

ASSESSMENT OF LANDSLIDE HAZARD VULNERABILITY-CASE STUDY OF AREAS AROUND SOCHE HILL, IN BLANTYRE CITY, SOUTHERN MALAWI

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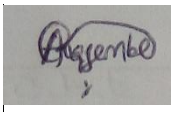
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19 July, 2021

DECLARATION

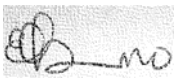
I Anthony Kazembe declare that this research project represents my own work and that it has never been submitted to this institution or any other institution for any academic purpose. All sources of information have been appropriately acknowledged.

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ABSTRACT

The study was conducted in areas surrounding Soche Hill in Blantyre city. The area was chosen for the purpose of this study since it has been experiencing several landslide events though most of them were not recorded. In addition, there has been increased urbanization due to population growth thereby people expanding their settlements to unstable parts of the hill increasing their level of vulnerability. A total of 20 buildings surrounding this hill were purposively sampled and using a checklist that was developed stating the building characteristics, it was possible to categorize the buildings into three vulnerability levels; high, medium, and low vulnerability levels after further analysis. From this study, it was found that 14 buildings are more vulnerable, 6 buildings have medium vulnerability and no building is less vulnerable. Finally, a vulnerability map of the area was produced using ArcGIS 10.5 that will assist Blantyre City council to take proper mitigation measures like land use zonation and thereby encouraging those who are settling in this hazard zone constructing strong buildings that can withstand any future landslide events.

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ACRONYMS/ABBREVIATIONS

DEM Digital Elevation Model

DoDMA Department of Disaster Management Affairs

DRMP Disaster Risk Management Plan

GPS Global Positioning System

MVAC Malawi Vulnerability Assessment Committee

NRA National Roads Authority

NSO National Statistical Office

RRO Disaster Relief and Rehabilitation Officer

USGS United States Geological Survey

VCPC Village Civil Protection Committee

VDC Village Development Committee

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1. INTRODUCTION

1.1 Background

Landslide is a term used to describe a wide range of processes responsible for the downward and outward movement of slope forming material composed of rock, soil, artificial fills or a combination of all these down a slope (Huabin et al., 2005). They occur under the direct influence of gravity and does not require transporting medium such as wind, water or glacial. Further, there are different forms of landslides with the common ones being falling, toppling, sliding, spreading and flowing. This classification is based on the type of material involved, the kind of motion displayed and the velocity/speed of the movement (Lutgens, 2006).

Landslides are some of the catastrophic and disastrous phenomena of geological origin that may cause immeasurable damage to life, environment and property. For example, the Department of Disaster Management Affairs (DoDMA) reported that on 22 April, 2019 in Rumphi district, landslides killed three people, leaving five missing and many injured. In addition, the National Roads Authority (NRA) reported one of the events that occurred on 5 February, 2020 at Mbuta Mountain in Rumphi and destructed M1 road between Karonga and Mzuzu. This was due to earth flows, rock falls and debris flows after heavy rains, from the mountain downward into the road causing heaving and breaking the road surface (Times Malawi, 2020).

However, vulnerability to a hazard means the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard. Vulnerability is categorized into four namely physical, social, economic and political. However, this study focuses on physical vulnerability particularly of buildings to landslide hazards. Physical vulnerability to land sliding depends on volume of material, velocity of sliding and nature of the elements at risk including buildings and other infrastructure. In Malawi, vulnerability to landslides is very high due to a number of factors. Now compared to the past years many people are

concentrated around the two major cities of Lilongwe and Blantyre and often inhabit in hilly areas that may be likely to experience landslides. Due to high levels of poverty and increasing urbanization, a large percentage of Malawians is forced to build their homes and other important infrastructure in marginalized lands. These areas may have high probability of being affected by a wide range of geotechnical hazards including landslides. For instance, people in urban areas are forced to live on hills and steep slopes that are prone to landslides. They do this even though they have no or low coping capacity to such events, subjecting themselves vulnerable to the hazard (Collins, 2009).

This study will provide a dataset of vulnerability levels of people in Blantyre to landslide hazard, which may then be helpful to town planners to take important mitigation measures against this hazard.

1.2 Problem statement

Landslides may lead to a significant number of losses and damages that hinder socio-economic development of Malawi. In developing countries like in this case Malawi, societal and economic problems are often so large and serious that little attention is given to the negative effects of natural hazards in general, and they fail to address vulnerability of their citizens to natural hazards like landslides. Although the government of Malawi has been making different interventions and policies in order to mitigate the impacts of these events but with continued rapid population growth and urbanisation in our cities, there is still threat to landslides occurrence. It is so since people in the cities are building their infrastructure on hills and unstable slopes and most often without building codes and proper planning exposing themselves to landslide hazards. In addition, there is lack of complete datasets on the areas that have high risk of being affected (susceptibility) by landslides to both town planners and the government thereby no serious planning of settlements is done in the cities of Malawi that may increase exposure to the threat of landslides. For instance, in some locations of the Blantyre city like Machinjiri and Soche, people are expanding these locations to the point of inhabiting on the steep slopes of the

hills. With this poor planning, in the years to come there might be serious sliding in these locations that in the end will results in serious disruption of their assets including life. For example, the Disaster Risk Management (DRMP) plan for Blantyre district council for 2019-2023, only focuses on floods, just because they have been causing damages leaving out landslide events as they do not cause any damages (Blantyre District Council, 2019). Therefore, without proper consideration on these events and ignoring their occurrence, the risk to landslides in the city will be exacerbated thereby increasing vulnerability of buildings to future events.This study focused on the areas around Soche hill which are at risk of being affected by landslide hazards that the hill experiences. It is so since people are expanding their settlements to the steep slopes of the hill thereby increasing their risk. With all this, there is need to conduct assessment on the vulnerability of such locations and then provide suggested mitigation measures that might limit or reduce the risk and vulnerability to landslides. The availability of such data will be very essential to both town planners and the local people.

