



A Risk Analysis of Landslides on the Morawaka “Kanda” Area in the Matara District of Sri Lanka

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Abstract

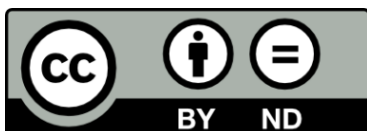
The Morawaka Kanda area has become heavily impacted by the landslides in the recent years resulting in socio-economic and environmental damages. This area which consists of steep slopes, soft soil layers with feldspar, poor drainage, constructions, deforestation, settlements and gardens may be at high potential risk for landslides. Therefore, in this study, special attention has been drawn to examine the risks of landslides on the Morawaka “Kanda” area in the Matara district. The research framework of this study was planned based on field surveys for the data collection of landslide risks using a data collection sheet and questionnaire. Satellite data taken by survey department was used for the risk area mapping using Geographical Information Systems (GIS). According to the analysis of causative factors, high risky land area is about 18 km² and it is 24% of the area. The land extent of moderate and low risk is nearly 64% of the total area in this study area. The moderate landslide risk areas covered 24.14km² land. It is about 31%. 25km² is about low risk. 45% is low and no risk. Still there is a risk for future landslides in the unstable slope on the right bank of the Morawaka Kanda landslide path in 2017. 55% of the families live in the high risk area and only 20% of the families are in the moderate risk while 25% of the families have low or no risk. 50% of the high risk families are in Morawaka Kanda and Yati Horagala. The identification of landslide prone areas play an important role in avoiding or minimizing hazards and the identification of potential landslide risk areas is very important to ensure the safety of lives and property.

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INTRODUCTION

Landslides are one of the most effective natural disasters among floods, cyclones, droughts and earthquakes in Sri Lanka and it is a disaster that can be defined as a downward or outward movement of soil, rock and vegetation under the influence of gravity (Bandara, 2005). It is scientifically defined as “mass wasting” i.e. according to the gravitational force, rocks and soil materials in a mountain area, flow downwards. The Earth slips which cause the flowing of rock masses and weathering materials are classified into various types according to their ways of movements. They are, rock falls, rockslides, debris flow, bedding glides, debris slides, rock creep and bedding slumping. These types of landslides can be broadly identified in the hill country of Sri Lanka. (Dahanayake.2004 and Weerakkody.1996)

During 1901-2000, about three landslides were recorded in Sri Lanka and 119 persons were killed. Between 1977 and 2002 alone, about 70 slope failures were recorded in the country, taking 200 lives and causing serious damages to buildings, infrastructures and plantations in mountainous regions. Sri Lanka faced two devastating landslides in the Ratnapura and Matara districts in 2003. In 2007, there was a severe landslide in the Haguranketa region too. Approximately about 22,328 people were displaced in 2003 while about 26,989 and 27,497 people were

displaced in 2006 and 2007 respectively (Sangasumana, 2018). (Galappatthi and Weerasinghe, 2007). In 2008 the number of affected people was 2068 and in 2012 it was 2890. The death toll in 2008 was 10 while in 2011, it was six and in 2014 it was 45 and 3 in 2015. Approximately 30% of the area from the 65610km² of total land area, nearly 20000 square kms in Sri Lanka was identified as the landslide prone areas by the Natural Building Research Organization (Ranasinghe and Bandara, 2005, Wijeratne, 2015, Statistic Handbook, 2012). These landslide prone areas are broadly in Badulla, Nuwara ELLiya, Kandy, Matale, Ratnapura, Kegalle, Galle, Matara and Hambantota.

The hill area of the Matara district is one of the high-risk landslide areas in the Southern Province of Sri Lanka. During the last few decades, there has been a rapid increase of landslides in this district and 101 Grama Niladhari divisions were badly affected by landslides and floods. The most affected areas were Kotapola, Morawaka, Pitabaddara, Pasgoda and Mulatiyana. Among these, the Morawaka “Kanda” area which consists of Morawaka, Kotapola, Diyadawa, Kosmodara, Horagala, and the Gatabaru Kanda mountains are severely affected by landslides.

The landslide which occurred in May 2003 is the worst episode in the recent past which affected the Diyadawa in the Kotapola North GN division. There were seventeen deaths and missing,



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fifteen families displaced, and five houses were completely and partially damaged. After this event, the most dangerous landslide experienced in the Morawaka Kanda area occurred on the 26th of May 2017 and it can be recognized as a “debris flow” which had not previously occurred in Southern Sri Lanka. It caused the heavy loss of lives, property and natural resources. The length of this landslide area is about 250meters and the width of the landmass of the slide s 145m. The length of the path along the debris flow is about 450m and the length of the area where the colluvial was deposited is about 800m. The depth of the escarpment is about 40m. Joints and cracks which developed close to the summit of the landslide in the left and right valleys can be seen and the land has been displaced vertically and horizontally through the fault valley (Saroja.K.G.N., Manikpura.C.S., Gunatilake.J.,2019). According to the field survey and collected secondary data by the District Secretariat, nine people had died and fourteen people were found missing. Sixty-four families were affected, and fifteen houses were completely or partially damaged. The extent of debris flow is 270m in length and 60m in width with a slope angle of about 30° the flow path is 680m with a stream bed gradient of 15° on average. The length of the depositional area is 1200m, maximum width is 250m Tract of land, about 2.5km in length was degraded and fifteen acers of paddy land has been filled with sediments. As

such, there may be a continuing risk of landslides in this area (NBRO 2019).

