *et al.*, 2020; Khasanov, *et al.*, 2021), an open dynamic system (Liu *et al.*, 2018; Yufeng & Fengxiang, 2009) as well as a non-linear open system (Yufeng & Fengxiang 2009)**.**

It is imperative to note that landslides are landforms-associated processes linked majorly to geomorphological, hydrological/climatic, geological and anthropogenic conditions in an area (Crozier & Glade, 2005). According to Simonovic (2015), landslides are likely to occur as a result of complex dynamic interaction among numerous anthropogenic and natural factors at a place in time (Yufeng & Fengxiang 2009)**.** For instance heavy rainfall in hilly areas leads to the weakening of the slope stability as a result of increased soil wetness resulting to the occurrence of a landslide in an area (Huho *et al.*, 2016). In that case, a landslide is viewed as a complete entity made-up of sub-systems. The systems theory is vital in modeling the landslide scenarios (Laszlo & Krippner, 1998) by combining the causal/trigger factors. The theory enables the splitting of reality into smaller components of causal factors (Von Bertalanffy, 1973). In the study, landslide has been split into sub-systems, each with characteristic intervening pre-disposing/causal/trigger factors. A landslide is viewed to occur as a result of the interaction of geomorphological, hydrological, geological and anthropogenic sub-systems/elements/factors/components, which qualifies landslides to be a system according to the criteria set by Ackoff, (2000).

Several authors have eluded and supported the notion of landslides being a system. For instance Davis (1996) stated that Kenya’s landslides occur mostly due to a unique combination of geological and geomorphological conditions in the prone areas. Systems theory fits the study as according to Haigh (1985) contention, Geography is a 'general systems science' which accommodates the systems theory as it is integrative in nature and links physical and social sciences studies (Haigh, 1985).

The strengths of adopting a system perspective lies in the fact that it affords:

i) The vision of the 'big picture' and balances short-term and long-term perspectives. The perception of a holistic approach solution when dealing with multifaceted situations emanating from multiple interactions (Laszlo & Krippner, 1998).
ii) Human intuition where a person's thinking is accommodated in modelling the system (Tehranian, 1974). The model builder (researcher) has an opportunity to explain the world or part of by modeling it and defining the model in terms of the purpose, elements/components/inputs and their structures, connections and eventually the final model outputs (Checkland, 1981).
iii) The integration of both measurable and non-measurable factors, which are dynamic, complex and interdependent (Khyrina *et al.*, 2012; Laszlo & Krippner, 1998).
iv) Laszlo & Krippner contends that the theory is not algorithmic in nature. This means that it does not strictly follow a definite step by step path to yield the final results but its non-algorithmic procedures (heuristics) are fine to yield powerfully sufficient and satisfactory results (Laszlo & Krippner, 1998 *P. 12*)
v) The potential for trans-disciplinary framework to simultaneously explore the relationships between peoples' perceptions and conceptions in a locality (Laszlo & Krippner, 1998).

Weaknesses of the systems theory

Nevertheless, the systems theory has some shortcomings in application. One of the key weaknesses is the fact that the theory is not discipline-specific but just a general a framework (Stichweh, 2011) for testing, and validating trans-disciplinary study queries (Laszlo & Krippner, 1998; Lalande & Baumeister, 2014). This is against the contention that development of a theory is meant to bring about major changes and advancement in any science discipline. The revolutionary change (paradigm) brought about by a theory should make a discipline stand tall in the eyes of other practitioners, which the systems theory seem to fall short of (Kuhn, 1962). However, some scholars are of the feeling that the systems theory provide an opportunity for theorist to craft paradigm of a discipline-specific system theory. It is contended that the systems theory brings about new paradigm in social sciences studies but just lacks the precision (Kast & Rosenzweig, 1972).

2.8.2 The Concept of Integration

Effective research and management of risks calls for the integration of a wide scope of interests (Crozier & Glade, 2005). The concept of integration is applicable in the study as it helps to link the scientific and social aspects. It resonates well with the systems theory which has been described 'to integrate natural and social sciences' (Von Bertalanffy, 1973). The study seeks to integrate the scientific and indigenous knowledge, the two arguably incompatible knowledge and the concept fits well in the study due to the fact that landslides studies are at the nexus of both social and scientific concerns. In the same argument, social sciences (Geography included) are concerned with human beings interacting with the environment, just as open systems studies (discussed above) demand (Parsons, 1980). Apart from bringing together the scientific and local peoples' knowledge in natural and social science, the concept of integration is also vital in the bringing together both measurable and non-measurable factors in the landslide system (Khyrina *et al.,* 2012; Laszlo & Krippner, 1998).

Good enough, GIS techniques have the tools and functionalities to integrate techniques from many disciplines (Van Westen, 2006). Examples of studies focusing on integrating citizens in studying landslide can be seen in Cieslik, *et al.*, (2019), Rohan, *et al.*, (2020) and Lee, *et al.,* (2020).

2.9 The Conceptual Framework of the study

The conceptual framework is important in doctoral research (Leshem & Trafford, 2007) and should be designed to guide the study in answering the research questions aimed at addressing the study objectives (Berger and Patchner, 1988). The research on Landslides Disaster Risks (LDR) in Murang'a County is domiciled in the Systems Theory and the concept of integration as discussed earlier. The study master-plan focuses on landslide disasters with specific interests on the scientific and local peoples' indigenous knowledge understanding and the nexus between the two.

The study concept is well demonstrated in the conceptual framework shown in Figure 2.4. The study progresses from left to right through Parts A, B and C. Part A shows the research problem being the landslide disasters and the two levels of understanding i.e. the scientific and local peoples' knowledge. The study is anchored on the systems theory and the concept of integration as articulated in part B. Under the systems theory, the landslide is considered a system (See Shi, *et al.*, 2020; Khasanov, *et al.*, 2021), made-up of sub-systems with pre-disposing/causal/trigger factors characterized under broader categories of climatological, geological, topographical, geomorphological and anthropogenic factors. The pre-disposing/causal/trigger factors in the study are rainfall, soils, slope, altitude and LULC. For a landslide event (system) to occur, the factors must play-out in a certain way as scientifically and/or otherwise understood. The sub-systems and associated factors are the independent variables of the study (see Mancini, *et al.*, 2010, Tekin and Can, 2018) while the scientific and/or indigenous knowledge and understanding are the dependent variables. The landslide inventories are used to assess, check and validate the reliability of the outcomes (Zhou, *et al.*, 2020) as they are considered the basic necessity for any quantitative landslide studies (Tekin and Can, 2018). Part B further demonstrate the concept of integration in the study.

Firstly, integration is depicted in the way pre-disposing/causal/trigger factors work-out to contribute to a landslide disasters event, the system. Secondly, integration is demonstrated in the scientific and local peoples’ understanding nexus under research objective 3 of the study. Of particular interest is how the local people, using their indigenous knowledge understand the scientifically-known landslide disaster causal/trigger factors. Finally part C of the conceptual framework advances the understanding of LDR through an assessment of the effects and how local people use indigenous knowledge for early warning, a crucial part of DRM.

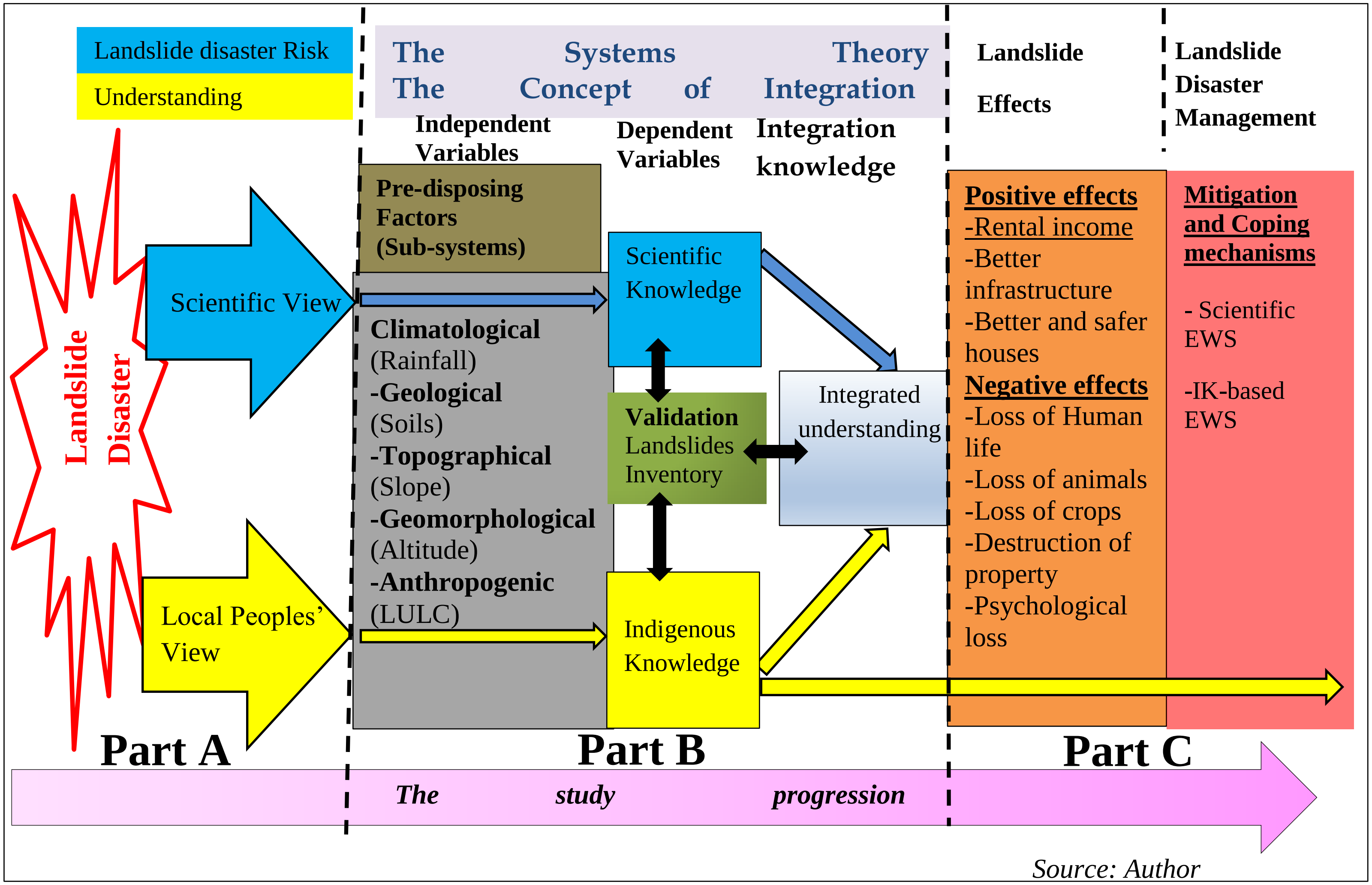


Figure 2.4: ***Schematic representation of the conceptual framework of the study***

2.10 Chapter Summary

The chapter outlined a detailed review of literature and set the debate on the study problem of landslide disasters with respect to among others the causal/trigger factors, spatio-temporal distribution, effects, and study approaches of landslides. Through the reviewed literature, the debate on scientific and IK understanding of landslide disasters is set out, more specifically the question of the two levels of understanding and whether they can be useful in understanding the landslide disasters in an area. Important policy and strategic literature at both national and international level are consulted to aid in understanding the importance of the two levels of knowledge in disaster risk management. However, as far as the study area of Murang'a County and Kenya as a country are concerned, no clear framework could be cited on the integration of IK into the disaster management continuum, hence making the study relevant in filling the research gaps on the understanding of landslide disasters risk in Murang'a County based on scientific and IK understanding and nexus between the two levels of knowledge.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter focuses on the description of the research in terms of: design and the approach, study population, sampling; sampling frame, sampling design and techniques, sample size calculation, data types and sources as well as the data treatment and processing. Table shows a brief summary framework of the research objectives, study approach, tasks and the expected results for the study.

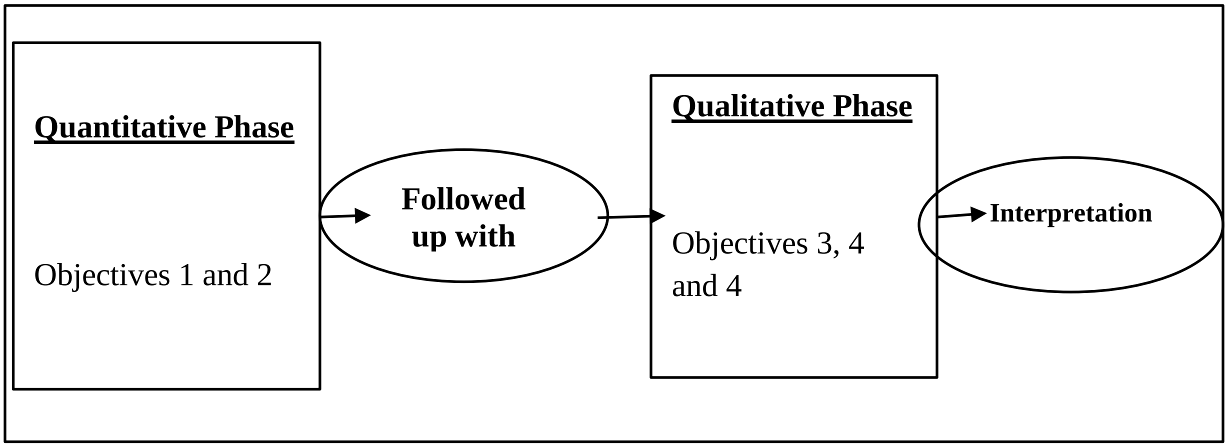
3.2 Research design and approach

Research design is important in any research as it gives an indication of the framework of data collection, analysis and priorities given to research process (Bryman, 2016). The research adopted mixed methods sequential explanatory design (Ivankova, *et al.,* 2006), which is suitable for social science research (Subedi, 2016, Creswell & Clark, 2017). The sequential approach entailed first the collection of quantitative data that were then analyzed, after which qualitative data were collected to help explain/clarify the results obtained from the quantitative data in order to get an in-depth understanding of the results. The choice of the mixed methods approach was informed by similar studies that used the approach and yielded robust results. For example, Shisanya, (2017) used the approach in a study about role of traditional knowledge in sustainable land management in Western Kenya. The quantitative data were obtained from secondary sources through remote sensing techniques and were analyzed through raster-GIS in both MCE and WLC for the scientific and IK understanding respectively. Primary quantitative data captured through questionnaire and entered into IBM SPSS software for both descriptive and inferential statistics.

On the other hand, qualitative phase data were collected through both primary sources and secondary sources from field data collection and literature reviews. The analysis of the qualitative data were through content analysis as text or in IBM SPSS software for both descriptive and inferential statistics. Qualitative data collection methods have been widely used in most landslide hazards research, more so those which exploit the IK on mitigating disasters through focused discussions (Lunga & Musarurwa, 2016). Combining this with quantitative methods, as in the current study served to enrich the findings.

The mixed method approach is preferred as it can, to some extent, reduce the subjectivity and the level of generalization brought forth by the purely quantitative approaches (Ciurean *et al.,* 2013). Further justification for not utilizing a purely quantitative design is that such methods are only applicable for large scale studies such as for single structures by engineers or other actors for refined technical analysis (Li *et al.,* 2008; Fuchs *et al*., 2007) and such a scenario-based approach is data intensive (Uzielli *et al.,* 2010) which is not the case for the current study. The explanatory sequential mixed method research design, as diagrammatically illustrated in Figure 3.5, was suitable for the study as it enabled the integration of the two phases of the research:

i) The quantitative phase, which defines the fundamental part of the research and
ii) The qualitative Phase, which explains the quantitative phase and helps in further interrogation of the study concerns hence bringing out a better understanding.



Adapted from: Creswell & Clark (2017)

Figure 3.5*: A prototype of explanatory sequential mixed method design*

A detailed summary of the phases in the explanatory sequential design's tasks and expected results objective-by-objective is shown in Table 3.4

Table 3.4: ***A Summary of objectives, tasks, study approach and the expected results***

Research Objectives	**Tasks**	**Approach**	**Expected Results**
Objective 1: Mapping and delineating the scientifically-defined landslide risk zones.	-Identifying, evaluating, classifying and integrating the landslide causal/trigger factors to map and delineate the landslide risk zones according to scientific knowledge	Quantitative	Landslide disaster risk maps based on the scientific understanding
Objective 2: Mapping and delineating the indigenous knowledge-based landslide risk zones.	-Identifying, evaluating, classifying, weighting and integrating the landslide causal/trigger factors to map and delineate the landslide risk zones according to indigenous knowledge	Quantitative	Landslide disaster risk maps based on indigenous knowledge understanding
Objective 3: Assessing the nexus between the scientific and indigenous-based landslide disaster risks understanding zones in comparison with the documented landslide inventories.	-Comparing the scientific and indigenous knowledge maps to establish the nexus and with the documented landslide inventory to validate the zonation.	Quantitative	Derivative map of the comparison between landslide disaster risk zones and how they relate to the documented landslide inventories.
Objective 4: Assessing the landslide disasters effects	-Assessing the landslide effects on the local people	Qualitative	Descriptive statistics and narrative explanation of landslide effects
Objective 5: Assessing the local peoples' early warning systems through the use of indigenous knowledge and the nexus with the scientific systems	-Analyze the prominent early warning systems by the locals and in science	Qualitative	Descriptive statistics and narrative explanation of the EWS

Modified from Omondi, 1994

3.3 The study population

According to Taherdoost (2016), a clear definition of the study population is the first stage in the sampling process. Population is usually related to the inhabitants of a given region. A target population is the finite collection of units from which data is sought in a survey (Lavrakas, 2008). The study area comprised of six sub-counties (Kangema, Mathioya, Kiharu/Kahuro, Kigumo, Kandara and Gatanga) which were purposively. The study locations were also purposively selected from the six sub-counties based on the reported landslides cases for the MAM, 2018 as recorded by KMD, Murang'a County. Murang'a has had recurrent landslides over the years but March-April-May (MAM) 2018 had the highest number of serious landslide cases ever reported in the county in a single rainy-season according to the Murang'a Meteorological Services (KMD, 2021). Out of the seven sub-counties of Murang'a County, only Maragwa had no serious cases reported in the reference year hence was not studied. The study locations had a total population of 85,895 people distributed over 26,201 HHs (KNBS, Volume II, 2019) as shown in Table 3.5

Table 3.5: ***Population per location in each study sub-county***

Sub-county	Location	Total Population	Total HHs
Kangema	Kihoya	6,423	1,984
	Rwathia	7,417	2,261
Mathioya	Gitugi	7,682	2,308
	Kiru	10,381	3,266
Kiharu/Kahuro	Murarandia	11,880	3,714
Kigumo	Mariira	10,180	3,130
	Kinyona	7,911	2,440
Kandara	Kibage	16,913	4,870
Gatanga	Mbugiti	7,108	2,228
Total		**85,895**	**26,201**

Source: *Population and housing data from Kenya National Bureau of Statistics (KNBS, Volume II, 2019)*

3.4 Sampling frame, sample size and the target population

3.4.1 Sampling frame

A sampling frame aids in obtaining the actual cases from which the survey is done and it must adequately represent the entire population (Taherdoost, 2016). The sampling frame of the study are HHs in the landslide disaster affected administrative locations as per MAM 2018 when the county experienced the largest number of landslide events over the history (KMD, 2021). The respondent for each HH was the head of each household who is a male or female of mature age. In the cases where HH heads were unavailable, any other person of above 18 years of age were selected as respondents for the HH questionnaires.

3.4.2 Sample size computation

The sample size was calculated using the Slovin's (1960) computation formula expressed as follows:

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

Where:

N is the total HH numbers,

n is the sample size,

e is the margin of error at 0.05

$$n= 26{,}201/1+26{,}201(0.05)^2$$

$$n=26{,}201/66.5025= \mathbf{393}$$

Based on this formula, a sample size of 393 HHS was arrived at (at confidence level of 95%). Previous study on indigenous perception and strategies on climate change (Cobbinah

& Anane, 2016) has used the Slovin's computation to derive appropriate sample size for a similar target population hence its preference in this study.

Weighted computation were calculated to standardize the final HHs to be sampled through proportionate HHs for each administrative. The computation were done for each location according to the respective population and the total population for all the target locations (Scheaffer *et al.*, 2011). For proportionate sampling, below formulae was used:

$$\boldsymbol{n} = \frac{\boldsymbol{p}}{\boldsymbol{u}}$$

Where:

n is the proportionate HHs for each study location

p is the total sample size for a specific study location

u is the total HHs in all study locations

From the proportionate HHs computation, a total of 393 proportionate HHs were to be sampled in the study. The complete proportionate HHs computation are shown on Table 3.6 and each full computation for each study location are shown thereafter below the table.

Table 3.6***: Total and proportionate households for the study locations***

Sub-county	**Study Location**	**Total HHs**	**Proportionate HHs**
Kangema	Kihoya	1,984	30
	Rwathia	2,261	34
Mathioya	Gitugi	2,308	35
	Kiru	3,266	49
Kiharu/Kahuro	Murarandia	3,714	56
Kigumo	Mariira	3,130	47
	Kinyona	2,440	37
Kandara	Kibage	4,870	73
Gatanga	Mbugiti	2,228	33
Total		**26,201**	**393**

Source: *Populations and housing data from Kenya National Bureau of Statistics (KNBS, Volume II, 2019)*

<u>Computation for each study location</u>

$$Total\ proportionate\ HH\ for\ Kihoya\ stdy\ location\text{:}\ \left(\frac{1{,}984}{26{,}201}\right) * 393 = 30$$

$$Total\ proportionate\ HH\ for\ Rwathia\ study\ location\text{:}\ \left(\frac{2{,}261}{26{,}201}\right) * 393 = 34$$

$$Total\ proportionate\ HH\ for\ Gitugi\ study\ location\text{:}\ \left(\frac{2{,}308}{26{,}201}\right) * 393 = 35$$

$$Total\ proportionate\ HH\ for\ Kiru\ study\ location\text{:}\ \left(\frac{3{,}266}{26{,}201}\right) * 393 = 49$$

$$Total\ proportionate\ HH\ for\ Murarandia\ study\ location\text{:}\ \left(\frac{3{,}714}{26{,}201}\right) * 393 = 56$$

$$Total\ proportionate\ HH\ for\ Mariira\ study\ location\text{:}\ \left(\frac{3{,}130}{26{,}201}\right) * 393 = 47$$

$$Total\ proportionate\ HH\ for\ \ Kinyona\ study\ location\text{:}\ \left(\frac{2{,}440}{26{,}201}\right) * 393 = 37$$

$$Total\ proportionate\ HH\ for\ Kibage\ study\ location\text{:}\ \left(\frac{4{,}870}{26{,}201}\right) * 393 = 73$$

$$Total\ proportionate\ HH\ for\ Mbugiti\ study\ location\text{:}\ \left(\frac{2{,}228}{26{,}201}\right) * 393 = 33$$

3.4.3 Sampling design and techniques

Purposive sampling

Purposive sampling is non-probability judgmental sampling where a researcher deliberately selects the samples to obtain information that cannot be obtained from the rest of alternative choices (Maxwell, 2012) such as certain culture domains (Tongco, 2007). The techniques was selected as it is said to be suitable for studying and analyzing real-life phenomena (Yin, 2003). The information in the context of the study is about the landslide disaster risks and more specifically the local peoples' understanding. Key informants were purposively selected from the sub-counties and locations in Murang'a County. For each of the study sub-county, administrative locations were also purposively selected based on the serious cases from MAM 2018 report by KMD. During the period, over thirty village were adversely affected by landslide disasters as shown in Table 3.7.

Table 3.7: ***MAM 218 landslides cases per location and the affected villages***

Study Location	Number of reported cases	Affected villages
Kihoya	28	Mithanga/Mithanga-ini, Nyagatugu, Kirundu, Mukeu-ini, Kayu and Kihoya.
Rwathia	38	Kiriri, Rwathia, Kihindu and Kiawambogo.
Gitugi	26	Kanyenya-ini, Kanjahi, Kiawambogo, Ngutu and Wang'ondu.
Kiru	5	Kanjama, Kahaaro and Umbui
Murarandia	26	Kagaa, Kiyu, Kiboi, Kaganda, Inooi, Githambo, Theri, Gathaithi, Gatuya and Kiriko-ini.
Mariira	5	Mariira.
Kinyona	6	Karinga.
Kibage	10	Kariua, Gachaki and Mukuria.
Mbugiti	4	Mbugiti and Kirangi.

Source: *KMD, (2021)*

Systematic random sampling for the households (HHs)

The final stage in establishing the respondents for the questionnaires was through systematic random sampling of the HHs in each of the selected administrative locations under study. The starting was a randomly selected HH located centrally within the study location as identified from the spatial distribution and positions of HHs on a remote sensing image of each area. A centrally located HH with a previously reported landslide case was preferred, but where such a scenario was impossible, any random HH was picked. Subsequent HHs were randomly selected radially in all directions from the starting point at an interval k^{th} number for each study location. The k^{th} number was 67^{th} HH.

3.5 Data types and sources

The study's primary data were obtained from the sampled participants and respondents and the instruments used were FGDs, KIIs and HH questionnaires. It also had secondary data obtained from diverse sources for both qualitative and quantitative analysis. Table 3.8 gives a summary of the data types, sources and capture instruments as discussed below.

Table 3.8: ***A Summary of main data types and data collection instruments***

Data Type	**Data Source**	**Data capture Method/Instrument**
GPS Coordinates	Primary	Hand-held GPS receivers and GPS enabled digital gadgets
Digital Elevation Model (DEM)	Secondary	Remote sensing
Remotely sensed satellite images	Secondary	Remote sensing
Rainfall	Secondary	Remote sensing
Land-use Land-cover	Secondary	Remote sensing
Landslide effects	Primary	Questionnaires, Focus Group Discussions and Interview schedule
Landslide disasters' EWS	Primary	Questionnaires, Key Informants, Focus Group Discussions and Interview schedule

Source: Author, 2021

3.5.1 Primary data sources

Household (HH) Questionnaires

Semi-structured and open ended questionnaires *(see Appendix II.188*) was mainly be used to collect data. Structure of the questionnaires in terms of the type of data to be collected and the purpose of each section as far as the research questions were concerned is summarized on Table 3.9.

Table 3.9: ***Structure of the household (HH) survey questionnaires***

Questionnaire Section/Part	Type of data captured	Purpose
Part 1: The study location	Geographic coordinates and administrative location of the study site	For spatial orientation and description of the study site
Part 2: Personal information of the respondents	Respondent's name, age, sex, marital status, occupation, education and income levels	Social-economic status of the respondents
Part 3: Respondent's residency information	Respondents' place of birth, residency period, land size and personal experience of the LULC and population change in the area	Addressing the specific objective 2 and characteristics of study site
Part 4: Local peoples' understanding about landslide disaster risks	Local peoples' understanding about landslide disaster risks, frequencies and effects	Specific objectives 2, 3 and 4
Part 5: IK on landslide disaster risks with respect to the scientifically known causal/trigger factors	Local peoples' understanding about the landslides' causal/trigger factors and their gravity	Specific objectives 1, 2 and 3
Part 6: Landslide disaster risk management	Local peoples' understanding about the Landslide Disaster Risk Management (LDRM) and measures undertaken to mitigate the landslide occurrences	Specific objective 4
Part 7: IK in LDRM	Local peoples' understanding of what IK is and how it can be applied in LDRM. Local peoples' tactics and constraints in LDRM.	Specific objective 2 and 4

Source: *Author, 2021*

Key Informant Interview (KII)

KII interview was used to obtain first-hand and in-depth information from the local people (Shisanya, 2017). KIIs supplemented the HH questionnaires as they provided data that would not have been captured through the main questionnaires (Sapkota, 2017). KII have been used in a similar studies such as research on the role of traditional knowledge in botanical sustainable land management in Western Kenyan Highlands (Shisanya, 2017), indigenous perception and strategies in climate change adaptation in rural Ghana (Cobbinah & Anane, 2016). The key informants for the study were drawn from people with knowledge about the landslides, the experts and administrators or community leaders each of whom were interviewed through structured interview guides shown in appendix on P. 193. Each had a significance in understanding the landslide disasters as outlined in Table 3.10

Table 3.10: ***Key Informants categories and significance of each in the study***

KII	KII Category	Significance
KII-1	County Director of Meteorological Services	Information on scientific understanding of weather/climate and landslide disasters
KII-2	County Commissione	Information on population, and landslide disasters at county level
KII-3	Deputy County Commissioner	Information on population and local people's understanding of landslide disasters at sub-county level
KII-4	Chief	Information on population and local people's understanding of landslide disasters at location level
KII-5	*Mzee wa mtaa**	Information on population and local people's understanding of landslide disasters at grassroots
KII-6	Disaster management Directorate and county ministry of environment and climate change	Scientific and local people's information on landslide disasters: pre, post during disaster management
KII-7	Local Media (FM Station)	Scientific information on weather/climate and landslide disasters occurrences, preparedness, mitigation, early warning and information dissemination and local people's understanding
KII-8	Kenya Red-Cross	Information on landslide disasters; during and post disaster activities

Source: Author, 2022

**Some of the consulted wazee wa mitaa were retired teacher and civil servants with proper formal training and education on among other areas disaster management, the reason why they were consulted as key informants*

Focus Group Discussion (FGD)

FGD was used mostly to get an in-depth knowledge about the indigenous understanding of the landslide disasters in each study location. Members were largely drawn from the local population regardless of their education background or leadership status. Previously, FGD has been used to obtain indigenous knowledge for disaster mitigations through the discussions with community elderly and traditional leaders (Lunga & Musarurwa, 2016) and in studying the role of traditional knowledge in botanical sustainable land management in Western Kenyan Highlands (Shisanya, 2017). It is notable that small cohorts of the population focuses on specific areas of study to yield valuable information (Shisanya, 2017). The participants in the FGD were subjected to preset questions as shown in shown in appendix on P. 198. A total of six FGDs were conducted in each location with a group of between six to twelve members, a number which is considered adequate in research (Lasch, *et al.,* 2010). Diverse data were derived from the six focus groups comprising of different memberships as summarized in Table 3.11 **s**hown below.

Table 3.11*: Focus Group Discussion information*

Sub-county	FGD name	Composition	Kind of data generated
Kangema	Kangema Ranet FM and other experts	Media personality and experts from KMD and Kenya Red-cross, Murang'a Disaster management team	History of landslides in terms of frequencies, post-disasters preparations and mitigations, effects, rescue, relief, reconstruction and general information on landslides in Murang,a County.
Kandara	Witheithia women group	Local women	General information about landslides in terms of frequencies, causes, effects, interventions, landslide trends and mitigations.
Mariira	Mariira tea growers	Peasant tea farmers	General information about landslides: frequency, trends, causes, effects, mitigations and possible solutions.
Ndakaini	Ndakiani traders	Local business men and women	Information on effects of landslides on families, frequency of landslides and possible solutions.
Rwathia	Rwathia leaders	Local leaders (chiefs, assistance chief and *wazee wa nyumba kumi*	History of landslides in terms of frequencies, post-disasters preparations and mitigations, effects, rescue, relief, reconstruction, applicable EWS
Murarandia	Murarandia men and youth leaders	Men and youth leaders	Effects of landslides on families, possible mitigations and solutions to the adverse landslide effects
			Source: Author, 2022

Other the techniques of data capture included the use of handheld GPS receiver which was used to capture the location data for each HH sampled and also aided in navigation in the study location. Garmin Etrex 30 GPS with an accuracy of (+,-) 3 m were used to pick the planimmetric x and y coordinates and the elevations, z coordinates of the HH and landslide affected areas. Dated photographs/plates were used to record important data during the study. Examples are plates/photographs showing the terrain, type of LULC and the development on the land with a bearing on LDR causal/trigger. Photographs also document the various activities during the study for instance the research assistants training and FGD sessions among others.

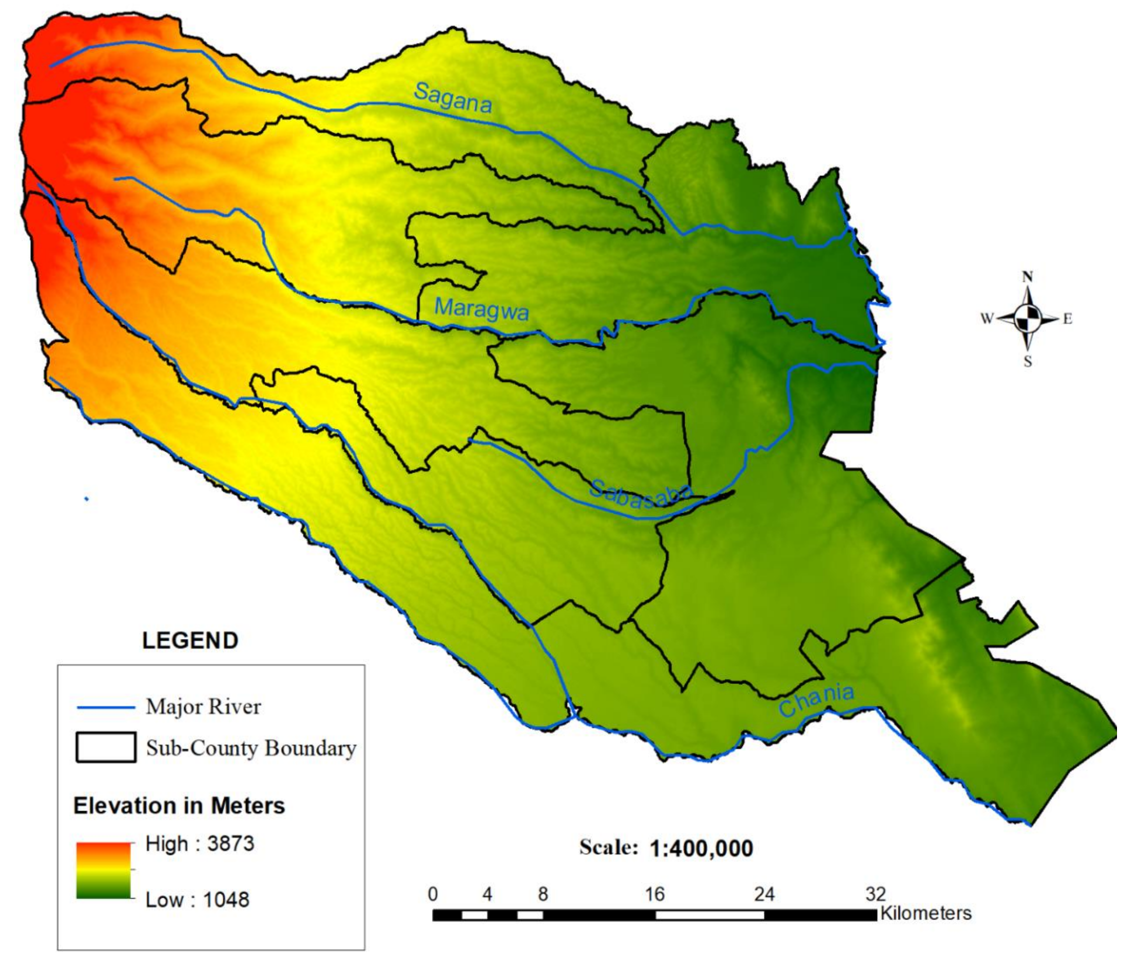
3.5.2 Secondary data sources

Landslide inventories

Data on the landslide inventories is crucial in assessing, checking and validating the reliability of the outcomes (Zhou, *et al.,* 2020) of the scientific and local peoples' knowledge and is considered the basic necessity for any quantitative landslide studies (Tekin and Can, 2018). The data were gathered from the records by the county disaster management offices and county meteorological services in Murang'a. However, overall there were continuously reported landslide cases between the years 2016 and 2021. Murang'a Meteorological Services (2021) reports indicated that landslides in the county are recurrent and on upsurge but MAM 2018 had the highest number of reported landslide cases within a single rainfall season, i.e. March-April and May (MAM). The reason why the period is considered to be the reference for the study.

