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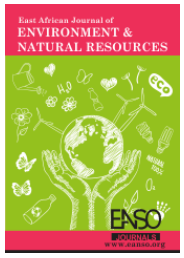

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Original Article

Scientific and Indigenous Knowledge Understanding of Rainfall Induced Landslides in Murang'a County, Kenya.

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Rainfall, Causal/Trigger Factor, Landslides, Scientific Knowledge, Indigenous Knowledge, Murang'a County.

ABSTRACT

The East African region has reported major landslides and Kenya is indeed characterised as a disaster-prone country. Landslides are a recognised but poorly studied phenomenon in the Eastern foot-slopes of the Aberdare Ranges in Central Kenya. A dearth of information about landslides has been cited in the country. Landslides in Murang'a County are known to occur especially during the two rainy seasons and has been recurring in the recent past. Such a scenario makes rainfall factor of interest in understanding the landslide occurrences. People living in landslides prone areas are said to have huge experiences and knowledge about landslides but have remained hugely unexploited. The adaptation and integration of both the scientific and indigenous knowledge may be an option to increase the understanding of landslide disaster risks in the prone areas. The aim of this study is to fill the existing gap in the understanding of the recurrent landslide disaster risks in Murang'a County through an investigation of the rainfall as a major causal/trigger factor as viewed through both indigenous and scientific understandings. Primary data were collected through household questionnaires administered to a total of 336 household heads, complemented with 8 Key Informants Interviews and 6 Focus Group Discussion interviews conducted across the study administrative locations. Quantitative data were analysed through descriptive and inferential statistics in the SPSS package. Secondary data obtained from remote sensing were quantitatively analysed using Raster-GIS in ArcGIS software. The study findings showed that Rainfall is a major factor in causing/triggering landslides in Murang'a County as understood by experts from among other institutions the meteorological department, where a rainfall threshold of 1,160mm mapped 99% of the

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March-April-May 2018 reported landslides in the 'high risk zones'. Rainfall factor had an approval rate 98% as being the most prominent landslide contributing factor as viewd by the indigenous people. In conclusion, both scientific and indigenous knowledge concur that rainfall is a major landslide causal/trigger factor in Murang'a County. The study recommends that since landslides are highly localized, an in-depth research on other causal/trigger factors using both scientific and indigenous knowledge should be done, especially in areas which have previously been affected by landslides. Such would give a better understanding of landslides in terms of the causal or trigger factors with the aim of enhancing the disasters management in the county and formulating a policy framework integrating the two levels of knowledge.

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INTRODUCTION

Landslide studies are available only in areas where development projects are to be initiated (Crozier & Glade, 2005). A noticeable geographical bias can be seen 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). The East African region has reported major landslides (Ngecu *et al.,* 2004) and Kenya is indeed characterised as a disaster-prone country (Republic of Kenya, 2010). 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 of billions of dollars loss (Wannous & Velasquez, 2017). Landslide disasters are not a new phenomenon in Kenya (Davies, 1996; Wahlstrand, 2015; Salome *et al*., 2004), yet a dearth of information about the same has been cited in the country (Davies, 1996; Wahlstrand, 2015; Zhou, *et al.,* 2020). 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 (Salome *et al.,* 2004) and deadly (Ngecu *et al.,* 2004). Landslides are a recognised but poorly studied phenomenon in the Eastern foot-slopes of the Aberdare Ranges in Central Kenya (Ngecu & Ichang'i, 1999).

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The disasters occur especially during the two rainy seasons (Wahlstrand, 2015) and have been recurring in the recent past (Salome *et al.,* 2004). The study area has unique, favourable characteristics for occurrences of landslide disasters (Kimani, 2020). Landslides are highly localised and occur in small geographical extents. They are caused or triggered by different factors as scientifically proven and documented. Generally, landslide disaster research has concentrated on the scientific understanding of landslides and their effects. Indigenous people are some of the main players in the disaster risk management continuum and are the ones affected in one way or another (Salome *et al.,* 2004). People living in landslide-prone areas have huge experiences with landslides but have remained hugely unexploited. Kenya's disaster management policy is silent on indigenous knowledge, one of the possible reasons for the exclusion being the fact that the knowledge is not documented and is characterised as informal (Antweiler, 1998). The adaptation and integration of both the scientific and indigenous knowledge may be an option to increase the understanding of landslide disaster risks in the prone areas of Murang'a County and could add value to disaster management. The aim of this study is to fill the existing research gap in understanding of the recurrent landslide disaster risks in Murang'a County through an investigation of knowledge of rainfall induced landslide in Murang'a County, Kenya