AIMS AND OBJECTIVES OF THE STUDY

In the recent past, Sri Lanka has been identified as a country facing numerous natural disasters among South Asian countries. Every year, increasing death tolls, property damages and environmental damages by means of natural disasters such as floods, droughts, cyclones and earthquakes in Sri Lanka can be identified. Landslides are a major disaster which is a high risk on the mountaineous areas of Sri Lanka. Therefore, the aim of this study is to examine the risk analysis of landslides in the Morawaka “Kanda” area in the Kotapola divisional secretariat of the Matara district.

In order to fulfill the overall aim, the focus will be on the specific objectives as mentioned below:

- to identify the disaster damages of landslides in the Morawaka “kanda” area.
- to investigate the causative factors that contribute to the increase in the intensity of the landslides.
- to analyze the potential landslide risk on the basis of causative factors
- to compile a landslide risk area map based on the landslide risk level.



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THE STUDY AREA

Morawaka Kanda is a high-risk area for Landslides in the Kotapola Divisional Secretariat Division which belongs to the Matara district in Southern Sri Lanka. This Divisional Secretariat

division area covers about 175.5 km² of land (Divisional Secretariat, Koptapola, 2021) and considering the landslide affected areas, six sites have been selected out of this Divisional Secretariat division for the study.

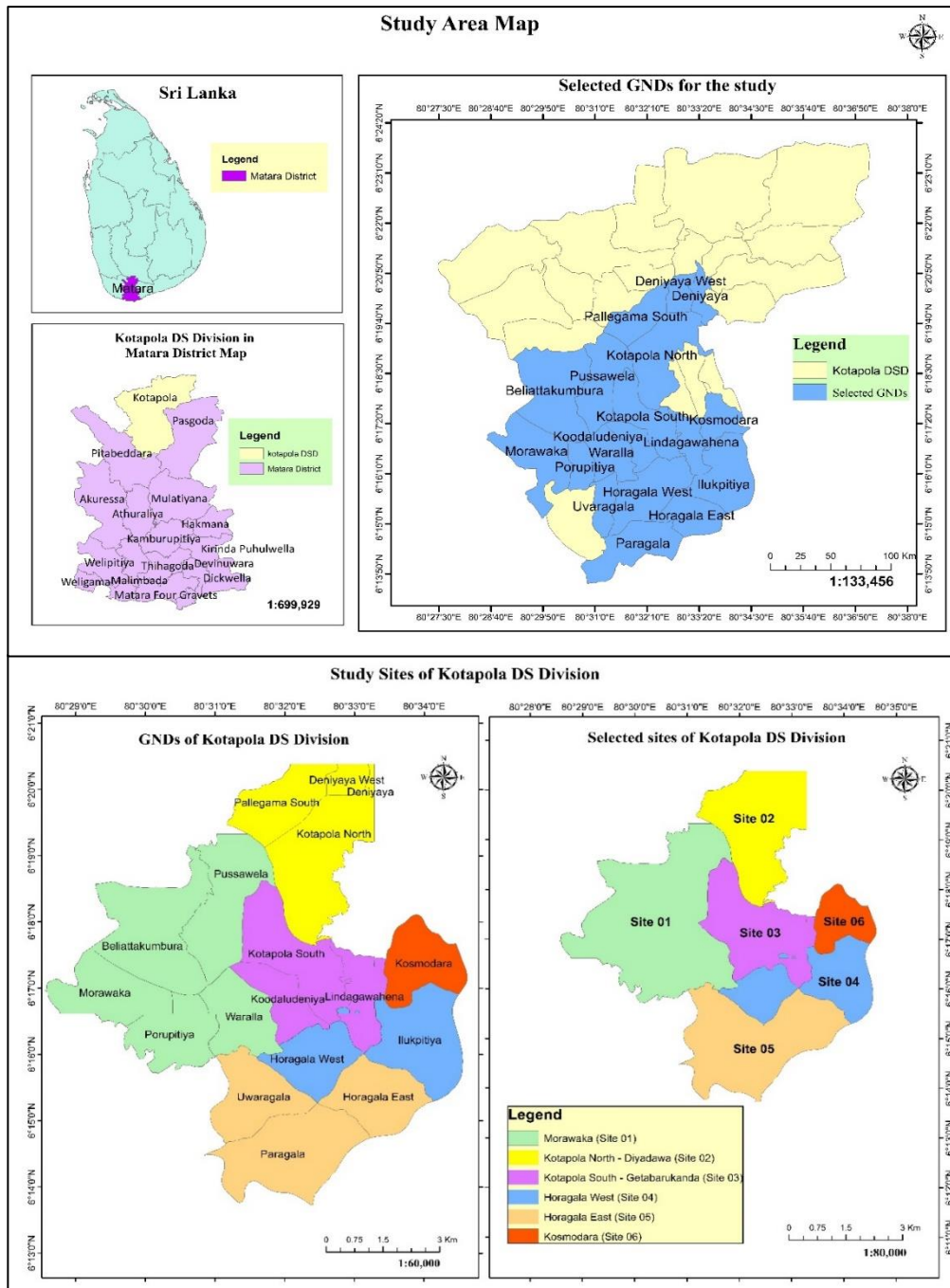


Figure 01: The Study Area map
Source: Kotapola DS Division, 2021

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They are Morawaka Kanda (site 01), Kotapola North (site 02), Kotapola South (site 03), Horagala West (site 04), Horagala East (site 05) and the Kosmodara (site 06). Among these, Morawaka Kanda in site 01, Diyadawa in site 02, Gatabaru Kanda in site 03, Horagala West in site 04, Horagala East in site 05 and Kosmodra in site 06 are the specific selected areas given special attention based on the highest elevation and severe affected areas. They are identified as the study sites with the intention of finding out whether there is a further risk for landslides. Figure 01 shows the GN Divisions and selected sites of the Kotapola DS Division for the study. It is located within the coordinates from 6° 13' 20" N to 6° 22' 30" N and from 80° 28' 30" E to 80° 35' 30" E and this area covers about 76.5234km² land extent, out of 175.5 km² land of the Kotapola DS Division.