Elevation data

The elevation data is crucial in landslides research as the disasters are known to occur in certain topographies. The data was freely downloaded from United States Geological Survey's (USGS) Shuttle Radar Topographical Mission (SRTM) through Earth Explorer via https://earthexplorer.usgs.gov/. The study county is covered in three grid of 1° X 1° tiles: s01_e036, s01_e037 and s02_e037 in GEOTIFF format. The resolution for the images are 30 m or 1 Arc Second available over Africa in 1° X 1° tiles released in October 2014 for the whole of Africa. The void-filled SRTM was released by NASA to the world in 2015 (USGS, 2015). The study area spans between an elevations of 1048 m to3873 m above msl stretching from the lower elevation lowlands to the high elevation alpine zones along the Aberdares Ranges as shown in Figure 3.6 below.



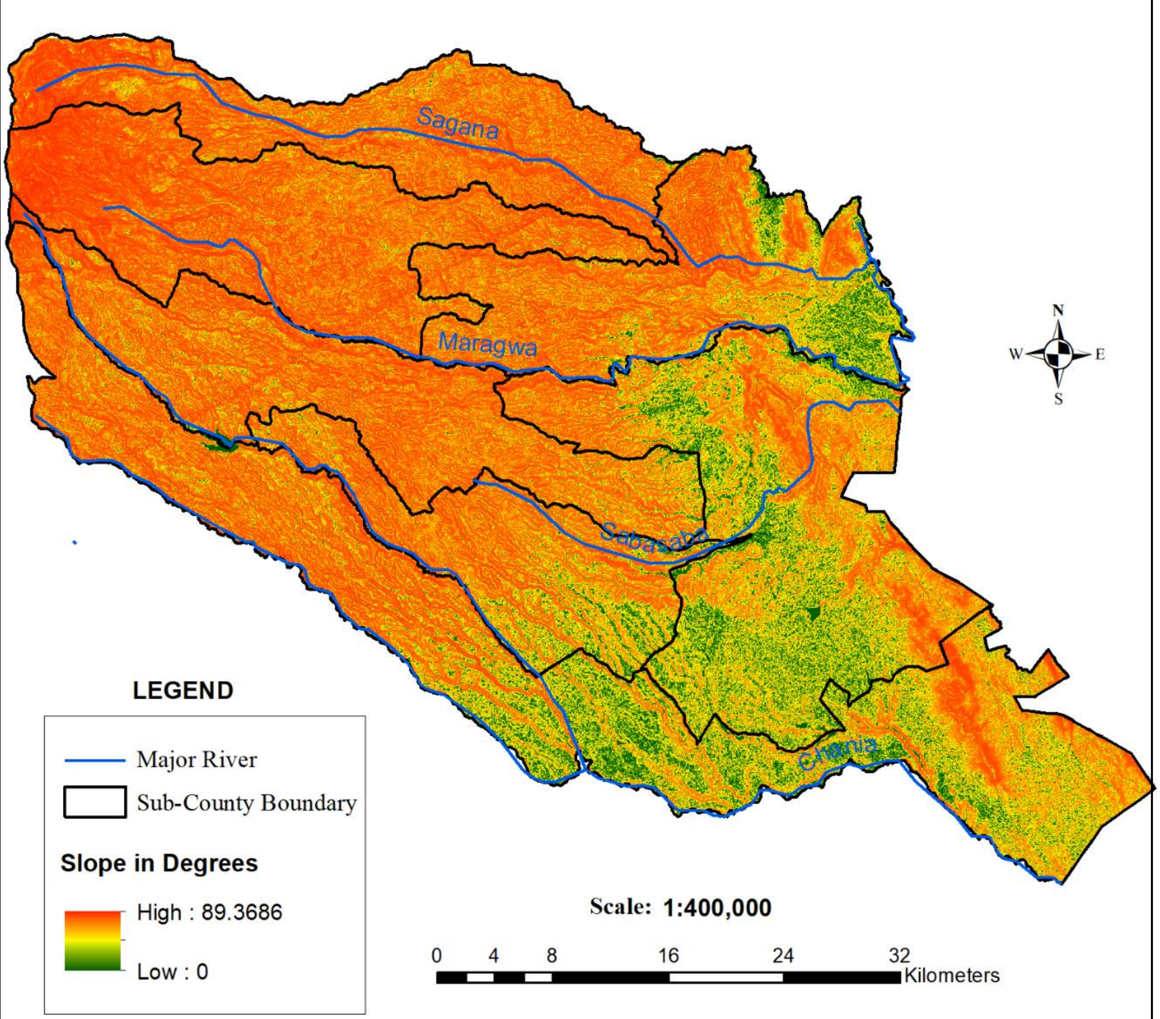
Note: Data from USGS (2015) and Google Earth (2021). Source: Author

Figure 3.6: ***Shuttle Radar Topographical Mission (SRTM) generated elevation model***

The slope data

Slope data was a derived from the Shuttle Radar Topographical Mission-Digital Elevation Model (SRTM-DEM) through ArcGIS's 3-D analyst tools. As shown in

Figure 3.7**,** the slope computed in degrees, ranges from 0^0 in flat areas to almost 90^0 in the steep areas. The latter are vulnerable to the landslides as opposed to the former.

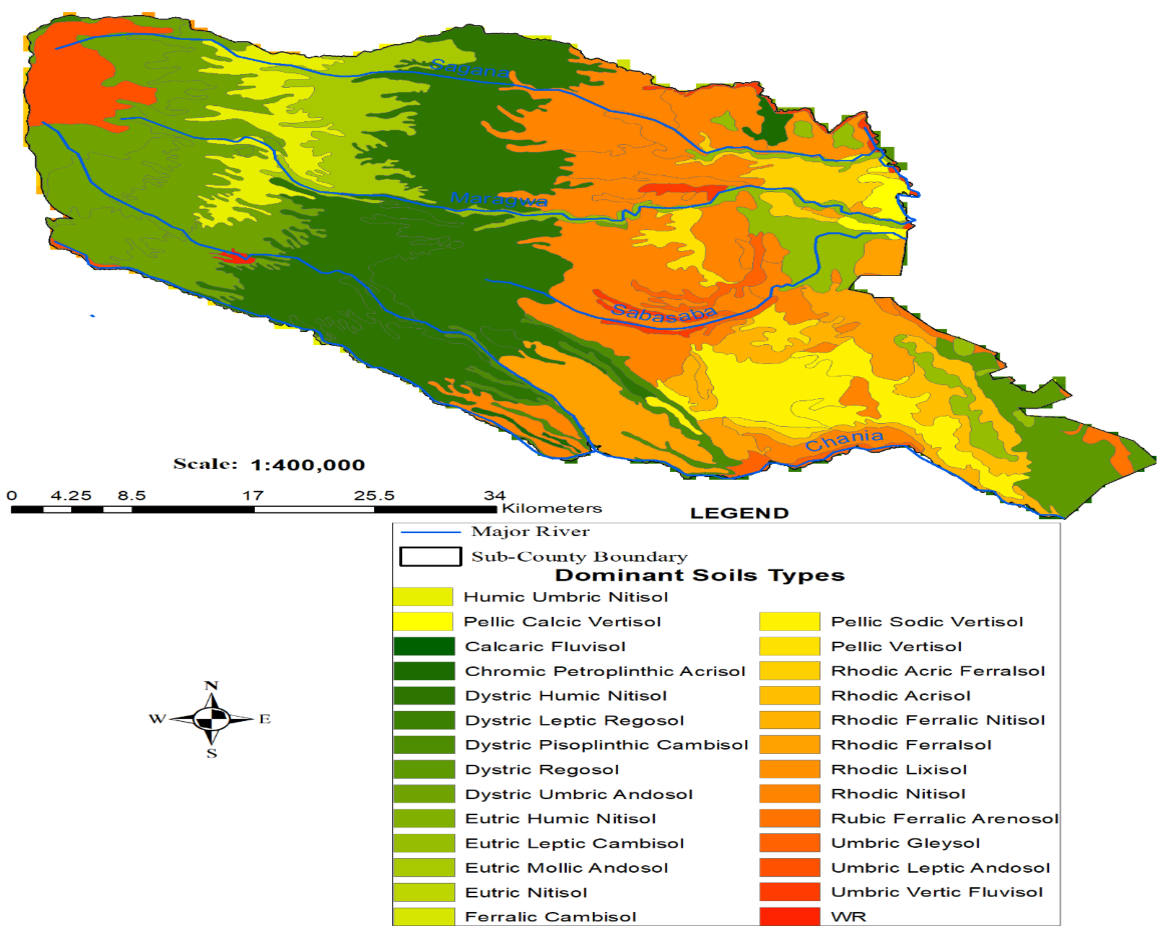


Note: Data from USGS (2015) and Google Earth (2021). Source: Author

Figure 3.7: ***Shuttle Radar Topographical Mission (SRTM)-derived slope***

Soils

The soil data is from FAO soil portal's World Reference Base (WRB) which is the international soil classification standards endorsed by the International Unions of Soil Sciences. The vector soil data, shown in Figure 3.8 below, is extracted from the Upper Tana Kenya drawn from Soil and Terrain (SOTER) databases at a scale of 1:100,000 (Dijkshoorn *et al.*, 2011) while raster soil data is from ISRIC-World Soil Information (Batjes, 2010). The vector data contain soil component profile, the most important one for the study being the dominant soil types which are used in classification of the raster grid.



Note: Data from WRB-SOTER and Google Earth (2021). Source: Author

Figure 3.8: ***Dominant soil types***

The rainfall data

The historical rainfall data is downloaded from SERVIR, a collaboration between USAID and NASA using the climate SERV tool from the website https://climateserv.servirglobal.net/aboutclimateserv.html. Kenya is in the SERVIR alongside other regions in Mesoamerica, East Africa and Hindu Kush-Himalayan (Leahy, 2011). The Earth observation data provided are for use by in the developing countries to address among other challenges disasters, climate change, weather focusing and agriculture. For the purpose of the study, the downloaded data were daily raster gridded data for the relevant years reported to have landslide disasters in Murang'a County at a spatial resolution of $0.05^{0.}$ (Approximately 5.6 km grid). High resolution annual climate data is obtained from WorldClim via https://www.worldclim.org/data/index.html at a spatial resolution of 1 km from *Very High Resolution Interpolated Climate Surfaces for Global Land Areas* (Hijmans, *et al.*, 2005) as shown in

Figure 3.9 below:

Note: Data from WorldClim and Google Earth (2021). Source: Njiraini, 2021

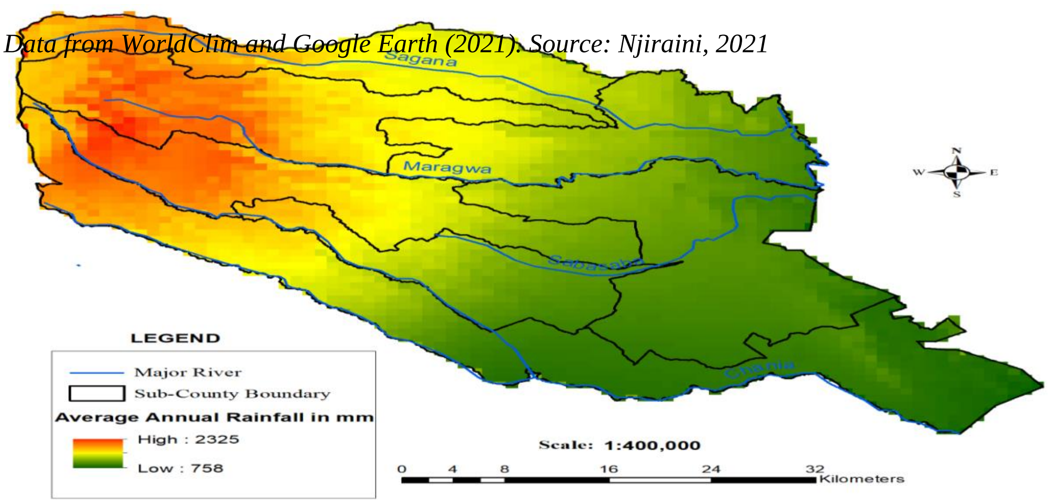


Figure 3.9: ***Average annual rainfall***

Land-Use Land-Cover (LULC) data

LULC data was generated from a Google Earth (GE) image, Landsat/ Copernicus of August 2018. The year is the reference for the landslide disaster cases while the month was chosen because it is outside the rainy season and usually Murang'a County receives less or no rainfall during the month. Such conditions are suitable for unbiased LULC analysis. The image was downloaded, georeferenced and classified

Figure 3.10 show the LULC classified through interactive supervised classification in ArcGIS. The broad LULC types, as shown in were: water bodies, bare-land and outcrop rocks, built-up areas, forest characterized as thick natural and planted forest/shrubs. There were also farmlands of which the upper parts of the county had tea, coffee, bananas, nippier grass (as confirmed and verified through ground checks and verification exercise). The lower parts had different crops on the farms such sweet potatoes.

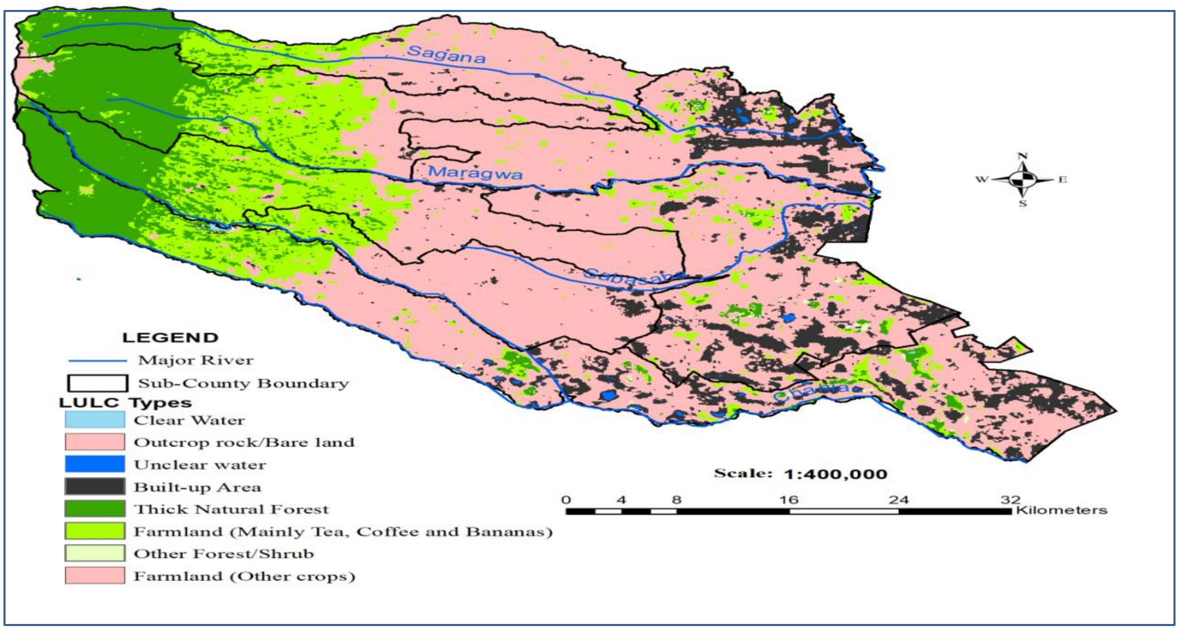


Figure 3.10: ***Land-use land-cover (LULC) Types***

3.6 Data treatment, processing, analysis and output

Data were treated, processed and analyzed on case-by-case basis depending on data types such as whether is qualitative or quantitative in nature resulting to different outputs as discussed below.

3.6.1 Households (HHs), Key Informants (KIIs) and Focus Group Discussion (FGDs) data

For data acquired from FGDs, KII and HH questionnaires, IBM-SPSS software, version 25, was used for both descriptive and inferential statistical analysis. After the questionnaires were coded in the software, the HH responses were analyzed for descriptive statistics by computing percentages and frequencies for single dichotomy factors and multiple responses questions. The data were presented inform of tables, pie and bar charts. Further inferential statistical analyses were done using correlations analysis techniques to establish the relationship and strengths between and among variables. The following formulae was used for the correlation analysis:

$$R_{xy} = S_{xy}/S_xS_y$$

Where:

R_{xy} *is the Spearman's Rank Correlation*

S_{xy} *is the sample covariance*

S_xS_y *are the sample standard deviations*

Qualitative data from the KII and FGDs were presented as raw narratives in paraphrases and in some cases as direct quotes, some in local dialect where applicable to maintain originality from the source. The two sets of data were used to support other types of data in the study discussions.

3.6.2 Remotely sensed and GIS data treatment and processing

Remotely sensed data and images were geo-processed using ArcGIS 10.5 Software as schematically shown in

Figure 3.11**.** The remotely sensed data representing the landslide causal/trigger factors were in raster grid format and included SRTM DEM for elevation and slope, soil, LULC and rainfall grids. The SRTM DEM was used to derive the slope grid.

The slope grid was converted from degrees to radians because ArcGIS' trigonometric tools use radians as opposed to degrees. The conversion formulae used is:

$$slope\ Grid\ in\ Radians = Slope\ Grid\ in\ Degree * \pi/180$$

Where:

$$\pi\ is\ Pi = 3.142$$

All the input grids for the landslide causal/trigger factors were examined for polarity as the execution in a multi-criteria evaluation requires that the polarities of the input factors be the same. Such means that for each of the factors, low grid values and high grid values should represent low risks and high risk areas respectively. Standardization was then done for each and every factor to put them on the same measurement and evaluation scale of between 0 and 1. Standardizing was done in GIS raster calculator using the formulae:

$$(original\ grid' - minimum\ value)/(maximum\ value - minimum\ value)$$

In which case original *grid* is the raster image to be standardized from which its maximum and minimum values are read and applied in the standardization formulae above. After standardizing all the factors, simple linear and weighted MCE are executed for the scientific and IK respectively. The former entails linearly combining the standardized landslide causal/trigger factors grids in ArcGIS without assigning weights for the scientific understanding as opposed to the latter where weights were computed according to the IK and applied in WLC. For each case, derivative grid maps were the outputs which showed the landslide risk maps. The simple linear combination for computing the landslide understanding were done using the formulae:

$$\text{Landslide risk map} = \text{Rainfall grid} * \text{Elevation grid} * \mathit{Slope}\ \text{grid} * \text{Soil grid} * \text{LULC grid}.$$

For the IK understanding, weights were assigned to reflect the understanding of the causal/trigger factors by the locals in a Weighted Linear Combination (WLC) of factors. WLC is the simplest factors aggregation criteria to yield a single score index for the risks (Gorsevski, *et al.*, 2006) on a scale which add-up to a unit. Below formulae was used:

$$\text{Fi} = \sum Wj$$

Where:

Fi is the suitability index (Landslide risks zone grid map),

Wj is factor j's weight

$\sum$ *Summation*

The final suitability index maps for both levels of understanding were classified using natural breaks in ArcGIS to yield three zones: High risk zones (high grid values), medium risk zones and low risk zones (low grid values).

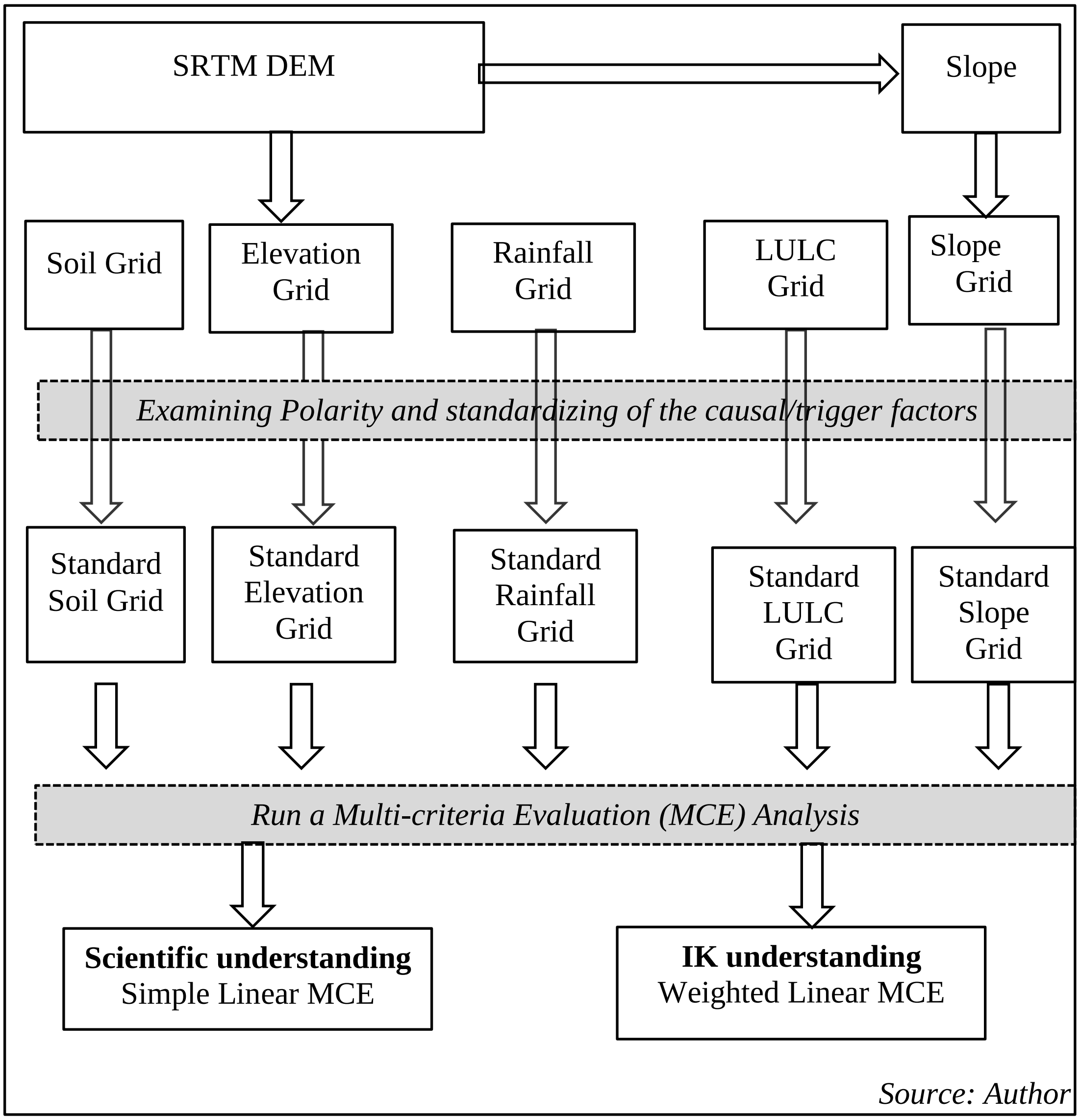


Figure 3.11: ***Flow chart showing remotely sensed data treatment and processing in GIS***

A detailed objective-by-objective summary of data treatment, processing, analysis and output is as shown in Table 3.12 below.

Table 3.12: ***Summary of objective-by-objective summary of data treatment, processing, analysis and output***

Study objective	Data treatment and processing	Data analysis	Data output
1. Mapping and delineating scientifically-defined landslides disaster risk zones	-Georeferencing -Raster data conversion to grids -Examination of grid polarities -Standardization of the grids -Reclassification of the grids into risk zones based on scientific facts	-Overlay analysis for simple linear MCE in ArcGIS software	-Derivative Boolean maps for landslide zones on each factor -Pie chart for individual landslide factor -Final simple linear MCE maps for the combined factors
2. Mapping and delineating indigenous-knowledge-based landslides disaster risk zones	-Georeferencing -Raster data conversion to grids -Examination of grid polarities -Standardization of the grids -Reclassification of the grids into risk zones based on IK weights	-Overlay analysis for weighted SMCE in ArcGIS software	-Final weighted SMCE maps for the weighted combined factors
3. Assessing the nexus between the scientific and indigenous-knowledge-based landslide disasters risks understanding in comparison with the documented landslide inventories in Murang'a County	-Data entry and coding in SPSS	-Extracting values from final MCE and SMCE to the reported landslide points in ArcGIS	-Final pie chart for the simple linear MCE map -Final pie chart for the weighted SMCE map -Derivative comparative map for MCE and SMCE -Statistical tables and charts
4..Assessing the landslide disasters effects	-Data entry and coding in SPSS	-Descriptive statistically analysis to compute the frequencies and percentages in SPSS -Inferential statistical analysis to compute correlations in SPSS	-Text narrative, tables and charts
5. Assessing the local peoples' early warning systems through the use of indigenous knowledge and the nexus with scientific systems	-Data entry and coding in SPSS	-Descriptive statistical analysis to compute the frequencies and percentages in SPSS	-Text narrative, tables and charts

Source: Author

3.7 Reliability of the research instruments

3.7.1 Cronbach's Reliability test for the HH Questionnaires

Cronbach's reliability test is considered to be one of the most reliable tests for the questionnaires (Cortina, 1993). Cronbach (1943) test was used to test the reliability of the questionnaires in which the scaled questions were subjected to Cronbach's test to and ascertain the actual reliability and internal consistency of the instruments. On average, an 'acceptable' Cronbach's Alpha coefficient of 0.708 was recorded for a total of thirty items spread across six thematic areas as shown in Table 3.13 was recorded. The selected thematic areas were core to the research and a detailed factor analysis, are as shown in Appendix IX.

Table 3.13*: Cronbach's Reliability Test*

Thematic Area	**Cronbach's Alpha**	**Number of Items**
Area population	0.718	3
Landslide experiences and understanding	0.712	3
As landslide causal/trigger factor	0.816	8
Degree of causality for factors	0.765	8
Understanding of DRM and Government assistance	0.708	2
Application of IK in landslide DRM	0.711	6

Source: Field Data

Questions about eight factors viewed as landslide causal/trigger factors were subjected to a reliability test where the results were an Alpha value of 0.765 and 0.816 for all the factors in terms of their contribution to landslides as causal/trigger and degree of causality respectively. These 'acceptable' values were for the factors were as shown in Table 3.14

Table 3.14: ***Landslides causal/triggers factors' reliability test***

Theme	**Cronbach's Alpha**
As a Landslide Causal/Trigger Factor	
Rainfall	0.810
Slope	0.802
Elevation	0.802
Soil	0.801
LULC	0.777
Vegetation cover	0.787
Infrastructural development	0.797
Population	0.780
Degree of causality	
Rainfall	0.768
Slope	0.749
Elevation	0.741
Soil	0.762
LULC	0.716
Vegetation cover	0.723
Infrastructural development	0.726
Population	0.716

Source: Field Data

3.7.2 Reconnaissance

Before the actual fieldwork, reconnaissance was done to familiarize the researcher and data collection field research assistants with the routes prior the actual data collection day. The research assistants traversed their respective sub-counties during the recce and no challenges were encountered as the recruits were locally sourced hence had a clear picture of the area and the routes.

3.7.3 Field checks and verification

During the secondary remote sensing LULC data classification using the satellite image, some features could not be identified without ambiguity. Due to that fact, field checks and verification to ascertain what was on the ground was necessary. For instance it was difficult to differentiate between the different vegetation types like agricultural crops and shrubs, both of which were to be classified differently on the image. During the field visits, the doubts were cleared and correct classification arrived at during supervised image classification.

3.8 Limitations of the study

Data limitation in terms of inconsistencies in resolution and currency is a key issue. Such is due to the fact that in many countries, Kenya included, no single authority has a complete landslide data (Van Westen, 2006). For instance in Kenya, the readily available soil data is of low spatial resolution (scale of 1:250,000). To mitigate that, the researcher uses the available high quality data to compensate for the lower quality ones to have a fair and balanced data output. For instance the available monthly rainfall data grid is at 5.6 km spatial resolution. However the author uses the annual rainfall grid from Very High Resolution Interpolated Climate Surfaces for Global Land Areas (Hijmans, *et al.*, 2005) at a spatial resolution of 1 km. since the study adapts a heuristic study approach, which is less data intensive and resonates well with semi-quantitative studies (Van Westen, 2006) the data issues are of less consequences. The approach is one of the most direct methods of landslide analysis in GIS using location-specific information (Barredo, et al., 2000). The spatial datasets are also harmonized and scaled to a common level through raster grid cells resampling.

3.9 Ethical considerations

At the current technological age, ethical considerations in research have become of increasing importance yet more complex where human beings are used as subjects of investigations in research (Rogers, 1987). Ethical considerations focuses on the research instruments, the respondents and the collected data. The research upholds moral and ethical considerations in data confidentiality, anonymity, security and freedom from physical or mental harm or discomfort during the acquisition, processing and presentation.

3.9.1 Research permits and authorization from the relevant authorities

A letter request letter from Moi University's Department of Geography (now Department of Geography and Environmental Sciences) to National Commission for Science, Technology and Innovation (NACOSTI) for research permit application was granted by the departmental Chair after successful presentation and defending of the research proposal (see appendix V). After successful online application, a research permit from NACOSTI was issued on 17th March, 2021 (appendix VI**).** Both letters and the researcher's introductory letter) were used to obtain research authorization from the Murang'a County Commissioner (see appendix VII) and County Educational Office (see appendix VIII).

3.9.2 Disclosure and participation consent from participants/respondents

Every respondent and participant was briefed about the research in terms of the topic, purpose and objectives of the study, data usage and confidentiality before making a decision to voluntarily participate in the exercise. To formalize the consent, a field data collection consent form (see appendix I) was filled and signed by the respondent/participant, the researcher (authors), supervisors and the research assistant where applicable.

3.9.3 Adherence to the ministry of health guidelines on the novel COVID-19 virus containment measures

The fieldwork was being carried out during the novel COVID-19 pandemic and everyone had to strictly follow the government containment measures to control the spread of the corona virus. Measures strictly observed included wearing of face-masks and keeping safe social distance for instance during the KII conducted to the County Commissioner (CC) and County Meteorological Service Director on the first day of fieldwork as shown in Appendix I. Other measures included sanitizing and washing hands especially after handling the research instruments.

3.9.4 Acknowledgement

The author appreciated the data providers and collectors and where applicable, relevant citations and referencing was done. Consulted literature materials were also properly referenced alongside any other material and non-material supports obtained from diverse groups and individuals during the study.

3.9.5 Debriefing

To wrap-up the study, the research work will be communicated through debriefing meetings, seminars, peer-reviewed journal publications, workshops and other dissemination media organized by the researcher and other relevant stakeholders in different forums. The aim is to publicize and disseminate the information about landslide disasters risks in Murang’a County and how the scientific and indigenous knowledge play part in the understanding of the said disasters. To support the information dissemination process, copies of the final document will be availed to the Murang'a County Education Office, County Meteorological Services, Moi University's department of GES, SASS and Margaret Thatcher Library for reference and archiving. Dissemination media of global coverage such as the World Wide Web (WWW) and internet will be highly utilized.

3.10 Chapter summary

The study research design is explanatory sequential mixed method suitable for studies with both qualitative and quantitative data collection and analysis phases. Primary qualitative data were collected from HH questionnaires administered in nine sub-locations purposively selected from six sub-counties in Murang'a County based on the MAM 2018 landslide inventories. To complement the HH questionnaires data, other sources of primary data were eight KIIs and seven FGDs. These data were analyzed through descriptive and inferential statistics in IBM-SPSS package. Qualitative data obtained through interviews and FGDS were analyzed through content analysis. Secondary data were obtained from remote sensing techniques and quantitatively analyzed using Raster-GIS in ArcGIS software. Applicable ethical considerations were applied in the research methodology.

CHAPTER FOUR

DATA ANALYSIS, RESULTS PRESENTATION AND DISCUSSIONS

4.1 Introduction

Chapter Four contains presentation of the empirical results and is considered the 'bedrock of the study' (Wamithi, 2018). In-depth, objective-by-objective and comprehensive data analyses were done and presentation made for each result to build a discussion, which places the study in the scholarly world. The specific research objectives are discussed and presented in this chapter. To start the chapter off, the questionnaires response rate was analyzed and the respondents' characteristics evaluated in terms of their demographic and socio-economic characteristics. Then the study proceeds as guided by the specific research objectives.

4.2 Household (HH) questionnaires response rate

Out of the Three hundred and ninety-three (393) HH questionnaires, a total of three hundred and thirty-six (336) were successfully completed and returned by the respondents, an overall average questionnaire return rate of approximately 86%. The rate is above the recommended return rate of 80% (Okaka, 2016). Individual return rate though varied per the purposively selected administrative locations. The HH questionnaire response rate per the study administrative location had a high rate recorded being 100% for Kibage Location while the lowest was recorded in Rwathia Location at 78%. The overall and the individual response rates per location were above the prescribed threshold of 70% (Dillman, 2011), hence considered sufficient for a scientific study. Table 4..15 shows a breakdown of individual questionnaire completion and return rates per administrative location.

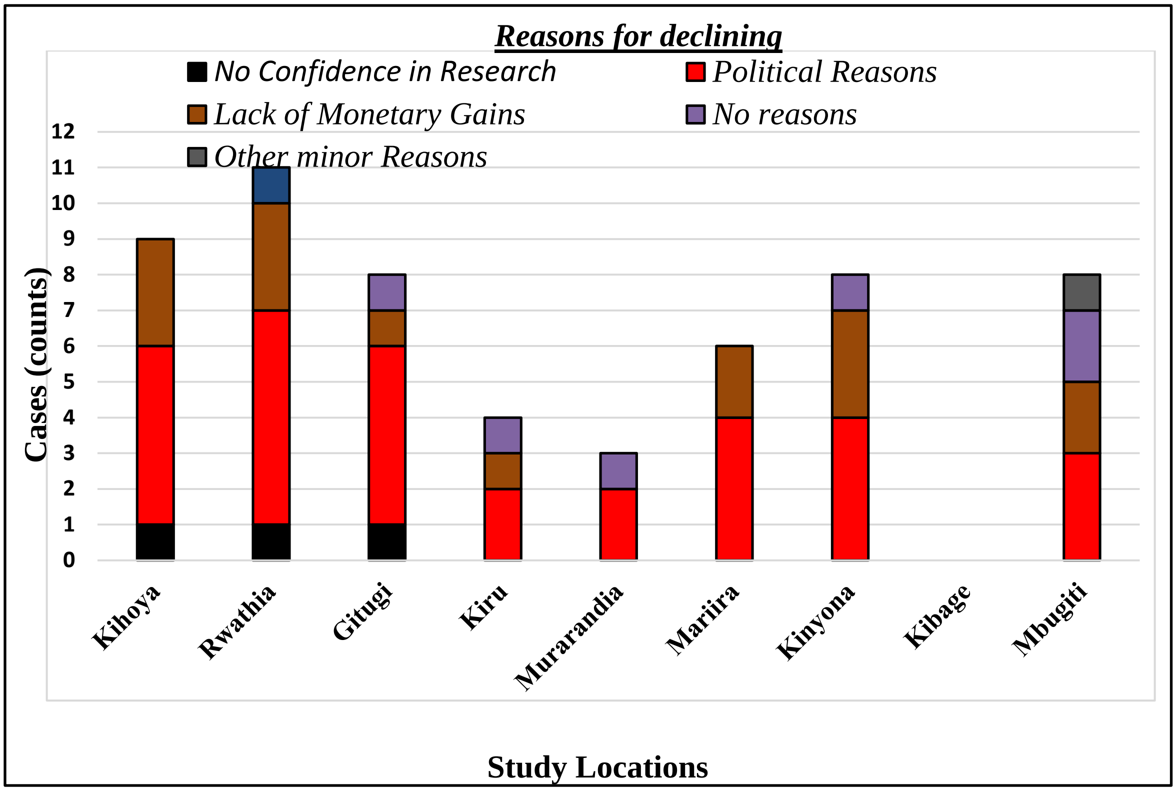
Table 4.15: ***Household (HH) questionnaire return rate per administrative location***

Sub-county	Location	Proportionately Computed HHs	Actual HHs Sampled	Response Rate in Percentage (%)
Kangema	Kihoya	57	48	83.8%
Kangema	Rwathia	51	40	78.0%
Mathioya	Gitugi	50	42	83.3%
Mathioya	Kiru	37	33	88.6%
Kiharu/Kahuro	Murarandia	33	30	90.4%
Kigumo	Mariira	39	33	85.3%
Kigumo	Kinyona	48	38	83.2%
Kandara	Kibage	26	26	100%
Gatanga	Mbugiti	52	44	84.7%
Total		**393**	**336**	**85.5%**

Source: *Population and housing data from Kenya National Bureau of Statistics (KNBS, Volume II, 2019)*

The researcher was interested in knowing the reasons for non-response by the respondents to the HH questionnaires hence reasons were sought from the participants who declined to respond. The reasons were varied ranging from: fear of political persecution (57%) where those who declined claimed that their information would be used for political reasons, lack of monetary gains from the exercise was cited by 26%, lack of confidence in any research findings out of previous experiences (5%), decline with no apparent reasons (12%) and other indefinite reasons by 2%.