1.3 Research objectives

The overall aim of this study was to assess physical vulnerability of buildings in areas around Soche hill to landslide hazards.

1.3.1 Specific Objectives

- Map the buildings as elements at risk to landslide hazards in areas around Soche hill
- Assessing the vulnerability of the mapped elements to landslide hazard

1.4 Research questions

- What are the elements at risk are in areas around Soche Hill?
- To what extent are buildings vulnerable to landslide hazard in areas around Soche Hill?

1.5 Significance of the Study

With rapid population growth, high poverty levels and increasing urbanization, it is very clear that many Malawians will still be forced to live in landslide prone areas (unstable slopes) despite low coping capacities they have to such events. Therefore, carrying out vulnerability assessment and thereby producing vulnerability maps will help to limit expansion of settlements to unsafe zones or if they still inhabit those high-risk zones, they will be able to take appropriate mitigation measures thereby increasing their coping capacity. In addition, the results of this activity will contribute to the country's sustainable development and attainment to the goal number 7 of the Sendai Framework for Disaster Risk Reduction 2015-2030 which focuses to substantially increase the availability of and access to multi-hazard information and assessment to people by 2030 (UN,2015a).

2.0 LITERATURE REVIEW

2.1 General overview on the importance of carrying physical vulnerability assessment

Many nations worldwide are now interested in landslide hazard assessment due to increasing awareness of the socio-economic significance or impact of landslides, and increased pressure of the development and urbanisation on the environment (Huabin *et al.*, 2005). Development increase on sloping urban areas leads to high risk of slope instabilities and occurrence of landslides. In Malawi, we have very little literature concerning these studies though the country has so far been affected by such events. Though we have the Department of Disaster Management Affairs (DoDMA) which has the overall mandate to coordinate and carry out all the disaster risk reduction activities including landslide vulnerability, it is very unfortunate that there are no papers on this (Groen and Jacobs, 2012). In addition, many researchers are only interested in hazard mapping and assessments of other hazards like in this case the Malawi Vulnerability Assessment Committee (MVAC), which put much emphasis in carrying out hunger vulnerability assessments.

According to Lutgens (2006) landslides may be triggered either naturally or by the influence of human activities. Some of the major landslide triggering mechanisms are weakening of rock and soil slope properties through water saturation by heavy rains; stresses, strains and excess of pore pressures induced by inertial forces during an earthquake; volcanic eruption with the production of loose ash deposits that may become debris (lahars) during heavy rains; and changes of natural topography caused by human activities.

According to Fell et al. (2005) natural sciences focus on physical vulnerability, which quantitatively describes the degree or probability of tangible damage, injuries, or deaths on a scale from zero (none) to one (complete). As such, physical vulnerability is a fundamental component of risk and vulnerability analysis.

2.2 The spatial vulnerability to landslides

Groen and Jacobs (2012) explains that some regions of Malawi are at a high risk of being affected with landslides more especially after heavy rains. In particular, Shire region areas belonging to the south and central-western coastal of Lake Malawi are much vulnerable. It is then generalized that the risk to landslide hazards in Malawi is absolutely low though many Malawians are vulnerable.

Landslides may have very significant impacts on buildings and are very expensive in terms of the cost for reconstruction, rehabilitation and ongoing maintenance for recovery. It is very unfortunate that the impacts of landslide hazards are underestimated as they usually occur in connection with such other hazards like floods, earthquakes and volcanic eruptions (USGS, 2001). Whilst Helmer and Hilhorst (2006) presents another issue of climate change as the driving factor for an increase in landslide hazards. This then calls that disaster risk management should encompass reduction of vulnerability to such events through enhancing capacity and resilience. Apart from just considering climate change and other environmental causes, there should also be the integration of build and human environments. This is very essential to robust disaster risk management as it aids understanding of vulnerability thereby coming up with proper mitigation and preparedness measures that may be designed to reduce loss of life and economic costs in Malawi.

2.3 Existing methods for landslide vulnerability assessment

For physical vulnerability, the elements at risk include roads, vehicles on the road and their frequency, land use, agriculture and forest land, buildings and other structures, their nature and proximity to landslides; persons, their proximity to slide, nature of the building and where they are (Das, 2011). However, there is no unique method for assessing landslide vulnerability due to complex nature of temporal variability of the elements at risk (Roberds, 2005; Birkmann, 2007). In addition, vulnerability is very dynamic as such many researchers opt for using temporal and spatial methods for

assessing landslides vulnerability (Galli and Guzzetti, 2007). In summary spatial-temporal vulnerability assessment to landslides is more challenging. Looking at the complexity in nature of vulnerability, it is better to consider the physical elements in order to address landslide vulnerability.