METHODOLOGY

This study on the "Risk Analysis of Landslides in Morawaka "Kanda" Area in Matara District of Sri Lanka" was carried out based on a field survey and remote sensing methods. The questionnaire survey, group discussions and field measurements are the main activities for the field surveying. GIS technology was used to analyse the collected data (figure 02). The field surveys and observation of this research was focused on the data collection of landslide risks using a data collection sheet and questionnaire.

The data collection sheet was used to collect the physical measurements in the study area. There is an extensive influence from morphologic features such as relief, slope, and soil types, to differentiate the landslide process and landslide risk. These morphometrics and changes can be determined from the field measurements and observations. A data collection sheet was applied in order to collect data on geology, geomorphology, lithology, land use pattern etc. and the data of relief, soil and rocks, geological factors, water drainage were collected using the data collection sheet. These physical measurements were taken for the calculation and identification of the factors that caused to an increased landslide risk in this area.

Eighty-one affected families were selected randomly for this study and the data was collected by providing a questionnaire for each family in Morawaka Kanda, Diyadawa, Gatabaru Kanada, Kosmodara, Horagala West and East representing each sites. The questionnaire was used to collect the general information of the people, the socio-economic, environmental impacts and the current issues of the population. The details of family, the house and property of the affected areas, the mostly affected people and the hazard frequency, the possible causes of landslides, the nature of the damages, the future vulnerability, the landslide risk management and mitigation actions, the resettlement programs and the



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problems and suggestions from vulnerable people were the most

focused factors in the questionnaire survey.