Figure *4.*12 shows the respective reasons for respondents declining to participate in the HH interview per study location. Political reasons were dominant attributed to the fact that Kenya was nearing the general elections and political activities had set in at the time of fieldwork.



Source: Field Data

Figure 4.12*: Preferred reasons for not participating in the household questionnaire interview*

4.3 Characteristics of the respondents

4.3.1 Social-demographic characteristics of the Household (HH) survey respondents

The socio-demographic characteristics of the HH questionnaire respondents were varied in terms of their age, sex, marital status, education levels, occupation, monthly income, place of birth and length of residence as shown in Table 4.16 showing the demographic characteristics of the HH survey respondents. Age and education characteristics are of importance in the study as both may influence the understanding of landslide causal/trigger factors. In terms of sex, a total of 207 respondents were males comprising (61.6%) while 129 (38.4%) were females. There were no reported cases of intersex, which is in conformity with the Kenya Population and Housing Census (KPHC), 2019 data by Kenya

National Bureau of Statistics (KNBS) which indicated insignificant intersex composition in the county. The marital status recorded comprised of 274 (81.5%) being married, 46 (13.7%) singles, 08 (2.4%) deceased and 04 (1.2%) being either separated or divorced. Age-wise, respondents who were above 50 years were 47.9%, with the youngest and oldest being 20 and 102 years respectively. The upper age cohorts were considered relevant to the study because of their accumulated years of experience and knowledge. The highest levels of educational attainment were reported as being primary and education levels at 139 (41.4%) and 130 (38.7%) respectively. Only 19 respondents representing a 5.7% had attained at least either diploma or undergraduate education level whereas 11.9% had no formal education but still considered relevant for the study.

Table 4.16: ***Demographic characteristics of the HH survey respondents***

Demographic characteristics of the respondents	**Frequency (N=336)**	**Percentage (%)**
Sex		
Male	207	61.6
Female	129	38.4
Intersex	00	0.0
Marital status		
Single	46	13.7
Married	274	81.5
Divorced	04	1.2
Separated	04	1.2
Deceased	08	2.4
Age cohorts in years		
18-20	1	0.3
21-35	49	14.6
36-50	125	37.2
Above 51	161	47.9
Highest education attainment		
No formal education	40	11.9
Primary school	139	41.4
Secondary school	130	38.7
College certificate	08	2.4
College diploma	17	5.1
Undergraduate degree	02	0.6

Source: *Field data*

The respondents were also evaluated in terms of their occupation, approximate monthly income, place of birth, length of stay, land size, and the perceived population change in their localities as shown in Table 4.17**.** The dominant occupation was farming by 226 (67.3%) with tea farming being prominent crop by164 (48.8%), followed by coffee 60 (17.9%) and a mixture of the two crops by 51 (15.2%). Other notable crops on land included avocados, maize, bananas, Napier grass and a mixed cropping of at least two crops in one farmland. The type of crops on land is important in the study as LULC types have an influence on the occurrence of landslides (Nicholas & John, 2022). The average farmland size was 1.79 acres with a vast number of occupants (84.4%) occupying less than 2.0 acres of land, an indication of land fragmentation which also puts pressure on the farmlands. Impacts of diminished land sizes were portrayed also in in the income bands where 82.7% of the HHs, majorly made up peasant farmers, reportedly having less than Kenya Shillings ten thousands (Ksh. 10,000) on average as the monthly income. Only 11.0%, mostly in formal employment, were earning more than Kenya Shillings thirty thousands (Ksh. 30,000) per month.

As far as the population dynamics were concerned, it was almost unanimously agreed by 324 respondents (96.4%) that generally the population has changed over time. 294 respondents (87.5%) were in agreement that the population had increase over time as opposed to 29 (8.6%) and 13 (3.9%) who contended that there were a decrease and no change in population respectively. A vast number of respondents were locally born 280 (83.3%), out of which 94.7% have lived in their areas for more than thirty (30) years hence forming an important constituency with accumulated years of experience and knowledge. Respondent’s age (in years) were significant (r=0.923 at 0.01 level (2-tailed) and positively correlated with the years lived in the area, which simply means that elderly people had accumulate years of living in their respective areas. The numbers were boosted by 67.3% of immigrants, born elsewhere but relocated to their current locations and had over 30 years of stay as well. The immigrants age also significant and positively correlated with the accumulated years of stay since relocation (r=0.788 at 0.01 level (2-tailed). Age and period of stay are important considerations for the study because IK is considered as a dynamic and complex body of understanding, skills and way of doing things maintained and practiced by people or community with a common understanding and experiences in a given locality (Castree, 2017). It is an adaptive management strategy developed within a community over time (Berkes, *et al.*, 2000). It is important to note that indigenous people are amongst the key stakeholders and informants at the grass-root level in case of a landslide occurrence and they have experience and traditional knowledge. It is therefore believed that older people in the community hold years of knowledge, skills and wisdom, all which are key to reducing disaster risks and should be part and parcel of disaster risk reduction plans and policies (UNISDR, 2015).

Table 4.17: ***Socio-economic characteristics of the HH questionnaires respondents***

Socio-economic characteristics of the respondents	Frequency (Counts)	Percentage (%)
Livelihood occupation		
Artisan	02	0.6
'Boda boda' operator	04	1.2
Business person	67	19.9
Carpenter	02	0.6
Casual labourer	04	1.2
Chief	02	0.6
Civil servant	06	1.8
Driver	03	0.9
Farmer	226	67.3
Jua kali artisan	01	0.3
Masonry	02	0.6
'Mzee wa mtaa'	02	0.6
Receptionist	01	0.3
Sub-chief	01	0.3
Teacher	03	0.9
Unemployed	08	2.4
Average monthly income in Kenya Shillings		
Below 10,000	278	82.7
10,001-20,000	30	8.9
20,001-30,000	17	5.1
30,000-50,000	11	3.3
Place of birth		
Born in the area	280	83.3
Not born in the area	56	16.7
Length of stay in years if born in the area		
20-30	23	6.8
31-40	61	18.2
40-90	252	75.0
Description of population density in the area		
Sparsely populated	03	0.9
Moderately populated	96	28.6
Densely populated	237	70.5
Description of population dynamics over		

the years		
Population has decreased	29	8.6
Population has increased	294	87.5
Population has not changed over years	13	3.9
Land size in Acres		
0.0-1.0	153	45.5
1.1-2.0	130	38.7
2.1-3.0	36	10.7
3.1-4.0	03	1.8
4.1-6.0	11	3.3

Source: *Field data* **, 2021**

4.4 Mapping and delineating landslide disaster risk zones based on scientific knowledge

4.4.1 Introduction to scientific understanding of landslides' causal/trigger factors

The first specific objective of the study was *'Mapping and delineating landslide disaster risk zones based on scientific knowledge.*' The objective required a collection of scientific data and information about the landside disasters' causal/trigger factors for Murang'a County. The information were sought from experts through key informant interviews (KIIs) whose opinions were backed-up by the existing scientific literature. The KI were drawn from experts from the Kenya Meteorological Services (KMD), Kenya Red-Cross, Disaster Management Department, Kenya Forest Services, County Ministry of Environment and Climate Change, Radio Communication fraternity, County and National Government administrators in the county. The KMD officials who are the custodians of the weather and meteorological data in the country provided information about the weather and specifically rainfall patterns in Murang'a alongside the landslide occurrences. The Kenya Red-cross officials were mostly actively involved in the post-disaster activities gave among other information the experts opinions on the spatial distribution of landslide disaster zones. The disaster management department works closely with Kenya Red-cross and the county ministry of environment and climate change department and were useful in giving expert opinions on the distribution, zoning and possible contributors to the landslides in affected areas. Kenya Forest Services provided information on the status and trends of the forest cover in various parts of the county and the link with the landslide occurrences. Existing scientific literature which backed-up the experts' opinions were sought from online and offline published books, journal and other materials on landslides with specific focus on the study area.

In addressing the specific objective, the first step in mapping and delineating the landslide disaster risk zones was to identify the respective causal/trigger factors as scientifically understood and defined by the experts and existing scientific literature. The identified landslide causal/trigger factors were: rainfall, slope, elevation, soils and LULC. Each of the factors was mapped according to a scientifically defined threshold to delineate landslide risk zones for the county. Generally, each factor had a different conformity with the landslide cases reported in the base rainfall season of MAM 2018 as shown in Table 4. 18 below: Rainfall registered the highest conformity percentage, at 99%, making it the most prominent and outstanding landslide causal/trigger factor in Murang'a County as opposed to LULC, at 72% conformity with the landslides inventories recorded for the MAM 2018.

Table 4.18: ***Landside causal/trigger factors and conformity with the March-May 2018 (MAM 2018) reported landslide cases***

Landslide causal/trigger factor	Conformity with MAM 2018 cases (Percentage)
Rainfall intensity	99 %
Altitude	94 %
Slope	95 %
Soils	88 %
LULC types	72 %

Source: Field data

The Mapping and delineating landslide disaster risk zones based on scientific knowledge for each of the contributing factors is as described below:

4.4.2 Mapping and delineating landslide disaster risk zones based on rainfall factor

Rainfall is a major factor in causing/triggering landslides in Murang'a County. The average annual rainfall for the county are lows and highs of 758 mm and 2,325 mm, respectively. Lower rainfall amounts are less lethal in causing/triggering landslides compared to the higher amounts. According to Mwaniki *et al.,* (2011) rainfall amounts higher than 1,160mm would trigger or cause landslides in combination with other favourable conditions in an area (Chepkosgei *et al.,* 2022). In their study titled, '*Rainfall induced landslide probability mapping for Central Province,'* a rainfall threshold of 1,160 mm was to discriminate zones of high and low landslide risks. The results had areas with rainfall amounts higher than 1,160mm, representing 60.4% of the mapped area being zoned as 'high landslide risk areas' whereas lower rainfall areas, representing 39.6% of the landmass fell under the low risk landslide risk zones. In another scientific study by Zhou*, et al.,* (2020), rainfall thresholds used were amounts between 1,000mm and 2,000mm to represent *'high risks'* and amounts above 2,000mm to represent '*extremely high risks'* in a study of *Nationwide Susceptibility Mapping of Landslides in Kenya Using the Fuzzy Analytic Hierarchy Process Model.*

For the study, a rainfall threshold of 1,160 mm was executed in ArcGIS to delineate regions of high and low landslide risks for the higher and lower rainfall amounts than the threshold through Boolean analysis. The results were compared with the MAM 2018 landslide cases where 99% of the reported landslide cases in the reference period fell within the zones mapped as ‘high risk’ and only 1% were in the ‘low risk zones’ as shown in Figure 4.13 (b) below: Therefore rainfall causal/trigger factor would have been a perfect ‘predictor’ of the landslide susceptibility based on the MAM 2018 landslide cases as spatially mapped in **Figure 4.13(a).** Such is a clear demonstration that rainfall is a definite landslide causal/trigger factor and rainfall amounts beyond the threshold have contributed to landslide cases in the study area. The results were supported by KII-1 who was verbatim in local dialect as follows:

> “Sehemu za juu za Murang’a zimekuwa na mvua zaidi hasa hivi maajuzi. hiyo imesasabibisha visa vya maporomoko ya ardhi kuongezeka kwa kiwango kikubwa sana. Hii imeletwa no kuongeza kwa maji ya mvua. Sisi kama idara tuko macho wakati wa mvua na huwapa wananachi mawaidha kwa njia zozote. Hatuzimi simu zetu wakati kama huo! Katika historia ya hapa, mvua ya Mechi hadi mwezi wa Tano mwaka wa kumi na nane ilikuwa na majanga kupindukia na ilituzidi! hivo ilitulazimu kufanya kazi usiku na mchana” -*Male informant (KII-1*)
> Translated to:
>
> “The upper parts of Murang’a County have been experiencing huge amounts of rainfall, especially in the recent past leading to recurrent and destructive landslides. All factors held constant, rainfall is the most notable trigger factor for landslides in the areas. We are always on the look-out during the rainy season and never hesitate to give advisories to Murang’a people, especially when rain falls. We don’t switch our mobile phones off! The year 2018 saw the county records the largest number of landslide cases in a single rainy season that is March-April-May (MAM)”. It was overwhelming!-*Male informant (KII-1*)

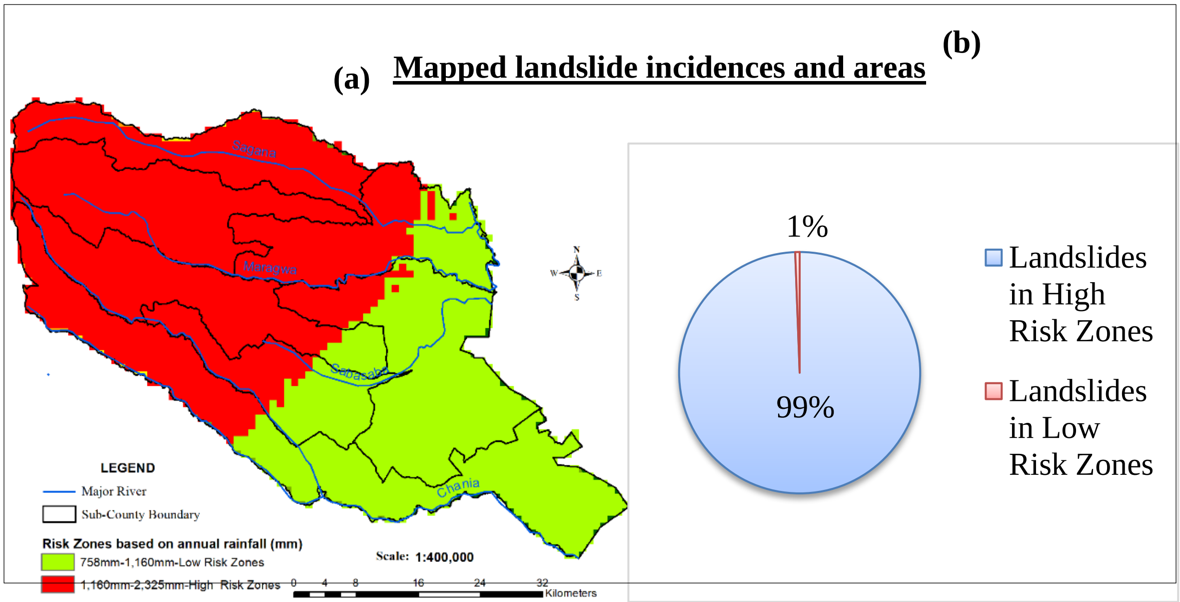


Figure 4.13: ***Mapped landslide risk zones in Murang'a County based on annual rainfall causal/trigger factor***

(a) Classified and standardized annual rainfall delineated grid risk zones, (b) MAM 2018 Reported Landslide cases distribution against the Rainfall Delineated Risk zones

Supporting scientific literature of rainfall being a major landslide causal/trigger factors in Murang'a County was cited in County Integrated Development Plan (CIDP) which indicates that rainfall is a major causal/trigger factor particularly in the upper (northern) parts of the county which are characterized by high amounts of rainfall. The said areas are considered as rainfall catchment zones in the Aberdares Ranges (CIDP, 2018). Also, in support is the fact that generally, Kenya is said to be a disaster-prone country (Republic of Kenya, 2010), of which over 70% are hydro-meteorological in nature. A research carried out by Huho and others in 2016 indicated that such hydro-meteorological disasters, which are triggered by heavy rainfall in mountainous parts of the country, are the landslides (Huho *et al.*, 2016). Further to that, according to Maina-Gichaba *et al.*, (2013), most of landslides in Kenya are triggered by rainfall and that water saturated slopes are fundamental causes of landslides. Another separate findings by Mwaniki and others showed that the Central Highlands of Kenya are known for rainfall-triggered landslides (Mwaniki *et al*., (2017).

Based on available statistical data for the county, the question of high amounts of rainfall contributing to high landslide cases can also be demonstrated in landslide trends between the years 1990 and 2020 as shown in Figure 14. The year 2018 had the lion-share of serious cases of landslides ever reported with a total of 148 cases, the highest documented cases for the years between 1990 and 2021. From the data also, it is evident that other than the year 2018, a notable strike in the reported landslide cases were reported in the year 1997/98 when the country experience *El-Nino* rains, a climatic period of exceptionally high rainfall amounts in a geographical region and which caused massive destruction and loss in Kenya (Wachira & Cumiskey, 2022). The data for the period were scanty may not be complete as no proper records could be assessed, an indication of how landslide disasters have attracted less interest in Murang'a County.

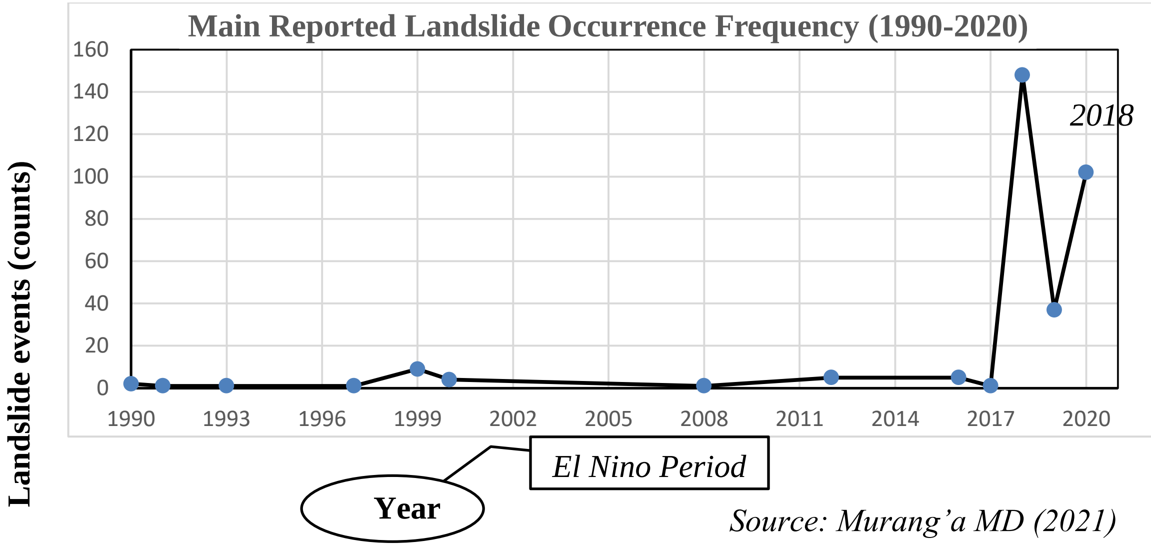


Figure 4.14: The frequency of reported landslide occurrence (1990-2021)

Expert's opinions in support of rainfall being a major contributor to landslide occurrences in the area were in plenty. Firstly, KII-7 was also in support of rainfall being a major landslide causal/trigger factor in Murang'a County. The informant reported that broadcasting and dissemination landslide of rainfall prospects and landslide related information is escalated during the rainy seasons because that is the period the county experiences high reported cases of landslides. In such times, weather, disasters, agriculture and other experts are invited to give to advisories and expert opinions to members of the general public through Kangema-RANET FM, a local community-based radio station located in Kangema Sub-County and supported by Kenya Meteorological Department (KMD). In agreement and support of the rainfall factor also was KII-8, drawn from the Kenya Red-Cross Society who reported that rainfall was a 'key' landslide causal/trigger factor and that during the rainy season, the needs for landslide disaster response services are higher than any other times. In support of that, she asserted the following:

> "*We are always alert during the rainy season and every gadgets are ready for operation to save lives and properties from landslide disasters especially in the upper parts of Murang'a County*"-Female informant (KII-8).

In conclusion, the available scientific literature and the consulted experts pointed out that rainfall is a major landslide causal/trigger factor in Murang'a County. The experts were in agreement that all the landslide prone zones of the county experienced heavy rainfall and that rainfall was a major contributor to landslides.

4.4.3 Mapping and delineating landslide disaster risk zones based on elevation factor

The elevation of Murang'a County ranges between 1048 m and 3873 m above msl and stretches from the lowlands to the high alpine zones along the Aberdares Ranges. The scientific understanding of elevation as a landslide causal/trigger factor was guided the existing scientific literature. Firstly, a study by Mwaniki *et al.*, (2011), put a threshold of elevation in causing landslides at 1,600 m above msl in which regions of higher elevation values were characterized as high landslide risks areas while those with lower values as low risk areas. The threshold also corresponded with a classification by Zhou, *et al.*, (2020). Adopting the same criteria, all the mapped high risk zones in the study fell in the bands of *'high'* and '*extremely high'* landslide risk classification zones in Kenya as per the previous studies. Through elevation zoning, the county is divided into two almost equal zones; low risk and high risk zones at 53.3% and 46.7% respectively as shown in

Figure 15(**a).** In ArcGIS's *extract value to points* operation in spatial analyst tools, the spatial location of the MAM 2018 landslide events were evaluated against the scientifically defined landslide risk zones based on the elevation where the low risk zones were mainly in the lowlands (southern part) while the high risk zones were in highlands (northern part) except for a few exceptional cases. The results showed a conformity with the reported landslide cases for MAM 2018 where 319 cases, accounting for 94%, fell in the 'high risk zones' as opposed to 20 cases (6%) which were in the 'low risk zones' as shown in

Figure 15(b). It therefore means that, elevation is also a key factor in triggering or causing landslides in the area. Such a conclusion is supported by experts from Murang'a County Ministry Environment and Climate Change who in support added that:

> '*Elevation is also an important landslide causal/trigger factor which is closely linked to rainfall amount as high elevation areas receives enhanced rainfall amounts compared to the lower elevation zones*-A male informant (KII-6)

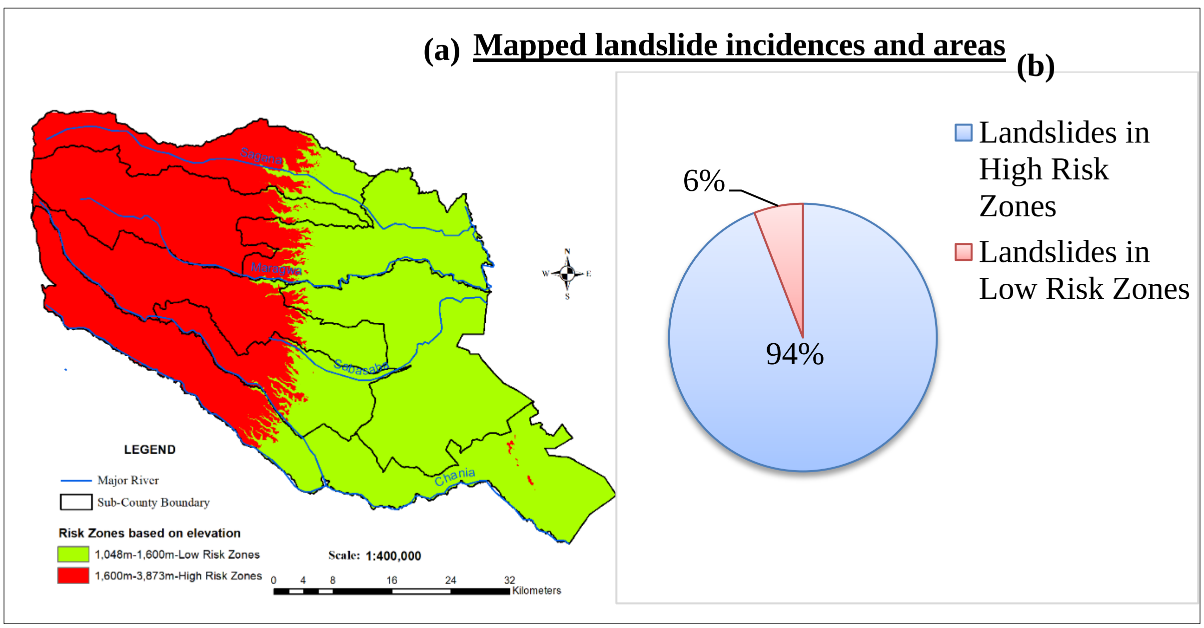


Figure 4.15: ***Mapped landslide risk zones in Murang'a County based on elevation as a landslide causal/trigger factor***

(a) Classified and standardized elevation delineated risk zones grid, (b) MAM 2018 Reported Landslide cases distribution against the Elevation Delineated Risk zones

4.4.4 Mapping and delineating landslide disaster risk zones based on slope factor

For this study, the slope data were derived from the elevation grid through three-dimensional (3-D) analysis in ArcGIS software. Murang'a slopes ranges between 0 to 89.5 degrees in the flat and high sloping zones respectively where the most flat areas (least sloppy) have values of zero (0) degrees while the steepest (most sloppy) have values of 89.5 degrees. The scientific mapping of landslide risk zones based on slope causal/trigger factor had a threshold of 60 degrees, with slopes greater than 60 degree posing high risks compared to the less risks for the slopes below that threshold. The thresholding is in conformity with other scientific studies by Cardinali *et al.,* 2006, Mwaniki *et al.*, (2011) and Zhou, *et al.,* (2020).

The result of the scientific mapping and delineation of landslide zones according to the slope factor resulted to 81.6% of the county's landmass being classified as high risk zones compared to the low risk zones covering 18.4%. The high risk zones are spatially spread almost evenly, especially in the upper parts of the county as shown in

Figure 4.16(a). In comparison with the MAM 2018 reported landslide cases, the resultant slope-delineated landslide zones showed that 95% of the reported cases were in the high risk zones and only 5% fell in the lower risk zone as shown in

Figure 4.16(b) below. The results are a good approximation of the landslide disasters for the base period.

Available literature in support of slope as key landslide causal/trigger factor could be cited from Van Westen (2006) and Othman and others (2012). In Asia, the existence of slopes is said to be the main causal factor for landslide occurrence in Central Asia (Khasanov *et al.*, 2021). The sloppy regions of Murang'a County are no exception as Maina-Gichaba *et al.*, (2013), in a research entitled *"Overview of landslide occurrences in Kenya: causes, mitigations and challenges"* also reported that water saturated slopes are 'fundamental causes of landslides.' It is also documented that the Central Highlands of Kenya are known for rainfall-triggered landslides due to the 'rugged landscape' (Mwaniki *et al*., 2017) and the upper part of Murang'a is said to be 'deeply dissected' (CIDP, 2018) and mass movement occurs downhill following the force of gravity.

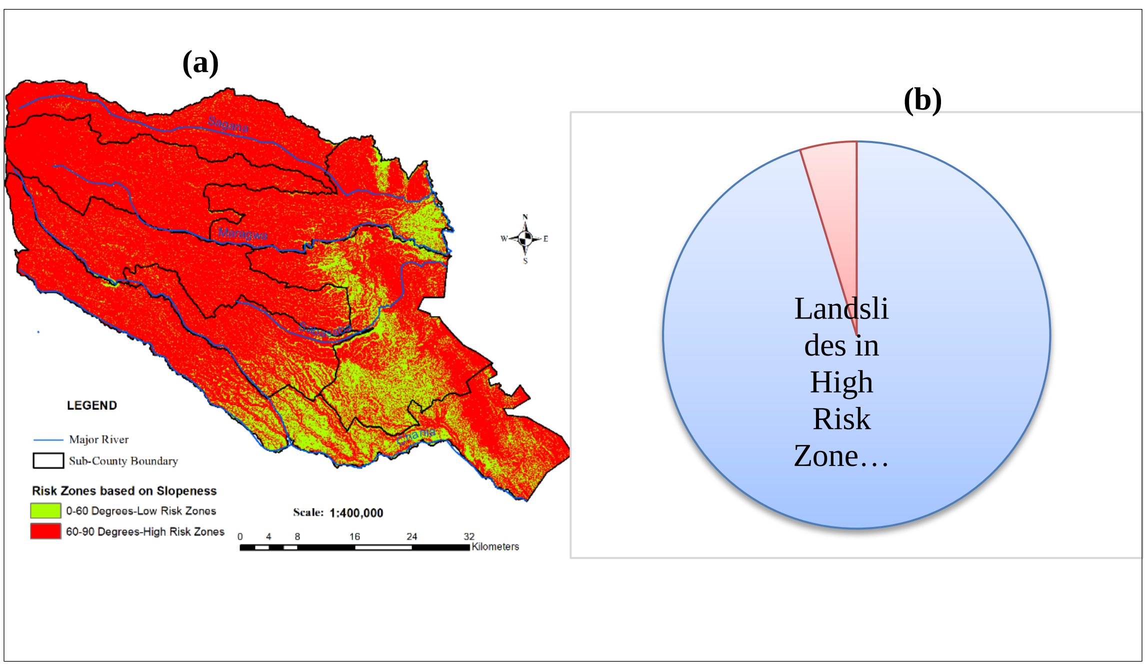


Figure 4.16: ***Mapped landslide risk zones in Murang'a County based on slope as a landslide causal/trigger factor***

(a) Classified and standardized slope delineated risk zones grid, (b) MAM 2018 Reported Landslide cases distribution against the Slope Delineated Risk zones

In the study, an epitome of the slope factor was witnessed during the fieldwork in Gatanga Sub-County where in Kirangi Sub-Location of Mbugiti Location, a landslide had occurred and swept away tea bush downslope, across a road and down to a near-by River Kimakia. The resultant scars were evidently visible at the time of the fieldwork *(Longitude: 36.791143°, Latitude: -0.844376°)* as seen in *Figure* 4.17(b). Slope in the area extended from a high of 2,162 m to a low of 2,070 m above msl as shown in cross-sectional profile in Figure 17(a) and was one of the contributing factors causing the landslide. Of importance to note was the fact that the area experienced a landslide despite the presence of heavy rich vegeation cover.

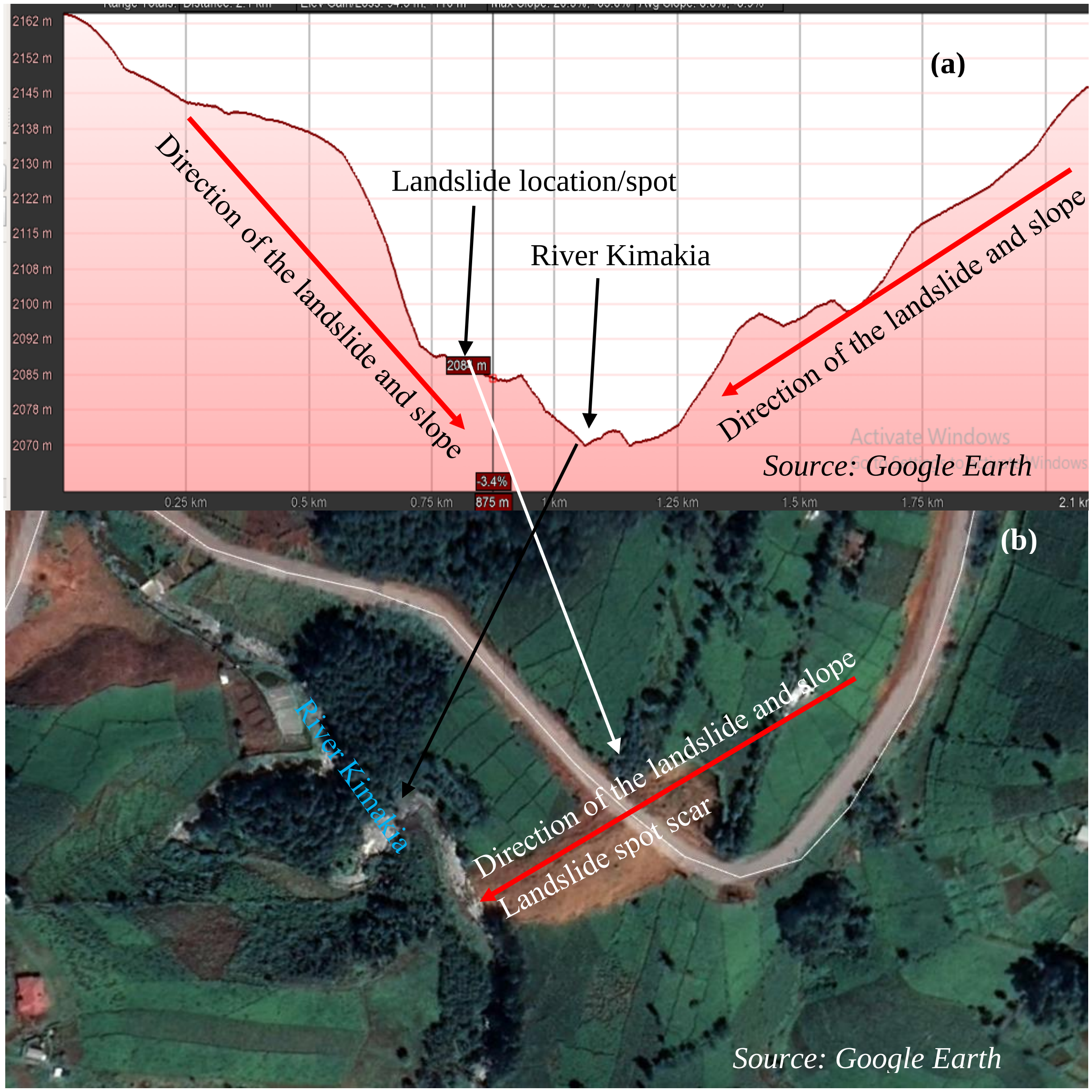


Figure 4.17: ***Slope profile and landslide scar of a landslide site in Kirangi, Mbugiti Location, Gatanga Sub-County***

(a) Elevation cross-sectional profile of the landslide area, (b) A GE image showing the reported landside spot and the scar

4.4.5 Mapping and delineating landslide disaster risk zones based on soils factor

Soil is also considered a key landslide causal/trigger factor in Murang'a County. According to experts, the dissected topography of the area is mainly as a result of the prevailing soils which lead to erosion and landslides in the upper parts of the county which is characterized by volcanic soils (CIDP, 2018). The county has areas with *Nitsols*, which have undergone intense weathering and *Andosols*. These soil types are cited to be 'highly susceptible' to landslides (Westerberg & Christiansson, 1999). A field photograph,

Plate below shows loose and heavily weathered soils in Rwathia Location, Kangema Sub-County in which through water action, it is deeply cut and washed away along a well-defined line. The consulted experts also explained that the soil is an important factor in contributing to the occurrence of landslides in Murang'a. In support of the fact that some areas have loosely connected soils, KII-2 drawn from the county administration in Kangema Sub-County asserted that:

> *"Kanjama area has very unstable soils and road construction at some point is almost impractical if the correct contour line is not followed. The soil are always cut-off by water action and engineers recommended the shifting of the road route in January, 2020 to avert the losses brought about by the landslide once it rains heavily."*-A male informant (KII-2)

As observed during the fieldwork, Kanjama is an area where a major tarmac road was completely cut-off by ranging water which washed away soil through water action despite the existence of enhanced engineering embankment on the said road. In such instance key contributors to the landslide were rainfall and soil types in the area.

