# The Nexus between Land Use Changes and Landslides Occurrences on the Slopes of Mt. Elgon, Bungoma County in Kenya

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**Abstract:**
Land use and land cover has been recognized throughout the world as one of the most important factors influencing landslides occurrence. Although many landslide episodes have been reported and observed on the slopes of Mount Elgon both in Uganda and Kenya, little literature exists describing the relationship between land use/land cover and landslide occurrences. The overall objective of the study was to establish the link between land use changes and landslide occurrence. The study adopted mixed method research design. The research used both primary and secondary data. Primary data was collected through interview schedules and questionnaires. Purposive sampling was used to select sites from the four wards for purposes of primary data collection and transect walk. Simple random sampling was used to select 381 households. Landsat satellite images for land cover change analysis was sourced from Regional Centre for Mapping of Resources for Development (RCMRD). Primary data which included quantitative data as analyzed using the statistical package for social scientist (SPSS) (version20). A linear regression model was run to get the predictor values between the variables. The results of this study revealed that; there is a positive link between land use changes characterized by agricultural practices, human activities, increased population, semi-urbanization and landslide occurrences in the Mt. Elgon region. On basis of the above findings, the study recommends that there is an urgent need by appropriate stakeholders from Government, both national and County, to restore forest cover on the deforested steep slopes and restrain the communities from encroaching on the pristine mid slopes of Mt Elgon.

*Keywords*: Land Use Changes, Landslide occurrences, human activities, agricultural practices

## 1.0 Introduction
Mountain ecosystems are continuously experiencing extensive land use changes due to natural and anthropogenic processes. These changes have been attributed to the increasing populations which have led to conversion of forest cover to farm lands and settlement areas. Unsustainable agricultural practices in these ecosystems have precipitated the forces of erosion which have opened the slopes making them susceptible to landslides. Landslides in the past have primarily been triggered by the removal of trees and other slope vegetation which subsequently weakened the anchorage holding the overburdens, (Omuterema, 2007). The occurrence of landslides leads to destruction of property and even loss of lives. To illustrate this, in Mt. Elgon, between 2008 and 2010, four massive landslides occurred that cumulatively killed approximately 24 people, injured many others and caused significant loss of property estimated at over 10 million Kenya Shillings

(Makuba, 2012). However, there exists a gap in literature as very scanty reviews have been done to ascertain the relationship between land use/land cover and landslide occurrence especially in Mt. Elgon Sub County in Kenya. Further the focus of many studies has not been on the noted relationship and an examination of best practices to help deal with the issue. This study sought to establish the extent to which landslides are influenced by land use/land cover changes of mountainous slopes. More specifically it sought to determine the link between land use changes and landslides occurrences.

### Hypothesis
$H_{01}$: There is no significant link between land use changes and landslides occurrences

## 2.0 Conceptual Framework
Two c models are used as they apply to the stud: the Pressure and release model /crunch model and the

Bohle et al vulnerability model.

## 2.1 Pressure and release model

As promoted by Blaikie et al. (1994), the Pressure and Release Model argues that this catastrophe (element at risk) happens when climate threats encounter fragile circumstances arising from pressure and the underlying cause. Thus, it sets out a sequence of steps that come together to create what is known as vulnerability progression. Vulnerability evolution starts with a number of what are considered root causes. The paradigm points out a number of more complex dynamic stresses in a country's culture, evolving from these. Finally, change leads to what are considered dangerous situations.

The model is applicable to the present study considering that the study's thesis is that human activity, agricultural malpractices, increased population and other risks characterize the land use changes which have in turn cause landslide occurrences. Basically, as already noted, a disaster occurs as a result of not only the potential hazards, but with them acting in combination with these vulnerabilities. But even more poignantly, the present study sought to highlight mitigation strategies that can help reduce landslide occurrences and this is a significant part of the pressure and release model.

## 2.2 Vulnerability model

The vulnerability model of Bohle et al (1994) suggests that dealing with climate fluctuations or potential climate change must be embedded in a complete understanding of the dynamic mechanisms and causes of present vulnerability and how it may improve over the next decades. In human ecology, extended rights and political economy, the social vulnerability model of food insecurity builds on explanations to map the risk of exposure to adverse shocks, the capacity to deal with disasters and the prospects for recovery. It also clearly argues that human behavior interacts with climatic situations to create precarious situations and emergencies for individuals and the natural environment.