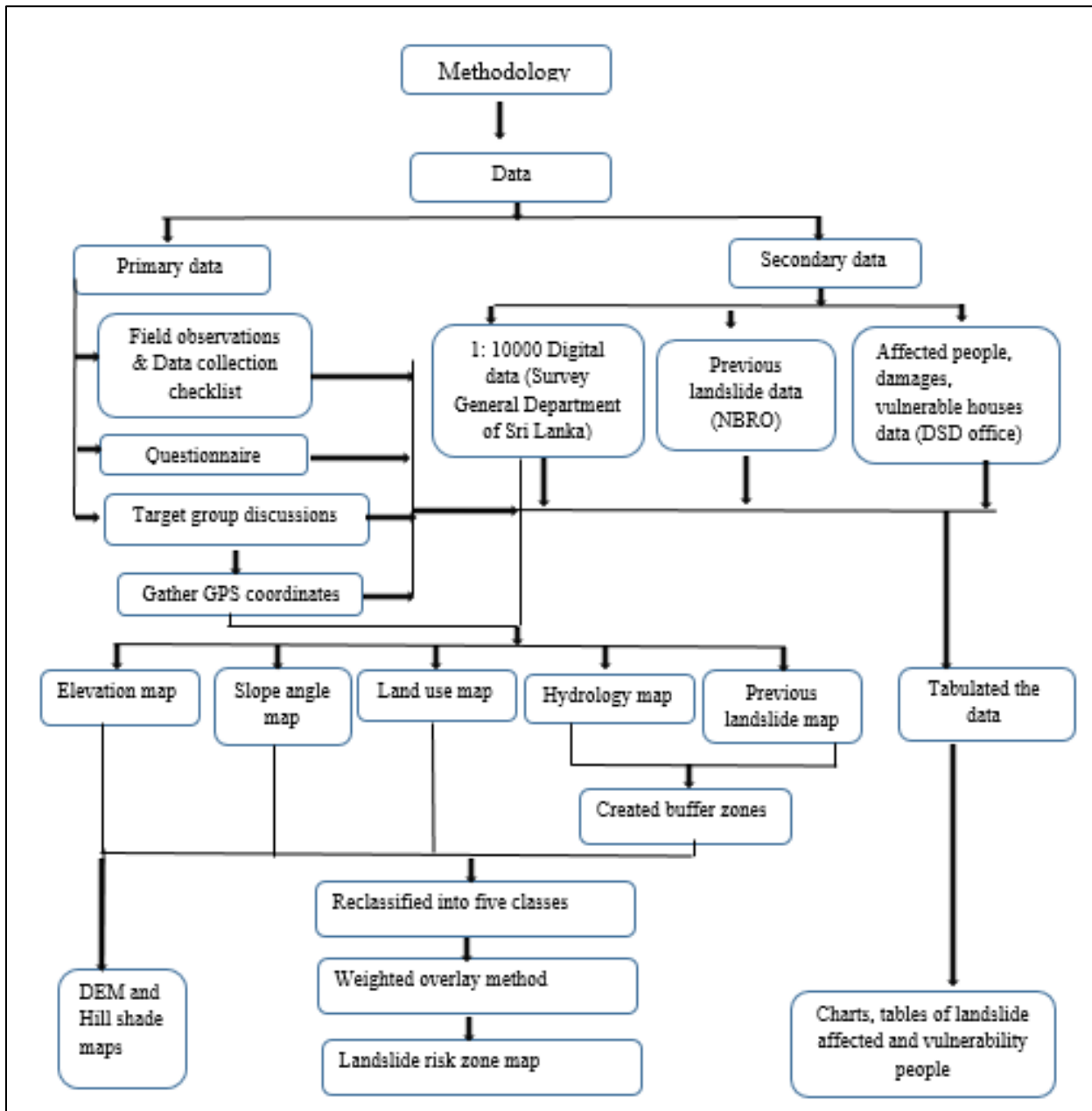


Figure 02-Research Methodology

In this research, remote sensing methods such as satellite data, the global positioning system (GPS) and field surveys were used as main data collection methods. GPS coordinates were obtained of the selected sites using the GPS hand survey instrument.

The purpose of having the GPS coordinates of the sites is to identify the spatial distribution of the affected areas and the vulnerable areas. Satellite data taken by the survey department was used as a basic tool for the risk area mapping.



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The data collected from these sources was analyzed using GIS to identify the disaster impacts, causative factors and landslide risk areas. By the analysis of causative factors, the potential risk areas of landslides were identified using GIS and Remote sensing techniques. Causative factors were used to compile the landslide risk map in the study area. The elevation, slope angle, land use, distance from previous landslides and distance from the streams are the factors used for the analysis and each factor is weighted based on the weight system used by the NBRO (Pushpakumara et.al.2013).

Main criteria	Influence value %	Sub criteria	Score/ Rank
Elevation	30	0 – 200	2
		200 – 400	4
		400 – 600	6
		600 – 800	8
		800 – 1000	10
Slope angle	25	0 – 6	2
		6 – 12	4
		12 – 19	6
		19 – 26	8
		26 – 48	10
Land use type	20	Forest	10
		Cultivated area	4
		Build up area	2

Distance from stream	15	Barren land	1
		Water body	1
		0 – 100	10
		100 – 200	8
		200 – 300	6
Distance from previous landslides	10	300 – 400	4
		400 – 500	2
		0 – 200	10
		200 – 400	8
		400 – 600	6
		600 – 800	4
		800 – 1000	2

Table 01: Main criteria and influence of weight system

Then, buffer zones were created surrounding the previous landslide areas with 200 meter intervals using the multiple ring buffer tool. Further, the buffer zone was created with 100 meter intervals to measure the distance from the stream. After creating these buffer zones reclassified into five new classes considering the proximity to water bodies or former landslides. The land use map also reclassified into five classes and a new score were assigned, according to the most affective land use type. Figure 03 shows the reclassified maps drawn to determine the weighted of land use, the elevation, slope angle, hydrology and previous landslides.