Source: Field Data

Plate 4.1: ***The researcher standing on a landslide site showing deeply cut soils in Rwathia Location Kangema Sub-county***

(a) Showing loose-grained soils (b) Showing deeply-cut soils

For the study, soil classification and mapping was guided by SOTER classification in which the scientifically-known landslide susceptible soils are *Nitisol (Drystric Humic Nitisol*, *Humic Umbric Nitisol)* and *Andosol (Drystric Umbric Andosol, Eutric Mollic Andesol)*. To zone the soil areas, the said soil data were rasterized and mapped as spatially shown in Figure 18(a). A complete table of SOTER soil types in Murang'a County is shown in Appendix VIII.

The mapped soil factor had the lowest conformity with the MAM 2018 landslide cases as shown in Figure 4.18 (b) in which only 88% of the then reported cases fell within the zones delineated as 'high risk zones' and 12% were in the 'low risk zones'. One of the probably reasons for the lower conformity compared to other causal/trigger factors could be attributed to the fact that soils are a continuum and change from one soil type to another is not abrupt but a transition zone of mixed characteristics will always exist. It means that there exists no clear-cut boundary between the soil zones in an area, a fact which makes it difficult to precisely delineate between the zones of high and low landslide disaster risks as desired.

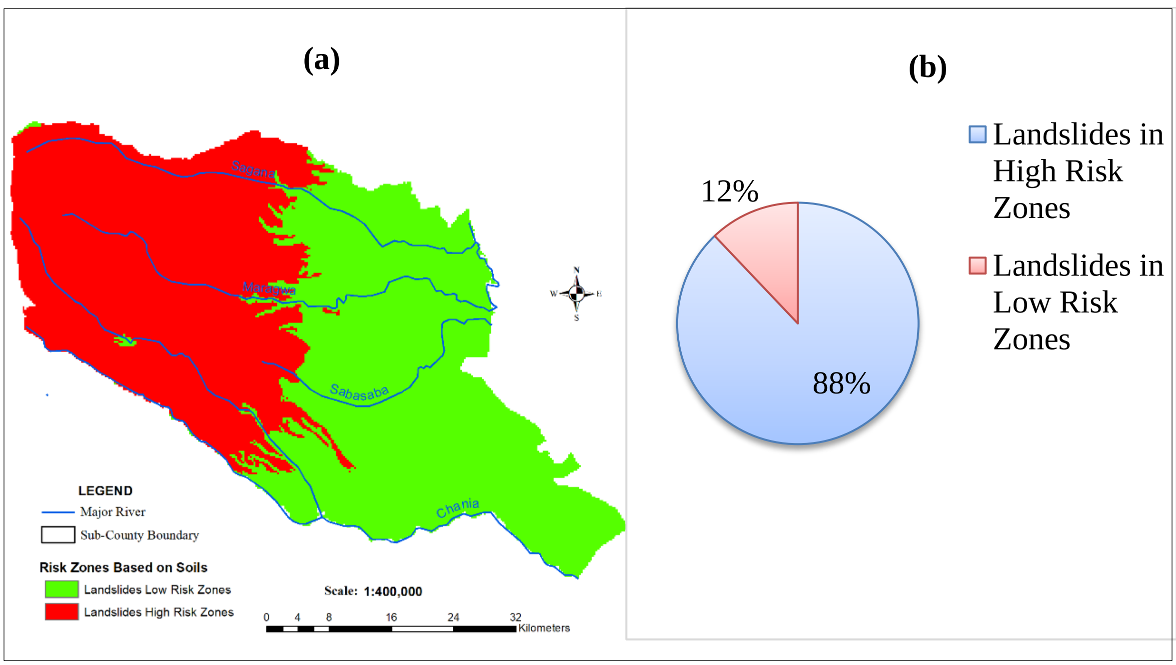


Figure 4.18*: Mapped landslide risk zones in Murang'a County based on soil as a landslide causal/trigger factor*

(a) Classified and standardized soil type delineated risk zones grid, (b) MAM 2018 Reported Landslide cases distribution against the Soil Delineated Risk zones

4.4.6 Mapping and delineating landslide disaster risk zones based on Land-use land-cover (LULC) factor

LULC classification was done on Landsat/Copernicus which was downloaded from the Google-Earth Engine (GE) for August 2018, the year which coincided with the landslide reference year. During the classification, some LULC cover types were verified through field visits especially in cases where ambiguity existed. The LULC classification as executed in ArcGIS supervised classification tools. Areas prone to landslides were characterized by agricultural activities and shrubs LULC types while those less prone had natural forests, water, rocks and buildings. The spatial distribution of various LULC is as shown in Figure 4.19 (a).

On average, LULC as landslide's causal/trigger factor had the lowest conformity percentage (72%) with the reported landslide cases of MAM 2018 in the county compared to rainfall, soils, slope and elevation factors. A possible reason could be attributed to the fact that cutting and planting of trees in the agricultural areas happen concurrently and in some cases the net difference of LULC might be marginal. The study area is largely rural and trees are some of the dominant LULC types even within the agricultural zones. This was verified to be true as explained by KII 5, a *'mzee wa nyumba kumi' (a village elder)* from Gacharage, Kandara, who is a retired forest officer hence an expert in his area. His verbatim words concerning the planting and cutting down of trees in the area were as follows:

> "Guku tutemaga miti tukihandaga hindi cioothe. Koguo ndinguga ati miti kana mititu nikunyiha inyihite riu kana kuuma tene"
> - *Male informant, a retired forest officer (KII-5*)

Translated to:

> *"Here we cut and plant trees at the same times throughout the years. So, I cannot say that there has been a decline in forest cover now and throughout the years"* - Male informant, a retired forest officer (KII-5)

The sentiments were re-echoed by KII-6 drawn from the county ministry of environment and climate change who said that there were reported cases of cutting down of natural forests and replacement of the indigenous trees with exotic ones, the main preferred replacement being the eucalyptus species. The overall results being a nearly no change in trees cover in Murang'a.

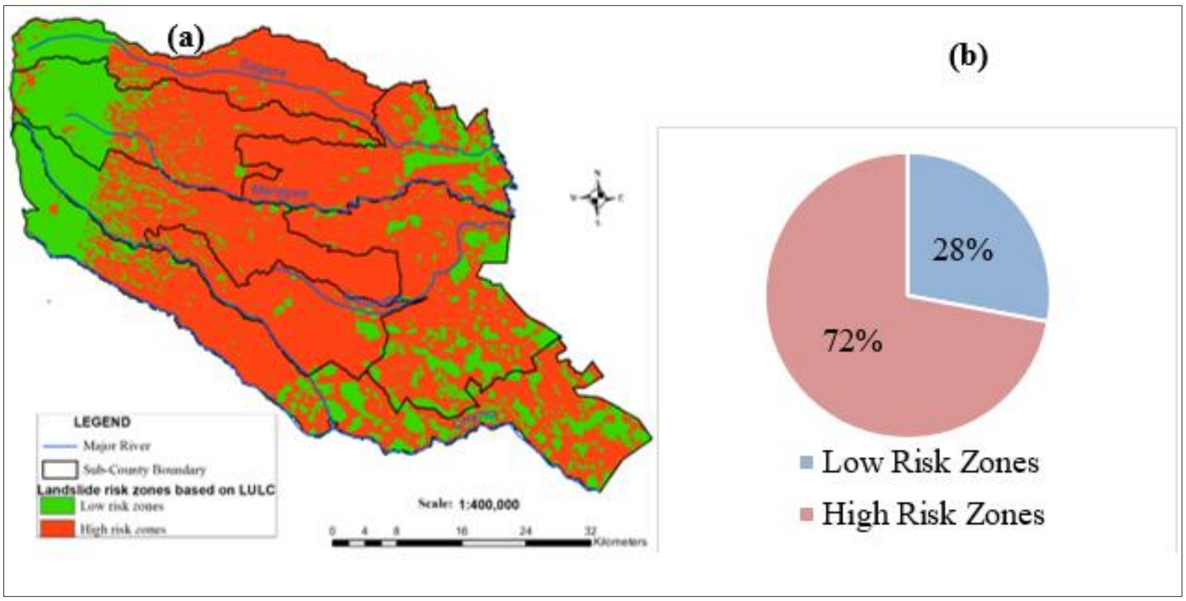


Figure 4.19: ***Mapped landslide risk zones based on Land-use land-cover (LULC) as a landslide causal/trigger factor***

(a) Classified and standardized LULC types delineated risk zones grid, (b) MAM 2018 Reported Landslide cases distribution against the LULC Delineated risk zones

In conclusion, each of the five landslide causal/trigger factors would be deemed to have a contribution, albeit in different degrees, to landslide occurrences as in the cases of the MAM 2018 inventories. Based on each factors mapped areas with respect to how likely an areas is to have a landslide, it is evident that rainfall is the best indicator of the high risk zones. This is because it had the highest conformity with the MAM 2018 cases hence it would have been the leading 'contributor' to the landslides which occurred then as opposed to LULC factor, which had the lowest conformity.

4.4.7 Multi-Criteria Evaluation (MCE) of landslides' causal/trigger factors based on scientific knowledge

Finally, in order to achieve the first specific objective of the study which is *'Mapping and delineating landslide disaster risk zones based on scientific knowledge,'* all the five causal/trigger factors (rainfall, elevation, soil, slope and LULC) were integrated and overlaid to a singular map showing landslide disaster risk zones for Murang'a County as scientifically understood. The map shows the final susceptibility zones of the cumulative effects of all the factors in a MCE in GIS. No weights were applied in the simple Spatial Multi-Criteria Evaluation.

The final results showed that landslide susceptible zones are concentrated at a certain belt as spatially shown in Figure 4.20. Incidentally. This is a zone of heavy concentration of human activities such as settlement and intensive farming due to conducive climatic and edaphic conditions. Land in the said zone is hugely fragmented through subdivisions under pressure from high human population. In the extreme ends of Murang'a, especially the lower parts of the county, there are low landslide susceptibility and the zones are mapped as being regions of low landslide risks. Surprisingly, isolated cases of high risk zones are also available within the Aberdares Forest despite the fact that the area is heavily forested to cushion it from the landslides. The explanation could be attributed to the fact that a landslide is a system which is made up of sub-systems characterized by the causal/trigger factors (Shi, *et al.,* 2020; Khasanov, *et al.,* 2021), all of which must work as a unit for landslide event to occur. A perfect demonstration of the causal/trigger factors working as a system is the occurrence of landslides in well forested areas, which would ordinarily have the advantage of ample tree cover to lessen the water action but also has the disadvantages of heavy rainfall due to high elevation and also has loosely connected volcanic soils which are highly susceptible to mass movements such as landslides.

In summary, according to the scientific understanding of the landslide causal/trigger factors for Murang'a County, landslide prone areas are largely concentrated in the mid-upper parts of the county as shown in Figure 20. In general, the lower, southern parts of the county have low chances of experiencing the landslide due to unfavourable landslide causal/trigger factors.

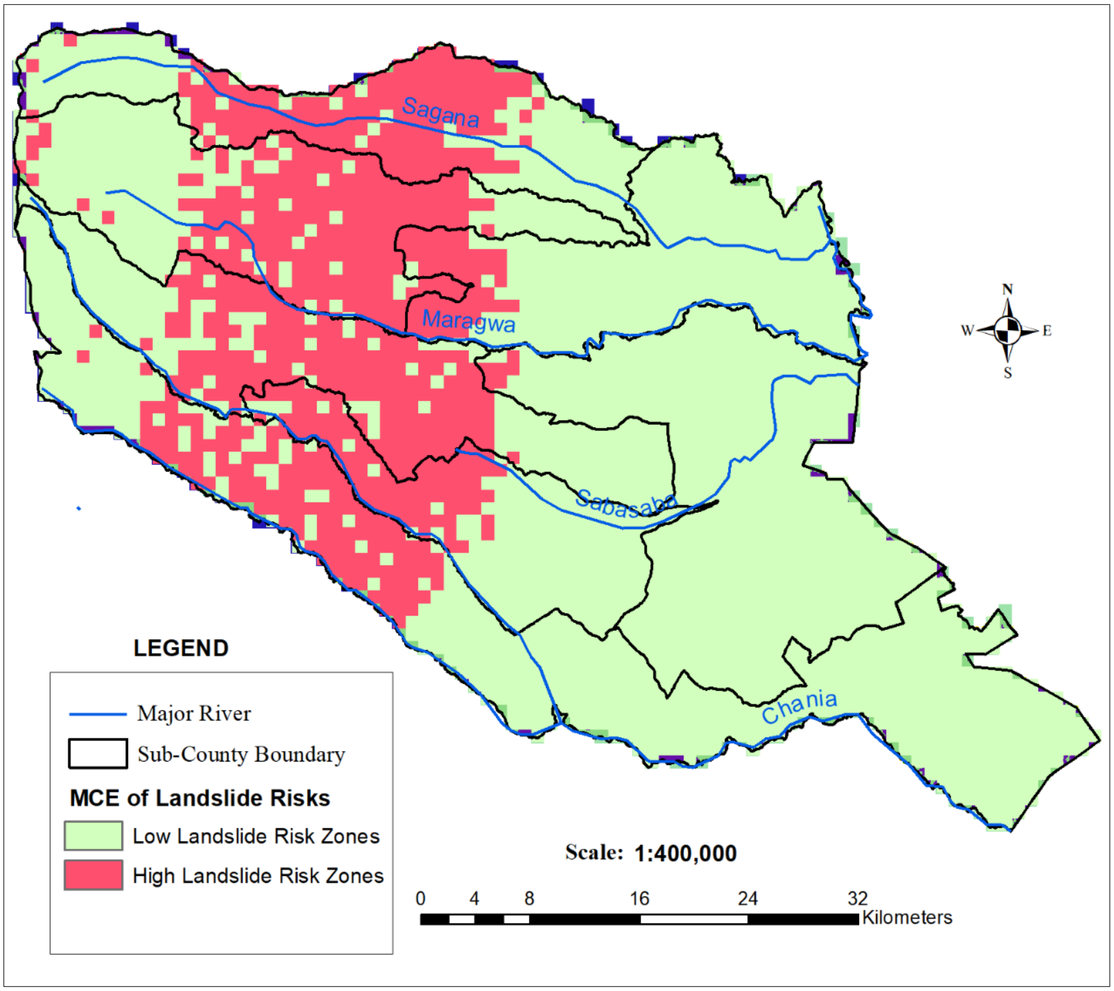


Figure 4.20: ***Final MCE for rainfall, elevation, slope, soils and LULC causal/trigger factors***

4.5 Mapping and delineating landslide disaster risk zones based on indigenous knowledge

The second specific objective of the study was *'Mapping and delineating landslide disaster risk zones based on indigenous knowledge.'* The initial task achieving it was to seek an understanding of the indigenous peoples' interactions and experiences with landslides over time. The indigenous people understanding can be rich in understanding the landslide but remains undocumented despite the fact that the local people are key players and stakeholders in disaster risk management as they are directly or indirectly affected by landslide occurrences. Table 4.19 highlights the different dimensions of the local peoples' experiences with the landslides. Worth noting is the affirmative that all the respondents (100%) indicated that they knew what landslides are and a total 97.0% termed them 'disasters'.

In terms of their landslide frequencies, 298 of the respondents which constituted 88.7%, were in agreement that there has been an increase in cases over time although 24 (7.1%) and 14 (4.2%) respondents were of contrary opinions as they indicated no increase and decrease respectively. Those who reported to have experienced a landslide were 317 (94.3%) out of which 252 (80.8%) cases were within a close proximity of less than 1 km from their homes. Important to note also was that 66.4% of the respondents reported that they had been affected by a landslide at least once in their stay. Such a confession is a testimony that landslide in Murang'a are recurrent and can also be termed as 'localized' disasters as one of the participants who had been affected four times over the years asserted as he lamented the recurrent nature of landslides and frustrations of not having alternative land to resettle after being adversely affected. He said that:

> *Guku nikwendetwo muno ni matuika! O hindi kungiura mbura nene no nginya gutuike. Riu ni rita ria kau…kana! No tutire kundu gwa guthamira"- A male FGD participant in* Rwathia, Kangema Sub-county

Translated to:

> "This area is 'loved by' ('prone to') landslides! Every time it rains heavily, landslides must occur. It's now the fourth time! But we have nowhere to relocate to" - *A male FGD participant in Rwathia, Kangema Sub-county.*

Table 4.19: ***Local peoples' interactions and experience with landslides***

Landslide aspect	**Number (Counts)**	**Percentage (%)**
Understanding of landslides as a disaster		
No	08	2.4
Yes	326	97.0
Not sure	02	0.6
Frequency of landslides as a disaster		
Increasing	298	88.7
Constant	24	7.1
Decreasing	14	4.2
Ever experienced a landslides		
No	16	4.8
Yes	317	94.3
No response	03	0.9
Directly affected by a landslides	143	42.6
No	180	53.6
Yes	13	3.9
Was the landslides destructive?		
No	10	3.0
Yes	310	92.3
Not applicable	16	4.8
Number of times affected by a landslides in lifetime		
1 (once)		
2 (Twice)	69	33.7
3 (Thrice)	69	33.7
4 (Four times)	51	24.9
5 (Five times)	06	2.9
Distance from one's home in km for those who ever experienced landslides	10	4.9
0.0- 1.0 km (Affected)		
1.1-3.0 km	252	80.8
3.1-6.0 km	52	16.7
	08	2.6

Source: Field data

4.5.1 Understanding and ranking of landslides' causal/trigger factors by the indigenous people

The respondents who had interacted and experienced landslide disasters in their lifetime, had varied understanding of the causal/trigger factors and the individual contributions of each to a landslide occurrence. Nearly the same factors which are scientifically known to contribute to a landslide event by either causing or triggering it were mentioned by the respondents. An overwhelming majority (97.6%) of the respondents reported that they were aware of the factors which cause or trigger landslides. The prominently mentioned factors included: rainfall intensity, slope/steepness/gradient of the land, altitude/elevation, soil characteristics, land-use-land-cover, vegetation types, infrastructural development and population increase in an area (see Table 4.20).

Nevertheless, the big question and which was contentious is how much each factors contributed to a landslide event as understood by the local people. Generally and on average, all factors were ranked by respondents as being over 70.0% in contributing to the occurrence of a landslide as shown in Table 4**.** However, rainfall was ranked as the most prominent landslide causal/trigger factor by 329 respondents (97.9%) who termed it as 'the most dreaded' factor. A significant number of respondents (r=0.806 at 0.01 level (2-tailed) who had migrated in their current locations described rainfall as a major causal/trigger factor. In support of rainfall being a major factor, an elderly female FGD participant from Murarandia Location, Kiharu/Kahuro Sub-county asserted the following describing rainfall as the 'most dangerous' landslide causal/trigger factor in her area. The statement is verbatim in local dialect:

> *"Kungiura mbura utuku mugima nginya kiroko, tuikaraga na wasiwasi tondu nitumenyaga no hindi yothe kungituika guku*"- An elderly female FGD participant in Murarandia Location, Kiharu /Kahuro Sub-county

Translated to:

> *"When it rains the whole night, we are always worried because we know that anytime a landslide may hit the area"*-An elderly female FGD participant in Murarandia Location, Kiharu /Kahuro Sub-county

Gradient or steepness of the land was also mentioned as a major causal/trigger factor by 95.5%. Further in support of that, a significant number of people (r=0.806 at 0.01 level (2-tailed) who had migrated to their current locations described steepness as a major causal/trigger factor. On the same note, a significant 86.2% (r=0.862 at 0.01 level (2-tailed), who reported to have experienced a landslide at least once in their home areas also termed slope steepness as a major factor. Also, further in support of that, a participant drawn from a FGD in Kiharu/Kahuro said that an area called '*Kiriko-ini,*' a Gikuyu name which means *'the sunken-land'* experienced a landslide due to steep gradient which caused the land to sink and curve-in to a depression and hence the name *'kiriko-ini'*.

About 96% of the respondents mentioned soils as the other prominent landslide causal/trigger factor. In Kigumo, Kangema and Mathioya Sub-Counties, the locals described some areas as having loosely-layered soils with middle parts being 'slippery and riding on a hard rock' making the land prone to sliding upon trigger from rainfall. Some specific parts in Kigumo Sub-county were locally described as having '*kingare soils*', which basically means soils which are *'smooth and slippery'* (FGD participant at Mariira, Kigumo Sub-County).

Elevation factor was mentioned by 90.2% of the respondents as a significant factor in contributing to occurrence of landslides. The percentage is comparatively lower. Some of the respondents who considered elevation as being less influential in contributing to landslides argued that since elevation rarely changes throughout time, it cannot be considered to be a serious causal/trigger factor, especially in view of the increasing landslide cases in Murang'a amid no change in elevation over time. To illustrate this, one FGD participants from Rwathia, Kangema said:

> *"Elevation is not a key causal/trigger factor as it never changes. Our area has always been in high altitude but we are seeing an increase in landslide cases no more than ever. Is there elevation change with increase in landslides? The answer is No!"* – A male FGD participant in Rwathia Location, Kangema Sub-county

Apart from the above listed factors, other interesting but equally notable causal/trigger factors mentioned by the participants and respondents were act of 'god' whereby some respondents argued that 'god' was not happy with human beings and through landslides, he wanted to punish the people as a results of their wrong doings. The narrative was explained by a participant in a FGD in Murarandia, Kiharu, Kihuro Sub-county who said:

> "God is not happy with man due to the social evils and sins being committed against him. This is the reason why he has increasingly released his anger on man through increased calamities in our society to show his might. Such is the reason why we experience increasing cases of landslides in the world. With increasing rebellion against God, landslides and indeed other calamities will continually strike the world in huge ways. All these can be traced in the holy book of God as it also happened in the ancient days, long before our generation"-*A FGD participant in Murarandia, Kiharu/Kahuro* Sub-county

Another narrative given as a contributor to landslides was that of a fallen heavenly body. It was believed that a heavenly body which fell from heaven many years ago could be causing/triggering landslides in a way. Surprisingly, the narrative of the said heavenly body, which looked like a circular star was given in two separate sessions in both Kangema and Kiharu/Kahuro sub-counties. In the two separate cases, the participants explained that long time ago, a heavenly body fell from heavens and was buried deep in the ground. The body looked like a circular star and has been causing landslides to happen since then, especially once it is triggered to move underneath. The explanations went on that for a landslide to occur, the star tends to marginally sink under pressure from the earth's surface under trigger such as heavy rainfall and as it sinks, cracks would emerge and land would slide along the crack lines. In that case, the landslide boundary looked curved (see the curved red line on *Plate* 4.2, the same way the fallen and sinking star is believed to be curved. One key FGD participant in Rwathia, Kangema Sub-county vividly supported the narrative by saying the following:

> "The circular shape of the recurrent landslides in this area is a clear indication of the fact that a star which fell long time ago, (as we were told by our fore-father) is the cause of the landslides here. Look!.... he said pointing at a fresh landslide scar, the crack separating the area washed away by the landslide and the unaffected area is curved, meaning the landslide boundary followed the circular shape of the fallen star. Our great grandparents were knowledgeable about it and passed the knowledge to us! – A female FGD participant in Rwathia Location, Kangema Sub-county

Such assertions were considered vital and are in line with Westerberg and Christiansson, (1999), who stated that there are 'myths' held by some rural populace which associate and consider disasters as being 'the work of God'. Such a contention makes them have less faith in the mitigation process.

Plate 4.2: ***The researcher standing on a curved landslide boundary in Rwathia, Kangema***

Other participants mentioned causal/trigger factors which included diverting of water from the roadsides to channels directed through the farms from the upper lying lands to the low lying streams. During the study, such diversions were evident especially on the newly tarmacked roads in all the sub-counties within the study area.

After establishing the prominent landslide causal/trigger factors as understood by the indigenous people, the next step was to rank them according to their individual contributions to causing or triggering landslides as understood by the locals. For uniformity in the study, similar factors which were considered in the scientific analysis were given precedence. These included rainfall, slope, altitude soil, and LULC. For ranking, multiple response analysis in IBM-SPSS was done to accommodate overlapping multiple responses and the final ranks were as shown in Table 4..20. The computed weights for all the factors were scaled between 0 and 1 for uniformity in measurement using the formulae:

$$Allocated\ Weight = individual\ Percentage\ Cases / Total\ PercentageCases * 1$$

Results showed that the respondents voted rainfall as the most influential landslide causal/trigger factor among the five under consideration. It was given a weight of 0.21, which was the highest, making it the most significant landslide causal/trigger factor as known by majority of the local people (99.7%). Such a huge conviction was in line with the experts' opinion that rainfall is the number one factor in causing/triggering landslides in the area. On the other hand, the factor which was said to be least in contributing to landslides was the LULC, which had the lowest weight of 0.18 as voted by 86.7%. The rest of the ratings and weights for the other factors are as shown in Table 4..20.

Table 4.20: ***Landslides causal/triggers factors ranks and weights by the indigenous people***

As a landslide causal/trigger factor	**Percentage Cases** (%)	**Allocated weight (%)**
Rainfall intensity	99.7	0.21
Slope	97.3	0.21
Altitude	91.8	0.19
Soil characteristics	97.9	0.21
LULC type	86.7	0.18

Source: Field data, 2021

4.5.2 Weighted Linear Combination (WLC) of landslide causal/trigger factors in Multi-Criteria Evaluation (MCE) based on indigenous knowledge

Finally, in order to achieve the second specific objective of the study which as *'Mapping and delineating of landslide disaster risk zones based on indigenous knowledge,*' all the causal/trigger factors were combined in raster GIS to a singular map showing landslide disaster risk zones for Murang'a County. The computed weights were used in deriving the WLC of the factors to output the MCE in GIS using the formulae:

$$WLC = (\text{Rainfall} * 0.21) + (\text{Slope} * 0.21) + (\text{Elevation} * 0.19) + (\text{Soil} * 0.21) + (\text{LULC} * 0.18)$$

Where: $WLC\ is\ the\ MCE\ of\ the\ factors\ as\ weighted\ by\ the\ local\ people's\ ranks\ and$

$Rainfall, Slope, Elevation, Soil, LULC\ are\ the$

$tandardized\ raster\ grids\ for\ rainfall, slope, elevation, soil\ and\ LULC$

$respectively, each\ multiplied\ by\ respective\ weight\ score\ as\ computed\ in$ Table 4. $above.$

The result of WLC was a derivative map shown in Figure 4.21 where the spatial distribution of the landslide disaster zones were in such a way that the northern (upper) part of Murang'a County were mapped as being the high landslide risk zones while the southern (lower) parts as being the low risk zones.

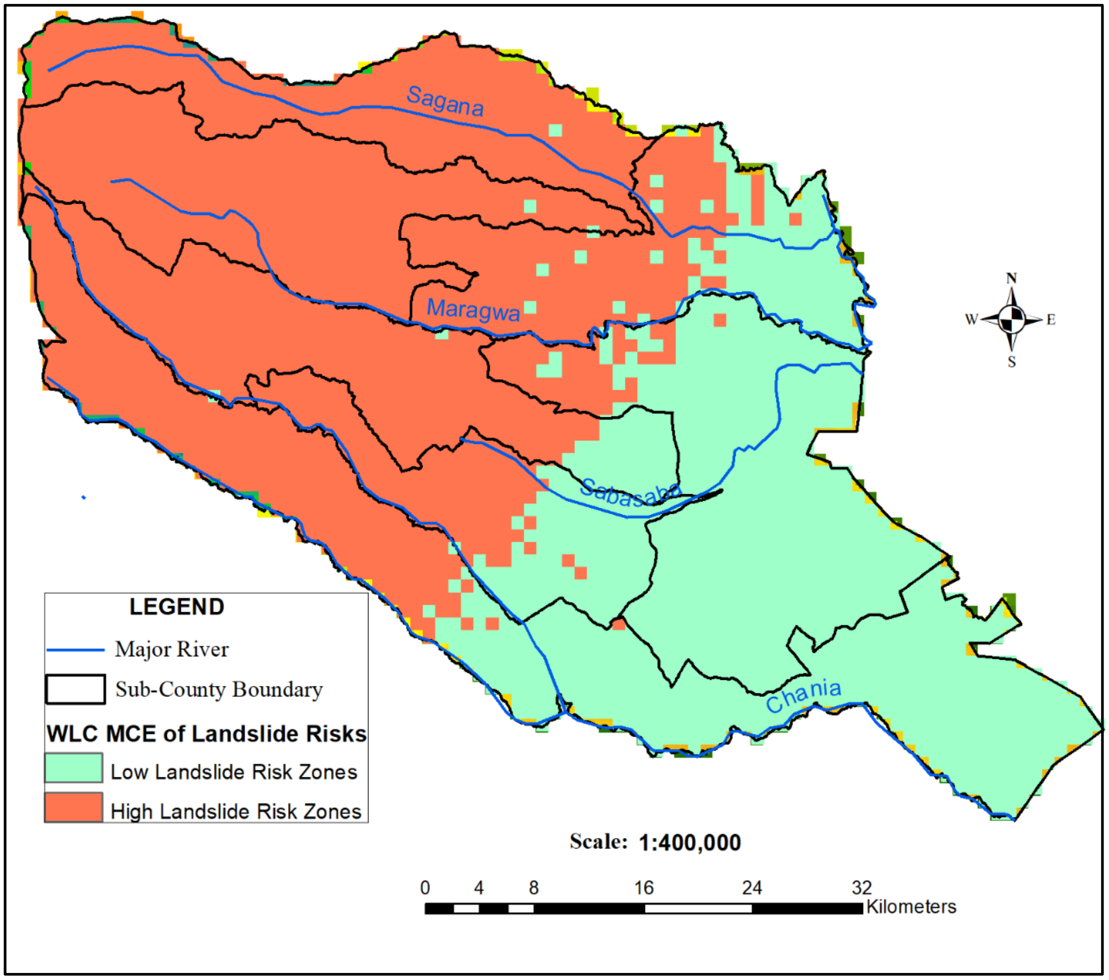


Figure 4.21: ***Final Weighted Linear Classification in Multi-Criteria Evaluation (MCE) for rainfall, elevation, slope, soils and LULC landslide causal/trigger factors***

4.6 Nexus between the scientific and indigenous knowledge landslide disaster risks understanding in comparison with March-April-May (MAM2018) landslide inventories for Murang'a County

The third specific objective of the study is partly constructed from the first two specific objectives and seeks to establish the relationship between the delineated landslide disaster risks zones for the scientific and indigenous knowledge understanding. The ultimate aim was to establish the connection and nexus between the landslide disaster risk zones delineated based on the two levels of knowledge. The zones are also analyzed and compared with the MAM 2018 inventories. According to Murang'a Meteorological Services (2021), MAM 2018 had the highest number of reported landslide cases within a single rainfall season in the history. This was the reason why the period was picked to be the reference base point for the study.

4.6.1 The nexus between MAM 2018 landslide disaster inventories and the mapped landslide disaster risk zones based on scientific understanding

The spatial distribution of the inventoried cases for MAM 2018 and the scientifically mapped landslide risk zones is shown in Figure 4.22. Generally, a high concentration of the MAM 2018 cases are distributed within the areas marked as high risks on the multi-criteria map.

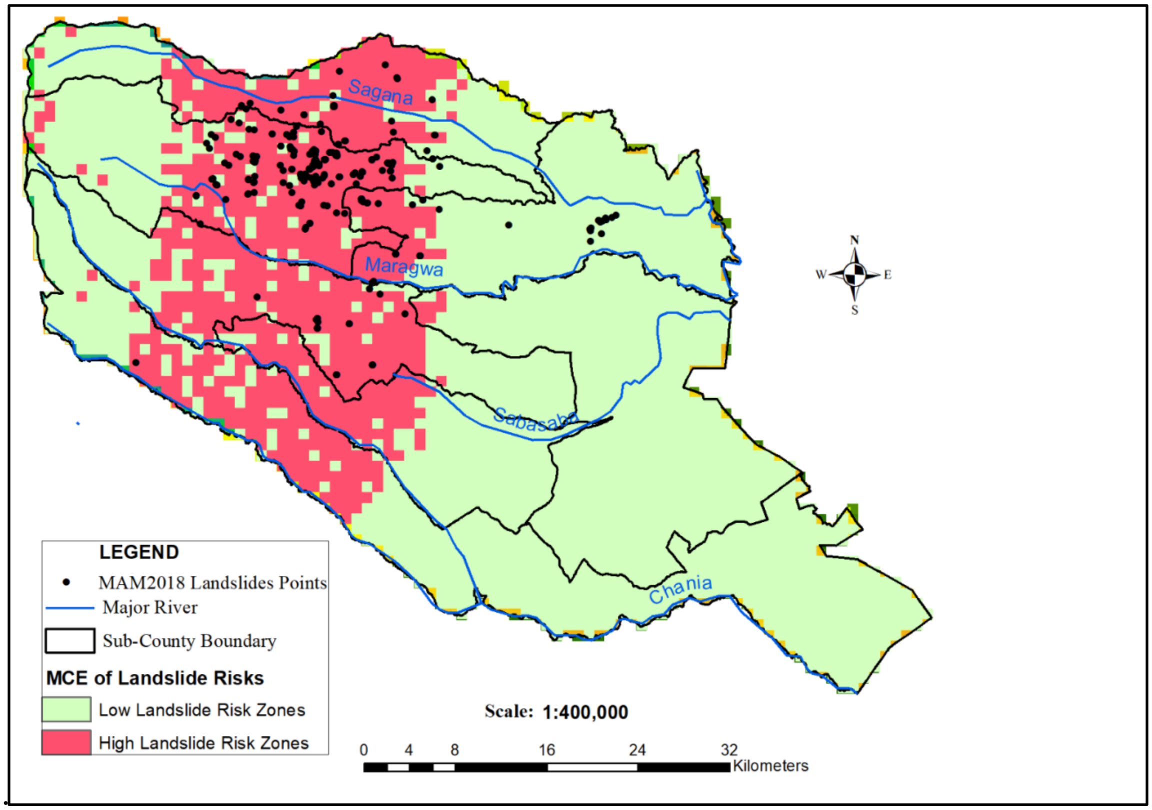


Figure 4:*22 Comparison between the scientifically delineated landslide zones and March-April and May (MAM) 2018 landslide inventories*

Futher quantitative analyses in raster GIS showed that 88% of the reported cases were within areas zoned and mapped as high risk based on scientific knowledge understanding while 12% were in the low risk zones as shown in Figure4.23 . Such a conformity percentage is considered a good approximation of the landslide risk zones based on the scientifically known and documented criteria. It therefore means that, based on the MAM 2018 cases, scientific knowledge would have had a significant ‘prediction’ of the areas which would were at high risk of experiencing landslides.

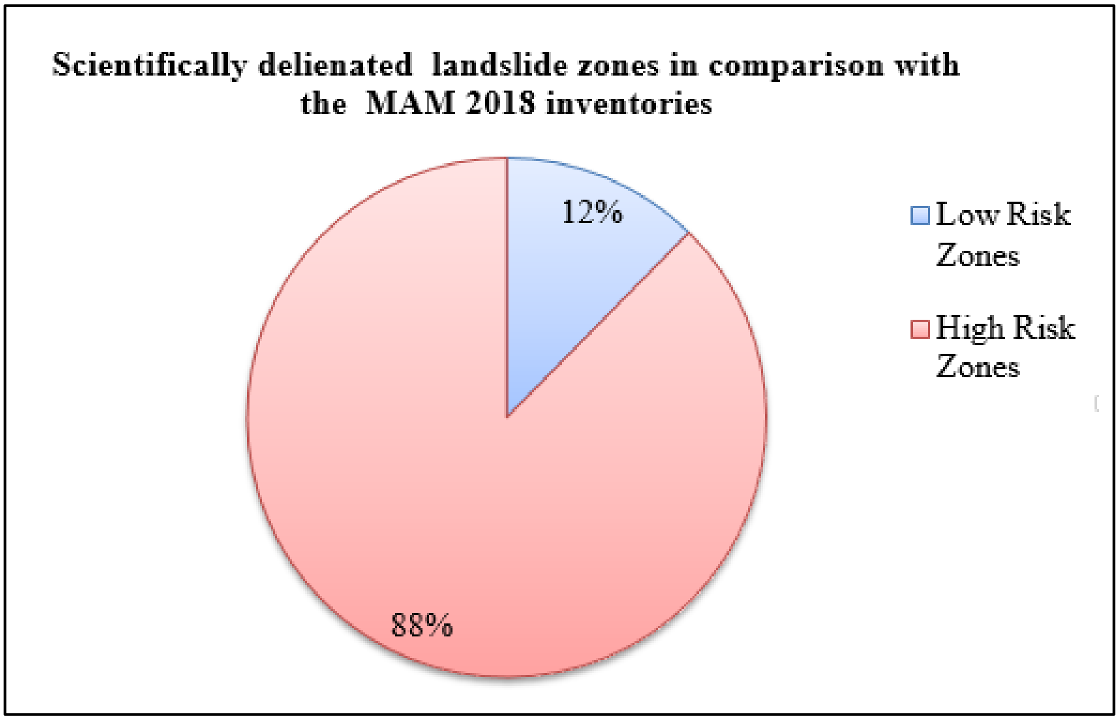


Figure 4.23***: Comparison between the scientifically delineated landslide zones and the March-April and May (MAM) 2018 landslide inventories***

4.6.2 Nexus between MAM 2018 landslide inventories and landslide disaster risk zones based on indigenous knowledge understanding

The spatial distribution of the inventoried landslide cases for MAM 2018 and landslide disaster risk zones based on the indigenous knowledge understanding are spatially mapped as shown in Figure 4.24. Generally, a high concentration of the MAM 2018 cases are distributed within the areas marked as high risks on the weighted multi-criteria map.