Many researchers carry out physical vulnerability assessment actually on the vulnerability of the buildings to landslide hazards. They use characteristics of the building including its surrounding to develop a risk and vulnerability database for the area under study (Papathoma-Kohle *et al.*, 2007). Some of the factors that are useful for this study are material and age of the buildings, existence of surrounding wall, existence of large windows toward the mountain slope and number of floors. The data collected for each building can be divided into three categories: (1) quantitative (population, population density, number of households); (2) qualitative (condition, building surroundings, etc.) and (3) descriptive (e.g., building use). The data that is used in the weighted linear combination are the quantitative ones. Standardisation is the method used in order to rescale the data to a common numerical basis by simple linear transformation (Voogd, 1983). In this study the standardisation method used is the transformation to raw data to scores from 0 to 1 by using the following formula:
Standardized score I = raw score I/maximum raw score (Voogd, 1983).....equation 1

Van Westen (2004) tries to bring an improvement to this by bringing criteria that can aid data collection at local and regional scales. It can be observed that in most cases it is convenient to consider more aggregated levels in the form of homogeneous units. These should consist of groups of buildings, characterized by a relative homogeneity of building type, construction materials, number of floors and land use distribution. He then proposes that in order to quantify the landslide effect on the exposed element (mainly structures and infrastructures), proper intensity parameters should be used as a link between the phenomenon and the response of the exposed element to it.

2.4 The analysis methods

Other researchers analyze physical vulnerability to landslide hazards using vulnerability curves. Vulnerability curves are functions relating to the degree of loss, of a specific element, to a specific hazard intensity(Orr, 2019). However, the problem with using vulnerability curves is that they require a significant amount of information about structural typologies and impact intensity which often is not detailed well in post-event damage assessments. Traditionally, historical data and numerical simulations integrate into vulnerability curves using height, velocity, and impact pressure (Quan Luna et al., 2011); however, as already said input data to derive vulnerability is scarce and vague about building states before damage.

In this work done by Voogd (1983), weighting of the factors that were previously given scores based on the categories was done. Finally, the vulnerability of each building in the inundation zone was calculated using this formula.

$V_b = (5 \times a) + (4 \times b) + (3 \times c) + (2 \times d)$ .....equation 2

Where *a*, *b*, *c*, *d*, *e* the standardised scores that are:

a: related to the material of the building

b: related to the surroundings of the building

c: related to the description of the building's side facing the slope

d: related to the number of floors of the building

Therefore, this has proved to be the most improved way of assessing vulnerability of buildings to landslides as it incorporates mapping homogeneous units.

3.0 METHODOLOGY

3.1 Study area

Blantyre city is located at 15°47'06''S and 35°00'30''E in the southern region of Malawi. The city covers an area of 220 square kilometers, has a population of 800,264 people and has the highest population density in the country. The district has annual population growth of 2.0% with a population density of 3587 (NSO, 2018). Soche Hill has an elevation of 5000ft and lies on 15°50'25.38"S and 35°01'22.67"E and is surrounded by areas like Chilobwe, Chimwankhunda and Kapeni.

Blantyre district lies 1024m above sea level. Its climate is mild and generally warm and temperate. The average temperature is 20.7°C and about 1086mm of precipitation falls annually. Areas around Soche hill are susceptible to landslide hazards due to landslide events that occur in Soche hill and also people in the areas are constructing their houses on the slopes of the hill increasing their exposure to such events. Therefore, this explains why these areas were chosen to be the study area. The figure below shows the map of the study area.