This is part of the argument of the present study that argues that human activity, agricultural malpractices, increased population and other risks characterize the land use changes which have in turn cause landslide occurrences and thus makes it reliably applicable to the present study. Further, while the Pressure and Release Model argues that that disaster (element at risk) happen when climate hazards meet with vulnerable condition which results from pressure and underlying cause, the Bohle et al (1994)'s vulnerability model argues that coping with climatic variations or future climate change must be rooted in a full understanding of the complex structures and causes of present vulnerability, and how it may evolve over the coming decades. Consequently, the first model is more general while the second is specific to human and climactic elements as causative to climactic vulnerabilities.

## 3.0 RESEARCH METHODOLOGY
### 3.1 Study Area

The study locale was the slopes of Mount Elgon, Bungoma County in Kenya. It is geographically located between latitude 0° 48′, and 1° 30′ North and Longitudes 34° 22′ and 35° 10′ East 1.1183° N, 34.5250° E. Most of the caldera of its extinct volcano lies within Uganda, while large parts of the southern and eastern slopes of the massif lie within Kenya, (UWA, 2000).



***Figure 1: Map of Mt Elgon Sub County in Bungoma*** County. (RCMRD, 2018)
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### 3.2 Study population

The population of the sample analysis was obtained from a representative sample of Mount Elgon's landslide-prone divisions with a population of 172,377 with 28,731households, as seen in Table 3.2, engaged in agriculture as a socio-economic operation within the landslide-prone areas cited. They provided information from analyzed remotely sensed data to verify the changes found in the spatial patterns in land use.

**Table 1**: Sample study population.

| Division | Population | Households |
|---|---|---|
| Cheptais Division | 59039 | 9840 |
| Kaptama Division | 52144 | 8691 |
| Kopsiro Division | 33183 | 5531 |
| Kapsokwony Division | 28011 | 4669 |
| **Total** | **172,377** | **28,731** |

**Source**: Kenya National Bureau of Statistics, (KNBS 2009)

## 3.3 Research design

This study adopted both descriptive survey design and correlation research design. Descriptive survey design was appropriate as it allowed data to be collected from members of a population in order to determine the current status of a population with respect to one or more variables under study. Correlational design on the other hand allowed for a test of the relationship between land use changes as a result of natural and anthropogenic processes in the study area and their influence on the occurrence of landslides. The descriptive survey design also allowed for qualitative analysis of focus group discussions to answer the questions on mitigation.

## 3.4 Sample size and sampling strategies

The Number of villages from the Sub County were obtained from the Bungoma county office. Both non-probability and probability sampling approaches were used. The four divisions, Cheptais, Kaptama, Kopsiro and Kapsokwony were purposely selected due to their landslide prone status both directly and indirectly. Purposive sampling was used to select the four divisions because of the variation in the number of household units in the divisions. The house hold drawn.

The **Fishers formula** below was then used to estimate the sample size out of the 28,731 households.

$$n = \frac{z^2 \hat{p}(1-\hat{p})}{m^2}$$

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. no
Where:

**p** = expected prevalence of landslides in the prone areas

**m**=degree of precision or a tolerance error margin or width of the confidence interval (a measure precision of the estimate).

**z**= Z statistic for a level of confidence or the normal distribution critical value for a probability of a/2 in each tail.

For a 95% CI, z=1.96

For this study, the level of confidence was specified as 95%, an error margin of ±5% as being considered acceptable. A study done in Uganda between November 2009 and February 2010 found a prevalence of 46% of landslides in East Africa. Thus;

$$n = \frac{z^2 \hat{p}(1-\hat{p})}{m^2} = (1.96\text{x}1.96\text{x}0.46)$$

(1-0.46)/0.05²⁾=381

A sample size of 381 households was necessary to achieve the required sufficient households or the sample size needed to be 95% certain that the landslide prevalence (rate) found was within 5% of the true prevalence rate. Approximately 95 households were simple randomly selected from each of the four divisions totaling 381.

Purposive sampling was also used to pick other main informants, including Chairpersons and Executive Secretaries of sample villages, Village Environmental Management Committees (VEMCs), members of different social classes such as village leaders, women, youth, business people and NGOs available in the respective villages, and various extension workers (e.g. farmers, Fo, etc.). Similarly, one Participatory Rural Assessment (PRA) was carried out in each sample village to achieve a group summary of the research area.