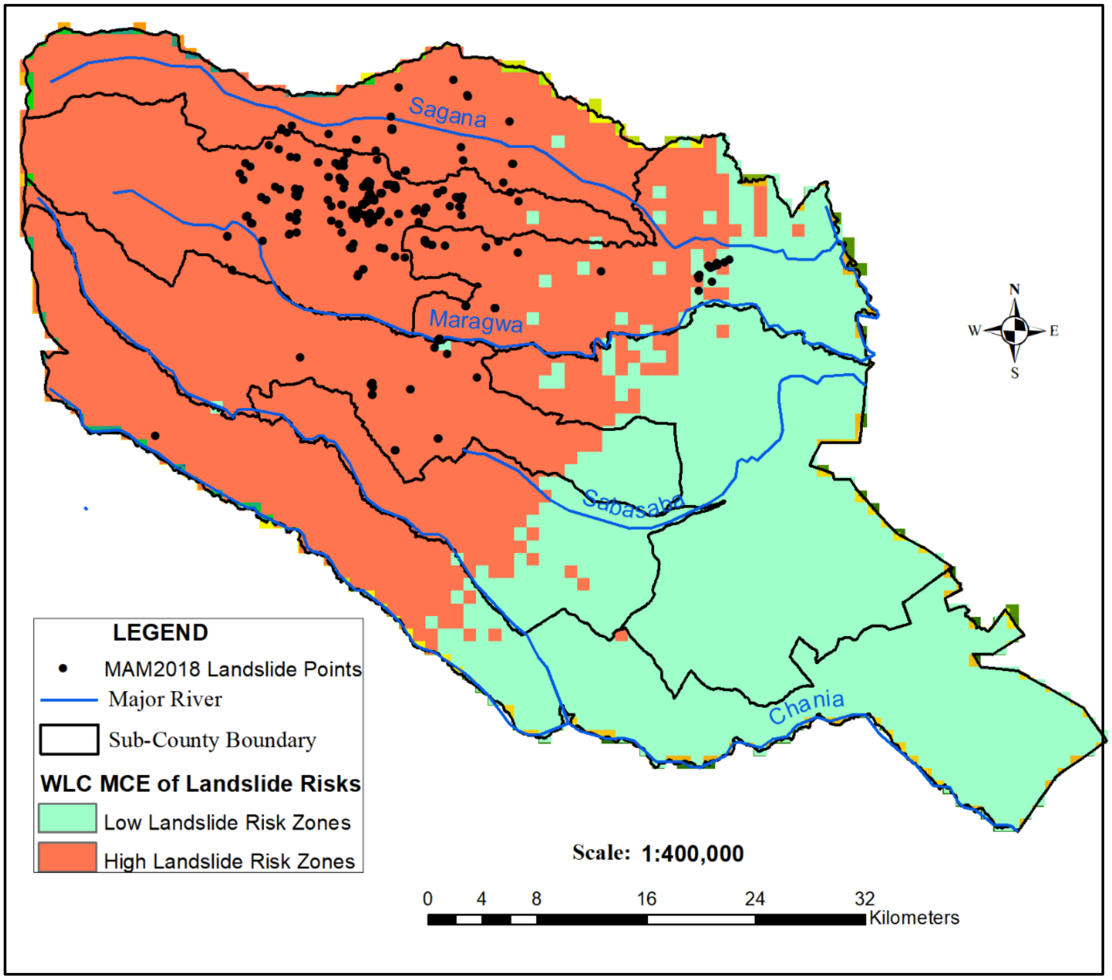


Figure 4.24: ***Comparison between the IK-based landslide zones with the March-April and May (MAM) 2018 inventories***

The quantitative results from raster GIS analysis showed that 97% of the MAM 2018 reported cases fell within areas zoned as high risk based on IK understanding while only 03% were in the low risk zones as shown in Figure4.25. According to the results, indigeneous knowledge understanding a significant prediction of the areas which would have been considered to be at high risks and likely to be hit by landslides as it occurred in 2018. Infact, the IK understanding through the weighted linear combination gave a better approximation of the high risk zones based on the MAM 2018 cases compared to the zoning in the case of the scientific knowledge understanding.

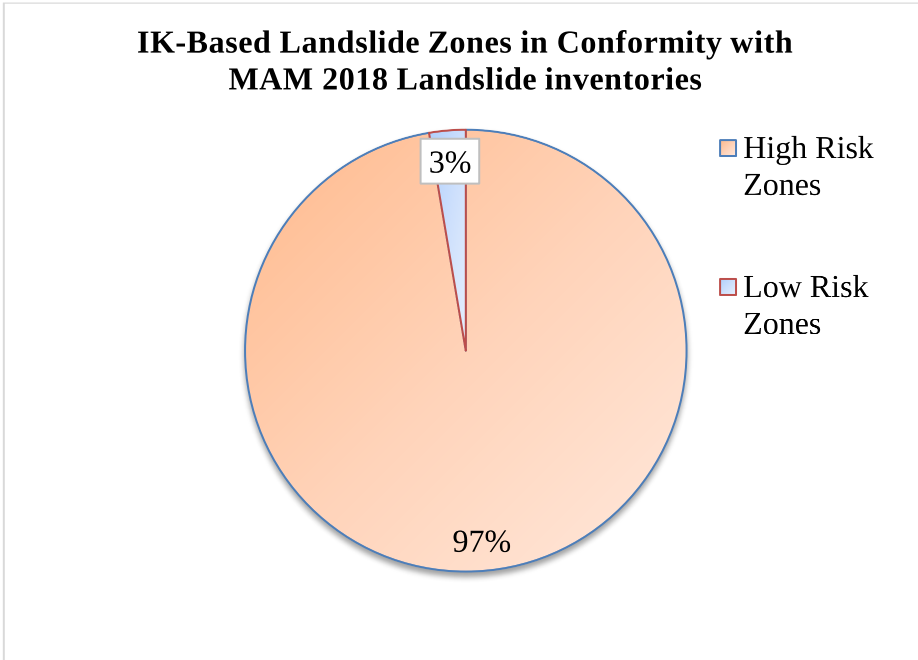


Figure 4.25: ***Comparison between indigenous knowledge-based landslide zones and the March-April and May (MAM) 2018 inventories***

In conclusion, the results point out to the fact that the local peoples' views, some of which are based on indigenous knowledge, cannot be ignored in the understanding of landslide disasters in Murang'a County.

4.6.3 The nexus between scientific and Indigenous Knowledge delineated landslide disaster risk zones

A convergence between the scientific and IK in delineating the landslide disaster risk zones exists and is visible as spatially depicted on Figure 4.26. In (a) and (b) of the figures 88%

and 97% of the MAM 2018 landslide cases fell within the high risk zones for the scientific and IK delineated zones respectively. The same causal/trigger factors were considered but the results showed that the IK zones has a wider and better predictability of the MAM 2018 landslide occurrences compared to the scientific knowledge.

For a better understanding of the nexus between the two zones, an integration of the maps in GIS was done in order to have a combined convergence map (see Figure 4.26c**)** and compare it with the two individual resultant maps for scientific and indigenous knowledge understanding of the landslide zones. The convergence analysis is done in ArcGIS's raster calculator using the formulae:

$$Convergence\ Landslide\ Disasater\ Risk\ Map = WLC == MCE$$

Where:

WLC and MCE are the delineated landslide disaster risks grid for IK and scientific knowledge respectively

The qualitative raster analysis of the resultant convergence map showed that 90% of the MAM 2018 reported cases fell in the zones delineated as high risk zones and only 10% were in low risk zones as shown in Figure 4.27. Again, the conformity level indicated a significant level of agreement in the zoning of landslide risk zoned based on combined knowledge in which 90% of the MAM 2018 cases would have been predicted to occur in the areas zoned as high risk zones and only 10% would be in the low risk zones. Such a prediction would be termed as 'moderated' and is common ground result between the high prediction of the IK and low prediction in the case of scientific knowledge.

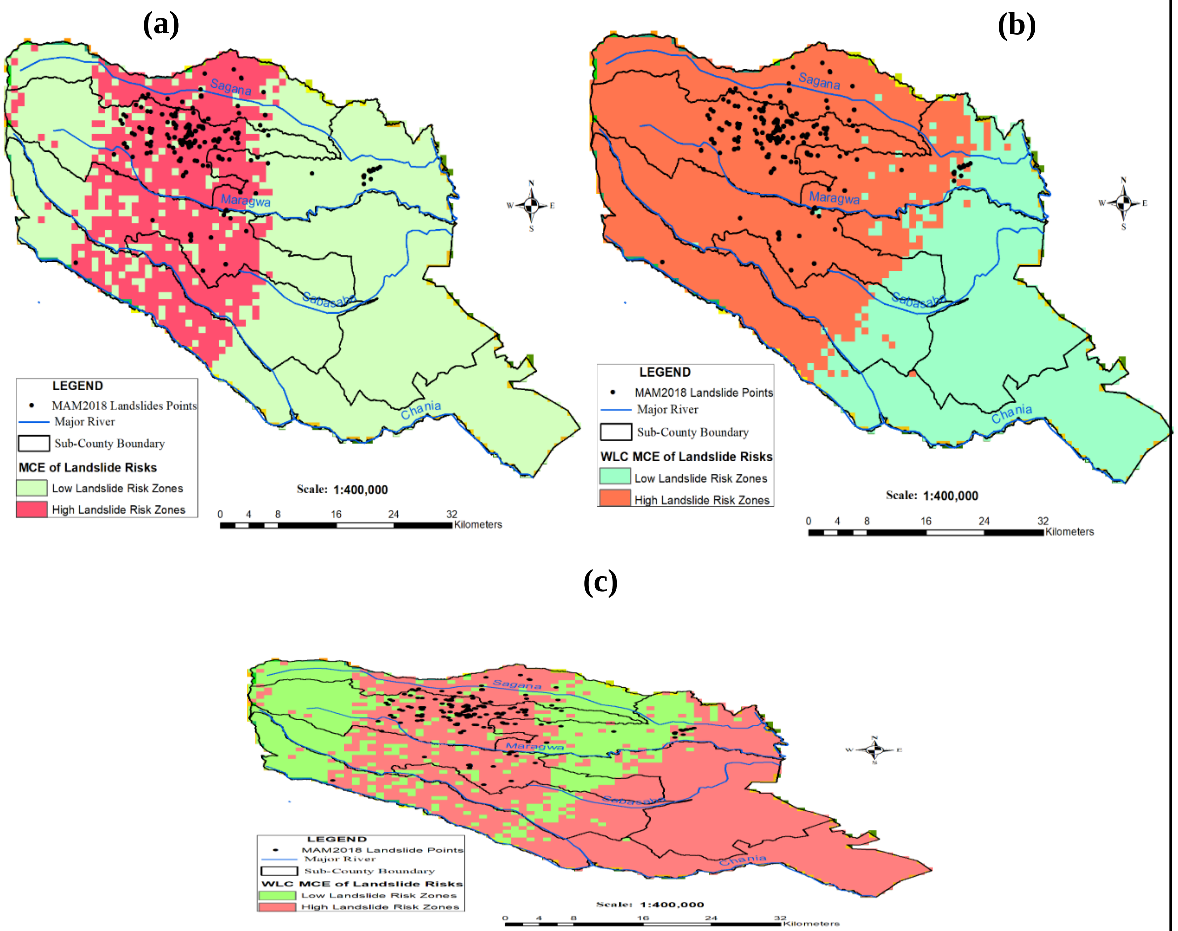


Figure 4:26 ***Nexus between scientific and IK delineated landslide zones***

(a) Scientific knowledge delineated landslide zones (b) IK delineated landslide zones and (c) Combined zonation

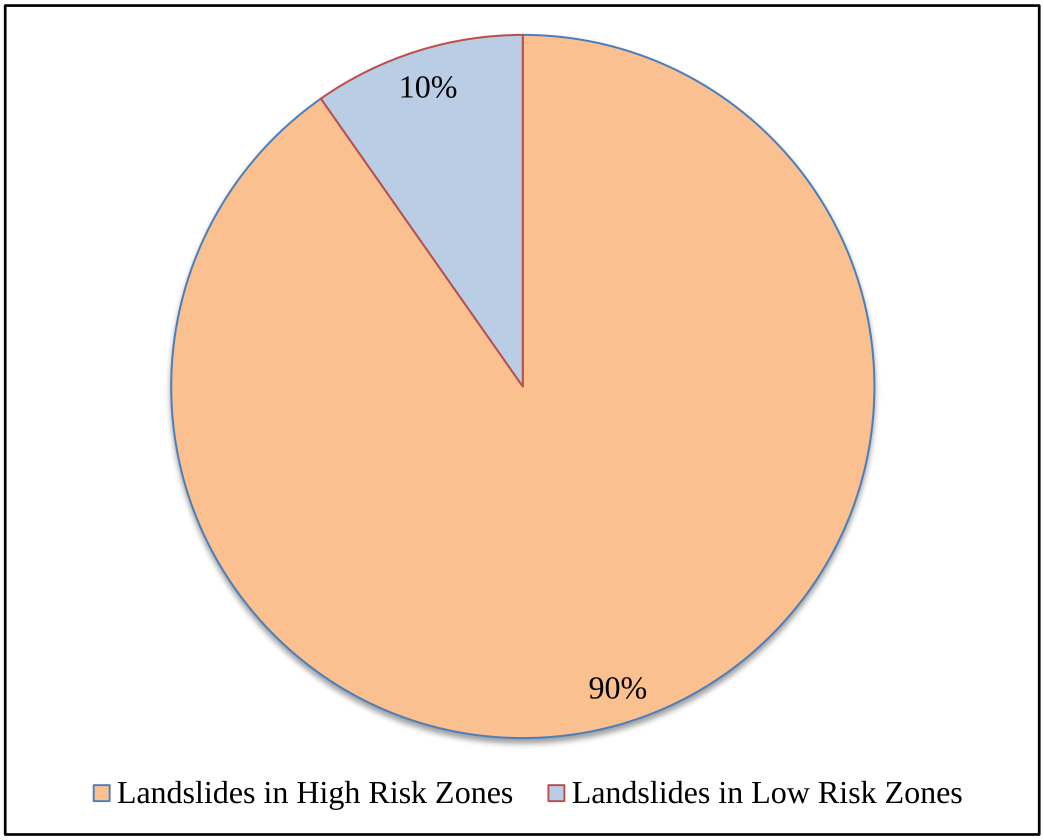


Figure 4.27: ***Conformity between scientific and IK delineated landslide zones***

Apart from the a convergence between the landslide disaster risk zones, the nexus between the landslide causal/trigger factors were also sought basing on the MAM 2018 inventory cases. An agreement in both cases were that rainfall was the most prominent landslide factor at a convergence rate of over 98% as opposed to LULC which had the lowest approval. Elevation and slope factors were also rated at above 90% in both understandings as shown in Table 4.21 for both the scientific and IK understandings of the causal/trigger factors. The key point is there existed a nexus between the IK and scientific knowledge in the understanding of the landslide causal/trigger factors.

Table 4.21: ***Conformity among the landslide causal/trigger factors with the scientific and indigenous knowledge (IK) delineated landslide disaster zones***

Causal/Trigger Factor	**Scientific Knowledge**	**IK Knowledge**
	Percentage of High Risk Zones	*Percentage of High Risk Zones*
Rainfall	99%	98%
Elevation	94%	90%
Slope	95%	96%
Soils	88%	96%
LULC	72%	87%
		Source: Field data

In conclusion, all the five considered factors were seen to have a contribution to the occurrence of a landslide through the lenses of the two levels of understanding. In both cases, rainfall was the most influential factor in determining areas to be considered as high risk zones compared to the least factor seen as the LULC.

4.7 Landslide disasters effects in Murang'a County

The fourth specific objective of the study is about the effects of landslide disasters in Murang'a County. The objective seeks to establish how the indigenous people, who are among the main players in disaster risk management continuum, are affected by the occurrence of landslides. Local people are affected by the disasters in one way or another (Salome *et al.*, 2004). The effects are mostly negative but there are some which are said to be positive gains from a landslide event. The latter are in most cases not documented in literature and some, in context of this study, are 'first-hand' and undocumented from the study are as discussed below.

4.7.1 Negative effects of landslides

The negative effects of landslides were both direct and indirect, but the study makes no attempt to discriminate between the two. Out of all the reported cases of MAM 2018 landslides in Murang'a, three hundred and ten (92.3%) were reported to have caused damages ranging from destruction of properties, displacements, loss of human life and animals, psychological stress among others as shown in Table 4.22 **be**low.

Table 4.22: ***Reported landslide disaster effects***

Landslide effect	**Frequency**	**Percentage (%)**
Loss of human life	16	4.8
Loss of crops	37	11.0
Loss of animals	39	11.6
Displacement	64	19.0
Destruction of property	176	52.4
Psychological effects	213	63.4
Other losses	23	6.8

Source: Field data

The most common negative effects of landslides were psychological effects and damages reported by 63.4% of the affected respondents in Murang'a County. Such effects are not documented anywhere for the study area, reason being that they are not direct effect as Knapen, et *al.*, (2006) and Kitutu, *et al.*, (2009) noted. Notable cases of psychological stress were witnessed in Kayu and Kihindu Villages in Kihoya and Rwathia Locations respectively, both in Kangema Sub-County. The epitome of such a scenario was as reported in one of the FGD comprising of affected extended family members living in ancestral land in Kayu Village where an elderly lady aged 80 years said:

> "*Guku twahanire ta twagurukire niundu wa matuika migunda-ini ya bamiri ciitu kuma rugongo nginya kianda- An elderly female FGD participant in Kayu Village, Kangema*

Translated to:

> "In our family is like we are insane because of landslide occurring in our ancestral lands from the upper to lower hills" - *An elderly female FGD participant in Kayu Village, Kangema*

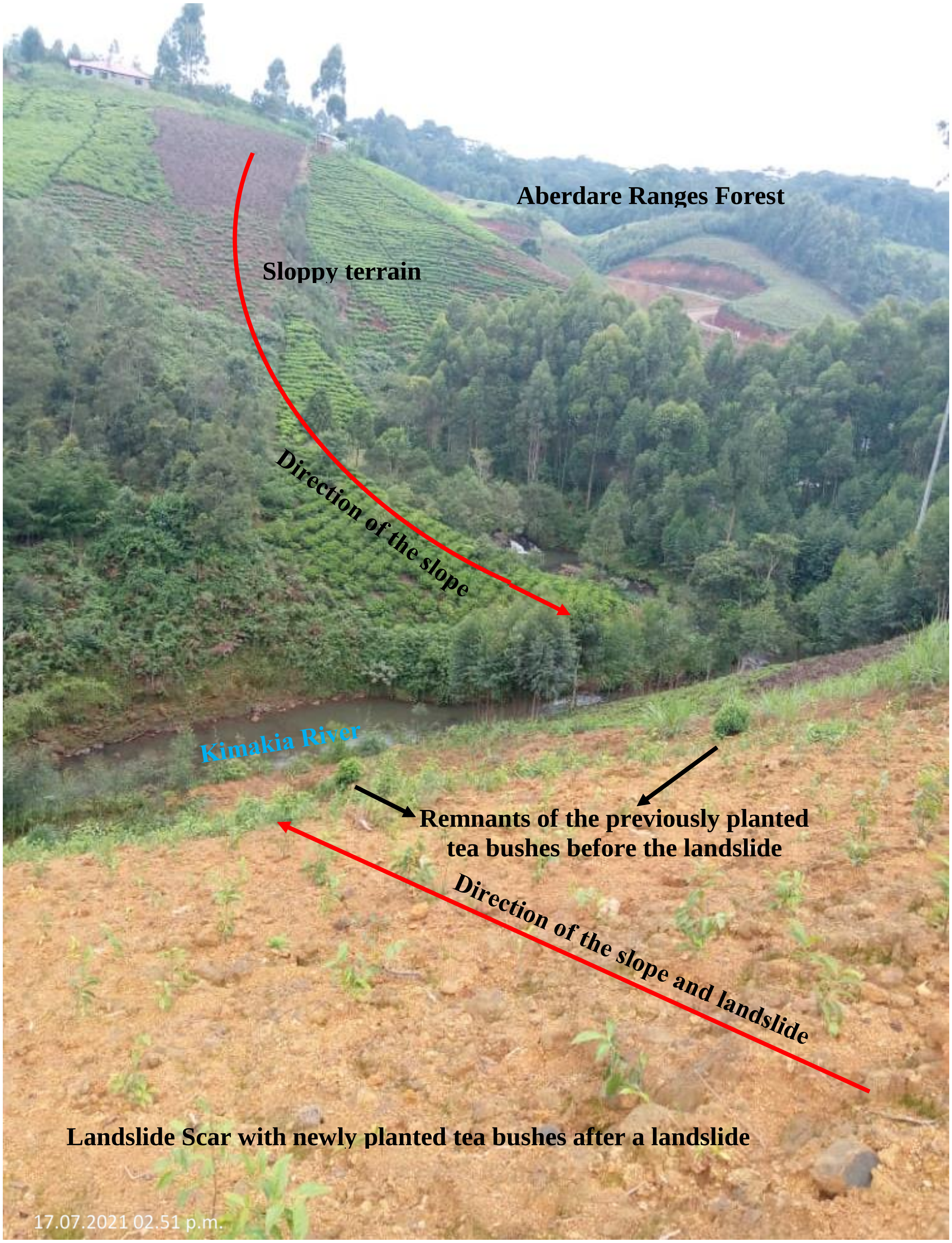
She painfully reported that that a deadly landslide occurred in the year 2018, washing away farms and destroying properties for a whole extended family in the same neighbourhood. It caused mental suffering to some family members. In the same locality, many cases of displacements were reported as evidenced by abandoned houses as shown in Plate 4.3 Displacement cases accounted for 19% of the reported landslide effects and were reported across all the locations. In Murarandia, two families were displaced in 2018 landslide. Cases of tea, coffee and other crops being washed away by landslides were reported in Gitugi (2018), Kahatia (2020), Murarandia (2019), Kihururu village (2016) and Kirangi in Mbugiti, Kandara Sub-County.

Plate 4.3*: Houses abandoned after the year 2018 landslides in Rwathia Location, Kangema Sub-County*

Source: Field Data

Shows (A) a destroyed and abandoned which is almost falling and (B) a standing but abandoned house of once a compound with several houses, on the forefront is a remnant showing a house foundation

Over eleven percent (11%) of the effects were reported in varying areas as being loss of crops and animals. For instance in Karia Village, a cow and houses were buried by a landslide in the year 2018. The crops which were lost during the landslide included crops included, trees, coffee, Napier grass and tea bushes. Among the reported cases were that some of the farmlands were washed and slide to the neighbourhood. A perfect example of such is shown in Plate 4.4 where a landslide which occurred in Kirangi Sub-Location, Mbugiti Location in Gatanga Sub-County washed away an entire tea farm down into River Kimakia. It is evident from the field plate and image that the area has a sloppy terrain, which makes it susceptible to landslides. Another example of farmland destruction was cited in Kihururu Village located between Githambo and Kanyanyeini where tea bushes were washed into River Kayahwe during a landslide which occurred in the year 2016. The main immediate resultant effects from these are blockage of rivers and water ways, psychological stress and land boundary conflicts and disputes between and among neighbours of the affected farms.



Source: Field Data

Plate 4.4*: The landslide site on a sloppy ground where tea bushes were washed down to River Kimakia in Kirangi, Mbugiti Location, Gatanga Sub-County*

Destruction of properties were also prominently reported by 53% of the affected respondents with cases being reported across all the sub-counties of Murang’a County. Examples are as shown in assorted field image in

Plate 4.5 and ranged from among others destruction of buildings, roads, crops, infrastructure such as roads, water pipes, bridges, forests, habitats, water ways and wetlands. Loss of life were also reported by close to 5%, a notable cases being from Gitugi where in the year 2018, a landslide swept and killed a man and in Gakira, Kigumo Sub-county, where also a woman was buried live by a landslide in the year 2016.

Source: Field Data

Plate 4.5*: Assorted images showing destruction from landslides*

(A) and (B) destroyed house in Rwathia Location in Kangema Sub-County and (C) road destroyed by a landslide in Mbugiti Location in Gatanga Sub-county

The main documented landslide effects are the direct effects. The indirect secondary effects are rarely reported and documented. Apart from the psychological effects, other unreported indirect effects from landslides included: Litigation from boundary and farm crop disputes after a landslide. In some instances, portions of soil/land and food crops were literary shifted from one place to another as the land slide, raising the issue of boundary and ownership problems among the neighbours. Another indirect effect is the shared resources disputes. In some areas, landslide blocked streams and water-ways hence obstructing the normal flow of water from the upstream. In such a scenario, some members of the community were denied access to water which is much needed especially during the dry-spell hence leading to disputes. Also reported were cases of branding and stereotyping of affected families as ‘cursed families’. These occurred mostly in cases where landslides were recurrent over the years, such families were stereotyped as being ‘cursed’ hence felt like they are living in rejection. Such branding adds to the psychological stress among the members of such families.

In conclusion, some of the negative effects of landslides are well known and documented in literature as opposed to others. The undocumented are mainly based on the IK and experiences of the local people but are also critical in understanding the landslide disasters.

4.7.2 Mitigations and coping mechanisms to negative effects of landslides

According to Maina-Gichaba *et al.,* (2013), landsides mitigation is localized and may be through a host of measures through restricting, prohibiting and other conditioning of land-uses policies and practices in prone areas. Experts such as the geologists, geotechnical, civil engineers among others can are useful in assessing the susceptibility of an area and elements at risk through informed empirical research works.

Mitigations are important in helping the people lessen the adverse effects of the disasters hence coping with it. Landslides, being natural occurrences, will always occur at some point and people should device ways and means of living with the disaster. There are many stakeholders involved in trying to mitigate the effects of landslides at different levels, times and through different activities. There are long, medium and long term interventions. The immediate short-term intervention carried out right after an occurrence entailed search and rescue operations by the humanitarian bodies such as the county disaster management and Kenya Red-cross in conjunction with the community members. The activities here are basically to safe life of the victims (both human and animals) and lasts for few days or hours depending on the seriousness of the disaster. Medical assistance is given to the affected through first aid operations. Also within the short-term interventions is the second phase which entails relief operations aimed at restoring the affected to near normal life. The activities here include relocation to safer grounds, provision of food and non-food items such as cereals, cooking fats, bedding, clothing, mosquito nets, medicines and monetary assistance for personal effects. During the relocation, some relatives, neighbours and faith-based organizations hosts the affected kins and families. A perfect example was reported in Gitiri village, Kiharu Sub-county, where an entire family of one elderly person, twelve adults and thirteen children had to be relocated to the neighbors and relatives houses in April, 2013 landslide case. The third phase entails reconstruction activities aimed at making the affected more resilient in case of recurrent landslides. These are medium-term operations and some of the activities here include building of stronger structures and houses in safer grounds. Such structures would withstand future recurrent landslides and have superior features such as being light in weight, having better water harvesting mechanisms to avert heavy logging of soils by rain water. Proper drainage and soil erosion prevention mechanisms through proper agricultural practices are also emphasized. Long-term mitigations included education and awareness creation especially at the village level. Such has been carried-out by the local chiefs and sub-chiefs in various locations through *barazas* and other public meetings graced by experts and other educators. The need for integrated efforts to reduce chances of landslide occurrences are highly emphasized. These includes among others planting deep-rooted trees, building strong embankments and gabions as was witnessed in Kangema as shown in

Plate 4.6 below.

Plate 4.6*: Road-side land embankment to prevent further landslides*

Enforcement of proper practices by the relevant authorities is another long-term intervention which was identified to work in mitigating landslides in Murang'a County. For instance the building codes whereby constructions are assessed and approved by the relevant authorities before construction starts in vulnerable areas. A case in time was reported in an area in Gitugi where geologists condemned the land as unfit for structural construction after the year 2018 landslide. Still on the building code, Kanjama area was identified to have very loose soils and a major road passing through the area has repeatedly been washed away by landslide due to the alteration of a water course by the contractors during the road construction. Due to this, in the year 2020, the government engineers recommended the shifting of the road to avert further losses in what the local residents called I local language *'ruui rucoke mukaro' ('the river to take its course'*.

4.7.3 Positive effects and support received by the residents affected by landslides

The residents affected by landslide disaster reported to have received support in various ways. The supports were in monetary gains and re-building of better infrastructures and houses in safer grounds. Such were received from the government and other well-wishers such as Kenya Red-Cross Society and local politicians. Interestingly, even though such deeds were termed as being positive, in some cases they ended up adding to the negative effects in one way or another. For instance, due to social evils such as favourism some undeserving locals, some of whom had not been affected by landslides in any way but were unfairly given priorities in receiving support from the authorities. In other cases, misappropriation and misuse of funds and other resources meant for the affected people were reported. All these added to the negative effects of landslides although they were intended to be of benefits to the local community. Nevertheless, a notable straight-forward benefit, which was said to be privy in the study area was the financial benefits to the so called ‘absentee landlords/landladies’ in areas affected by the landslides. ‘Absentee landlords/landladies’ are the indigenous people who own houses in their respective localities but do not reside in the said houses for the better part of the year. Such people are said to work in other areas and only come to their houses on selected occasions within a years. The house owners benefitted from rental income once their houses were leased by the relevant authority, albeit temporary, to settle the displaced person. In such cases, the authorities mostly drawn from the local and national governments would identify the occupants and through mutual agreements, the homes would be used to temporarily relocate the affected locals when need arises. Such instances were reported in Rwathia location in Kangema Sub-county.

4.8 Assessing the local peoples’ Early Warning Systems (EWS) through the use of indigenous knowledge and the nexus with the scientific systems.

Landslide EWS are among the many interventions known to reduce the risks caused by a landslide disaster (Piciullo, *et al.,* 2018) despite the fact that many areas affected by landslides globally are said to lack EWS (Guzzetti, *et al.*, 2020). It is therefore important to study the applicable EWS as understood in science and by the local people as applicable in the management of landslide disasters in Murang’a County.

4.8.1 The science in Early Warning Systems (EWS)

The UN, through UNEP (2012), outlines the elements of EWS as being:

i) Risk knowledge, monitoring and warning,

ii) Dissemination and communication and

iii) Response capacity.

According to UNEP (2012), scientific EWS on landslide risk information for monitoring and warning of landslides may be in form of landslide mapping and zoning, ground instability and deformation assessment and landslide inventories. These are the tenets of this study hence the justification of the inclusion of the final specific objective, *"Assessing the local peoples' Early Warning Systems (EWS) through the use of indigenous knowledge and the nexus with the scientific systems"*

4.8.2 The applicable scientific Landslides Early Warning Systems for Murang'a County

According to UNEP (2012), one of the main elements of a EWS is the risk knowledge, dissemination and communication. Scientific experts drawn from the county and national government reported that they have an elaborated multi-sectoral communication structure from the highest level of county administration and specialists in weather and climate related issues through to the community grassroots. Apart from the administrators, key players are drawn from the Kenya Meteorological Department (KMD), Kenya Red Cross Services, geology department, media, '*wazee wa nyumba kumi'* (some of the *wazees* are senior retired government official with relevant skills and training on natural disasters). Others included expert leaders drawn from youths, women, Community-Based Organizations (CBO) and faith-based organizations.

The KMD, through Murang'a meteorological services directorate, issue timely updates on the anticipated weather situations in the county. It issue warnings and alerts to the people through its community-based radio station, Kangema RANET FM (see Plate 4.7). The radio station was established in 2008 through the then ministry of Environment and Natural Resources, aimed at addressing environmental issues and in particular to help communities get timely and accurate reports of climate related issues such as on landslides. Community radio stations have been cited as being useful in availing necessary utilities and amenities such as among others education and protection from natural disasters (Wabwire & Ogalo, 2021). The station's signal covers 25 km radius, reaching thousands of farmers in the hills and valleys of Murang'a County, and spilling over into parts of Nyeri and Kirinyaga Counties. Its mission is to facilitate accessible meteorological information and infusion of scientific, agricultural, education and social knowledge to spur growth and development in society. According to the manager of the station, the radio has been crucial in encouraging development by facilitating dialogue about community needs so that people can identify problems and solutions. Most discussion programmes are call-in, where members of the public speak direct through the radio, with the presenters leading on local topics to provide accurate and reliable weather information, including discussion of seasonal changes and environmental issues. Specific and of interest to this study, the radio station has dedicated programs such as *'kinya kia riera na imera'*, which translates to *'the pot of weather and seasons'*, a program which is dedicated to landslide and other climatic related disasters'. In the program co-hosted by experts from the Kenya Meteorological Services and government ministry officials such as from the ministry of agriculture, diverse issues, including EWS are deliberated upon and communicated.

Plate 4.7: ***The researcher and a broadcaster on duty inside Kangema-RANET FM studios***

On landslide risk knowledge, technologies such as Earth Observatory through remote sensing methods, Global Positioning Systems (GPS) are also used by the experts to monitor the landslide and the weather situations in the area. KMD has embraced the use of such technologies and coupled with mobile telecommunication, the positioning and dissemination of the knowledge is timely and widely done. Functional communication channels were identified within the community. For instance, it was established that various stakeholders had active WhatsApp and other social media groups in which they communicated weather issues such as about any signs of an impending catastrophe in an area. Through the groups, participants could send images in case of a reported landslide or an early warning sign to alert one another and cascade the message to the ordinary community members and other concerned authorities to act appropriately and timely. The social media data were mentioned to be crucial in the contemporary world and compliments other communication (Kitazawa & Hale, 2021). Earth observatory techniques, enabled by the Global Navigation Satellite System (GNSS) technology made it possible for the experts to obtain images of areas of concerns at any given time using Google Earth Engine applications on digital gadgets. Handheld GPS and mobile phones with GPS enabled are used to send the absolute coordinates information in forms of longitudes, latitudes, elevation and time of a point where a landslide has occurred. Smart mobile phones and other smart devices were used to capture images and broadcast the same to as many people as possible within the shortest time possible.

Under monitoring and warning, the local community members living in landslide disaster-prone areas are warned to move to safer grounds especially after continued downpour, a well acknowledged precursor to landslide events in the susceptible areas. At such a time also, multi-sectoral players are usually on the ground to monitor the situation during the rainy seasons and once a landslide sign is reported. They advise people on the best option to take such as relocating to safer grounds to minimize or avert the adverse effects in case of a landslides.

Humanitarian organizations and well-wishers, among them, Kenya Red Cross Society, faith-based organizations, politicians and individual community members helps the affected members of the community during the response capacity element of the landslide EWS. They provide both monetary and non-monetary items to enable the affected reconstruct, restructure and restore their livelihood.