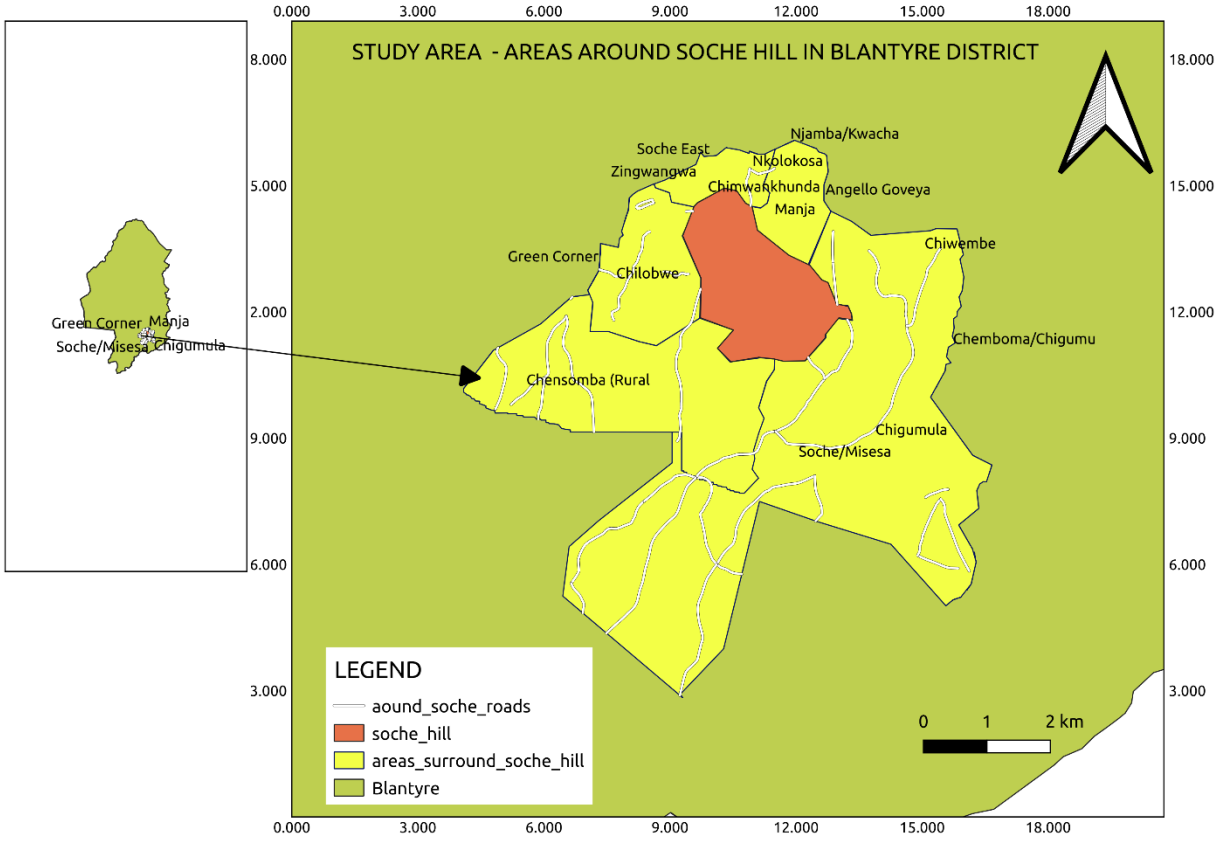


Figure 1 map showing the study area

3.2 Research design

The study involved a combination of both qualitative and quantitative methods. On part of the quantitative method, estimates of numerical values or scores of building characteristics were used, while the qualitative part was used to describe ranks of vulnerability levels such as high, moderate and low.

The following figure shows the methodology flow chart.