## 3.5 Data Collection

The researcher used both primary and secondary data. Primary data was collected through KII, FGD and direct observation while secondary data included remotely sensed data and ancillary data (slopes, soils and vegetation). Remote sensing data and integration of image processing and spatial analysis functions in GIS and questionnaires were used. Remote sensing data and integration of image processing and spatial analysis functions in GIS were the main source of data collection and analysis tools. The Landsat satellite images from 1990 to 2018 of the study area were selected through purposive sampling method of the times when landslide did occur and focusing on the areas where it did occur. This information was obtained from the secondary sources of data obtained from the Regional Centre for Mapping and Development

## 3.6 Data analysis and presentation

Primary data obtained via the household survey was analyzed using the Social Sciences Methodological Kit (SPSS Version 20). It developed descriptive

statistics such as frequencies and percentages. A Pearson Moment Correlations analysis was run to get the relational values between the variables. Once data from the Landsat images of the area under study had been collected, spatial analysis of this data commenced and entailed two major techniques which were, spatial sampling and spatial correlation modeling. The analyzed data then was presented using Graphs, charts, plates and tables. Qualitative data from the interviews and FGDs was analyzed using narrative and thematic analyses.

## 4.0 Findings And Discussions
## 4.1 Trends in Land Slide Occurrences

Part of the data included pictures showing landslide occurances, a correlations analysis and qualitative data. Plates 1 to 4 indicate the pictorial evidence of landslides in the study area



Plate 1: Landslide which occurred in Kaptama division, Kipchiria in 2014



Plate 2: Landslide which occurred in June 2012 in Kipsiro is an example of a slide where hill steepness seems to have been an important factor.
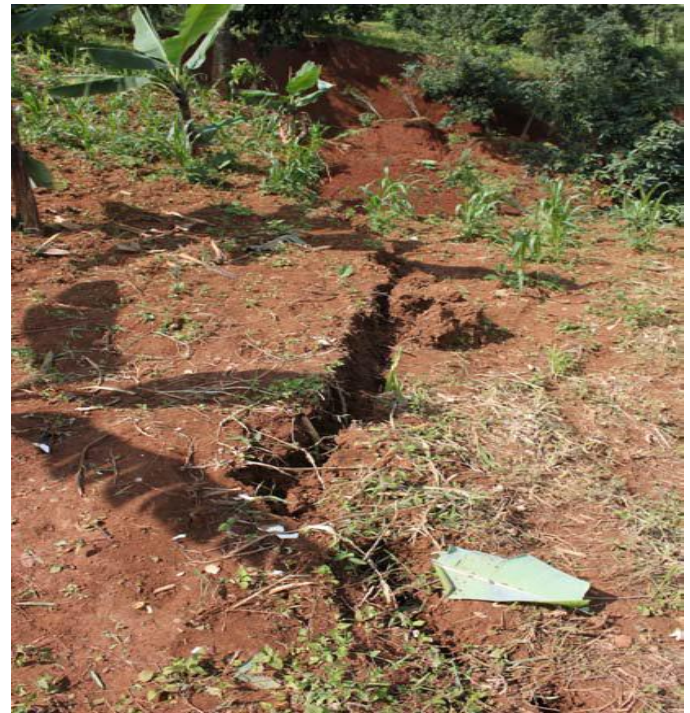


Plate 3: A crack in the soil like this one is a distinct early warning sign for landslides (source: Researcher's pictures taken on July 13th 2017)
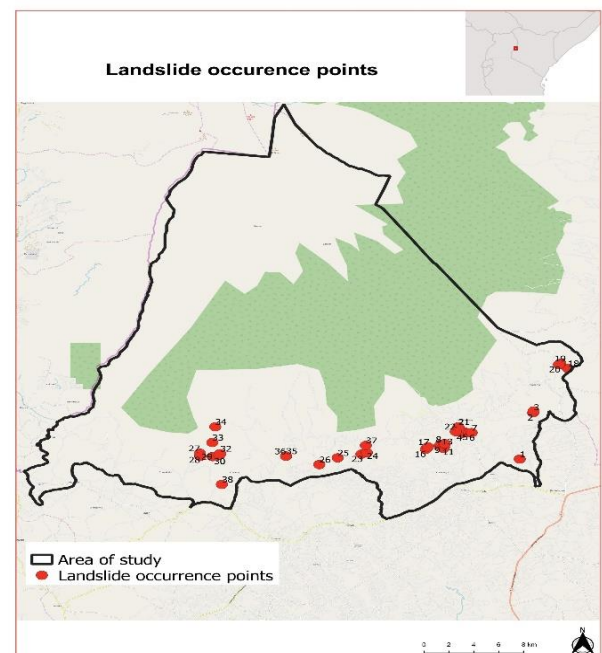