4.8.3 EWS by the indigenous people

The indigenous people have their own EWS developed through experiences over the years of living in the landslide-prone areas. Firstly, in order to understand the locals' EWS through IK, the question of whether they were aware of what IK is and how it can be applied in landslide disaster management was posed to the respondents in Murang'a County. Their understanding was sought to have an idea about their 'risk knowledge,' a crucial element of EWS as outlined by the UN (UNEP, 2012). Out of all the respondents, 283 (87.2%) respondents said that they were aware and understood what IK is but had different views on the applicability of the knowledge at different levels of landslide disaster management. Various management aspects and the approval ratings are as shown in Table 4.23. IK was said to be applicable mostly in landslide disasters EWS connected to preparedness by 273 respondents (81.3%) were affirmative. Other landslide management aspects noted and voted for were the application of IK in landslides EWS linked to prevention as mentioned by 267 respondents (79.5%), relief and response by 242 respondents (72%) and reconstruction as observed by 73.5%. In conclusion, it was evident that the indigenous people knew what IK and EWS are and noted that such IK is an important ingredient of EWS as can be applicable in different phases of landslide disaster management.

Table 4.23: ***Application of IK in landslide disaster management***

Landslide management aspect and application of IK	**No (%)**	**Yes (%)**	**Don't know (%)**
IK application in landslide prevention	**2.4**	**79.5**	**18.2**
IK application in landslide preparedness	**3.6**	**81.3**	**15.2**
IK application in landslide relief and response	**10.7**	**72.0**	**17.3**
IK application in landslide reconstruction	**8.3**	**73.5**	**18.2**

4.8.4 Dominant EWS through application of IK

Having noted the appreciation of the importance of EWS and the application of IK by the local people, the next step was to study the specific EWS domiciled in the local community. Different EWS were pointed out as shown in Figure 4.28 and are discussed below.

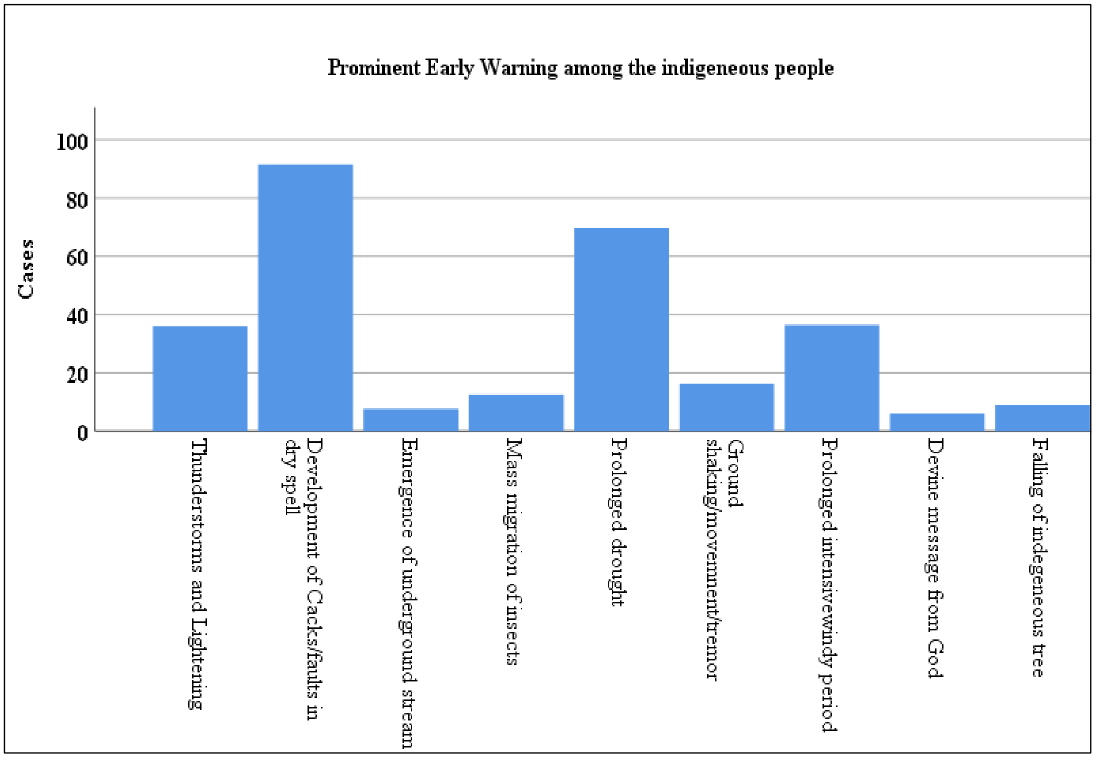


Figure 4.28: ***Dominant Early Warning Systems (EWS) used by the local people through the application of indigenous knowledge (IK)***

Development of huge cracks on land

Development of cracks on land during unusually prolonged dry spell was the most prominent precursor event to a landslide occurrences as mentioned by 67.3 % of the respondents from different study locations. In one of the FGDs held in Rwathia Location, Kangema Sub-county, it was reported that the locals have devised their own ways of analyzing the risk posed by cracks on land over time through ‘measuring’ the crack extent over time using traditional techniques. The locals would continuously monitor if the cracks were extending by assessing how deep and wide the cracks become by fitting an object such as a stick on the crack and monitoring its movement in either direction every day. If the stick had subsided by any chance, that was taken to be a clear indication of escalating crack, which was taken to be a precursor to a landslide occurrence, especially upon being triggered by a trigger factor such as heavy rainfall. The technique falls short of the scientific threshold of having good monitoring system designed on sound scientific and mathematical principles as prescribed by Motsi *et al.*, (2019). Nevertheless, it was vividly explained and demonstrated in a FGD where one of the participant reported in local dialect that:

> *"Niguo tumenye ugwati wa itukika-ri, nituthimaga uriku na warie wa mwatuka na tumiti niguo tutikahobanirio ni ituika tutekumenya. Twona mwatuka waneneha o uria mathaa marathie, tukamenya kwina ugwati" -A male FGD participant in Rwathia Location, Kangema Sub-county*

Translated to:

> "*As an EWS, we normally measure the breadth and depth of cracks on land so that we are not caught off-guard by landslides. If and when we ascertain that the crack is escalating as time progresses, we conclude that an eminent landslide disaster is bound*" -A male FGD participant in Rwathia Location, Kangema Sub-county

Unusually long dry spells

Another EWS tactic by the locals was presence of unusually long dry spell within a year as voted by 51.2% of the respondents. The condition was also linked to the cracking of land due to water shortage in the soils, meaning that the two precursor to landslides were closely connected.

Prolonged periods of strong winds, excessive thunderstorms and lightening

Also mentioned signs of an impending landslide included the weather related precursors such as prolonged periods of strong winds and excessive thunderstorms and lightening during the rains.

Other indigenous EWS

Others were seasons of ground shaking and tremors (11.9%), mass migration of insects (9.2%), unusual falling down of indigenous trees (6.5%) and divine intervention from 'gods' through some spiritual revelations of an impending landslide disaster (4.5%). For instance in the case of migration of insect, the locals mentioned '*thigiriris*', which are tiny insects found in the soil as being a good example of signs of an impending danger. Some said that once such insects were seen migrating en-mass from one place to another, it was a clear indicator of impending disaster. Migration of insects was also cited as an EWS for landslides in a research by Timilsena & Devkota, (2022). For the unusual falling down of indigenous trees Mugumo tree was mentioned by some locals as a perfect example. Mugumo is a tree which is highly regarded by the Agikuyu tribe for a very long time. Under Mugumo tree, the community's fore-fathers would assemble and give their sacrifices, offerings and prayers to their God, *Mwene Nyaga/Ngai,* while facing Mount Kenya (Kirinyaga). Such trees are in existence and still highly regarded and respected. At times, the trees would fall down (due to various reasons) and once such an occurrence happened, it was considered to be a bad omen and some attributed it to be an indication of impending disasters, which included landslides. One of the participants in a FGD who termed himself 'a faithful follower of Christ' said that even the Bible was in support of the movement of birds and insects being precursor to and knew the time to migrate to new location to impeding mitigate danger as he quoted a section of the Holy Bible *Jeremia 8, verse 7* as saying:

> "thũngũrũrũ na cũũcũ wa njoka
> nĩciũĩ rĩrĩa ciagĩrĩirwo nĩgũthaamĩra kũndũ kũngĩ…"

Translated to:

> *"Even the stork in the heavens Knows her appointed times; and the turtledove, the swift, and the swallow Observe the time of their coming…"*-Bible, New King James Version, Jeremiah 8 Verse 7

However, it is worth mentioning that no any single mentioned EWS was devoid of controversy and objection from a section of respondents, which calls for further studies on the subject to ascertain why the controversies and aim at having standardized EWS.

4.8.5 Nexus between scientific and indigenous knowledge (IK) Early Warning Systems (EWS)

The analysis of the link, if any, between the understanding of EWS through scientific and IK was done and results were that the indigenous people have EWS for landslide disaster risk monitoring. Some of the indigenous knowledge on EWS were scientifically proven to point out in a favourable situation or condition for a causal/trigger factors to positively contribute to occurrence of a landslide in an area. For example the indigenous people indicated that unusually prolonged dry seasons lead to the development of cracks on soils, a condition which makes it easy for rain water to infiltrate and percolate into the soils easily. The faults are scientifically known to be the weak point in aggregated soil particles. Such a condition is exacerbated by the fact that the landslide prone areas are sloppy, hence are highly susceptible to sliding under the force of gravity from a higher to a lower point. On rainfall, a factor which is scientifically known to contribute to landslides, the indigenous people have indicators of prospects of unusually high rainfalls which serve as a precursor to the occurrence of landslides. Such indicators include presence of unusually heavy thunderstorms and lightening as well as intensive winds before the onset of rains. These weather conditions have a close connection with rainfall, a landslide causal/trigger factor which is well known to the locals. These examples are clear indications that the indigenous people, despite their levels of education, have well known EWS which can be grounded in science. It implies that the two levels of knowledge can be used to complement one another and can be integrated in understanding the landslide disaster risks in Murang'a County. On the contrary though, other EWS by the locals like migration of insects, divine message from god and falling of indigenous trees may not be justifiable in science. However, there have been cases where the migration of animals prior to the occurrence of a disaster has been proven to be perfect prediction of the disaster. It therefore means that informal EWS cannot be overlooked in policy matters as was recommended by Adams, *et al.*, (2022) in a case of hazards related to climate change.

4.9 Chapter summary

Chapter four has presented the empirical data analysis, result and the study discussions based on the specific objectives of the study. Both qualitative and quantitative data are analyzed and results presented in form of tables, charts, maps and texts. It is an important chapter which positions the current research in the scholarly debate about landslide disasters and shed more light on the topic in the case the study are of Murang'a County. The chapter lays the foundation for chapter five on the research findings, conclusions and recommendations.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents objective-by-objective summary of the research findings on '*Landslide disaster risk management in Murang'a County, Kenya-scientific and indigenous knowledge nexus*.' It draws conclusions and make recommendations based on the research findings.

The five factors which are scientifically-known as landslide causal/trigger factors as explained by the interviewed indigenous people, experts and backed-up by existing scientific literature were: rainfall, elevation, slope, soils and LULC.

The first objective of the study was mapping and delineating landslide risk zones based on scientific knowledge. After evaluating and thresholding each of the factors according to the scientific understanding, the overall mapping of landslide disaster risk zones was achieved. The respective zoned landslide areas were compared with the MAM 2018 landslide cases and key findings were that rainfall was the greatest contributor to landslides and had the greatest conformity with the MAM 2018 cases at 99%. The other factors in conformity were the slope, altitude, soils and LULC at 98%, 94%, 88% and 72% respectively. Findings on mapping and zoning of landslides based on the scientific understanding showed that, rainfall had the greatest influence in causing or triggering rainfall in Murang'a while LULC had the lowest. Another finding was that for each of the five factors in consideration, the mapping through thresholding each of the factors according to scientific understanding, had the northern parts of Murang'a, towards the Aberdares Ranges, being zoned as the 'hotspots' of landslides as opposed to the lower, southern parts of the county.

The second specific objective was mapping and delineating landslide disaster risk zones based on indigenous knowledge. It was established that, the indigenous people, made up of those who were locally born and others who had migrated into Murang'a County, were all aware of what landslides are. An overwhelming majority (97% of the respondents) termed landslides as disasters which are recurrent and to be on the increase as reported by 88.7% of the respondents. In terms of their understanding of the landslide causal/trigger factors, 97.6% of them indicated that they were aware of landslide causal/trigger factors and mentioned the five factors (rainfall intensity, slope, altitude, soil characteristics and LULC) to be the most influential. To map the factors, an assessment of the factors rating was done for each to ascertain the local peoples' view about how much each would contribute to a landslide. Each of the five factors was rated by respondents above 70% in contributing to landslide events. Rainfall was rated the highest (97.9%) and was assigned the highest weight as a landslide causal/trigger factor as opposed to LULC factor which was rated as the least influential. Other than the five factors under consideration for the purpose of this study, there were others mentioned by study participants during the FGDs. Such included: act of God as a punishment for wrong and evil deeds by human beings, fallen heavenly body which was believed to buried underground and diversion of road sides water to the low-lying areas down to the streams. To map and delineate disaster risk zones based on the IK, all the factors were combined in a WLC based on the weighted given to each by the indigenous people. The final results showed that the northern (upper) parts of Murang'a, towards the Aberdares Ranges, were zoned as the being the ‘hotspots’ of landslides while the southern (lower) parts as being regions of low landslide disaster risks.

The third specific objective was finding the nexus between the scientific and indigenous-knowledge-based landslide disasters risks understanding in relation to MAM 2018 documented landslide inventories for Murang’a County. The MAM 2018 landslide inventories for Murang’a County were used as reference base for the study, the reason being that the months of March, April and May (MAM) of the year 2018 had the highest number of ever reported landslide cases within a single rainfall season (Murang’a Meteorological Department, 2021). The result showed that there existed nexus between the scientific and IK delineated landslide disaster risk zones was evident in many ways. Firstly, the mapping and landslide disaster risk zonation for both indigenous and scientific knowledge understandings showed that landslides were concentrated in the northern (upper) parts of the county, towards the Aberdare Ranges, as opposed to the (lower) southern parts. Secondly, the convergence between the understandings of the landslides’ causal/trigger factors. In both the IK and scientific knowledge understanding of the factors, rainfall was the most prominent landslide factor in predicting the MAM 2018 landslide zones of occurrences at a convergence rate of over 98% as opposed to LULC which had the lowest approval. Elevation and slope factors were also rated at above 90%. The rainfall factor was ranked highest by the indigenous people and the choice as also supported by EWS systems, some of which (intensive winds, unusual lightning and thunderstorms) have close connection to intensive rainfall in an area. The final combined maps for the IK-delineated landslide zones showed that 97% of the MAM 2018 landslide events occurred in areas mapped as ‘high landslide risk zones’ while 88% of the cases were in ‘high landslide risk zones' in the case of scientific knowledge delineated of landslide zones. Such results show a high level of convergence between the two zonation. Finally, due to the convergence of the two levels of knowledge, a combined analysis of integrated understanding of the landslide was essential to moderate the MAM 2018 landslide occurrences as would have been predicted bases on IK and scientific knowledge. The integrated landslide disaster risk maps showed that 90% of the cases are in the high risk zones as opposed to only 10% in low risk zones. This as a moderated value for the highs of IK (97%) and lows of the scientific knowledge (88%).

In summary, for the first three objectives, the findings showed the northern parts of Murang'a, towards the Aberdares Ranges, are the 'hotspots' of landslides as opposed to the lower, southern parts of the county. This is agreement with Davies (1996) and Wahlstrand (2015) both who found out that farmers living in Kenyan highlands such as the upper Murang'a are said to be at risk of landslide disasters. Also, the convergence between the two levels of landslide disaster risks understanding and the conformity with the MAM 2018 cases was clear indication that each level of knowledge is critical in understanding the landslide disasters in the case of Murang'a County.

The fourth specific objective was assessing the landslide disasters effects in Murang'a County. The assessment of landslide effects is important in an attempt to understand how the locals are positively or negatively impacted by landslides. The results showed that Murang'a people are directly and indirectly affected by landslides in many ways. Some of the effects are known and well documented while others are privy and not available in literature. The most outstanding negative effects reported was psychological stress. The effect was indirect and could be attributed to other adverse direct effects such as among others loss properties, displacements, loss of life, animals and crops. Other secondary and indirect reported negative effects such boundary disputes, resource conflicts, disruption of services such as water supply. Most landslide reporting is on the negative effects of landslides in an area but this study makes an attempt to report on the positive effects of the said disasters in Murang'a County. The findings established notable positive effects of landslides in Murang'a County. These included reconstruction of better and safe infrastructures such as bridges, roads and buildings after a landslide event and which would withstand subsequent stress from the disasters. Surprisingly, even though such deeds were termed as being positive, in some cases they ended up adding to the negative effects in one way or another. For instance, due to social evils such as favourism, some undeserving locals, some of whom had not been affected by landslides in any way could unfairly be given priorities in receiving support from the well-wishers during the rescue and reconstruction phase of landslide management. To add to the negative effects brought about by positive deeds, in other cases, the misappropriation and misuse of funds and other resources meant for the affected people were reported all which lead to more sufferings and conflicts.

An interesting positive benefit reported as on the local people who have houses but never use them for habitation at all times. Such are called the 'absentee landlords/landladies'. Perfect examples were witnessed in Rwathia Location in Kangema Sub-county where the 'absentee landlords/landladies' benefitted from rental income for leasing of their houses to momentarily resettle people displaced by the landslides. Their houses would otherwise be lying without any occupancy most of the time within a year as they only come to spend in their respective areas on selected occasions within a year.

The fifth and final specific objective was assessing the local peoples' EWS through the use of indigenous knowledge and nexus with scientific EWS. It was established that over eighty seven percent (87.2%) of the respondents understood what IK knowledge entail. A good number of them, 273 (81.3%), were of the opinion that the knowledge can be applied in in various phases of landslide disaster management such as landslide disaster preparedness 267 (79.5%) and prevention 242 (72.9%). The concurrence on the usefulness of IK is in line with findings by Nirwansyah and others (2022) who established that the knowledge not only existed within the Banyumas People in Gununglurah Village, Central Java, Indonesia, but was also applicable in landslide mitigations. Different EWS used in landslide disaster management by the indigenous people were identified, the dominant ones being development of cracks during unusually long dry spells as well as abnormally long drought seasons. Of importance to note was that some of the mentioned EWS had links with the scientifically known climatic and weather events. For instance winds, thunderstorms and lightening can be connected to rainfalls instances, hence an indication of nexus and convergence between scientific and IK in managing landslides through EWS exists. The findings were in line with those of Adams and others (2022) that informal EWS cannot be overlooked in policy matters.

The study however found some out that there were some others unique EWS known and used by the indigenous people but which are not scientifically proven but based on traditional myths which are highly regarded by the community. These included EWS such as ‘god’ spiritual revelation for a punishment to his people for evil deeds over a period of time, mass migration of insects (*thigiriris*) and unusual falling off of indigenous trees (Mugumo trees). The greatest handle with the EWS by the indigenous people which comes to anyone’s mind is to do with the standardization of the EWS in such a way that they can be applied across the board in landslide disaster management not only in the study area but also elsewhere.

5.2 The study conclusions

The study is considered to be timely and important based on the fact that landslides in Murang’a County are recurrent and with numerous effects on the local people. Such people are mostly affected by the disasters in one way or another yet evidently not voiced in the disaster management continuum in the county.

The specific conclusions which are drawn from the study are that:

1 The following are the causal/trigger factors for landslide disasters in Murang’a County as identified by the indigenous people and backed-up in scientific understanding: rainfall, elevation, slope, soils and LULC. Each of the factors delineates and maps the northern (upper) parts of Murang’a County as being ‘high’ landslide disaster risk zones as opposed to the southern (lower) parts which are mapped as ‘low’ disaster risk zones.

2 A nexus between the indigenous knowledge and scientific understanding of landslide disaster risk zones exists in the following ways:

   i) Firstly, the nexus and concurrence on landslide disaster causal/trigger factors which are: rainfall, elevation, slope, soils and LULC.

ii) Secondly, nexus and concurrence in delineating and mapping of landslide zones in which both cases showed commonality in that the upper parts were zoned as of ‘high’ risks and the lower sides as of ‘low; risks.

iii) Thirdly, the conformity between the mapped landslide disaster risk zones for both levels of knowledge with the MAM 2018 reported landslide cases. An interesting finding was that the zones delineated using indigenous knowledge weights on the factors gave a better approximation of the areas that were in conformity with the reported landslide cases of the year 2018. For the indigenous knowledge, 97% of the MAM 2018 reported cases fell in ‘high’ risk zones as opposed to 88% for the scientific knowledge.

iv) Finally, a convergence in knowledge about the EWS, in which some practices and beliefs by the local people could be explained in science as precursors to favourable conditions for occurrence of landslides such as prospects of abnormally high rainfall in a season.

3 The local people are positively or negatively affected by landslides either directly or indirectly. However, the adverse effects outweigh the positive effects. In either case, it calls for the inclusion of their views in the disaster management continuum to minimize the adverse effects.

4 EWS are gaining traction among the different stakeholders in the disaster management (Guzzetti, *et al.*, 2020 and in the case of Murang’a County, indigenous people have devised their own coping mechanisms in form of EWS, some of which have basis in science. However, divergent and scientifically contentious findings on the same were cited for instance EWS such as falling down of indigenous trees and migration of insects. The big questions which beg answers are whether the EWS by

the local people can be said to be standard and whether there is a good consistence monitoring system. Also, whether the EWS could be applied across the board in landslide disaster management not only in the study area but also anywhere else.

In conclusion therefore, the study presents important research findings some of which are un-documented but found to resonate and are in conformity with the scientific studies while others are contrary or uncertain but valid for the research in filling the research gaps in the research problems in the '*Landslide disaster risk management in Murang'a County, Kenya-scientific and indigenous knowledge nexus*. Based on the findings, the study makes the theoretical conclusion that landslides being a system, an integration approach to landslide disasters management should be considered for adoption in landslide understanding and studies. The author is of the opinion that landslide being a 'system' which is usually 'localized', it is important to bring on board different players and actors from diverse backgrounds in an attempt to understand landslide disasters hence manage it better not only in Murang'a but also in other places.

5.3 Recommendations

The study makes both policy and further research recommendations as explained below:

4.9.1 Policy and strategies recommendations

The indigenous people are among the main players in disaster risk management and are affected in one way or another through displacements, destruction of properties, death, psychological stress and other effects. In the case of landslide disasters in Murang'a, there is no clear framework on the management of such disasters as it is a shared responsibility by both the national and county government. The local peoples' involvement at the grassroots have not been entrenched in any statute.

This research therefore makes the recommendation that the local people, who have years of experience with the landslides and accumulated knowledge, should be accorded a chance to have their voices in landslide disaster management in Murang'a County. Such a recommendation is in line with Sendai Disaster Risk Reduction 2015-2030 (Reduction, 2020), which was adopted at the third United Nations World Conference on disasters held in Sendai, Japan, countries of the world and which among other recommendations call on the global community to seize the unique opportunities of having a robust and more people-oriented approaches to reduce the effects of disasters through multi-sectoral and all-inclusive engagement. It is also aligned to the Kenya's disaster management policy which stipulates that the local community to be viewed as not only vulnerable but as having potential and strength in disaster management. In research world, the inclusivity is also in conformity with the current approach in disasters risks management approaches in the world which advocates for local participation and a people-centered approach (Scolobig *et al*., 2015).

Finally, the research recommends, public participation meetings should be organized to collect their views, the outcome of which should be officially entrenched in policies and other strategic documents.

5.3.1 Recommendations for further research

The researcher recommends makes the following recommendations:

i) Research about the asserted causal/trigger factors and EWS mentioned by the indigenous people should be considered and investigated further in science for a better understanding and possible integrating the IK with science where applicable.

ii) Since landslides are highly localized, an in-depth research targeting HHs which have previously been affected by landslides should be carried out to for an in-depth insight on their experience and knowledge on landslide disasters and how well the disasters can be managed, by among other stakeholders, the indigenous people.

5.4 Chapter summary

The final chapter of the study has outlined a summary of the main research findings, conclusions and recommendations drawn from empirical data analyses and result presentation. It places the current study within the scholarly debate as far as landslide study are concerned and specifically in Murang'a County and the integration of scientific and IK in landslide disaster management.

REFERENCES

ACKOFF, R. L. (2000). Creating the corporate future. *M. Lucas, Understanding Business*.

ADAMS, I., GHOSH, S., & RUNESON, G. (2022). Access to Early Warning for Climate Change-Related Hazards in Informal Settlements of Accra, Ghana. *Climate*, *10*(5), 62. [Google Scholar] Accessed on 17th June, 2022.

AGRAWAL, A. (1995). Dismantling the Divide Between Indigenous and Scientific Knowledge. Development and Change 26 (3): 413–39.

ANDERSON, MALCOLM G.; HOLCOMBE, ELIZABETH. *(2013).* Community-Based Landslide Risk Reduction: Managing Disasters in Small Steps. *Washington, DC: World Bank: https://openknowledge.worldbank.org/handle/10986/12239 License: CC BY 3.0 IGO.*

ANTWEILER, C. (1998). Local knowledge and local knowing. An anthropological analysis of contested" cultural products' in the context of development. *Anthropos*, 469-494.

ARTICTE, P. N. (1995). Raster Procedures for Multi-Criteria/Multi-0biective Decisions. *Photogrammetric Engineering & Remote Sensing*, *61*(5), 539-547

ASETA, J. A. (2018). Landslide occurrences and their effects on land use activities in Kittony area of Elgeyo-Marakwet County, Kenya. *European Journal of Social Sciences Studies*.

BARKER, D. (2017). Indigenous Knowledge. In International Encyclopedia of Geography: People, the Earth, Environment and Technology (eds D. Richardson, N. Castree, M. F. Goodchild, A. Kobayashi, W. Liu and R. A. Marston). DOI:10.1002/9781118786352.wbieg0119

BARREDO, J., BENAVIDES, A., HERVÁS, J., & VAN WESTEN, C. J. (2000). Comparing heuristic landslide hazard assessment techniques using GIS in the Tirajana basin, Gran Canaria Island, Spain. *International journal of applied earth observation and geoinformation*, *2*(1), 9-23.

BATJES, N. H. (2010). Soil property estimates for the Upper Tana, Kenya, derived from SOTER and WISE (Ver. 1.0). Report 2010/07, ISRIC-World Soil Information, Wageningen (41p. with data set).

BERGER, R. M., & PATCHNER, M. A. (1988). *Implementing the research plan: A guide for the helping professions*. Sage Publications, Inc. [Google Scholar]. Accessed online. Accessed on 9th April, 2021

BERKES, F. (2010). Indigenous ways of knowing and the study of environmental change. *Journal of the Royal Society of New Zealand:* Volume 39, Number 4, December, 2009 151–156 1175-8899 (Online). Accessed on 13th October 2018. Accessed via: https://doi.org/10.1080/03014220909510568.

BERKES, F., COLDING, J., & FOLKE, C. (2000). Rediscovery of traditional ecological knowledge as adaptive management. *Ecological applications*, *10*(5), 1251-1262.

BERNARD, H.R. 2002. Research Methods in Anthropology: Qualitative and quantitative methods. 3rd edition. AltaMira Press, Walnut Creek, California. Cited in Tongco, Ma Dolores C, 2007.

BOMMER, J. J., & RODRÍGUEZ, C. E. (2002). Earthquake-induced landslides in Central America. *Engineering Geology*, *63*(3-4), 189-220.

BOULDING, K. E. (1956). General systems theory—the skeleton of science. *Management science*, *2*(3), 197-208.

BROECKX, J., VANMAERCKE, M., DUCHATEAU, R., & POESEN, J. (2018). A data-based landslide susceptibility map of Africa. *Earth-Science Reviews*, *185*, 102-121. [Google Scholar] Accessed on 1st June, 2022.

BRYMAN, A. (2016). *Social research methods*. 4th Edition. Oxford university press. Online Resource Centre. Assed from [Google Scholar]. Accessed on 11-May-2021.

CARDINALI, M., GALLI, M., GUZZETTI, F., ARDIZZONE, F., REICHENBACH, P., & BARTOCCINI, P. (2006). Rainfall induced landslides in December 2004 in south-western Umbria, central Italy: types, extent, damage and risk assessment. *Natural Hazards and Earth System Sciences*, *6*(2), 237-260

CALVELLO, M. (2017). Early warning strategies to cope with landslide risk. Riv It Geotecnica 2: 63–91.

CASTREE, N., GOODCHILD, M. F., KOBAYASHI, A., LIU, W., & MARSTON, R. A. (2017). The International Encyclopedia of Geography: People, the Earth, Environment, and Technology.

CHECKLAND, P. (1981). Systems thinking, systems practice. New York. Wiley.

CHEPKOSGEI, E., UCAKUWUN, E. K., & NDURU, G. M. (2022). Mapping Landslide Susceptibility along the Nandi Escarpment in Malava Sub-County Kakamega County, Kenya. *Africa Environmental Review Journal*, *5*(2).

CIESLIK, K., SHAKYA, P., UPRETY, M., DEWULF, A., RUSSELL, C., CLARK, J. & DHAKAL, A. (2019). Building resilience to chronic landslide hazard through citizen science. *Frontiers in Earth Science*, *7*, 278.

CIUREAN, R. L., SCHRÖTER, D., & GLADE, T. (2013). Conceptual frameworks of vulnerability assessments for natural disasters reduction. In *Approaches to disaster management-Examining the implications of hazards, emergencies and disasters*. Cieslik

COBBINAH, P. B., & ANANE, G. K. (2016). Climate change adaptation in rural Ghana: indigenous perceptions and strategies. *Climate and Development*, *8*(2), 169-178. [Google Scholar]. Accessed on 13-April-2021

CONSTITUTION 2010. Kenya: The Constitution of Kenya [Kenya], 27 August 2010. *Government Printer. Kenya*: Nairobi, Kenya. Online. Available at https://www.refworld.org/docid/4c8508822.html. Accessed on 15 January, 2021

CORTINA, J. M. (1993). What is coefficient alpha? An examination of theory and applications. *Journal of applied psychology*, *78*(1), 98.

CRESWELL, J. W., & CLARK, V. L. P. (2017). *Designing and conducting mixed methods research*. Sage publications.

CRONBACH, L. J. (1943). On estimates of test reliability. *Journal of Educational Psychology*, *34*(8), 485.

CROZIER, M. J., & GLADE, T. (2005). Landslide hazard and risk: issues, concepts and approach. *Landslide hazard and risk*, 1-40.

DAVIES, T. C. (1996). Landslide research in Kenya. *Journal of African Earth Sciences*, *23*(4), 541-545.

DAVIES, T. C., & NYAMBOK, I. O. (1993). The Murang'a landslide, Kenya. *Environmental Geology*, *21*(1-2), 19-21. DOS https://doi.org/10.1007/BF00775046

DAVIES, T.C. AND NYAMBOK, I.O. (1992). The Murang'a Landslide, Kenya. Manuscript presented at the International Workshop in Capacity Building in Forestry Research and Soil and Water Management in Africa. Kampala, Uganda, 9-11 Nov 1992.

DEPICKER, A., GOVERS, G., JACOBS, L., CAMPFORTS, B., UWIHIRWE, J., & DEWITTE, O. (2021). Interactions between deforestation, landscape rejuvenation, and shallow landslides in the North Tanganyika–Kivu rift region, Africa. *Earth Surface Dynamics*, *9*(3), 445-462.

DEWITTE, O., DILLE, A., DEPICKER, A., KUBWIMANA, D., MAKI MATESO, J. C., MUGARUKA BIBENTYO, T., & MONSIEURS, E. (2021). Constraining landslide timing in a data-scarce context: From recent to very old processes in the tropical environment of the North Tanganyika-Kivu Rift region. *Landslides*, *18*(1), 161-177.

DHAKAL, A. S., AMADA, T., & ANIYA, M. (2000). Landslide hazard mapping and its evaluation using GIS: an investigation of sampling schemes for a grid-cell based quantitative method. *Photogrammetric Engineering and Remote Sensing*, *66*(8), 981-989.

DÍAZ, S. R., CADENA, E., ADAME, S., & DÁVILA, N. (2020). Landslides in Mexico: their occurrence and social impact since 1935. *Landslides*, *17*(2), 379-394.

DICTIONARY, C. (2008). Cambridge advanced learner's dictionary. Online. Accessed on 18th December, 2022. Accessed via website https://dictionary.cambridge.org/dictionary/english/reference

DIJKSHOORN JA, MACHARIA PN, HUTING JRM, MAINGI PM and NJOROGE CRK, 2011. Soil and terrain conditions for the Upper Tana River catchment, Kenya. (ver1.1). Green Water Credits Report 11 / ISRIC Report 2010/09b, ISRIC – World Soil Information, Wageningen. Online. Accessed from on 17-April-2021 from: https://data.isric.org/geonetwork/srv/eng/catalog.search#/metadata/ce32091e-006d-4438-8e03-cf7b4c500df7

DILLMAN, D. A. (2011). *Mail and Internet surveys: The tailored design method--2007 Update with new Internet, visual, and mixed-mode guide*. John Wiley & Sons.

EASTMAN, J. R. (2012). IDRISI selva manual and tutorial manual version 17. *Worcester (USA): Clark University*.

EISER, J. R., BOSTROM, A., BURTON, I., JOHNSTON, D. M., MCCLURE, J., PATON, D., & WHITE, M. P. (2012). Risk interpretation and action: A conceptual framework for responses to natural hazards. *International Journal of Disaster Risk Reduction*, *1*, 5-16.

ESPOSITO, G., CARABELLA, C., PAGLIA, G., & MICCADEI, E. (2021). Relationships between morphostructural/geological framework and landslide types: Historical landslides in the hilly piedmont area of Abruzzo Region (Central Italy). *Land*, *10*(3), 287.

EVANS, S. G. (2018). Fatal landslides and landslide risk in Canada 1. In *Landslide risk assessment* (pp. 185-196). Routledge

FAIA, M. A. (1986). The strategy and tactics of dynamic functionalism. Department of Sociology College of William & Mary Williamsburg, VA 23185.

FAYAZ, M., KHADER, S. A., & RAFIQ, M. (2022). Landslides in the Himalayas: Causes, Evolution, and Mitigation—A Case Study of National Highway 44, India. *Disaster Management in the Complex Himalayan Terrains* (pp. 43-58). Springer, Cham.

FELL, R. (1994). Landslide risk assessment and acceptable risk. *Canadian Geotechnical Journal*, *31*(2), 261-272.

FINLAY, P. J., & FELL, R. (1997). Landslides: risk perception and acceptance. *Canadian Geotechnical Journal*, *34*(2), 169-188.

FIORUCCI, M., MARTINO, S., DELLA SETA, M., LENTI, L., & MANCINI, A. (2022). Seismic response of landslides to natural and man-induced ground vibrations: Evidence from the Petacciato Coastal slope (central Italy). *Engineering Geology*, *309*, 106826.

FROUDE, M. J., & PETLEY, D. N. (2018). Global fatal landslide occurrence from 2004 to 2016. *Natural Hazards and Earth System Sciences*, *18*(8), 2161-2181.

FUCHS, S., HEISS, K., & HÜBL, J. (2007). Towards an empirical vulnerability function for use in debris flow risk assessment. *Natural Hazards and Earth System Science*, *7*(5), 495-506.

FUSCH, P. I., & NESS, L. R. (2015). Are we there yet? Data saturation in qualitative research. *The qualitative report*, *20*(9), 1408.

GARCIA-DELGADO, H., PETLEY, D. N., BERMÚDEZ, M. A., & SEPÚLVEDA, S. A. (2022). Fatal landslides in Colombia (from historical times to 2020) and their socio-economic impacts. *Landslides*, 1-28.

GLADE, T. (2003). Vulnerability assessment in landslide risk analysis. *Erde*, *134*(2), 123-146.