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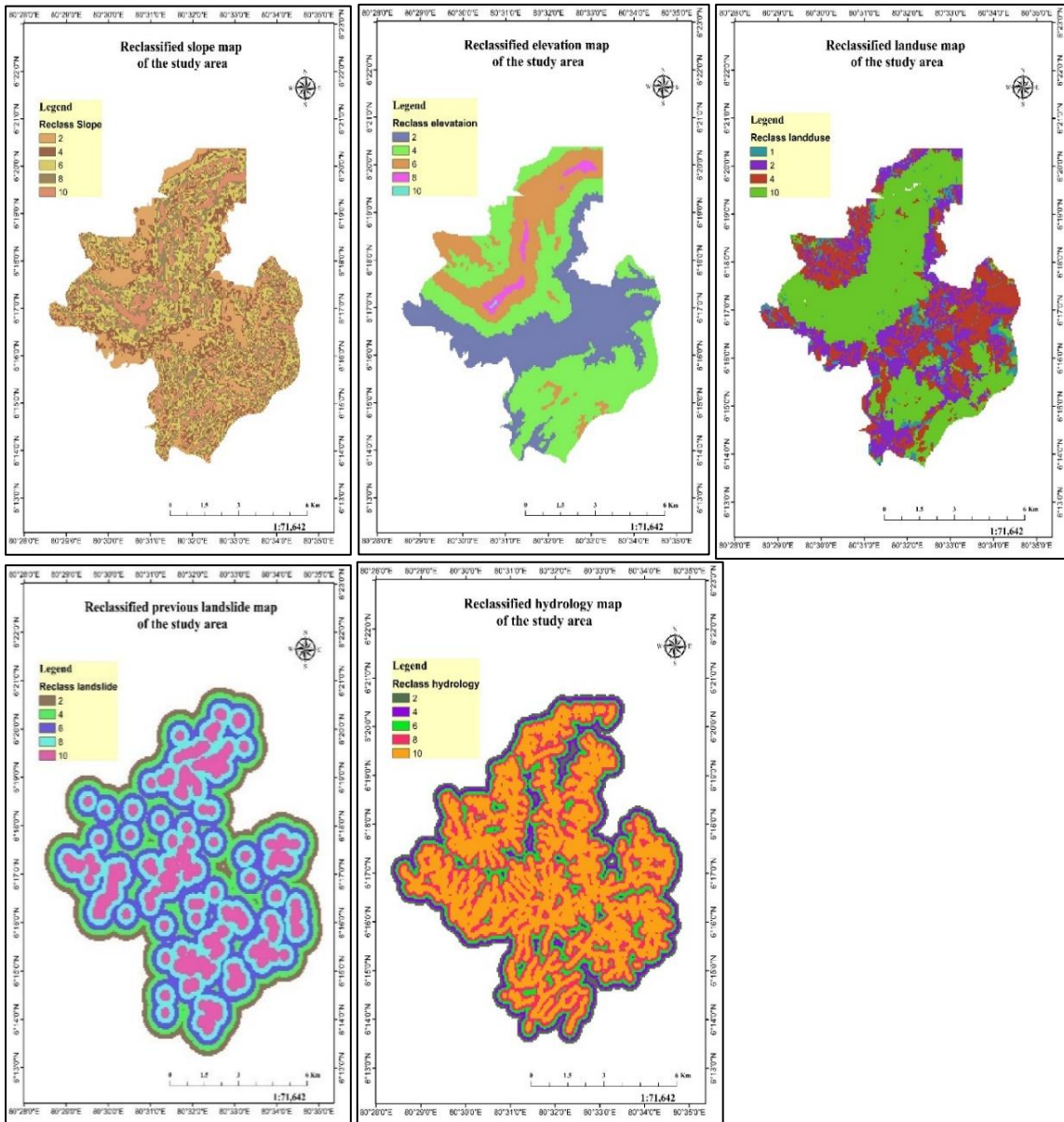


Figure 03: Reclassified maps of land use, elevation, slope angle, hydrology and previous landslides. Source: Prepared by the author using satellite data taken by the Survey Department, 2021.

All reclassified layers of land use, elevation, slope angle, hydrology and previous landslides were overlaid by using the weighted overlay method giving the influence values in each factor. 30% for elevation, 25% for slope, 20% for land use, 15% for hydrology and 10% influence value for previous landslides were used to create the

landslide risk map. The above table illustrates the main criteria, influence value and reclassified classes for the same. After weighted new score values on each factors the final map was created by weights of 05 factors. It was helpful to identify the risk areas.



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The Risk areas were identified and categorized in to four groups based on the risk levels as "no risk", "low", "moderate" and "high" landslide risk map was compiled by using this weighted overlay method.

RISK ANALYSIS OF LANDSLIDES IN MORAWAKA KANDA AREA

The risk is introduced as "the probability that a community's structures or geographic area is to be damaged or disrupted by the impact of a particular hazard. Landslide risk analysis include the degrees of hazards, identifying elements at risk and risk assessment". The assessment begins with an analysis of hazards and consequences. Hazard analysis consists in identifying the landslide mechanisms and in quantifying their corresponding spatial and temporal occurrence and their intensity. Consequence analysis includes identifying the element at risk (property, persons, environmental assets etc.) and their vulnerability (NBRO, 1998 and DMC, 2010.). Accordingly, this study indicates, potential risk areas, elements and the risk level of the Morawaka Kanda area.