METHODOLOGY

The Study Area

The study area is located in Kenya, which is in the Eastern part of Africa, lying approximately between Eastings 34^{o} and 42^{o} and Northings 4^{o} 22' and -4^{0} 28'. 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 administrative units of are Murang'a East, Kahuro, Murang'a South, Gatanga, Kigumo, Kandara, Mathioya, Kangema (KNBS, 2019a). Administrative units Murang'a East, Kahuro and Kiharu are in Kiharu Subcounty, while Muragwa Sub- County is made up of Maragwa and Murang'a South administrative units.

Secondary Data on Landslide Inventories in Murang'a County

Data on the landslide inventories are 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 an upsurge, but MAM 2018 had the highest number of reported landslide cases within a single rainfall season i.e., March-April and May (MAM). Thus, the reason why the period is considered to be the reference for the study.

Secondary Data on Rainfall

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/about. 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 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)

Primary Data

Primary data for the study were sourced from Household (HH) questionnaires, six Focus Group Discussions (FGD) and eight Key Informants

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Interview (KII) schedules to get an in-depth understanding of the rainfall as a landslide causal/trigger factor in Murang'a County**.** KII has 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. FGDs participants were largely drawn from the local population regardless of their educational background or leadership status.

Research Design

Research design is important in any research as it gives an indication of the framework of data collection, analysis and priorities given to the research process (Bryman, 2016). The research adopted a cross-sectional survey that utilises the explanatory sequential mixed-method approach, 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 analysed, after which qualitative data was collected to help explain/clarify the results obtained from the quantitative data to get an in-depth understanding of the results. The quantitative data were obtained using questionnaire and from secondary sources from remote sensing sources and analysed through raster-GIS in both MCE and WLC for the scientific and IK understanding of rainfall factor respectively. 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 to a study about the role of traditional knowledge in sustainable land management in Western Kenya. The quantitative data were obtained from secondary sources from remote sensing sources and analysed through raster-GIS in both MCE and WLC for the scientific and IK understanding of rainfall factors, respectively.

Sampling

The study was carried out in nine purposively selected administrative locations across six sub-counties of Murang'a County based on March-April-May (MAM) 2018 landslide disasters inventories. The reference period is selected as it marks the rainfall season with the highest number of recorded landslide cases ever within a single rainy season in history. A total of 393 proportionate HHs were to be sampled in the study from a population of 30,247 as shown in Table 1 below. The sampling frame of the study is 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).

Table 1: Sample Size and proportionate sample Households (HH)

Sub-county	Location	Total Population	Total HHs	Proportionate HHs Sampled
Kangema	Kihoya	6,423	1,984	57
	Rwathia	7,417	2,261	51
Mathioya	Gitugi	7,682	2,308	50
	Kiru	10,381	3,266	37
Kiharu/Kahuro	Murarandia	11,880	3,714	33
Kigumo	Mariira	10,180	3,130	39
	Kinyona	7,911	2,440	48
Kandara	Kibage	16,913	4,870	26
Gatanga	Mbugiti	7,108	2,228	52
Total		**85,895**	**26,201**	**393**

Source: (KNBS, Volume II, 2019)

The final stage in establishing the respondents for the questionnaires was through a systematic sampling of the HHs in each of the selected administrative locations under study. The starting

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point for the sampling was a centrally-located HH as identified from the spatial distribution and positions of HHs on remote sensing images of each area. A centrally located HH with a previously reported landslide case was preferred, but where such a scenario was impossible, any central HH was picked. Subsequent HHs were selected radially in all directions from the starting point at an interval k^{th} number for each study location.

RESULTS AND DISCUSSIONS

Introduction

The first step in mapping and delineating the landslide disaster risk zones was to qualify rainfall as a causal/trigger factor as scientifically understood by the experts and existing literature. The factor was then assessed in conformity with the landslide cases reported in the base rainfall season of MAM 2018 when Murang'a County reported the highest number of landslide cases ever within one rainfall season.