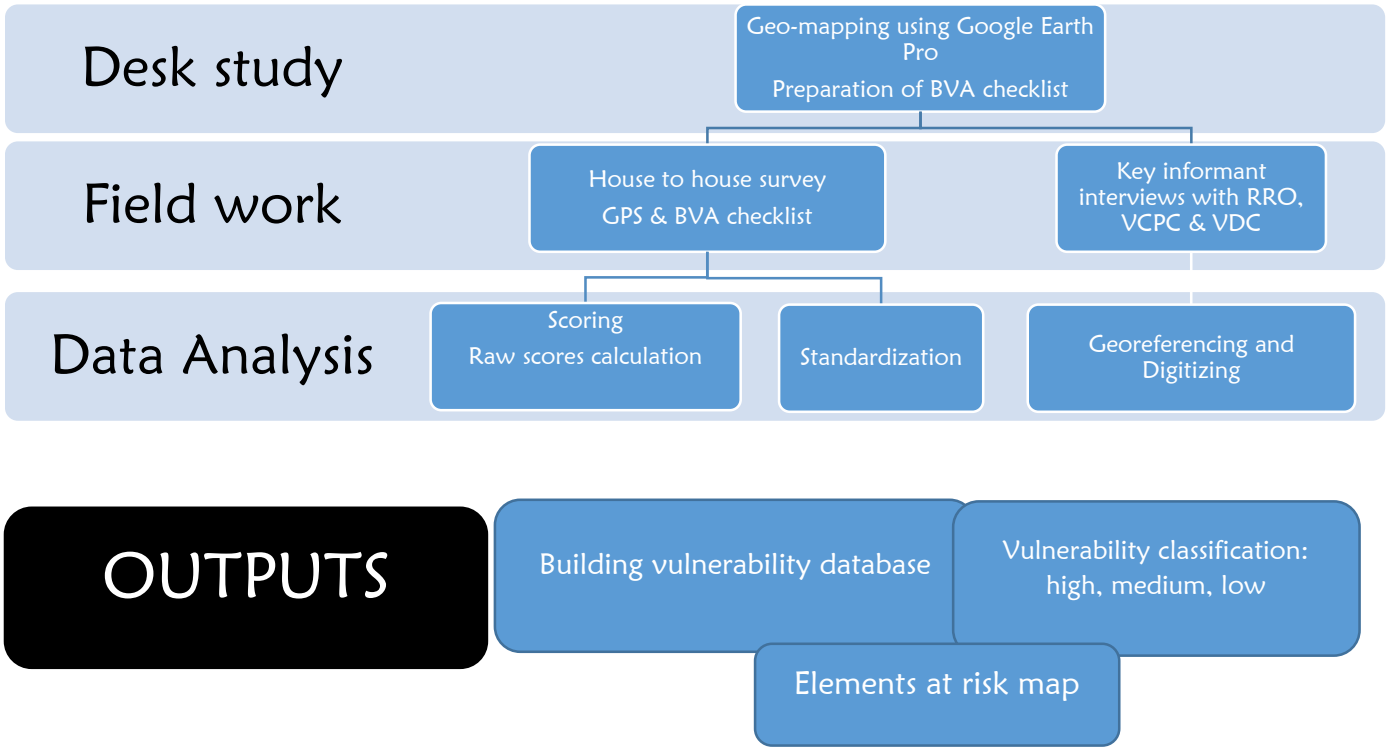


Figure 2 showing the methodology flow chart

3.3 ASSESSING THE VULNERABILITY OF THE BUILDINGS AS ELEMENTS AT RISK TO LANDSLIDE HAZARDS IN AREAS AROUND SOCHE HILL

3.3.1 Desk study

In this study, 20 houses were purposively sampled from the areas surrounding Soche hill; Somba village to the South, Chimwankhunda to the East and Chilobwe township to the North-West. 20 sample houses were chosen for this study since there was no dataset for the number of houses in this area which in this case was supposed to be provided by Blantyre district council. As such it was difficult to calculate the required sample size

where there is no house population data. In addition, though the area has a high density of houses, it was reasonable to select few buildings that would be physically visited to assess some of the characteristics that could not be assessed in a GIS environment. This was done to catch up with the limited time that was allocated to conduct this study and for the accuracy of the results. Only houses that are close to Soche hill were selected for this study since their proximity to the hill which has been experiencing some landslide hazards, increases the risk. Using satellite image from Google Earth Pro, general information like the geographical location (coordinates) of the buildings, was recorded. In this exercise apart from the coordinates, the elevation of the position at which each building stands was also recorded. This was done to facilitate fieldwork that is to say, instead of going in the field to physically sample the buildings which could be tiresome and time-consuming, the selected buildings were easily reached as the basic information was already in hand. However, it was also possible to determine the roof of the buildings as the satellite image was able to show the roofs of the buildings. This was done to ease the work that was required to be done to collect such data on the buildings in the field.

3.3.2 House to house survey

This was carried out to identify parameters that might help in determining the vulnerability of houses to landslide hazards and relevant data was collected to create a GIS database. This was carried out since the local authority and the district council does not have data on the characteristics of the buildings. Global Positioning System (GPS) was used to locate buildings using the recorded coordinates that was done as this was done in the desk study using Google Earth Pro. Then, each building was given a code (building ID) and using a checklist that was developed, information of each building was collected based on the type of building/construction materials, surrounding walls, age, roof type and foundation depth. The type of construction materials, in this case, depicts such basic

construction materials that determine how strong the building can be more especially concrete, cement and mudbricks. For surrounding walls, the type of construction material, thus cement and mud that was used helped to decide if the building can resist damage from landslides occurrence. The number of years the building has been there also helped to determine its resilience to landslides as older buildings might become weak for example, developing cracks on the walls compared to newly built structures. Type of roof either glass thatched or iron sheet thatched also determined if the building can withstand landslide impacts and lastly, how deep the foundation has been built from the ground was being assessed. Condition of the slope whether its cut, vegetated or bare was also used to determine its contribution to landslide vulnerability of the buildings as the slope aspect may trigger the occurrence of the hazard.

Thereafter, each building indicator/characteristic was given a score based on its contribution to building strength or resistance. In this case, those characteristics that can help the building to have high resistance to any landslide occurrence were given low scores for example, if the construction material is concrete, then its score was 1 whilst those that may weaken the building resistance were given high scores, for example, a building built with mud bricks was assigned a score of 5. The assignment of scores was also applied to the other indicators depending on the likely landslide type that the house is exposed to as well as the intensity of damage that can be incurred by that landslide type. In general, these scores are the ranks that are assigned to every single indicator depending upon its contribution in making a building vulnerable during a landslide. Table 2 below shows the checklist that was used in the field to facilitate this study. For the fieldwork to be more efficient and to catch up with the time frame of this study, coordination with the local structures more especially the Village Civil Protection Committee (VCPC) was the basis as they have local knowledge of their area and pictures of some of these buildings were taken as have been shown in the appendix section of this document.

INDICATORS	CATEGORIES	SCORES
1. Building location	a. Debris flow b. Mudflow c. Slow slide d. Rockfall	1 2 3 4
2. Type of construction material	a. Concrete b. Cement c. Burned bricks d. Mud bricks	1 2 3 4
3. Surrounding walls	a. Strong high wall b. Medium wall c. No/low surrounding wall	1 2 3
4. Building age (depending on the year of construction)	a. 1-5 years b. 5-10 years c. More than 10 years	1 2 3
5. Type of roof	a. Grass thatched b. Iron sheets c. Concrete	3 2 1
6. Foundation depth	a. Less than 1 meter b. More than 1 meter	2 1
7. Building position from the steep slope	a. Greater than 10 m b. Less than 10 m c. On the steep slope	1 2 3
8. State of maintenance	Cracks in the structure due to: a. Slope movement b. Cracks in the plaster material c. Water seepage in the building	 3 2 1
9. Condition of the slope	a. Cut slope b. Bare slope c. Vegetated slope	3 2 1

Table 1 showing a checklist for building vulnerability assessment

3.3.3 Key informant interviews

To understand the occurrence of landslides in the area, key informant interviews were conducted with Blantyre District Relief and Rehabilitation Officer (RRO), Village Civil Protection Committee (VCPC) and Village Development Committee (VDC). During this exercise, data on the trend of landslides, their effects and impacts as well as causes/triggers were collected. Among other things, key informant interviews were conducted to aid community participation and thereby collecting data on landslide events that have been occurring in the past 10 years since there was no landslide hazard inventory on the type of landslides, demographic data on the population that was once affected by the hazardous events, and structural damages.