Potential landslide risks can be identified considering landslide symptoms in the mountainous areas. Ground faults, cracks, joints, subsidence along the cracks, cracks on the buildings, sudden appearance of spring with muddy water, death of trees and displacement of boulders are

the criteria that are used to assess the landslide risk. Apart from this, in this research, five causative factors were used to compile the landslide risk map in the study area. The elevation, slope angle, land use, distance from previous landslides and distance from water resources are the factors used for the analysis and each factor is weighted based on the weight system used by NBRO (Pushpakumara et.al.2013). Table 01 shows the weights given in each factor to identify the potential risk areas and risk level. As shown in figure 04, the landslide risk zonation map is the result of the analysis carried out in the raster data model using the weight values of the obtaining factors using Arc GIS software and the risk areas which were identified using these criteria were further classified into four groups as high risk, moderate, low risk and no risk areas (Figure 04).

The following table 02 shows the total land extent of risk areas in this study area. According to the following table, there is a high landslide risk in 24% of land and it covers nearly 18 km² in this study area. According to the risk map, high risk zones are located throughout the entire area including Morawaka, Gatabaru Kanda, Diyadava, Horagala and Kosmodara. The right bank of the Morawaka Kanda landslide path in 2017, the upper part of Gatabaru Kanda, Deniyaya Watta in Diyadawa, Kohila watta-Henyaya in Horaga West were identified as high risk areas. These high-risk areas are approximately located in the high



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elevation and consists of higher slope angles. Most of the above high-risk areas are occupied by tea or other cultivation and cleared areas as well as most of the previous landslides are reported in these areas.

distributed in the entire area. These moderate risk areas can be identified with a medium range of elevation and by improper land use practices in this area. Kotapola North, Morawaka and Horagala East areas have more moderate landslide risk areas than the other areas. Approximately, 55% of the lands in the study area tend to be high and moderate areas.

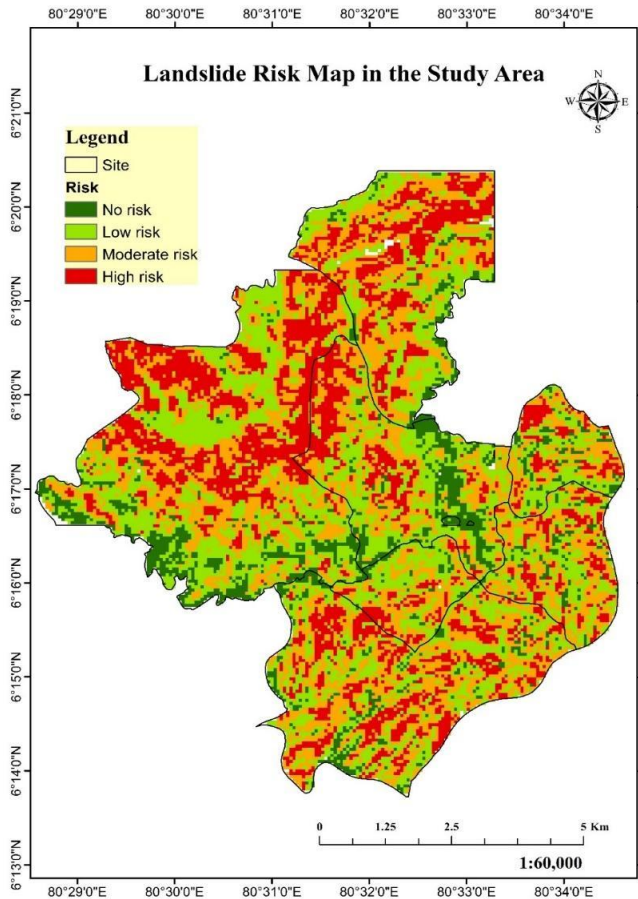


Figure 04: Landslide risk of the study area
Source: Prepared Using satellite data taken by the Survey Department of Sri Lanka, 2022

The land extent of moderate and low risk is nearly 64% of the total area in this study area. When considering about the moderate landslide risk, the areas covered 24.14km² land and are

Table 02: The distribution of landslide risk areas based on risk level

Risk Level	Land Extent (km ²)	Percentage of land extent %
High Risk	18.67	24
Moderate Risk	24.14	31
Low Risk	25.85	33
No Risk	7.84	12

Source: Prepared by author, 2022

There is 25.85 km² land for low landslide risk and it is represented by the dark green colour in the following map. The low-risk areas can be identified in low elevation areas with low slope angles. According to the following map, most of the low-risk areas can be shown in the settlement areas which have gentle slopes and undulating terrain. There is no risk for landslides in nearly 7.84km² land in this study area. The south part of the Morawaka area, the east part of Diyadawa and the middle part of Getabaru Kanda area have low or no risks for landslides. Most of these areas can be identified in lowlands with flat terrain.