Rainfall Factor as Understood in Science

The average annual rainfall for the county is 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 and others (2011), rainfall amounts higher than 1,160 mm would trigger or cause landslides in combination with other favourable conditions in an area. In their study titled, '*Rainfall induced landslide probability mapping for the Central Province,'* a rainfall threshold of 1,160 mm was used to discriminate zones of high and low landslide risks. The results had areas with rainfall amounts higher than 1,160 mm, 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 1,000 mm and 2,000 mm to represent *'high risks'* and amounts above 2,000 mm to represent '*extremely high risks'* in a study of *Nationwide Susceptibility Mapping of Landslides in Kenya Using the Fuzzy Analytic Hierarchy Process Model.*

To delineate the study area based on the rainfall factor, a threshold of 1,160 mm was executed in ArcGIS to map out regions of high and low landslide risks defined by the higher and lower rainfall amounts through GIS Boolean analysis. The results were compared with the MAM 2018 landslide cases from the inventory in which 99% of the reported landslide cases in the reference period fell within the zones mapped as 'high risk' and only 1% was in the low-risk zones, as shown in *Figure 1(a)* below. Therefore, rainfall as a causal/trigger factor was a perfect 'predictor' of the landslide susceptibility based on the MAM 2018 landslide cases as spatially mapped in *Figure 1(b).* Such is a clear demonstration that rainfall is a clear landslide causal/trigger factor and amounts beyond the threshold have contributed to landslide cases in the study area. The results were supported by the Murang'a County Director of Meteorological Services, who was explained that:

> *"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 lookout during the rainy season and never hesitate to give advisories to Murang'a people, especially when rainfalls. We do not 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!*

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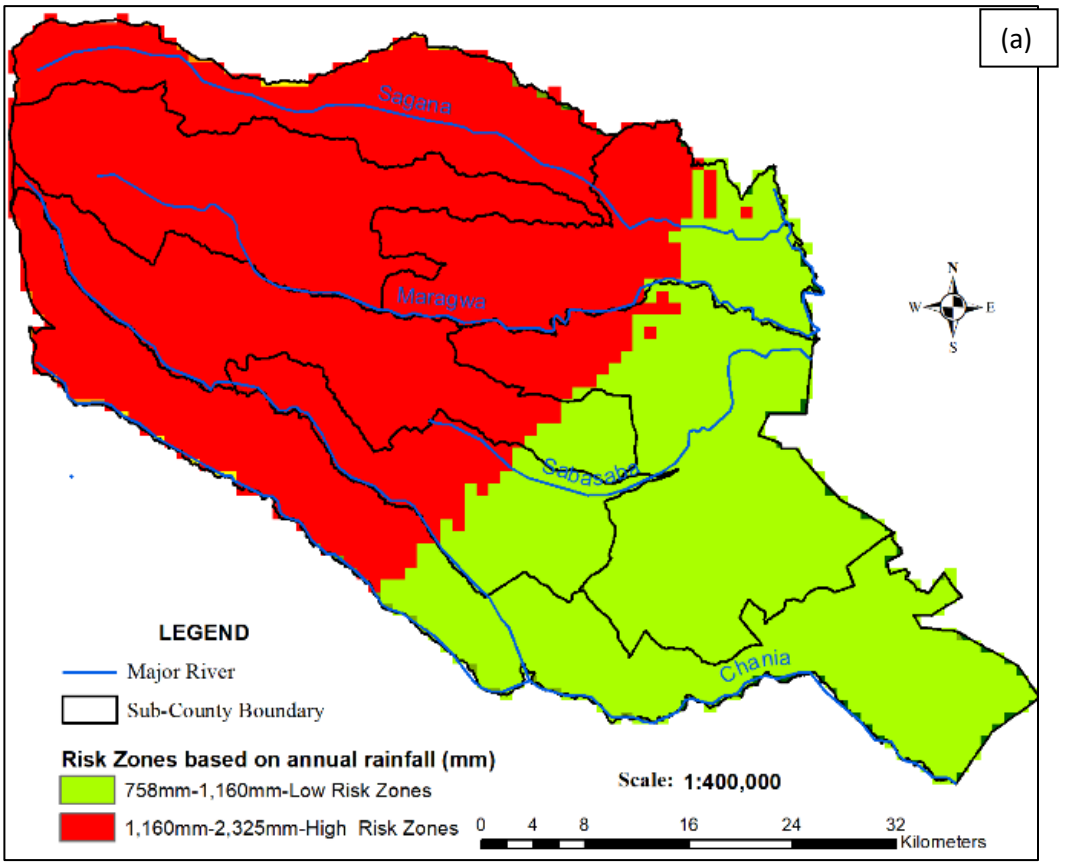
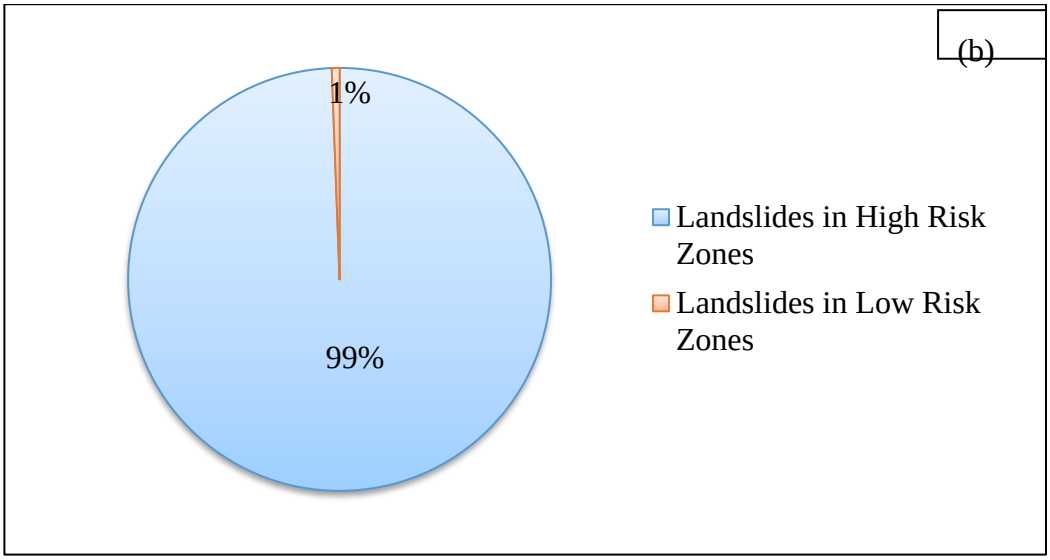
Figure 1: Mapped landslide risk zones in Murang'a County based on annual rainfall causal/trigger factor