**Plate 4: Overlay map for past landslide sites in the study area**

From plate 4 above, the community during primary data collection identified the locations of where previous landslide incidences had occurred, however, they could not remember the actual dates of occurrence of the incidences. Therefore, to get the link between land use changes and landslide occurrences, information from Key Informants and from the focus group discussion was sought and

| | | Land slide Occurrences | Crop Land | Grassland | Forest Land |
|---|---|---|---|---|---|
| Landslide Occurrences | Pearson Correlation | 1 | | | |
| | Sig. (2-tailed) | | | | |
| | N | 92 | | | |
| Crop Land | Pearson Correlation | .667** | 1 | | |
| | Sig. (2-tailed) | .000 | | | |
| | N | 92 | 92 | | |
| Grassland | Pearson Correlation | .534** | 332** | 1 | |
| | Sig. (2-tailed) | .001 | .001 | | |
| | N | 92 | 92 | 92 | |
| Forest Land | Pearson Correlation | .732** | .005** | .205 | 1 |
| | Sig. (2-tailed) | .000 | .006 | .012 | |
| | N | 92 | 92 | 92 | 92 |

examined.

**Table 2. Trends of landslide Occurrences in Mt.Elgon, Kenya**

| Division | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|
| Cheptais | 12 | 9 | 13 | 7 | 18 | 17 |
| Kaptama | 18 | 23 | 14 | 16 | 21 | 19 |
| Kopsiro | 29 | 34 | 46 | 33 | 31 | 32 |
| Kapsokwo | 19 | 7 | 5 | 13 | 19 | 21 |

| ny | | | | | | |
|---|---|---|---|---|---|---|
| **Total** | **78** | **73** | **78** | **69** | **86** | **89** |

**4.2 Correlational Analysis to link land changes and landslide occurrences**

Pearson's Correlation analysis was computed, analyzed, presented and interpreted for Mount Elgon, Kenya and the results presented in table 3

**Table 3 Correlational Analysis between land use changes and Landslide occurrences**

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

Wong and Hiew (2005) in their seminal thesis concisely asserted that the correlation coefficient value was bounded within certain limits which are: a score of 0.10 to 0.29 should be viewed as weak, 0.30 to 0.49 should be viewed as medium and lastly 0.50 to 1.0 should be viewed as pointedly strong. Nonetheless, Field (2005) in expanding the Wong and Hiew assertion noted further that the figure should not read 0.8 and above as that would create a multicollinearity problem. Consequently, in the present thesis the highest computed correlation coefficient is 0.732 which is below 0.8 creates no multicollinearity problem.

From table 3, all the independent variables (crop land changes, grassland changes, and forest land changes) had a positive relationship with landslide occurrences in Mt. Elgon. Forest land changes posted the highest correlation (r=0.732, p< 0.00), followed by crop land at (r=0.667, p< 0.00) and finally grassland posted the least correlation with landslide occurrence in Mt. Elgon (r=0.534, p< 0.01). This implied that crop land changes, grassland changes, and forest land changes have a positive relationship with landslide occurrence and thus land use changes have a positive relationship with landslide occurrence to the extent that continued changes led to more landslide occurrences.

**4.3 Test of Hypothesis**
**Regression Analysis**

Since the measures that are used to assess the primary constructs in the model are quantitative scales, regression analysis can be used to achieve this end. Regression analyses are a set of techniques that can enable us to assess the ability of an independent

variable(s) to predict the dependent variable(s). As part of the analysis, Regression Analysis was done. The results are as seen on Table 4, 5 and 6

**Table 4 Model Summary**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .862[a] | .737 | .631 | .106 |

a. Predictors: (Constant), Land Use Changes

b. Dependent Variable: landslide occurrence

From table 5.3 it is clear that the R value was .862 showing a positive direction of R is the correlation between the observed and predicted values of the dependent variable. The values of R range from -1 to 1 (Wong and Hiew, 2005). The sign of R indicates the direction of the relationship (positive or negative). The absolute value of R indicates the strength, with larger absolute values indicating stronger relationships. Thus, the R value at .862 shows a stronger relationship between observed and predicted values in a positive direction. The coefficient of determination $R^2$ value was 0.631. This shows that 63.1 per cent of the variance in dependent variable (landslide occurrence) was explained and predicted by independent variables (Land Use Changes)