3.4 MAPPING ELEMENTS AT RISK TO LANDSLIDE HAZARDS IN AREAS AROUND SOCHE HILL

To understand the exposure of the area to landslide hazards, satellite images in the Google Earth Pro were studied since it was not possible to physically visit all parts of the study area. However, with critical manual analysis, it was possible to identify areas with vegetation, slope by looking at the altitude of the area as well as settlement pattern complexity. Therefore, the best way to make sure that those hard-to-reach areas have been incorporated into this study was to use Google Earth Pro, GIS software. Then the satellite image was then exported to ArcMap 10.5 where it was georeferenced and then digitized. In this exercise, buildings, rivers/streams and roads that are located in these areas were mapped as elements at risk that is to say, these things are might be affected by landslide occurrence and thereby experiencing great losses and damage.

4.0 DATA ANALYSIS

The data that was collected using the building vulnerability assessment checklist on the characteristics of the buildings, was analyzed using the standardization method. In this case, since vulnerability indicators/characteristics, the physical vulnerability of the buildings was calculated using the assigned raw scores of the resistance indicators to landslide hazard. These scores are values that have been assigned to each indicator based on its contribution to building vulnerability. Since the methodology used to characterize the buildings is based on expert judgment, then it has some uncertainties that are required to be removed, therefore the use of standardized values. Each score is divided by the total maximum score of all the scores of the categories of each indicator. The standardized score may range from 0 to 1, whereby 0 score means that the indicator can not cause any damage to the building and 1 depicts that the indicator might cause total damage to the building. The formula below adopted from what (Singh et al., 2019) wrote, was used to come up with the raw scores and the complete dataset including standardized scores has been shown in appendix 2.

$$\text{Standardized score} = \frac{raw\ score}{maximum\ raw\ score} \qquad \text{(equation 3)}$$

Table 2 showing the standardized scores for the categories based on their indicators

INDICATORS	CATEGORIES	SCORES	STANDARDISED SCORES
1. Building location	a. Debris flow b. Mudflow c. Slow slide d. Rockfall	1 2 3 4	0.25 0.5 0.75 1
2. Type of construction material	a. Concrete b. Cement c. Burned bricks	1 2 3	0.25 0.5 0.75

	d. Mud bricks	4	1
3. Surrounding walls	a. Strong high wall b. Medium wall c. No/low surrounding wall	1 2 3	0.33 0.67 1
4. Building age (depending on the year of construction)	a. 1-5 years b. 5-10 years c. More than 10 years	1 2 3	0.33 0.67 1
5. Type of roof	a. Concrete b. Iron sheets c. Grass thatched	1 2 3	0.33 0.67 1
6. Foundation depth	a. ≥ 1 meter b. ≤ 1 meter	1 2	0.5 1
7. Building position from the steep slope	a. Greater than 10 m b. Less than 10 m c. On the steep slope	1 2 3	0.33 0.67 1
8. State of maintenance	Cracks in the structure due to: a. Slope movement b. Cracks in the plaster material c. Water seepage in the building	 3 2 1	 1 0.67 0.33
9. Condition of the slope	a. Cut slope b. Bare slope c. Vegetated slope	3 2 1	1 0.67 0.33

To determine the vulnerability level of each building using these standardized scores, all that is needed is, to sum up, all the corresponding standardized scores of all the 9 indicators, taking the fact that a building can have only one standardized score per indicator. This means that the maximum total score a building can have is 9. This is calculated using the following summation formula.

$$\sum_{i=1}^{n} x\, i = x_1 + x_2 + x_3 \ldots . \mathrm{xn}$$

Therefore, this expression means the sum of the values of x (standardized scores as per indicator), starting at x_1(first indicator) and ending with x_n (final indicator).

However, the buildings have been classified into low, medium and high levels of vulnerability based on the total sum of standardized scores an individual building can score. A building is to be put into a certain class based on the following scales:

1. 0>total standardized score≤3.0 = low vulnerability
2. 3.0>total standardized score≤6.0= medium vulnerability
3. 6.0>total standardized score≤9.0= high vulnerability

Taking the example of building 1, the total standardized value will be calculated using the following standardized scores:

CATEGORY	SCORE	STANDARDISED SCORE
Rockfall	4	1
Mud bricks	4	1
Medium wall	2	0.67
1-5 years	1	0.33
Iron sheets	2	0.67
<1 meter	2	1
On the steep slope	3	1
Cracks in the plaster material	2	0.67
Bare slope	2	0.67
Total vulnerability		7.01

Table 3 showing the standardized scores for building 1.

*For all the calculated standardized scores and vulnerability levels of all the buildings, table 5 in the appendix section shows them.

5.0 RESULTS AND DISCUSSIONS

The following table summarizes the results on building vulnerability assessment.