(a) Classified and standardised annual rainfall delineated grid risk zones,



(b) MAM 2018 Reported Landslide cases distribution against the Rainfall Delineated Risk zones

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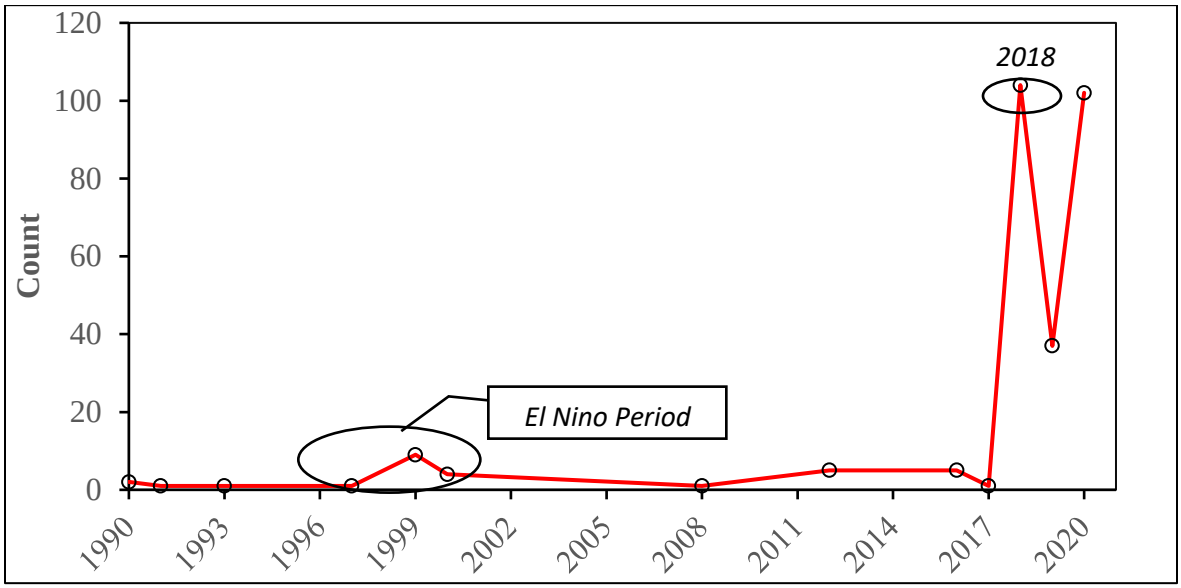
Further, secondary source from the Murang'a County Integrated Development Plan (CIDP), support that rainfall is a major causal/trigger factor particularly in the upper (northern) parts of Murang'a County have where high rainfall amounts are received. These areas are considered as rainfall catchment zones in the Aberdares Ranges (CIDP, 2018). Generally, Kenya is said to be 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). The question of high amounts of rainfall contributing to high landslide cases can also be demonstrated in the available data from the year 1990, as shown in *Figure 2.* The year 2018 had the lion-share of the reported landslide cases for the period with a total of 104 (31.0%) major landslide cases having been reported. Other than the year 2018, a notable strike in the reported landslide cases was in the year 1997 when the country experienced *El-Nino* rains.