GLADE, T., ANDERSON, M. G., & CROZIER, M. J. (Eds.). (2006). *Landslide hazard and risk*. John Wiley & Sons.

GOOGLE EARTH Pro 7.3.3.7786. (April, 02, 2021). Kenya, lat 37.020436^0, long -0.937603^0, Eye alt 20.75 km, elev. 1577 m. image at Maxar Technologies. CNES/Airbus 2013. (Accessed on May 10, 2021)

GORSEVSKI, P. V., JANKOWSKI, P., & GESSLER, P. E. (2005). Spatial Prediction of Landslide Hazard Using Fuzzy k-means and Dempster-Shafer Theory. *Transactions in GIS*, *9*(4), 455-474.

GORSEVSKI, P. V., JANKOWSKI, P., & GESSLER, P. E. (2006). An heuristic approach for mapping landslide hazard by integrating fuzzy logic with analytic hierarchy process. *Control and Cybernetics*, *35*, 121-146.

GOVERNMENT OF KENYA (GoK), 2007. Kenya Vision 2030. The Popular Version. Online. Accessed on 10th April, 2020. Accessed from www.planning.go.ke.

GOVERNMENT of KENYA (GoK), 2009. National Policy for Disaster Management in Kenya. Ministry of State for Special Programmes, Office of the President

GUPTA, V., CHAUHAN, N., PENNA, I., HERMANNS, R., DEHLS, J., SENGUPTA, A., & BHASIN, R. K. (2022). Geomorphic evaluation of landslides along the Teesta river valley, Sikkim Himalaya, India. *Geological Journal*, *57*(2), 611-621.

GUZZETTI, F., GARIANO, S. L., PERUCCACCI, S., BRUNETTI, M. T., MARCHESINI, I., ROSSI, M., & MELILLO, M. (2020). Geographical landslide early warning systems. *Earth-Science Reviews*, *200*, 102973.

GYAMPOH, B. A., AMISAH, S., IDINOBA, M., & NKEM, J. (2009). Using traditional knowledge to cope with climate change in rural Ghana. *Unasylva*, *60* (281/232), 70-74.

HAIGH, M. J. (1985). Geography and general system theory, philosophical homologies and current practice. *Geoforum*, *16*(2), 191-203.

HAQUE, U., BLUM, P., DA SILVA, P. F., ANDERSEN, P., PILZ, J., CHALOV, S. R., & KEELLINGS, D. (2016). Fatal landslides in Europe. *Landslides*, *13*(6), 1545-1554.

HIGHLAND, L. (2006). Landslide types and processes. Fact Sheet 2004-3072, July 2004.

HETHERINGTON, S. (2012). Knowledge, Internet Encyclopedia of Philosophy. US Department of Interior. US Geological Survey Online. Accessed on 29-December, 2022. Accessed from: http://www.iep.utm.edu/knowledge/.

HIGHLAND, L.M., AND BOBROWSKY, PETER, (2008). The landslide handbook- A guide to understanding landslides: Reston, Virginia, U.S. Geological Survey Circular 1325, 129 p.

HIJMANS, R. J., CAMERON, S., PARRA, J., JONES, P., JARVIS, A., & RICHARDSON, K. (2005). WorldClim-global climate data. *Very High Resolution Interpolated Climate Surfaces for Global Land Areas*.

HILL, R., ADEM, Ç. ALANGUI, W. V., MOLNÁR, Z., AUMEERUDDY-THOMAS, Y., BRIDGEWATER, P. & XUE, D. (2020). Working with indigenous, local and scientific knowledge in assessments of nature and nature's linkages with people. *Current Opinion in Environmental Sustainability*, *43*, 8-20.

HO, K., LEROI, E., & ROBERDS, B. (2000). Quantitative risk assessment: application, myths and future direction. In *ISRM International Symposium*. International Society for Rock Mechanics.

HONEA, R. B., HAKE, K. A., & DURFEE, R. C. (1990, March). Incorporating GISs into decision support systems: where have we come from and where do we need to go. In *GIS'90 conference (Geographic Information Systems), Vancouver, British Columbia, Canada*.

HUHO, J. M., MASHARA, J. N., & MUSYIMI, P. K. (2016). Profiling disasters in Kenya and their causes. *Academic Research International. Volume 7(1*).

HOWELL, P. (2003). Indigenous early warning indicators of cyclones: potential application in coastal Bangladesh. London: Benfield Greig Hazard Research Centre.

ILOKA, N. G. (2016). Indigenous knowledge for disaster risk reduction: An African perspective. *Jàmbá: Journal of Disaster Risk Studies*, *8*(1), 1-7.

IVANKOVA, N. V., CRESWELL, J. W., & STICK, S. L. (2006). Using mixed-methods sequential explanatory design: From theory to practice. *Field methods*, *18*(1), 3-20

JACOBS, L., DEWITTE, O., POESEN, J., DELVAUX, D., THIERY, W., & KERVYN, M. (2016). The Rwenzori Mountains, a landslide-prone region? *Landslides*, *13*(3), 519-536

JOHNSON, E. J., & TVERSKY, A. (1984). Representations of perceptions of risks. *Journal of experimental psychology: General*, *113*(1), 55.

KAMAU, N. R. (1981). A study of mass movements in Kangema area, Murang'a District, Kenya. *Project report for postgraduate diploma in soil conservation, University of Nairobi, Kenya*.

KAST, F. E., & ROSENZWEIG, J. E. (1972). General systems theory: Applications for organization and management. *Academy of management journal*, *15*(4), 447-465.

KENYA METEOROLOGICAL DEPARTMENT (KMD), 2021. Murang'a Meteorological Services. Ministry of Environment and Forestry. Website: https://meteo.go.ke/

KENYA NATIONAL BUREAU OF STATISTICS VOLUME II (KNBS, VOLUME II), 2019. 2019. Distribution of Population by Administrative Units. November 2019. Online. Accessed from Website: http://www.knbs.or.ke. ISBN: 978-9966-102-11-9.

KENYA NATIONAL BUREAU OF STATISTICS VOLUME IV (KNBS, VOLUME IV, 2019. Distribution of Population by Socio-Economic Characteristics. November 2019. Online. Accessed from Website: http://www.knbs.or.ke. ISBN: 978-9966-102-11-9.

KENYA NATIONAL BUREAU OF STATISTICS, VOLUME I (KNBS, VOLUME I), 2019. Population by County and Sub-County. November 2019. . Online. Accessed from Website: http://www.knbs.or.ke. ISBN: 978-9966-102-09-6.

KETER, J. K. A., & AHN, P. M. (1986). Profile characteristics, and form and surface activity of inorganic phosphorus in a deep red Kenya coffee soil (Nitosol). *Journal of Soil Science*, *37*(1), 89-91.

KHASANOV, S., JULIEV, M., UZBEKOV, U., ASLANOV, I., AGZAMOVA, I., NORMATOVA, N., & HOLOV, N. (2021). Landslides in Central Asia: a review of papers published in 2000–2020 with a particular focus on the importance of GIS and remote sensing techniques. *GeoScape*, *15*(2).

KHYRINA, A. F. A. S., BURAIRAH, H., & ABD, S. (2012). A Systems Thinking in Natural Disaster Management: Evacuation Preparedness. *Advances in Economics, Risk Management, Political and Law Science*.

KIBET, S. (2021). *The Role of Forest Cover in Landslide Risk Reduction in Marakwet East Escarpment, Elgeyo-Marakwet County, Kenya* (Doctoral dissertation, University of Nairobi).

KIMANI, M. N. (2020). *A tool for mapping and monitoring landslides emergency management and disaster response: case study Murang'a County* (Doctoral dissertation, Strathmore University). Online. Accessed on 5th September, 2021.

KITAZAWA, K., & HALE, S. A. (2021). Social media and early warning systems for natural disasters: A case study of Typhoon Etau in Japan. *International Journal of Disaster Risk Reduction*, *52*, 101926.

KIPSEBA, E. K., OGORA, M., MAINA, G., & KOTUT, J. (2013). Preliminary reports on Kijabe landslides, Lari district, Kiambu County. *Mines and Geology Department, Ministry of Environment and Mineral Resources (Unpublished)*.

KIRSCHBAUM, D. B., ADLER, R., HONG, Y., HILL, S., & LERNER-LAM, A. (2010). A global landslide catalog for hazard applications: method, results, and limitations. *Natural Hazards*, *52*(3), 561-575.

KITUTU, M. G., MUWANGA, A., POESEN, J., & DECKERS, J. A. (2009). Influence of soil properties on landslide occurrences in Bududa district, Eastern Uganda. *African journal of agricultural research*, *4*(7), 611-620.

KNAPEN, A., KITUTU, M. G., POESEN, J., BREUGELMANS, W., DECKERS, J., & MUWANGA, A. (2006). Landslides in a densely populated county at the footslopes of Mount Elgon (Uganda): characteristics and causal factors. *Geomorphology*, *73*(1-2), 149-165.

KORIR, J. C. (2019). Level of Awareness about Climate Change among the Pastoral Community. Environment and Ecology Research 7(4): 197-207, 2019. DOI: 10.13189/eer.2019.070401

KUBWIMANA, D., BRAHIM, L. A., NKURUNZIZA, P., DILLE, A., DEPICKER, A., NAHIMANA, L., & DEWITTE, O. (2021). Characteristics and distribution of landslides in the populated hillslopes of Bujumbura, Burundi. *Geosciences*, *11*(6), 259

KUHN, T. S. (1962). The Structure of Scientific Revolutions. Chicago (University of Chicago Press) 1962.

KURADUSENGE, M., KUMARAN, S., & ZENNARO, M. (2020). Rainfall-induced landslide prediction using machine learning models: The case of Ngororero District, Rwanda. *International journal of environmental research and public health*, *17*(11), 4147

LALANDE, D., & BAUMEISTER, R. F. (2014). Systems theories. Salem Press Encyclopedia of Health, January, 2014. Access number 93872299

LASCH, K. E., MARQUIS, P., VIGNEUX, M., ABETZ, L., ARNOULD, B., BAYLISS, M. & ROSA, K. (2010). PRO development: rigorous qualitative research as the crucial foundation. *Quality of Life Research*, *19*(8), 1087-1096. . [Googe Scholar]. Accessed on 13-April-2021.

LASZLO, A., & KRIPPNER, S. (1998). Systems theories: Their origins, foundations, and development. *ADVANCES IN PSYCHOLOGY-AMSTERDAM-*, *126*, 47-76.

LAVRAKAS, P. J. (2008). *Encyclopedia of survey research methods*. Sage Publications.

LEAHY, B. D. (2011). SERVIR: changing responses to a changing climate. *SERVIR: changing responses to a changing climate*, (60), 10-12. . [Google Scholar]. Accessed on 19-April-2021.

LEE, K. A., LEE, J. R., & BELL, P. (2020). A review of Citizen Science within the Earth Sciences: potential benefits and obstacles. *Proceedings of the Geologists' Association*

LESHEM, S., & TRAFFORD, V. (2007). Overlooking the conceptual framework. *Innovations in education and Teaching International*, *44*(1), 93-105.

LI, Z., NADIM, F., HUANG, H., UZIELLI, M., & LACASSE, S. (2010). Quantitative vulnerability estimation for scenario-based landslide hazards. *Landslides*, *7*(2), 125-134.

LIU, Y., QIN, Z., HU, B., & FENG, S. (2018). State fusion entropy for continuous and site-specific analysis of landslide stability changing regularities. *Natural Hazards and Earth System Sciences*, *18* (4), 1187-1199.

LOICE, K. J., ROP, K. B., & NAMWIBA, W. H. (2021). Recurrent landslides of Lagam escarpment, Kaben Location, Marakwet East, Kenya. *Global Journal of Geological Sciences*, *19* (1), 15-28.

LUHMANN, N. (1995). *Social systems*. Stanford University Press.

LUNDGREN, L. (1978). Studies of soil and vegetation development on fresh landslide scars in the Mgeta Valley, Western Uluguru Mountains, Tanzania. *Geografiska Annaler: Series A, Physical Geography*, *60* (3-4), 91-127. [Google Scholar]

LUNGA, W., & MUSARURWA, C. (2016). Exploiting indigenous knowledge commonwealth to mitigate disasters: from the archives of vulnerable communities in Zimbabwe. Indian Journal of Traditional Knowledge. Vol. 15 (1), pp.22-29.

LUNYOLO, J., NSEKA, D., MUGUME, I., & OPEDES, H. (2021). Community interventions in landslide scar use in the upper Manafwa catchment, Eastern Uganda. *International Journal of Environmental Studies*, pp. 1-14.

MAINA-GICHABA, C., KIPSEBA, E. K., & MASIBO, M. (2013). Overview of landslide occurrences in Kenya: causes, mitigation, and challenges. In *Developments in earth surface processes* (Vol. 16, pp. 293-314). Elsevier.

MAKI MATESO, J. C., BIELDERS, C., MONSIEURS, E., DEPICKER, A., SMETS, B., TAMBALA, T. & DEWITTE, O. (2021). Natural and human-induced landslides in a tropical mountainous region: the Rift flank west of Lake Kivu (DR Congo). *Natural Hazards and Earth System Sciences Discussions*, pp. 1-26.

MACHERERA, M., & CHIMBARI, M. J. (2016). A review of studies on community based early warning systems. *Jamba (Potchefstroom, South Africa)*, *8*(1), 206. https://doi.org/10.4102/jamba.v8i1.206

MALCZEWSKI, J. (1999). *GIS and multicriteria decision analysis*. John Wiley & Sons.

MALCZEWSKI, J. (2004). GIS-based land-use suitability analysis: a critical overview. *Progress in planning*, Volume 62, Issue 1, Pages 3-65. https://doi.org/10.1016/j.progress.2003.09.002

MANCINI, F., CEPPI, C., & RITROVATO, G. (2010). GIS and statistical analysis for landslide susceptibility mapping in the Daunia area, Italy. *Natural Hazards and Earth System Sciences*, *10*(9), 1851-1864.

MAXWELL, J. A. (2012). *Qualitative research design: An interactive approach* (Vol. 41). Sage publications.

McWILLIAM, A., WASSON, R. J., ROUWENHORST, J., & AMARAL, A. L. (2020). Disaster Risk Reduction, modern science and local knowledge: Perspectives from Timor-Leste. *International Journal of Disaster Risk Reduction*, 101641.

MEBRAHTU, T. K., HUSSIEN, B., BANNING, A., & WOHNLICH, S. (2021). Predisposing and triggering factors of large-scale landslides in Debre Sina area, central Ethiopian highlands. *Bulletin of Engineering Geology and the Environment*, *80*(1), 365-383.

MERCER, J. (2010). Disaster Risk Reduction or Climate Change Adaptation: Are We Reinventing the Wheel? *Journal of International Development* 22 (2): 247–64

MILAGHARDAN, A. H., DELAVAR, M., & CHEHREGHAN, A. (2016). Uncertainty in landslide occurrence prediction using Dempster–Shafer theory. *Modeling Earth Systems and Environment*, *2*(4), 188.

MILETI, D. (1999). *Disasters by design: A reassessment of natural hazards in the United States*. Joseph Henry Press.

MINES AND GEOLOGY DEPARTMENT, (2012). Map of landside prone areas in Kenya (Unpublished), Nairobi, Kenya.

MONSIEURS, E., JACOBS, L., MICHELLIER, C., TCHANGABOBA, J. B., GANZA, G. B., KERVYN, F., & NDAYISENGA, A. (2018). Landslide inventory for hazard assessment in a data-poor context: a regional-scale approach in a tropical African environment. Landslides, 1-15. *Springer Berlin Heidelberg*. Online ISSN 1612-5118. Accessed via https://doi.org/10.1007/s10346-018-1008-y. Accessed on 12/07/2018

MOTSI, P. K., MAPEKULA, L., KALUMBA, D., & CHIBVURA, C. (2019, March). Slope Stability Monitoring and Early-Warning System for Kariba Dam South Bank Slope. In *Geo-Congress 2019: Embankments, Dams, and Slopes* (pp. 86-95). Reston, VA: American Society of Civil Engineers.

MUGUME, I., SEMYALO, R., WASSWA, P., NGAILO, T., ODONGO, R. I., LUNYOLO, J., & TAO, S. (2021). Community views on water demands under a changing climate: The case of River Mpanga Water Catchment, Western Uganda. *African Journal of Environmental Science and Technology*, *15*(9), 371-378.

MURANG'A COUNTY INTEGRATED DEVELOPMENT PLAN (CIDP), 2018. *Murang'a County Integrated Development Plan (2018-2022)*. Unpublished.

MWANIKI, M. W., KURIA, D. N., BOITT, M. K., & NGIGI, T. G. (2017). Image enhancements of Landsat 8 (OLI) and SAR data for preliminary landslide identification and mapping applied to the central region of Kenya. *Geomorphology*, *282*, 162-175.

MWANIKI, M. W., NGIGI, T. G., & WAITHAKA, E. H. (2011). Rainfall induced landslide probability mapping for central province. *AGSE 2011*, 203.

MWANIKI, M., MÖLLER, M., & SCHELLMANN, G. (2015). Landslide Inventory Using Knowledge Based Multi-sources Classification Time Series Mapping: A Case Study of Central Region of Kenya. In *GI Forum-Journal of Geographic Information Science* (Vol. 1, pp. 209-219).

NAKILEZA, B. R., & NEDALA, S. (2020). Topographic influence on landslides characteristics and implication for risk management in upper Manafwa catchment, Mt Elgon Uganda. *Geoenvironmental Disasters*, *7*(1), 1-13.

NAMONO, M., MUGUME, I., NEGRU, R., MUJUNI, G., SULIN, T., NAKILEZA, B., & OYAMA, S. (2019). The Barriers to Landslide Responses over the Mt. Elgon in Bududa District, Uganda.

NGECU, W. M., & ICHANG'I, D. W. (1999). The environmental impact of landslides on the population living on the eastern footslopes of the Aberdare ranges in Kenya: a case study of Maringa Village landslide. *Environmental Geology, 38*(3), 259-264.

NGECU, W. M., & MATHU, E. M. (1999). The El-Nino-triggered landslides and their socioeconomic impact on Kenya. *Environmental Geology*, *38*(4), 277-284.

NGECU, W. M., NYAMAI, C. M., & ERIMA, G. (2004). The extent and significance of mass-movements in Eastern Africa: case studies of some major landslides in Uganda and Kenya. *Environmental Geology*, *46*(8), 1123-1133.

NICHOLAS, K., & JOHN, O. (2022). The Nexus between Land Use Changes and Landslides Occurrences on the Slopes of Mt. Elgon, Bungoma County in Kenya. *International Journal of Social Sciences and Humanities Invention*, *9*(11), 7495-7413.

NIRWANSYAH, A. W., DEMIRDAG, I., SARJANTI, E., & BRAMASTA, D. (2022). The Existence of Indigenous Knowledge and Local Landslide Mitigation: A Case Study of Banyumas People in Gununglurah Village, Central Java, Indonesia. *Sustainability*, *14*(19), 12765.

NSEKA, D., MUGAGGA, F., OPEDES, H., AYESIGA, P., WASSWA, H., MUGUME, I., & NALWANGA, F. (2021). The damage caused by landslides in socio-economic spheres within the Kigezi highlands of South Western Uganda. *Environmental & Socio-economic Studies*, *9*(1), 23-34.

NSENGIYUMVA, J. B., LUO, G., NAHAYO, L., HUANG, X., & CAI, P. (2018). Landslide susceptibility assessment using spatial multi-criteria evaluation model in Rwanda. *International journal of environmental research and public health*, *15*(2), 243.

NYAORO, D., SCHADE, J., & SCHMIDT, K. (2016). Assessing the evidence: migration, environment and climate change in Kenya. *International Organization for Migration* (IOM). Online. Assessed on www.iom.int. Accessed on 17th June 2022.

OGORA, M., KOTUT, J., (2013). Report on Yatta landslide, Machakos County. Mines and Geology, Ministry of environment and natural resources, (Unpublished), Nairobi, Kenya.

OKAKA, F. O., (2016). Urban Residents Perceptions and Adaptive Capacity and behavior to the Health Risks of Climate Change in Mombasa City. Kenya

OMONDI, P. (1994). *Wildlife human conflict in Kenya: integrating wildlife conservation with human needs in the Masai Mara Region* (Doctoral dissertation, McGill University, Dept. of Geography, Montreal, QC, CA).

OTHMAN, A. N., NAIM, W. M., & NORAINI, S. (2012). GIS based multi-criteria decision making for landslide hazard zonation. *Procedia-Social and Behavioral Sciences*, *35*, 595-602.

PARON, P., OLAGO, D. O., & OMUTO, C. T. (2013). *Kenya: A Natural Outlook: Geo-Environmental Resources and Hazards*. Newnes: Boston, MA, USA, 2013; pp. 293–314.

PARSONS, T. (1980). Social systems and the evolution of action theory. *Ethics* 90 (4):608-611 (1980).

PETLEY, D. (2012). Global patterns of loss of life from landslides. *Geology*, *40*(10), 927-930. [Google Scholar]. Online. Accessed on 30th June, 2022.

PICIULLO, L., CALVELLO, M., & CEPEDA, J. M. (2018). Territorial early warning systems for rainfall-induced landslides. *Earth-Science Reviews*, *179*, 228-247.

PIOTR JANKOWSKI (1995) Integrating geographical information systems and multiple criteria decision-making methods, *International Journal of Geographical Information Systems*, 9:3, 251-273, DOI: 10.1080/02693799508902036

PORTE, G. (2013). Who needs replication? *Calico Journal*, *30*(1), 10-15.

PRICE, P. C., CHIANG, I. C. A., & JHANGIANI, RAJIV. S. (2015). *Research methods in psychology*. Third American Edition. BC Campus. Available at URL: https://openlibrary-repo.ecampusontario.ca/jspui/handle/123456789/246. Accessed on 8th December, 2022.

REDUCTION, D. R. (2009). United Nations International Strategy Disaster Reduction (UNISDR) terminology on disaster risk reduction. United Nations, Geneva, Switzerland.

REDUCTION, R. (2020). Sendai Framework for Disaster Risk Reduction 2015_2030. UNDRR

REICHENBACH, P., ROSSI, M., MALAMUD, B. D., MIHIR, M., & GUZZETTI, F. (2018). A review of statistically-based landslide susceptibility models. *Earth-Science Reviews*, *180*, 60-91.

REPUBLIC OF KENYA, October, (2010). National Disaster Management Policy of Kenya (Final Draft). Government of Kenya.

REYES-CHAVES, J., & FERNÁNDEZ-ARCE, M. (2014). Landslide potential in Santo Domingo de Heredia, Costa Rica, Central America. Potencial de deslizamiento de tierra en Santo Domingo de Heredia, Costa Rica, Centroamérica. *Journal of Geography and Geology*. *6*(4), 1-11.

REYES-CHAVES, J., FERNÁNDEZ-ARCE, M., GRINESKI, S., & COLLINS, T. (2014). Spatial Analysis of Disaster Risk in Santo Domingo De Heredia, Costa Rica, Central America. *Journal of Geography and Geology*, *6*(3), 123-132

RITZER, GEORGE & BARRY SMART, (Eds.). (2000). *Handbook of social theory*. SAGE, Publications, 6 Bonhill Street, London. ISBN 0 7619 5840 1.

ROGERS, B. (1987). Ethical considerations in research. *AAOHN Journal*, *35*(10), 456-458. Issue. Accessed online via https://doi.org/10.1177/216507998703501008. Accessed on 29/07/2018.

ROHAN, T. J., WONDOLOWSKI, N., & SHELEF, E (2020). Landslide Susceptibility Analysis Based on Citizen Reports. *Earth Surface Processes and Landforms*.

RONCOLI, C., INGRAM, K., & KIRSHEN, P. (2002). Reading the rains: Local knowledge and rainfall forecasting in Burkina Faso. *Society & Natural Resources*, *15*(5), 409-427.

ROP, B. K. (2011). Landslide disaster vulnerability in Western Kenya and Mitigation options: A synopsis of evidence and issues of Kuvasali landslide. *Journal of Environmental Science and Engineering*, *5*(1)

ROWNTREE, K. M. (1989). Landslides in Kenya: a geographical appraisal. In *Landslides: Extent and Economic Significance* (pp. 253-259). AA Balkema Rotterdam.

RUSSELL, B., (1992). Human Knowledge. Its Scope and Limits, London: Routledge.

SALOME, K. R., OCHARO, R. M., & GAKURU, O. (2004). Strengthening rural community bonds as a means of reducing vulnerability to landslides: Kenya. In *Global symposium for hazard risk reduction: Lessons learned from the applied research grants for disaster risk reduction program* (pp. 129-37).

SAPKOTA, B. K. (2017). Landslide Loss and Damage in Darbung Village, Gorkha District, Nepal. In *Climate change research at universities* (pp. 153-173). Springer, Cham.

SCHEAFFER, R. L., MENDENHALL III, W., OTT, R. L., & GEROW, K. G. (2011). *Elementary survey sampling*. Seventh Edition, Advanced series. BROOKS/COLE CENGAGE Learning.

SCHLÖGEL, R., BELABBES, S., DELL ORO, L., DÉPREZ, A., & MALET, J. P. (2020, May). Disastrous landslides under changing forcing factors triggered end 2019 in West Kenya. In *EGU General Assembly Conference Abstracts* (p. 19153).

SCHUSTER, R.L., (1996) Landslides: Investigation and mitigation. Chapter 2- socioeconomic significance of landslides. Publisher: *Transportation Research Board*. Issue No. 247. ISSN: 0360-859X. Accessed online via https://www.mytrb.org/Store/Product.aspx?ID=5300. Accessed on 10/07/2018.

SCHUSTER, R.L., Highland, L.M., (2001) US Geological Survey Open-File Report 01-0276. *US Geological Survey.*

SCOLOBIG, A., PRIOR, T., SCHRÖTER, D., JÖRIN, J., & PATT, A. (2015). Towards people-centred approaches for effective disaster risk management: Balancing rhetoric with reality. *International Journal of Disaster Risk Reduction*, *12*, 202-212.

SEPÚLVEDA, S. A., & PETLEY, D. N. (2015). Regional trends and controlling factors of fatal landslides in Latin America and the Caribbean. *Natural Hazards and Earth System Sciences*, *15*(8), 1821-1833

SHAW, R., TAKEUCHI, Y., UY, N., & SHARMA, A. (2009). *Indigenous Knowledge: Disaster Risk Reduction*. From Practice to Policy. New York: Nova Science Publishers.

SHAW, R., UY, N., & BAUMWOLL, J. (EDS.). (2008). *Indigenous knowledge for disaster risk reduction: Good practices and lessons learned from experiences in the Asia-Pacific Region*. United Nations, International Strategy for Disaster Reduction.

SHI, P., YE, T., WANG, Y., ZHOU, T., XU, W., DU, J. & OKADA, N. (2020). Disaster risk science: A geographical perspective and a research framework. *International Journal of Disaster Risk Science*, *11*(4), 426-440.

SHISANYA, C. A. (2017). Role of Traditional Ethnobotanical Knowledge and Indigenous Institutions in Sustainable Land Management in Western Highlands of Kenya. *Indigenous People*, *159*.

SIMONOVIC, S. P. (2015). Systems Approach to Management of Disasters–A Missed Opportunity? *IDRiM Journal*, *5*(2), 70-81.

SINGH, S., JOSHI, A., SAHU, A., ARUN PRASATH, R., SHARMA, S., & DWIVEDI, C. S. (2022). Himalayan Landslides–Causes and Evolution. In *Disaster Management in the Complex Himalayan Terrains* (pp. 33-42). Springer, Cham.

SKOKO, H. (2013). Systems theory application to risk management in environmental and human health areas. *Journal of Applied Business and Economics*, *14*(2), 93-111.

SLOVIN, E. (1960). Slovin's formula for sampling technique. Retrieved on 13th June, 2019.

SSENNOGA, M., MUGAGGA, F., NADHOMI, D. L., & KISIRA, Y. (2022). Mapping the susceptibility of persons with disabilities to landslides in a highland landscape of Bushika Sub County, Mount Elgon, Eastern Uganda. *Jàmbá: Journal of Disaster Risk Studies*, *14*(1), 9

STEPHEN J. CARVER (1991) Integrating multi-criteria evaluation with geographical information systems, *International Journal of Geographical Information System*, 5:3, 321-339, DOI: 10.1080/02693799108927858.

STICHWEH, R. (2011). Systems theory. *International Encyclopedia of Political Science. New York: Sage*.

STORE, R., & KANGAS, J. (2001). Integrating spatial multi-criteria evaluation and expert knowledge for GIS-based habitat suitability modelling. *Landscape and urban planning*, *55*(2), 79-93.

SUBEDI, D. (2016). Explanatory sequential mixed method design as the third research community of knowledge claim. *American Journal of Educational Research*, *4*(7), 570-577.

SUFRI, S., DWIRAHMADI, F., PHUNG, D., & RUTHERFORD, S. (2020). A systematic review of Community Engagement (CE) in Disaster Early Warning Systems (EWSs). *Progress in Disaster Science*, *5*, 100058.

TAHERDOOST, H. (2016). Sampling Methods in Research Methodology; How to Choose a Sampling Technique for Research. *International Journal of Advance Research in Management*, *5*(2), 18-27.

TART JR, R. G. (2016). Why the Oso landslide caused so much death and destruction. In *Geotechnical and Structural Engineering Congress 2016* (pp. 1545-1554)

TEHRANIAN, M. (1974). *Toward a systemic theory of national development*. Industrial Management Institute. IMI Press.

TEKIN, S., & ÇAN, T. (2018). Effects of Landslide Sampling Strategies on the Prediction Skill of Landslide Susceptibility Modelings. *Journal of the Indian Society of Remote Sensing*, *46*(8), 1273-1283.

THAPA, M. B., LUINTEL, Y. R., GAUCHAN, B., & AMATYA, K. (2009). Indigenous knowledge on disaster mitigation: Towards creating complementarity between communities' and scientists' knowledge. *Indigenous Knowledge for Disaster Risk Reduction*, *30*. UN/ISDR-19-2008-Bangkok

THE STAR NEWSPAPER (unpublished). Saturday April 28, 2018. Online. Accessed on July 14, 2018 via https://www.the-star.co.ke/news/2018/04/28/three-killed-in-muranga-landslide-after-heavy rains_c1750820

THOMAS, M.F. *(1974)* Tropical geomorphology a study of weathering and landform development in warm climates. *Mac- Millan, London*

TIMILSENA, N. P., & DEVKOTA, K. M. (2022). Indigenous knowledge and local practices for disaster risk reduction: A study of Kailali district. *Geographical Journal of Nepal*, 119-130.

TONGCO, MA DOLORES C. "Purposive sampling as a tool for informant selection." *Ethnobotany Research and applications* 5 (2007): 147-158. [Google Scholar]. Assessed on 13-April-2021.

TRUNCELLITO, D. A., (2007). Epistemology, Internet Encyclopedia of Philosophy. Online. Accessed on 29-December, 2022. Accessed from: http://www.iep.utm.edu/epistemo/.

UN (2018), DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS (DESA). The sustainable development goals report 2018. *United Nations*. UN-iLibrary. ISBN 9789210478878. DOI: https://doi.org/10.18356/55eb9109-en. Online. Accessed on July 12th, 2018.

UNISDR, U. (2015). Sendai framework for disaster risk reduction 2015–2030. In *3rd United Nations World Conference on DRR*. Sendai, Japan: UNISDR.

UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP). (2012). Early warning systems: A state of the art analysis and future directions.

USGS - UNITED STATES GEOLOGICAL SURVEY, 2015. ‘Shuttle Radar Topography Mission (SRTM) 1 ArcSecond Global.’ Available via URL https://earthexplorer.usgs.gov/. Accessed on 17 April 2021

UZIELLI, M., NADIM, F., LACASSE, S., & KAYNIA, A. M. (2008). A conceptual framework for quantitative estimation of physical vulnerability to landslides. *Engineering Geology*, *102*(3-4), 251-256.

VAN WESTEN, C. J., VAN ASCH, T. W., & SOETERS, R. (2006). Landslide hazard and risk zonation—why is it still so difficult? *Bulletin of Engineering geology and the Environment*, *65*(2), 167-184.

VODACEK, A. (2021). A more dynamic understanding of landslide risk. *Nature Sustainability*, *4*(11), 930-931

VON BERTALANFFY, L. (1968). General system theory. *New York*, *41973*(1968), 40.

VON BERTALANFFY, L. (1973). The meaning of general system theory. *General system theory: Foundations, development, applications*, 30-53.

VON BERTALANFFY, L. (2010). General Systems Theory. *The Science of Synthesis: Exploring the Social Implications of General Systems Theory*, *103*.

VOOGD, H. (1983). Multi-criteria Evaluations for Urban and Regional Planning. Princeton University, London.

WABWIRE, J., & OGALO, J. O. (2021). Community Radio in Dynamics of Development in Kenya: A Perfect Voice of the Kenyan Poor in the Digital Age. *New Realities in Africa*, 334

WACHIRA, J., & CUMISKEY, L. (2022). Kenya—Local. *El Niño Ready Nations and Disaster Risk Reduction: 19 Countries in Perspective*, 249.

WAHLSTRAND, A. (2015). *Landslide scars in the Kenyan highlands: Physical and chemical topsoil changes and landslide susceptibility assessment under tropical conditions* (Doctoral dissertation, Department of Physical Geography, Stockholm University).

WALSHE, R. A., & NUNN, P. D. (2012). Integration of indigenous knowledge and disaster risk reduction: A case study from Baie Martelli, Pentecost Island, Vanuatu. *International Journal of Disaster Risk Science*, *3*(4), 185-194.

WAMITHI, K. R. (2018*).* Land use Changes and their Impacts on Wetlands in Loboi Plains Baringo County, Kenya.

WANNOUS, C., & VELASQUEZ, G. (2017, May). United Nations Office for Disaster Risk Reduction (UNISDR)—UNISDR's Contribution to Science and Technology for Disaster Risk Reduction and the Role of the International Consortium on Landslides (ICL). In *Workshop on World Landslide Forum* (pp. 109-115). Springer, Cham

WARREN, D. M., & RAJASEKARAN, B. (1993). Putting local knowledge to good use. *International Agricultural Development*, *13*(4), 8-10.

WESTERBERG, L.-O. AND CHRISTIANSSON, C., (1999): Highlands in East Africa: Unstable slopes, unstable environments? Ambio. Vol. 28, No. 5, Research for Mountain Area Development: Africa and Asia (Aug., 1999), pp. 419-429. Retrieved from http://www.jstor.org/stable/4314924 on 17 July 2018.

WORLD BANK. (1998). *World development report 1998/1999: Knowledge for development*. The World Bank. Online. Accessed on December 06, 2022, from http://www.worldbank.org/afr/ik/ikrept.pdf

YIN, R. K. (2003). Case study research design and methods third edition. *Applied social research methods series*, *5*.

YUFENG, S., & FENGXIANG, J. (2009). Landslide stability analysis based on generalized information entropy. In *Environmental Science and Information Application Technology, 2009. ESIAT 2009. International Conference on International Conference on Environmental Science and Information Application Technology* (Vol. 2, pp. 83-85). IEEE.

YU ZHUANG, AIGUO XING, YUEHUA JIANG, QIANG SUN, JINKAI YAN, YANBO ZHANG. *Typhoon, rainfall and trees jointly cause landslides in coastal regions*. Engineering Geology, Volume 298, 2022, 106561, ISSN 0013-7952. Online. Accessed on 1st July 2022 at https://doi.org/10.1016/j.enggeo.2022.106561.

ZHOU, S., ZHOU, S., & TAN, X. (2020). Nationwide Susceptibility Mapping of Landslides in Kenya Using the Fuzzy Analytic Hierarchy Process Model. *Land*, *9*(12), 535.