Vulnerability level	Number of buildings	Percentage (%)
High	14	70
Medium	6	30
Low	0	0

Table 4 showing a summary of the results of building vulnerability assessment

In this study, from the 20 buildings that were sampled, 14 buildings have high vulnerability levels since all of them have a total standardized score ranging from 6.0 to 9.0 representing 70% of the sample population in the area. Most of these have such indicators that they might cause them to suffer great damages from the occurrence of landslide hazards more especially rock falls. Whilst 6 buildings have a moderate vulnerability level to landslide hazards representing 30% of the sample building population. It is so since their total standardized scores range from 3.0 to 6.0. This means that the 9 indicators that were used to determine their vulnerability levels can strengthen them such that they can moderately resist landslide impacts. However, there are no buildings in the area that are not vulnerable to landslides. This is the case as there is no building from the sample population that its calculated standardized score ranges from 0 to 3.0.

It has been established from this study that 2 buildings are at risk of mudflows while 18 are exposed to rock falls. The buildings that are at risk of being affected by mudflows are located very close to streams that are channeled and originate from the hill thereby increasing the risk of experiencing mudflows and even the surrounding areas are wet allowing seepage of water into their foundations that are also very shallow, less than

1meter deep. Those that are exposed to rock falls are located in terrain with overhanging rock or fractured or jointed rock along steep slopes as this indicates the risk of rock fall. This threat is high in the areas around the hill since there are undercuttings on the slopes by human activities to construct houses as well as streams that originate from the hill (Highland, 2008). In addition, it was established during this study that heavy rainfall can trigger rock slides in the hill as this flourishes the streams thereby posing a threat to the buildings that are beneath the hill. For example, from the key informant interviews with the Somba 1 VCPC and VDC, it was found that in 2007 some rocks were sliding from the top of the mountain and being laid just below due to heavy rains, though this was not documented (see appendix 2 for pictures that were taken during field study). The threat is still there that these rocks will cause damages to the surrounding locations that are very close to the hill.

Thereafter, the map showing elements at risk to landslide hazards in the areas surrounding the hill was produced to aid understanding of things that might suffer damages and losses in case landslide events occur. The mapped elements are streams/rivers that may be greatly eroded by the debris flows thereby transporting rocks that overhang in the hill to the lower areas that may then lead to infrastructural and property damages. The buildings were also mapped as elements at risk as they might be destructed by rock falls, debris flows or mud flows thereby leading to deaths, injuries, property damages or even weakening the structural integrity of the buildings. Further, roads that are in these areas were mapped as the elements at risk as they ease transportation and movement of people between different locations, so when these washed away or destructed by landslides, movement and connectivity may be difficult. The following figure is a map 2 showing the elements at risk in areas around Soche Hill.