Figure 2: The frequency of reported landslide occurrence (1990-2021)



KII-7 was also in support of rainfall being a major landslide causal/trigger factor in Murang'a County. He reported that landslide related information broadcasting and dissemination is escalated during the rainy seasons. In such times, weather, disaster, agriculture and other experts are invited to give advisories through Kangema-RANET FM, a local community-based radio station located in Kangema Sub-County and supported by KMD. Also in agreement was KII-8, drawn from the Kenya Red Cross, who reported that rainfall was a key trigger factor and that during the rainy season, the needs for landslide disaster response services are higher than any other time. In support of that, the KII-8 asserted the following:

> *"We are always alert during the rainy season and every garget is ready for operation to save lives and property from landslide disasters especially in the upper parts of Murang'a County"-KII-8*

Rainfall as landslide trigger factor as understood by the indigenous people

The local indigenous people, made up of those who were locally born and others who migrated into Murang'a County and have been and who have been residents for over ten years, reported that they were aware of what landslides are. An overwhelming 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. The big question was how much each

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factor contributes to a landslide event. A significant number of respondents (r = 0.806 at 0.01 level (2-tailed) described rainfall as a major causal/trigger factor. Also, during a FGD, an elderly female participant from Murarandia Location in Kiharu/Kahuro Sub-county asserted the following in describing how rainfall is considered to be the most dangerous landslide causal/trigger factor in her area:

> *"Kungiuira mbura utuku mugima nginya kiroko, tuikaraga na wasiwasi tondu nitumenyaga no hindi ciothe 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."*

CONCLUSIONS AND RECOMMENDATIONS

The MAM 2018 landslide inventories for Murang'a County were used as a reference base for the study, the reason being that March-April and May (MAM) 2018 had the highest number of ever reported landslide cases within a single rainfall season (Murang'a Meteorological Services, 2021). The mapping and delineation of landslide disaster risk zones based on the rainfall causal/trigger factor as scientifically understood showed that landslides were concentrated in the northern parts of the county, towards the Aberdare Ranges, as opposed to the lower southern parts. The former receives considerably high amounts of rainfall. In terms of the indigenous peoples' understanding of the landslide causal/trigger factors, 97.6% indicated that they were aware of the factors. Rainfall was rated the highest (97.9%) and was assigned the highest weight as a landslide causal/trigger factor. In conclusion, the study is timely and important based on the fact that landslides in Murang'a County are recurrent and with numerous effects on the local people. Based on both scientific and IK understanding, the study concludes that rainfall is a major landslide causal/trigger factor in Murang'a County. The integration of both knowledge is important for better integrated management of the landslide disasters through the inclusion of the local people, who are usually adversely aafected in case of a landslide occuerence. The study recommends that since landslides are highly localised, in-depth research on causal/trigger factors should be done, especially in areas that have previously been affected by landslides. Such would give a better understanding of landslides in terms of the causal or trigger factors with the aim of enhancing the disasters management in the county.

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Competing interests

No competing interests were declared.

Authors' Contributions

The corresponding authors designed the study, conducted the fieldwork statistical analysis and wrote the manuscript with close guidance from Prof. Paul Omondi and Dr. F. Okaka. All authors read and approved the final manuscript."

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