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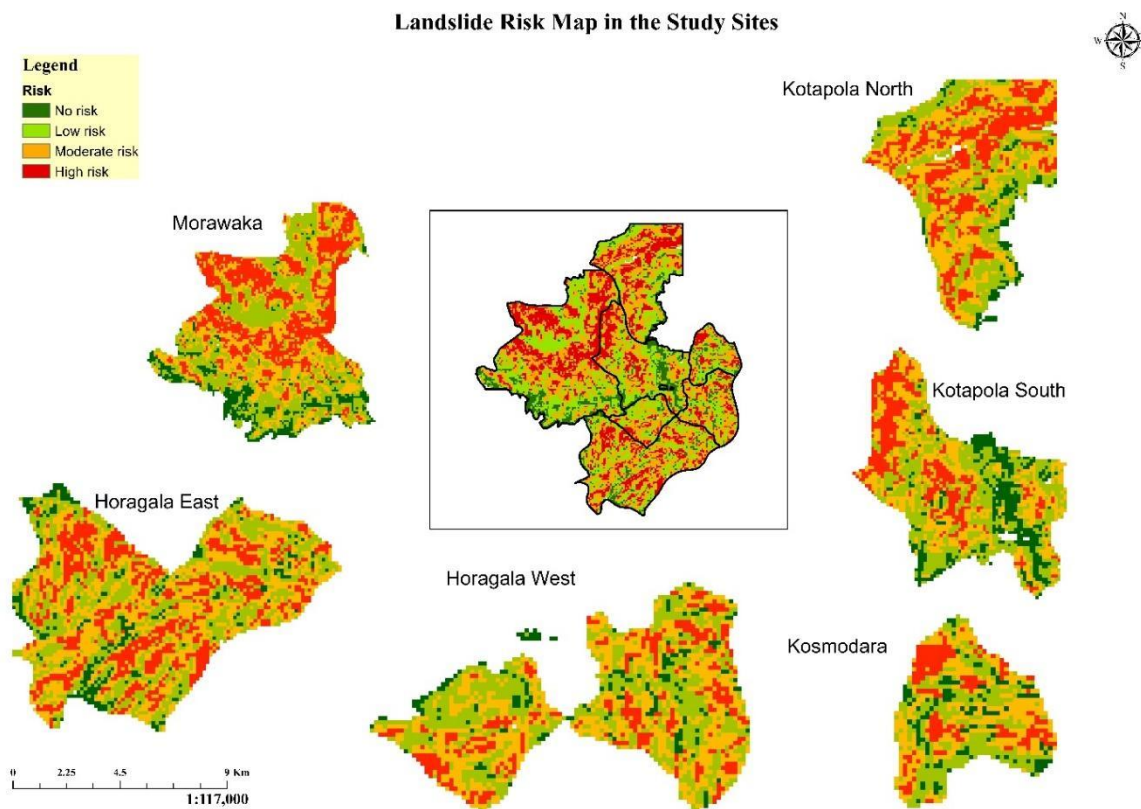


Figure 05: Landslide risk map in each site

Source: Prepared Using satellite data taken by Survey Department of Sri Lanka, 2022

When considering about the landslide risk in each area of this study area, the risk level of each site is varying from place to place. The above figure 05 shows the landslide risk of each site in this study area. According to the following table 03, it can be identified that the land extent of risk in each site is different. The largest amount of land is in the Morawaka kanda site area and it covers about 26.92km² land. The high risk in this area is about 7.53km² in extent, while nearly 12 km² land is in a

low risk or no risk level. According to the following table there is approximately the same land extent for high, moderate and low risk. However, mostly the top of the right bank of the Morawaka Kanda landslide path in 2017 and the surrounding hillside area is in the high-risk zone for future landslides. The foot of the Morawaka mountain and its surrounding flat and undulating lands are in a moderate or low risk zone for landslides.

Table 03: The land extent of landslide risks in each site

Risk Level	Morawaka		Horagala East		Horagala West		Kotapola North		Kotapola South		Kosmodara	
	Land extent km ²	%	Land extent km ²	%	Land extent km ²	%	Land extent km ²	%	Land extent km ²	%	Land extent km ²	%
High risk	7.53	28	2.19	27	2.54	21	3.93	29	1.91	20	0.57	21



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Moderate risk	7.81	29	3.11	36	4.04	39	5.10	37	2.94	30	1.14	42
Low risk	9.49	32	4.14	28	4.19	35	3.89	28	3.41	35	0.76	29
No risk	3.07	11	1.52	9	0.66	5	0.79	6	1.58	15	0.22	7

Source: Prepared by the author, 2022

The Horagala East site covers an area of 10.96 km² out of the total area of the study area and 27% of the area is in the high-risk zone. The upper part of the Horagala highland area is in a very high risk and it covers nearly 3km² land. The surrounding areas of the high-risk zone are in a moderate risk, and it represents 36% of the total land of the Horagala East site. Further, there are very few areas that are not prone to landslides in this area as 9% out of the total land.