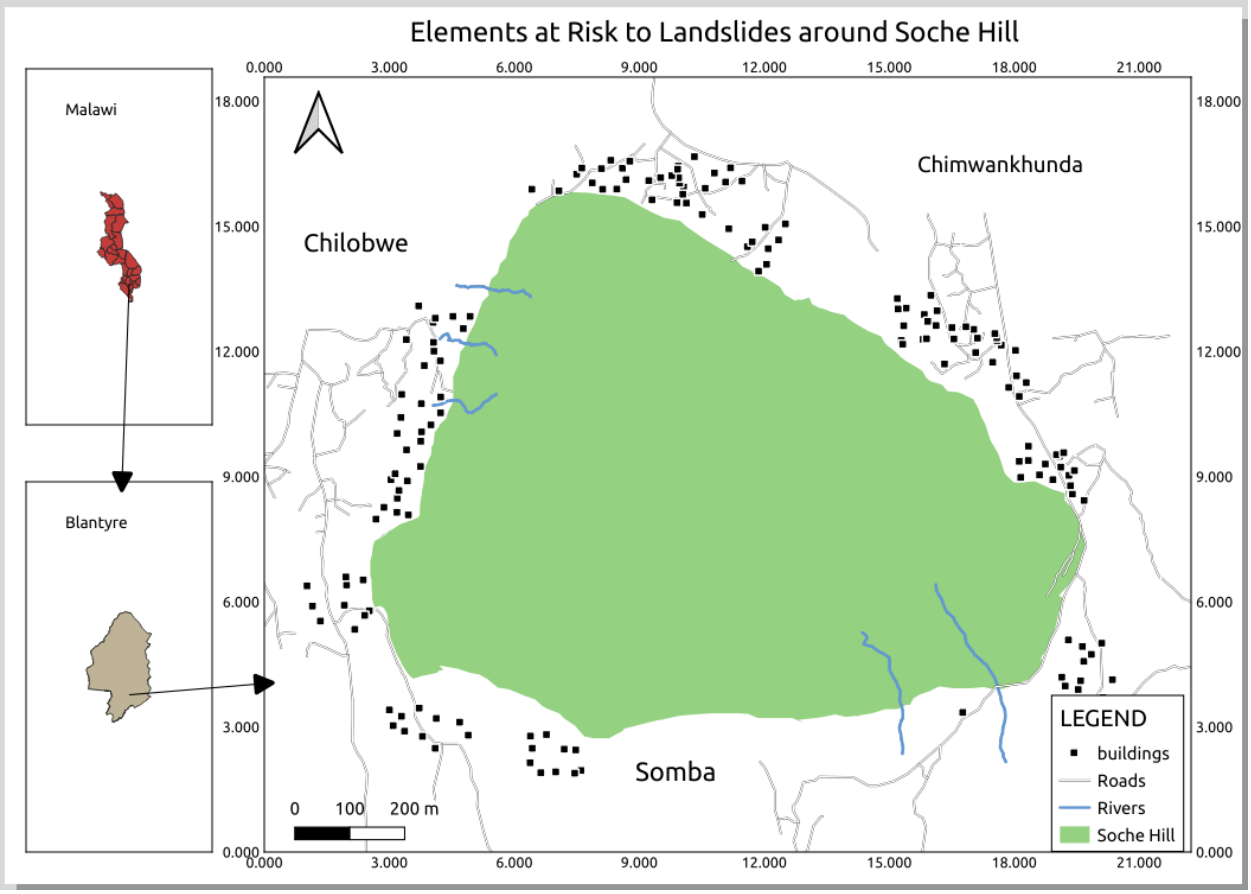


Figure 3 showing the map of elements at risk in areas around Soche Hill

5.0 CONCLUSION AND RECOMMENDATIONS

Conducting vulnerability assessment of buildings in the area to landslide hazard using the combination of houses to house study of buildings and GIS and remote sensing, is very vital. This study has presented the vulnerability levels of buildings in the areas around Soche hill which is an output that can be used by town planners and the Blantyre district council to take further action to limit expansion of the settlements to the hill slopes as well as using proper building standards. In addition, there is need to encourage reforestation on the bare land along the hill slopes as this will help to reduce slope falling.

In addition, there is no for Blantyre district council to set minimum building standards for those that are settling in these landslide prone areas. This will help to people to build their buildings that can have high resistance to the effects that may be incurred by future landslide events.

6.0 LIMITATIONS

The assessment of physical indicators and characteristics to determine the overall vulnerability of the buildings was not effective enough. This is so since the behavior of each individual building is characterized by many factors which can vary from building to building and displaying risk information at individual building level could lead to undesirable legal consequences as many building owners were resisting that their buildings should not be shoot for pictures. Another obstacle that this study met was limited time that was given to carry out this study as such few buildings were sampled and less data was collected on those buildings so that time for data compilation, analysis and presentation of the results should meet the time frame.

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8.0 APPENDICES

APPENDIX 1

Table 5 showing summary standardized scores with their respective vulnerability levels of all the sampled 20 buildings around Soche hill.

Building code	Standardised score	Vulnerability level
B1	7.01	High
B2	5.92	Medium
B3	6.59	High
B4	5.91	Medium
B5	6.26	High
B6	5.66	Medium
B7	5.25	Medium
B8	6.25	High
B9	6.0	Medium
B10	7.68	High
B11	6.26	High
B12	8.0	High
B13	5.66	Medium
B14	6.43	High
B15	6.26	High
B16	7.43	High
B17	7.09	High
B18	6.99	High
B19	7.33	High
B20	7.43	High

APPENDIX 2

Table 6 showing the control points of the digitized google earth map

Control point	X-coordinate	Y-coordinate
1	711454.89	8251084.92
2	721029.15	8249866.73
3	720358.60	8244832.75
4	710831.47	8245880.44

APPENDIX 3

Figure 4 shows one of the buildings on the steep slopes of Soche hill



Figure 4 showing a house on the slope of Soche hill









Figures showing construction activities along the slopes of Soche hill

APPENDIX 4



Figure 6 a Map of the study area extracted from Google Earth Pro

APPENDIX 6

Table 7 shows the summary of the data collected during the desk study.

Building code	Longitude	Latitude	Elevation(meters)
B1	35°00'43.34"E	15°50'46.79"S	1135.08
B2	35°00'40.56"E	15°50'40.16"S	1135.99
B3	35°00'39.81"E	15°50'38.35"S	1139.34
B4	35°00'39.04"E	15°50'35.57"S	1142.09
B5	35°00'40.14"E	15°50'33.88"S	1148.49
B6	35°00'39.99"E	15°50'33.15"S	1149.401
B7	35°00'42.23"E	15°50'31.18"S	1161.898

B8	35°00'59.97"E	15°49'48.38"S	1157.021
B9	35°01'01.11"E	15°49'44.52"S	1153.973
B10	35°01'04.68"E	15°49'45.08"S	1164.031
B11	35°01'08.43"E	15°49'45.70"S	1155.802
B12	35°01'11.48"E	15°49'46.04"S	1150.62
B13	35°01'19.53"E	15°49'50.62"S	1167.994
B14	35°01'21.75"E	15°49'52.18"S	1179.271
B15	35°01'44.88"E	15°50'08.21"S	1223.772
B16	35°01'48.90"E	15°50'10.76"S	1221.638
B17	35°01'06.70"E	15°50'59.89"S	1180.795
B18	35°01'03.36"E	15°50'57.71"S	1180.186
B19	35°01'02.15"E	15°50'59.35"S	1169.213
B20	35°00'52.61"E	15°50'56.23"S	1157.326