**Table 5 ANOVA[b]**

| Model | Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| 1 Regression | 202.700 | 4 | 47.046 | 98.391 | .000[a] |
| Residual | 12.788 | 228 | .663 | | |
| Total | 215.488 | 232 | | | |

a. Predictors: (Constant), Land Use Changes

b. Dependent Variable: Landslide Occurrence

The F-statistics produced (F = 98.391.) was significant at 5 per cent level (Sig. F< 0.05), thus confirming the fitness of the model and therefore, there is statistically significant relationship between Land Use Changes and Landslide Occurrence.

**Table 6 Coefficients**

| Model | Unstandardized Coefficients B | Std. Error | Standardized Coefficients Beta | T | Sig. |
|---|---|---|---|---|---|
| 1 (Constant) | 2.667 | .361 | .287 | 5.668 | .000 |
| Land use changes | .375 | .078 | .383 | 4.968 | .000 |
| Trends of landslide occurrence | .309 | .064 | .362 | 4.129 | .000 |

a. Dependent Variable: landslide occurrence

The t-value of constant produced (t = 5.668) was significant at .000 per cent level (Sig. F< 0.05), thus confirming the fitness of the model. Therefore, there is statistically significant relationship between Land Use Changes and Landslide Occurrences Thus:

**Table 7 Hypotheses Testing**

| Hypothesis | Regression Results | Comments |
|---|---|---|
| H01: There is no significant land use change in the last 28 years between 1990 & 2018. | $\beta_1 = .383$ p<0.01 | Rejected |
| H02 Land use change has no influence on the occurrence of landslides. | $\beta_2 = .362$ p<0.01 | Rejected |

This is supported by key informant and focus group discussions. One Key Informant, a village elder from Cheptais who had lived in the area for 69 years noted when asked if land use changes had a link with landslide occurrences. He succinctly mentioned that:

> *Yes, as soon as people began to increase and people began to cut down trees, the landslides also increased and it thus does not take a genius to know that one led to another, in other words, land use changes, particularly deforestation, led to increase in landslide occurrences (VEC, KI1, 2017).*

The idea behind deforestation being a significant land use change that caused landslide occurrences in Mt Elgon was supported by the Village Elder from Kapsokwony area that had seen the most significant increases in landslide occurrences in the whole region. The elder who had lived in the region for 64 years observed that:

> As soon as we began to cut trees, landslides also began to occur more frequently. Of course we needed trees to build houses and shops for our livelihoods and so I am not sure if we did the wrong thing because if we had not we would have remained poor (VEKy, KI4, 2017).

The response from the village elder from Kapsokwony gives the impression that while he admits that deforestation caused landslide occurrences in the region, he also admits that that was inevitable occasioned by their need for livelihoods and even wealth. This also implies that deforestation is linked to human livelihoods and both have detrimental effects on the environment which in this case means increased landslide occurrences.

Further, the link between land use changes and landslide occurrences was attested to by the FGD done in Kopsiro which in 2016 had seen the highest number of landslides at 512 more than the other areas in the region. From the FGD it was clear that there was consensus as to the link between human activity and landslide occurrences. In fact, one of the active respondents from the FGD noted that:

> Of course we admit that our efforts on land characterized by deforestation, agricultural malpractices and increased population leading to using land to build houses are the main reasons for landslides occurrences. However, honestly, what were we to do? We needed to live (FGD, Kopsiro, 2017).

This is a strong admission that human activity is one of the strongest precipitates to land use changes and consequently strongest influencer of landslide occurrences. There were others who however blamed landslide occurrences to rainfall which according to them was beyond their control while others blamed it on cultural beliefs.

One of those who blamed it on rainfall was from Kopsiro and a member of the FGD and who succinctly asserted that:

> Landslide occurrences often happen after a huge rainfall and to thus blame us and our activities is wrong. Only God brings rainfall not men (FGD, Kopsiro, 2017)

The one who blamed it on curses and other culturally inclined issues was from Kaptama and who noted that:

> Based on the killings and criminality that the region has experienced, landslides are the god's way of telling us that they are displeased and we need to change our ways. All this science talks about how human activity, agricultural practices and deforestation are the cause of landslides is false because all these practices happen in almost all places in Kenya but they do not see any landslides. It is the gods (FGD, Kaptama, 2017).