APPENDICES

Appendix I: Field Data Collection Consent Agreement Form

I have been fully briefed about the research work in Murang'a County and which I am voluntarily participating. The research title is "**LANDSLIDE DISASTER RISKS MANAGEMENT IN MURANG'A COUNTY, KENYA: SCIENTIFIC AND INDIGENOUS KNOWLEDGE NEXUS"** The study is in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy (Ph.D) in Geography from Moi University (Eldoret) and is being undertaken by John Maina Njiraini, SAS/DG/01/18, under the supervision of Prof. Paul Omondi (Ph.D) and Dr. Fredrick O. Okaka (Ph.D).

I therefore freely, willingly and objectively consent to participate and give the requested data/information to be used STRICTLY for the research purposes.

In case of any query about the research, I am free to contact the undersigned researcher and/or the supervisors directly or through the research assistant whose contacts have been given to me.

Consented and signed by:

1) *Respondent's Sign………..………………Date………………..National ID No………….*
2) *Candidate's Sign…………………………Date……………………….……………………….*
3) *First Supervisor's Sign………………….Date…………………………………………………*
4) *Second Supervisor's Sign……………….Date…………………………………………………*
5) *Research's Assistant's Sign……………Date…………………………………………………*

APPENDIX II: Household Survey Research Questionnaire

Questionnaire Number. ………of……….Date………………………….

LANDSLIDE DISASTER RISKS MANAGEMENT IN MURANG'A COUNTY, KENYA: SCIENTIFIC AND INDIGENOUS KNOWLEDGE NEXUS

A brief questionnaire consent note

This is an academic research being conducted by John Maina Njiraini, a Ph.D candidate of Moi University registered under number SAS/DG/01/18. The questionnaire is a field data collection tool for the above titled research. Data gathered will be confidential and strictly used for the research purposes only. Participation and cooperation from participants is highly appreciated. Thank you in advance.

Instructions to the respondent: Answer ALL the questions where applicable by ticking against the appropriate check-box or filling the spaces provided

PART 1: THE STUDY LOCATION

1. **GPS Coordinates:** X-Coordinates ☐ Elevation (m) ☐
   Y-Coordinates ☐
2. Sub-County Name…..…………………………………………….……………………..
3. Location Name………………………………………………………………………..
4. Sub-Location Name…...………………………………………………………………...
5. Village Name………………………………………………………………………

PART 2: PERSONAL INFORMATION OF THE RESPONDENT

6. **Name of Respondent** (Optional)………...…………………………………………...
7. **Occupation**…………………………………………………………………………...
8. **Sex:** Male ☐ Female ☐ Intersex ☐
9. **Marital status:** Single ☐ Married ☐ Divorced ☐ Separated ☐
   Others (Specify)……………………………………………………………………….
10. **Age**:…………… (in years)

11. **Highest education level attained:**

No formal education ☐ Primary ☐ Secondary ☐ Certificate ☐

H/Diploma ☐ Undergraduate ☐ Master ☐ Ph.D ☐ Others (Specify)
…………………………………………………………………………………………………

12. **Income:** What's your approximate income per month…………(in Kenya Shillings)

PART 3: RESPONDENT'S RESIDENCY INFORMATION

13. **Birth Place:** Were you born in this area? Yes ☐ No ☐
    a) If **Yes** above, how long have you lived in this area? …….... (in years) ☐
    b) If **No** above, when did you move into the current location?…(Month/Year)
14. **Land-size:** What is the approximate size of your land…...……………(in acres)
15. **Land-Use/Land-Cover (LULC) type:** What is the dominant land-use/Land-cover type of your land?...
    a) Has the vegetation changed in the area over time?
       Yes ☐ No ☐
    b) Have you experienced change in the dominant LULC for the last 10 years? Yes ☐ No ☐
    c) If **Yes** above, LULC changed from……………….......................................………………...
       to…………………………………………………………………………
16. **Area population:** How would you describe the population of this area?
    Sparse ☐ Moderate ☐ Dense ☐
    a) Have you witnessed any change in population over the past recent?
       Yes ☐ No ☐
    b) If **Yes** above, was it an increase or a decrease in population…….…………

PART 4: LOCAL PEOPLES' UNDERSTANDING ABOUT LANDSLIDE DISASTER (RISKS)

17. Do you understand what a landslide is? Yes ☐ No ☐

18. Do you understand what a landslide disaster risk is? Yes ☐ No ☐

19. How would you describe the landslide occurrence frequencies in the area?

    Increasing ☐ Constant ☐ Decreasing ☐ No idea ☐

20. Have you ever experienced a landslide event? Yes ☐ No ☐

    If **Yes**,
    a) How far was the landslide event from your home………..(Distance in kilometers)
    b) When did you experience the latest landslide event……… (Month/Year)
    c) Were you directly affected by the landslide? Yes ☐ No ☐
    d) Was the landslide destructive? Yes ☐ No ☐

21. Have you ever been affected by a landslide? Yes ☐ No ☐

    If **Yes,**
    a) How many times in your stay have you been affected by landslide(s)?

    b) In which way were you affected?
       Loss of animals ☐ Loss of human life ☐ Destruction of property ☐

       Displacement ☐ Psychological loss ☐ No loss ☐

       Other Losses (Specify) ☐

……………………..
....

PART 5: INDIGENOUS KNOWLEDGE ON LANDSLIDE DISASTER RISK WITH RESPECT TO THE SCIENTIFICALLY-KNOWN CAUSAL/TRIGGER FACTORS

Local people's understanding of the scientifically known causal/trigger factors:

22. Do you understand which factor(s) cause/trigger a landslide event to occur in the area? Yes ☐ No ☐

    a) If **Yes**, List the 5 main landslide causal/trigger factors
    1.………………………………………………………………………………………
    2.………………………………………………………………………………………
    3.………………………………………………………………………………………
    4.………………………………………………………………………………………
    5.………………………………………………………………………………………

b) An analysis of scientifically known landslide disaster causal/trigger factors and their respective causalities as understood by you. Answer the questions as per the table below:

Sr. No	**causal/trigger Factor**	**As a landslide causal/trigger** 0=Never 1=Yes 3= Don't know 4= Not sure	**Degree of landslide causality** 0=None 1=Least 2=Moderate 3=Most
1.	Intensive of rainfall		
2.	Steepness/Gradient of the slopes		
3.	Altitude (Height above MSL)		
4.	Soil types and characteristics		
6.	Change in land-use/land-cover types		
7.	Type of crop or vegetation on land		
8.	Infrastructural development on land		
9.	Population/settlement increase		
	Others (Name)		
10.			
11.			

PART 6: LANDSLIDE DISASTER RISK MANAGEMENT

23. Do you understand what is meant by disaster risk management? Yes ☐ No ☐
If **Yes,**
    a) List 5 measures you take to prevent and mitigate against landslide disasters from occurring

1...
2...
3...
4...
5...
....
....

PART 7: INDIGENOUS KNOWLEDGE IN DISASTER RISK MANAGEMENT

24. Do you understand what is meant by indigenous knowledge?

Yes ☐ No ☐

25. Has the government (either national and/or county) been involving the local people in landslide disaster management? Yes ☐ No ☐

26. With respect to the use of indigenous knowledge (IK) in disaster management, answer the following questions on a scale of 0-2:

Disaster management activity	**Landslide disaster management phase**	**Applicability of IK** 0=No 1=Yes 2=I don't Know
a) Can IK be useful in landslide disaster prevention?	Pre- disaster phase	
b) Can IK be useful in landslide disaster early warning and preparedness?		
c) Can IK be useful in landslide disaster mitigation?		
d) Can IK be useful in landslide response and relief?	During disaster	
e) Can IK be useful in landslide disaster reconstruction?	Post- disaster phase	

27. Do you have own tactics for landslide disaster management? Yes ☐ No ☐
If **Yes**, name the most prominent tactics…………………………………………………………………………..…
…………………………………………………………………………………………
…………………………………………………………………………………………

28. Have you faced any constraints in landslide disaster management? Yes ☐ No ☐
If **Yes**, name the most prominent constraints
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

29. Do you have any Early Warning Systems (EWS) for landslide disaster management:

Yes ☐ N ☐

If **Yes**, list the EWS techniques you apply
…………………………………………………………………………………………
…………………………………………………………………………………………

Thank you for your time

APPENDIX III: Key Informants Interview (KII) Guide

Questionnaire Number. ………of……….

Date…………………………………………..

LANDSLIDE DISASTER RISKS MANAGEMENT IN MURANG'A COUNTY, KENYA: SCIENTIFIC AND INDIGENOUS KNOWLEDGE NEXUS

A brief KII Guide questionnaire consent note

This is an academic research being conducted by John Maina Njiraini, a Ph.D candidate of Moi University registered under number SAS/DG/01/18. The KII schedule is a field data collection tool for the above titled research. Data gathered will be confidential and strictly used for the research purposes only. Participation and cooperation from participants is highly appreciated. Thank you in advance.

Instructions to the respondent: Answer ALL the questions where applicable by ticking against the appropriate check-box or filling the spaces provided

PART 1: THE STUDY LOCATION

1. **GPS Coordinates:** X-Coordinates ☐ Elevation (m) ☐
   Y-Coordinates ☐
2. Sub-County Name…..…………………………………………..……………………..
3. Location Name…………………………………………………………………………..
4. Sub-Location Name…...…………………………………………………………...
5. Village Name……………………………………………………………………

PART 2: KEY INFORMANT'S INFORMATION

6. Name of Respondent (Optional)…………………………...…………………………
7. Type/category of community leadership/Service..…………………….……………………..
8. For how long have you been a community leader/service in the study area.....(Years)
9. What capacity do you serve the community…………………………………………
10. Approximately how many people do you lead/serve?...
11. **Jurisdiction:** What is your leadership/service jurisdiction?.......................................
12. **Occupation:** What is your occupation?….……………………………………
13. **Sex:** Male ☐ Female ☐ Intersex ☐

14. **Highest education level attained:**

No formal education ☐ Primary ☐ Secondary ☐ Diploma ☐ HND ☐
Undergraduate ☐ Master ☐ Ph.D ☐ Others (Specify)……………

PART 3: INFORMATION ABOUT THE STUDY AREA

15. How long have you been in the study area?…………………………………..(years)
16. **Land-size:** What is the approximate land size for people in your area?…(in acres)
17. **Land-Use/Land-Cover (LULC) type:** What is the dominant land-use/Land-cover type in the area?...
Has the vegetation cover changed in the area over time? Yes ☐ No ☐

If **Yes** above, LULC changed from…………………...………..
to…………………………………………………………………………………………

18. **Area population:** How would you describe the population of this area?
Sparse ☐ Moderate ☐ Dense ☐

19. Have you witnessed any change in population in the study area? Yes ☐ No ☐
If **Yes** above, was it an increase or a decrease in population………………………..

PART 4: KI'S UNDERSTANDING ABOUT LANDSLIDE DISASTER (RISKS)

20. Do you understand what a landslide is? Yes ☐ No ☐
21. Do you understand what a landslide disaster risk is? Yes ☐ No ☐
22. How would you describe the landslide occurrence frequencies in the area?

Increasing ☐ Constant ☐ Decreasing ☐ No idea ☐

23. Have you ever experienced a landslide event? Yes ☐ No ☐

If **Yes**,
a) How far was the landslide event from your home………..(Distance in kilometers)
b) When did you experience the latest landslide event…………...(Month/Year)
c) Were you directly affected by the landslide? Yes ☐ No ☐
d) Was the landslide destructive? Yes ☐ No ☐

24. Have you ever witnessed a landslide event in the area? Yes ☐ No ☐

If **Yes,**
a) Approximately how many HHs were affected by landslide(s)?...........................

b) In which way were you affected?
Loss of animals ☐ Loss of human life ☐ Destruction of property ☐

Displacement ☐ Psychological loss ☐ Other Losses (Specify)

……………………..

PART 5: SCIENTIFICALLY-KNOWN LANDSLIDE CAUSAL/TRIGGER FACTORS

KI's understanding of the scientifically known causal/trigger factors:

25. Do you agree that there are scientifically known landslide causal/trigger factors?
Yes ☐ No ☐
26. Do you understand which factor(s) cause/trigger a landslide event to occur in the area? Yes ☐ No ☐

a) If **Yes**, in your understanding, name 5 main landslide causal/trigger factors

1……………………………………………………………………………………………
2……………………………………………………………………………………………
3……………………………………………………………………………………………
4…………………………………………………………………………………………
5……………………………………………………………………………………………
………………………………………………………………………………………..

b) An analysis of scientifically known landslide disaster causal/trigger factors and their respective causalities as understood by you. Answer the questions as per the table below:

Sr. No	**causal/trigger Factor**	**As a landslide causal/trigger** 0=Never 1=Yes 3= Don't know 4= Not sure	**Degree of landslide causality** 0=None 1=Least 2=Moderate 3=Most
1.	Intensive of rainfall		
2.	Steepness/Gradient of the slopes		
3.	Altitude (Height above MSL)		
4.	Soil types and characteristics		
5.	Change in land-use/land-cover types		
6.	Type of crop or vegetation on land		
7.	Infrastructural development on land		
9.	Population/settlement increase		
	Others (Name)		
10.			
11.			

PART 6: LANDSLIDE DISASTER RISK MANAGEMENT

27. Do you understand what is meant by disaster risk management? Yes ☐ No ☐
    If **Yes,** List 5 measures you take to prevent and mitigate against landslide disasters from occurring

1...
2...
3...
4...
5...

PART 7: INDIGENOUS KNOWLEDGE IN DISASTER RISK MANAGEMENT

28. Do you understand what is meant by indigenous knowledge? Yes ☐ No ☐
29. Can such knowledge be applied in defining and understanding landslide disasters?
    Yes ☐ No ☐
30. Has the government (either national and/or county) been involving the local people in landslide disaster management? Yes ☐ No ☐
31. With respect to the use of indigenous knowledge (IK) in disaster management, answer the following questions on a scale of 0-2:

Disaster management activity	**Landslide disaster management phase**	**Applicability of IK** 0=No 1=Yes 2=I don't Know
Can IK be useful in landslide disaster prevention?	Pre- disaster phase	
Can IK be useful in landslide disaster early warning and preparedness?		
Can IK be useful in landslide disaster mitigation?		
Can IK be useful in landslide response and relief?	During disaster	
Can IK be useful in landslide disaster reconstruction?	Post- disaster phase	

32. Do know any tactics used by the locals in landslide disaster management?
    Yes ☐ No ☐

If **Yes**, name the most common tactics
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………

33. Have the locals faced any constraints in landslide disaster management?

Yes ☐ No ☐

If **Yes**, name the most prominent constraints
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………

30. Do the locals have any early warning techniques for landslide disaster management:

If **Yes**, list any
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………

Thank you for your time

APPENDIX IV: Focus Group Discussion (FGD) Interview Schedule

LANDSLIDE DISASTER RISKS MANAGEMENT IN MURANG'A COUNTY, KENYA: SCIENTIFIC AND INDIGENOUS KNOWLEDGE NEXUS

A brief Interview Schedule FGD Interview Schedule consent note
This is an academic research being conducted by John Maina Njiraini, a Ph.D candidate of Moi University registered under number SAS/DG/01/18. The FGD Interview Schedule is a field data collection tool for the above titled research. Data gathered will be confidential and strictly used for the research purposes only. Participation and cooperation from participants is highly appreciated. Thank you in advance.

Instructions to the respondent: Answer ALL the questions where applicable by providing as much information as possible for each question.

.

The Guiding questions are as follows:

A) Understanding of landslide disasters

1. Do you understand what a landslide is?

   If yes in 1 above,

   a) Do you consider it as disaster?

   b) If yes in 1a above, why do you consider it a disaster?

B) Landslide disasters causal/trigger factors

2. Do you understand what is meant by landslide causal/trigger factors?

   a) If yes in 2 above, what do you think are the main causal/trigger factors for landslides in your area?

   b) If yes in 2 above, kindly give an account of each of the named factors in 2a above; how and to which extent each contributes to a landslide event in your locality.

C) Landslide disasters management

3. Do you understand what landslide disaster management is?

a) If yes in 3 above, who do you think should be included in landslide disaster management?

c) If yes in 3 above, kindly give an account of each of the named players in 3a above; how and to which extent each contributes landslide disaster management in your locality.

D) Indigenous knowledge (IK) understanding

4. Do you understand what is meant by IK?

    a) If yes in 4 above, do you think IK can be applied in LDRM?

    b) If yes in 4a above, explain how and in which stage of landslide disaster management where IK is applicable

    c) If yes in 4a above, do you think IK has been or is being applied in landslide disaster management in your area?

    d) If yes in 4a above, explain how IK has been or is being applied in landslide disaster management in your area.

E) Landslide disasters effects

5. Do you think landslide affect the locals in any way?

    a) If yes in 5 above, do you think that there are positive effects of landslides in your area?

    b) If yes in 5a above, list and explain such positive effects.

    c) If yes in 5 above, do you think that there are negative effects of landslides in your area?

    d) If yes in 5c above, list and explain such negative effects.

F) Early Warning Systems (EWS) for Landslides

6. Do you understand what is meant by EWS?

a) If yes in 6 above, do you think IK can be used in LDRM by providing early warnings?
b) Have you witnessed IK being applied in EWS in your area?
c) If yes in 6b above, explain how and to what extent IK has been used in providing early warning.
d) If yes in 6b above, how reliable are the EWS by the locals?

Appendix V: Moi University Research Letter

MOI UNIVERSITY

Telephone (053) 43001-8/43620
Fax No. (0321) 43047
Telex No. MOIVARSITY 35047

P.O. BOX 3900
Eldoret
KENYA

SCHOOL OF ARTS & SOCIAL SCIENCES

DEPARTMENT OF GEOGRAPHY

14th December 2020

To
The Director
National Commission for Science, Technology and Innovation

RE: RESEARCH PERMIT FOR JOHN MAINA NJIRAINI: SAS/DG/01/18

This is certify that Mr. John Maina Njiraini is a PhD students in the department of Geography, Moi University. He successfully presented his research proposal entitled ***"Landslides Disaster Management in Murang'a County, Kenya: The Scientific and Local Peoples' Knowledge Nexus in Pre-disaster Management"*** at a departmental seminar held on 17th Janaury2019. The department has therefore cleared him to proceed to the field for data collection. Kindly assist him process research permit to enable him undertake data collection.

Thanking you in advance.

Yours faithfully,

William Kiplagat
HEAD, DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES

Appendix VI: Research Permit-NACOSTI

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **309555**

Date of Issue: **17/March/2021**

RESEARCH LICENSE

This is to Certify that Mr.. John Maina Njiraini of Moi University, has been licensed to conduct research in Muranga on the topic: SCIENTIFIC AND INDIGENOUS KNOWLEDGE IN LANDSLIDES DISASTER RISK MANAGEMENT: THE SCIENTIFIC AND LOCAL PEOPLES' KNOWLEDGE NEXUS IN MURANG'A COUNTY, KENYA for the period ending : 17/March/2022.

License No: **NACOSTI/P/21/9233**

309555

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.

APPENDIX VII: letters of Authority from Ministry of Education

MINISTRY OF EDUCATION

STATE DEPARTMENT OF EARLY LEARNING AND BASIC EDUCATION

Email: cdemuranga@gmail.com
Telephone: 060 2030227
When replying please quote

COUNTY DIRECTOR OF EDUCATION
P.O BOX 118 – 10200
MURANG'A

REF: MGA/CTY/EDU/RESEARCH/GEN/64/VOL.III/29 **10th June, 2021**

JOHN MAINA NJIRAINI
C/O MOI UNIVERISTY
P.O. BOX 3900-30100
ELDORET

RE: RESEARCH AUTHORIZATION

The County Education office is in receipt of your request letter and authority from NACOSTI Ref No.309555 and license number NACOSTI/P/21/9233 dated 17th March, 2021 to carry out a research on **"Landslides Disaster Management in Murang'a County, Kenya: The Scientific and Local Peoples' Knowledge Nexus in Pre-disaster Management."**

Permission is hereby granted to carry out research in **Murang'a County** for a period ending **17th March, 2022.**

You are kindly advised to deposit a copy of the final research report to this office.

for Anne Kiilu
County Director of Education
MURANG'A

COUNTY DIRECTOR OF EDUCATION
MURANG'A
10 JUN 2021
P.O. Box 118-10200, MURANG'A

Ministry of Interior and Coordination of National Government

Authorization

REPUBLIC OF KENYA

THE PRESIDENCY

MINISTRY OF INTERIOR AND CO-ORDINATION OF NATIONAL GOVERNMENT

Telephone: 060-2030467
Email: cc.muranga@interior.go.ke

COUNTY COMMISSIONER
MURANG'A COUNTY
P. O. BOX 7-10200
MURANG'A

When replying please quote

REF.NO.PUB.24/11/VOL.IV/30 **10TH JUNE, 2021.**

ALL DEPUTY COUNTY COMMISSIONERS
MURANG`A COUNTY.

RE: RESEARCH AUTHORIZATION

In reference to the letter **NACOSTI/P/21/9233** dated **17TH March 2021,** on the above subject.

Mr.John Maina Njiraini is hereby authorized to undertake research on ***"Landslides Disaster Risks in Murang`a County."*** For The Period ending **17TH March, 2022.**

Please accord him the necessary support.

COUNTY COMMISSIONER
MURANG'A COUNTY

MISHECK K. MWANGI
FOR:**COUNTY COMMISSIONER**
MURANG'A COUNTY.

Copy To: John Maina Njiraini

Appendix VIII: A sample of researcher's data collection introduction letter

John Maina Njiraini,
C% Department of Geography & Environmental Studies,
School of Art & Social Sciences,
Moi University,
P.O. Box 3900-30100,
Eldoret, Kenya

8th June, 2021

To……………………………………..

………………………………………..

………………………………………..

Dear sir/ madam,

<u>Ref: Doctor of Philosophy (Ph.D) Data for Murang'a County</u>

I am a Ph.D-Geography student at Moi University's School of Arts and Social Sciences, Department of Geography and Environmental Studies (GES) under registration number **SAS/DG/01/18.**

My research is about **Landslides Disaster Risks in Murang'a County** and I am currently due for data collection, having obtained clearance from the university and research permit from National Commission for Science, Technology and Innovation (NACOSTI). See the attached supporting documents.

This letter is to kindly request you to facilitate me get the requested data, authorization and/or assistance as may be applicable within your mandate for the accomplishment of the noble task at hand. The acquired data will be used for academic purpose only.

I look forward to your positive feedback. Thanks in advance.

Yours faithfully,

John Maina Njiraini,
Mobile: +254 727 574 915, E-mail: maishjohn@gmail.com

APPENDIX IX: SOTER soil types and susceptibility to landslides

DOMNT_SOIL	WRB_LEGEND	LITHOLOGY	Landslide
NTu	Dystric Humic Nitisol	VB1	1
NTu	Humic Umbric Nitisol	VP	1
NTu	Humic Umbric Nitisol	VP	1
ANu	Dystric Umbric Andosol	VP	1
ANu	Dystric Umbric Andosol	VP	1
ANu	Dystric Umbric Andosol	VP	1
ANu	Umbric Leptic Andosol	VP	1
ANm	Eutric Mollic Andosol	VJ1	1
ANu	Dystric Umbric Andosol	VP	1
ANu	Dystric Umbric Andosol	VB1	1
ANu	Dystric Umbric Andosol	VP	1
ANu	Dystric Umbric Andosol	VP	1
ANu	Dystric Umbric Andosol	VP	1
NTu	Dystric Humic Nitisol	VP	1
ANu	Dystric Umbric Andosol	VP	1
ANu	Dystric Umbric Andosol	VP	1
ANu	Umbric Leptic Andosol	VB1	1
ANu	Dystric Umbric Andosol	VP	1
NTu	Dystric Humic Nitisol	VP	1
NTu	Dystric Humic Nitisol	VP	1
NTu	Dystric Humic Nitisol	VP	1
NTu	Dystric Humic Nitisol	VP	1
NTu	Dystric Humic Nitisol	VP	1
NTu	Eutric Humic Nitisol	VB1	0
RGd	Dystric Leptic Regosol	VP	0
CMo	Ferralic Cambisol	MA2	0
NTr	Rhodic Nitisol	VB1	0
FLu	Umbric Vertic Fluvisol	UY0F	0
ACp	Chromic Petroplinthic Acrisol	VP	0
NTr	Rhodic Nitisol	MA2	0
ACp	Chromic Petroplinthic Acrisol	VP	0
LXh	Rhodic Lixisol	MA2	0
CMx	Eutric Leptic Cambisol	MA2	0
NTh	Eutric Nitisol	VW	0

CMx	Eutric Leptic Cambisol	MA2	0
CMx	Eutric Leptic Cambisol	MA2	0
FRr	Rhodic Acric Ferralsol	VB1	0
NTr	Rhodic Nitisol	VW	0
CMx	Eutric Leptic Cambisol	VW	0
FRr	Rhodic Acric Ferralsol	VB1	0
VRk	Pellic Calcic Vertisol	VB1	0
VRk	Pellic Calcic Vertisol	VB1	0
Flu	Umbric Vertic Fluvisol	UY0F	0
NTr	Rhodic Nitisol	VB1	0
VRk	Pellic Calcic Vertisol	VB1	0
Flu	Umbric Vertic Fluvisol	UY0F	0
CMx	Eutric Leptic Cambisol	MB4	0
NTr	Rhodic Nitisol	VW	0
NTr	Rhodic Nitisol	VW	0
FRr	Rhodic Acric Ferralsol	VB1	0
NTr	Rhodic Nitisol	VB1	0
CMx	Eutric Leptic Cambisol	VW	0
FRr	Rhodic Ferralsol	MB4	0
NTr	Rhodic Nitisol	VB1	0
FRr	Rhodic Ferralsol	MB4	0
VRk	Pellic Vertisol	VJ	0
FRr	Rhodic Ferralsol	MA2	0
Flu	Umbric Vertic Fluvisol	UY0F	0
VRk	Pellic Calcic Vertisol	VB1	0
GLu	Umbric Gleysol	UY0F	0
NTr	Rhodic Nitisol	VP	0
NTr	Rhodic Nitisol	VP	0
WR	WR	WR	0
NTr	Rhodic Nitisol	VW	0
NTr	Rhodic Nitisol	VP	0
ARo	Rubic Ferralic Arenosol	MA2	0
FRr	Rhodic Ferralsol	MB4	0
NTr	Rhodic Nitisol	VP	0
Flu	Umbric Vertic Fluvisol	UY0F	0
CMx	Eutric Leptic Cambisol	VW	0
GLu	Umbric Gleysol	UY0F	0
VRk	Pellic Vertisol	VJ	0
CMg	Dystric Pisoplinthic Cambisol	VP	0

NTr	Rhodic Ferralic Nitisol	VB1	0
Flu	Umbric Vertic Fluvisol	UY0F	0
NTr	Rhodic Nitisol	VP	0
RGd	Dystric Regosol	MA2	0
CMx	Eutric Leptic Cambisol	MB4	0
ACh	Rhodic Acrisol	MB4	0
CMx	Eutric Leptic Cambisol	MA2	0
VRe	Pellic Sodic Vertisol	VP1	0
ARo	Rubic Ferralic Arenosol	MA2	0
FRr	Rhodic Ferralsol	VP	0
NTr	Rhodic Nitisol	VP	0
VRe	Pellic Sodic Vertisol	VB1	0
NTr	Rhodic Ferralic Nitisol	VP	0
NTr	Rhodic Ferralic Nitisol	VB1	0
CMx	Eutric Leptic Cambisol	MA2	0
NTr	Rhodic Nitisol	VP	0
NTr	Rhodic Nitisol	VP	0
ARo	Rubic Ferralic Arenosol	MA2	0
VRe	Pellic Sodic Vertisol	VB1	0
ACp	Chromic Petroplinthic Acrisol	VP	0
CMx	Eutric Leptic Cambisol	MA2	0
VRk	Pellic Vertisol	VJ	0
FRr	Rhodic Ferralsol	VP	0
NTr	Rhodic Ferralic Nitisol	VP	0
NTr	Rhodic Nitisol	VP	0
ACp	Chromic Petroplinthic Acrisol	VP	0
GLu	Umbric Gleysol	UY0F	0
FLc	Calcaric Fluvisol	VP1	0

Sources: SOTER

1 means susceptible to landslide
0 means not susceptible to landslide

Fieldwork pictorials

A Focus Group Discussion (FGD) session at Kibage Location in Gacharage, Kandara Sub-County, Murang'a County

The researcher (in yellow polo-shirt and black jacket) and a section of locals

A landslide site in Kirangi Sub-Location, Mbugiti Location in Gatanga Sub-County, Murang'a County

The researcher (Far end, touching the landslide ground) accompanied by a ‘mzee wa mtaa’

Source: Field data

Key Informant Interview (KII) session with the Murang’a County Commissioner and Murang’a County Director of Meteorological Services

From far left to right clockwise: Mr. Kamau (Research assistant), Mr. Maina (the researcher), Mr. Ndunga (the county commissioner) Mr. Murage (the Director of Meteorological Services) and Mr. Manyeki (Lead Research assistant).

Appendix IX: Itemized reliability test for the HH questionnaires

Inter-Item Correlation Matrix

	How is the population	Any change in population	Population Decrease/Increase	Understands LS disaster	Frequency of LS	Ever affected By LS	Rainfall as a C/T factor	Slope as a C/T factor	Altitude as a C/T factor	Soil as a C/T Factor	LULC as a C/T Factor	Vegetation as a C/T Factor	InfrustructuralDevepmnt a C/T Factor	Population as a C/T Factor	Degree_Rainfall	Degree_Gradient	Degree_Altitude	Degree_Soil	Degree_LULC	Degree_Vegetation	Degree-infrDev	Degree_Population	Understand_DRM	Understand_IK	Govt_help	IK_in_LSDM_Prevention	IK_in_LSDM_WarningAndPreparedness	IK_in_LSDM_Mitigation	IK_in_LSDM_ResponseRelief	IK_in_LSDM_Reconstruction
How is the population	1.000	0.145	0.091	-0.100	-0.092	0.065	0.006	0.032	-0.015	-0.010	-0.097	-0.141	-0.104	-0.204	-0.071	-0.017	-0.033	0.033	-0.191	-0.288	-0.268	-0.356	-0.140	-0.022	0.180	0.047	0.014	0.030	0.080	0.162
Any change in population		1.000	-0.530	0.075	-0.007	0.051	0.028	-0.008	0.035	-0.003	0.122	0.088	0.118	0.048	0.032	0.000	-0.024	-0.061	0.047	0.038	0.001	-0.067	-0.045	0.118	0.041	-0.079	0.054	0.038	0.055	0.070
Population Decrease/Increase			1.000	-0.077	-0.181	-0.088	-0.039	-0.046	-0.066	-0.045	-0.149	-0.062	-0.148	-0.078	0.010	-0.027	-0.073	-0.004	-0.095	-0.068	-0.045	-0.040	0.029	0.049	0.003	-0.009	-0.104	-0.066	-0.112	-0.142
Understands LS disaster				1.000	0.052	0.041	0.023	-0.007	0.237	-0.002	-0.040	-0.049	0.112	0.174	0.055	0.169	0.231	0.008	-0.021	-0.051	0.107	0.116	0.293	0.174	-0.042	-0.125	-0.143	-0.139	-0.092	-0.124
Frequency of LS					1.000	-0.238	-0.049	0.014	0.113	-0.062	0.014	-0.110	0.078	0.050	0.051	0.051	-0.030	0.077	0.020	-0.053	0.043	0.118	-0.008	-0.129	-0.046	0.063	0.097	0.079	0.021	0.092
Ever affected By LS						1.000	-0.060	-0.150	-0.086	-0.043	0.034	0.061	-0.055	-0.044	-0.016	-0.054	-0.020	0.065	0.021	0.106	-0.112	-0.042	-0.053	0.074	-0.054	0.040	0.023	0.002	0.002	-0.033
Rainfall as a C/T factors							1.000	0.599	0.346	0.638	0.372	0.335	0.328	0.281	-0.063	-0.019	-0.029	-0.024	0.057	0.086	0.070	0.065	-0.100	-0.131	-0.208	0.191	0.209	0.152	0.180	0.178
Slope as a C/T factors								1.000	0.583	0.429	0.291	0.182	0.399	0.421	-0.102	0.443	0.280	-0.031	0.020	-0.027	0.118	0.210	0.018	0.026	-0.089	0.049	0.046	0.008	0.032	0.036
Altitude as a C/T factor									1.000	0.386	0.310	0.260	0.282	0.417	-0.059	0.313	0.361	0.033	-0.003	0.049	0.050	0.167	0.063	-0.005	-0.070	0.055	0.047	0.017	0.047	0.073
Soil as a C/T Factor										1.000	0.442	0.415	0.325	0.371	-0.103	0.034	0.095	0.179	0.148	0.173	0.119	0.176	-0.088	-0.142	-0.043	0.184	0.186	0.134	0.204	0.153
LULC as a C/T Factor											1.000	0.675	0.412	0.516	-0.103	0.080	0.104	0.033	0.533	0.400	0.152	0.300	0.054	0.021	-0.123	0.152	0.167	0.188	0.153	0.129
Vegetation as a C/T Factor												1.000	0.405	0.506	-0.107	0.009	0.030	0.049	0.337	0.602	0.168	0.208	-0.031	-0.017	-0.172	0.181	0.169	0.180	0.209	0.129
As_a_CT_Factor_InfrustructuralDevepmnt													1.000	0.513	-0.179	0.179	0.143	0.070	0.208	0.140	0.405	0.238	-0.047	0.100	-0.203	-0.082	-0.016	-0.041	-0.004	-0.034
Population as a C/T Factor														1.000	-0.142	0.256	0.215	-0.012	0.226	0.236	0.238	0.597	0.063	0.034	-0.158	-0.054	0.005	0.019	-0.004	-0.061
Degree_Rainfall															1.000	0.269	0.275	0.251	0.169	0.131	0.140	0.031	0.033	0.042	-0.049	0.012	-0.008	0.081	0.087	0.052
Degree_Gradient																1.000	0.555	0.107	0.138	0.128	0.249	0.417	0.174	0.276	0.060	-0.204	-0.195	-0.194	-0.145	-0.185
Degree_Altitude																	1.000	0.273	0.291	0.176	0.231	0.336	0.196	0.140	0.113	-0.070	-0.073	-0.057	0.129	-0.034
Degree_Soil																		1.000	0.277	0.197	0.191	0.153	0.016	0.054	0.010	0.071	0.079	0.037	0.120	0.039
Degree_LULC																			1.000	0.666	0.402	0.398	0.226	0.222	0.020	-0.102	-0.085	-0.062	-0.050	-0.139
Degree_Vegetation																				1.000	0.444	0.431	0.182	0.181	-0.013	-0.062	-0.057	-0.047	-0.057	-0.139
Degree-infrDev																					1.000	0.558	0.216	0.390	0.010	-0.310	-0.235	-0.278	-0.223	-0.292
Degree_Population																						1.000	0.214	0.225	0.023	-0.205	-0.178	-0.177	-0.181	-0.316
Understand_DRM																							1.000	0.396	0.171	-0.316	-0.425	-0.377	-0.336	-0.367
Understand_IK																								1.000	0.138	-0.570	-0.641	-0.602	-0.546	-0.543
Govt_help																									1.000	-0.280	-0.291	-0.296	-0.167	-0.260
IK_in_LSDM_Prevention																										1.000	0.803	0.749	0.715	0.718
IK_in_LSDM_WarningAndPreparedness																											1.000	0.922	0.822	0.836
IK_in_LSDM_Mitigation																												1.000	0.800	0.819
IK_in_LSDM_ResponseRelief																													1.000	0.840
IK_in_LSDM_Reconstruction																														1.000

Plagiarism Checker X Originality Report

Similarity Found: 8%

Date: Saturday, July 09, 2022
Statistics: 4032 words Plagiarized / 50032 Total words
Remarks: Low Plagiarism Detected - Your Document needs Optional Improvement.

LANDSLIDE DISASTER RISKS MANAGEMENT IN MURANG'A COUNTY, KENYA: SCIENTIFIC AND INDIGENOUS KNOWLEDGE NEXUS
BY JOHN MAINA NJIRAINI