It should be noted however, that while the cultural belief angle was mentioned, it was not the predominant discourse. The predominant discourse was settled on human activities that led to deforestation, agricultural malpractices, reduction of vegetation cover and rainfall variability. This is illustratively so because some of the inhabitants who had stayed there's for a long period and who had had some education and training on how to mitigate against it mentioned the fact that when they planted trees in some piloted region, the landslide occurrences in that place drastically reduced. In fact, a thought leader from Kapsokwony through an interview noted that:

> After some training from the meteorological department came here and taught some of us about how to reduce landslides, I planted trees in about 3 acres of my land where landslides were very common. After about 7 years, the landslides kept reducing in that place while where there were no trees, landslides kept increasing. This means that yes; the cause of landslides is land use changes (TLKy, KI2, 2017).

The assertions above were considerably agreed to by many informants who were interviewed and even mentioned in the FGDs done. What was of vital concern however was the lack of knowledge about how rainfall was precipitated with many thinking that rainfall had got nothing to do with human activity and as such it was purely a natural non-precipitated action by God.

The results above show that clearly land use changes have a positive correlation and direct influence on landslide occurrences. This is consistent with important literature, such as Reichenbach et al (2014) in Italy, which showed that susceptibility maps indicate an improvement in the percentage of the area and the number of slope units identified as unstable in relation to the rise in bare soils to the drawback of forested areas. In addition, recent research focusing on the influence of changes in human-induced land use on slope stability in Norway, the Netherlands and Venice have shown that the effects of humans on the climate in settled regions contributes greatly to the initiation and reactivation of landslides (e.g., Vanacker et al. 2013; Meusburger and Alewell 2008; Van Den Eeckhaut et al. 2009; Bruschi et al. 2013).It is well recognized that various forms of land use can influence the stability of slopes and, in particular, vegetation improves slope stability in terms of mechanical and hydrological characteristics (Greenway 1987). In Enshi (China), Yi et al. (2010) presented a case study where human activity and cultivated areas (primarily dry land, rice field, and terrace) play an important role in speeding slope weathering and processes of instability. Glade (2013) identified examples from various parts of New Zealand that, after land use modifications, suggest improvements in sediment-generating processes. Landslides added greatly to sedimentation sequences in deposition basins following erosion, such as streams, swamps, estuaries, tidal wetlands, and continental platforms in the near shore and offshore zones.

In Africa, studies have also shown some important impact of changes in land use on landslide cases. In Equatorial Guinea, a report by Kervyn et al (2015) highlighted the widespread occurrence of LS in 4 representative study areas considered to be seriously impaired in Uganda (Mount Elgon, Mount Rwenzori) and Cameroon by rainfall-triggered LS (Limbe and Bamenda urban regions). The results demonstrate local stakeholders' strong knowledge of factors controlling the timing and spatial spread of these activities. A wide range of direct, but also far-reaching, indirect and intangible combined impacts of land use changes on landslides are defined by stakeholders in Kenya, Owiti (2018) sought to examine the effect of landslide occurrences in Elgeyo Marakwet County on land use changes. The research showed that from the 1960s there were profound changes in land use in the region due to widespread and incessant human activities and increased settlement that placed strain on land and triggered landslides.

## Conclusion

The study concludes that Land use changes characterized by changes in crop, forest and grassland increased landslide occurrences. The correlational analysis between Land use changes and landslides occurrence and further, from the FGDs and the Key Informants Interviews, there is significant consensus as to the positive link between land use changes characterized by agricultural practices, human activities, increased population, semi-urbanization and landslide occurrences in the Mt. Elgon region.

## Recommendation

Appropriate stakeholders should implement expansion and agricultural initiatives aimed at supporting agroforestry and increasing consciousness within farming communities of the risks of using slash and burn as an agricultural technique. However, on the emerging risks like industrial changes that create emissions, the national government should devise proper policies that would curb the use of carbon fuels which affect the composition of the land and inevitably then leads to massive landslide occurrences. Further the government should devise policies that determine the distinct acreage of land to be put under agriculture and in what format to reduce landslide occurrences.

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