When compared to the other areas, the Horagala West and Kosmodara area has more moderate risk zones for landslides. 42% land is in the moderate risk zone, and it covers nearly 1.2km² land in Kosmodara out of the study area. However, the Kosmodara area has more than 60% moderate and high-risk areas and the safe area has been less than 8% of the total area. The Horagala West site has more low risk areas and safe areas than the high-risk area for landslides. The mountain peaks in the Horagala West area and the surrounding area are risk zones for high and medium level landslides and that area is nearly 60% of the total area in Horagala West.

There are more high-risk areas in the Kotapola North site, compared to the Kotapola South site. The Kotapola North site is the second largest land

that consists of this study area. Approximately 70% of the land is in moderate and high risk in the Kotapola North site and it covers more than 9km² land out of the total land in Kotapola North. According to the above figure 19, most of the high and moderate risk areas are located on the steep slope areas with a high elevation. However, the east part and the south part of the Diyadawa area in Kotapola North has a low risk or no risk for landslides because there are more flat and low elevation areas. The Kotapola South area has more than 20% land in the high risk zone while 30% land is in a moderate risk. According to the above map, it can be clearly recognized that there are more high-risk zones in the western half than the eastern half of the Horagala west area. There are more no-risky areas in the eastern ward of this area, and it covers 15% of land.

This survey also aimed to determine the landslide risk on elements in the Morawaka kanda area. Considering the causative factors, the number of people, families and houses at risk were identified. According to the questionnaire survey in the selected areas, nearly 55% of families live in a high risk area and only 20% of the families are in a moderate risk while 25% families have low or no risk. Nineteen houses in the study area can



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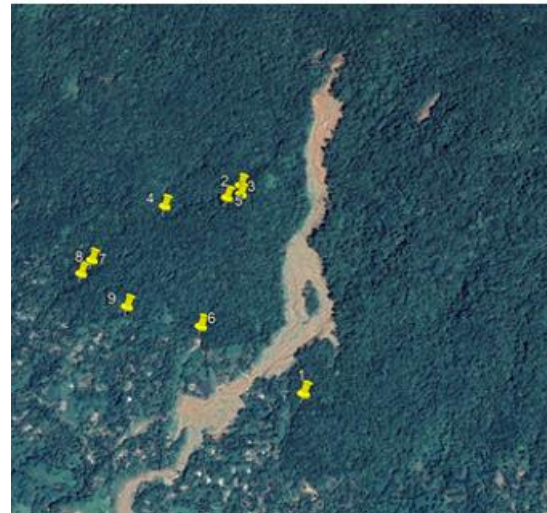
be identified at high risk. 50% of them are distributed in Morawaka Kanda and Yati Horagala. For example; the houses which belong to J.Y.Samantha, W.G.Nandawathi and Upali can be identified as high risk in Morawaka Kanda (Figure 06). Apart from this, the NBRO has identified nine landslide risk houses and locations in this area (figure 06 - A).

The houses which belong to Mr. H.K.Siripala, R.Dilip Rangana at Kohilawatta-Henyaya in Horagala West are also high risk houses with the crack of house walls, situated in higher slopes towards the stream valley and the emerging of springs on the ground in rainy periods. Although, the residents of these houses were informed to leave these houses, still they are living there, due to no safe places being provided yet. Accordingly, the people living in the risk area responded that unsafe areas is the most prominent factor for the future vulnerability for landslides. There are 21 responses for reluctance to move to safe areas while 31 respondents believe carelessness and negligence are also major causes for future vulnerability.

In addition, 68 respondents believe that the lack of disaster knowledge is another reason caused in the increase of landslide risk. In terms of education, it is significant that, most of the people in those households which are located in risk areas have not received formal education. Therefore, lack of knowledge can be a factor for increased

vulnerability and disaster risk. It is a major reason taking in actions to reduce landslides.

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Figure 06: Houses for the landslide risk in the study area

- A. Risky houses in right bank of the Morawaka Kanda
- B. Risky house belong to the J.Y. Samantha in Morawaka Kanda
- C. Risky house belong to S.Jayasinghe in Diyadawa
- D. Risky house belong to Sunil in Horagala West

Source: Field survey and NBRO, 2019

Most of the houses in this study area, are built without obtaining approval from any authorized institutions and most are built on very steep slopes and in high elevation areas. Further, most households use their land for agricultural purposes such as tea, citronella, coconut, fruits and pepper.

CONCLUSIONS

Landslide risk mapping is essential to describe the susceptibility of landslides in the Morawaka Kanda area of the Kotapola DS division. The factors used in the production of landslide risk map were selected by analyzing the parameters affecting the formation of landslides in the region. The landslide risk map divided the study area into four areas, as high, moderate, low, and no risk areas. Approximately, 24% of the lands in the study area tend to be high risk and 31% is moderate. According to the landslide risk map about 45% of land is prone to low and no risk areas. Mostly the top of the right bank of the Morawaka Kanda landslide path in 2017 and the surrounding hillside areas on the upper part of Gatabaru Kanda, Deniyaya Watta in Diyadawa, Kohila watta-Henyaya in Horagala West are in the high-risk areas for the future landslides compared to the other sites. According to the questionnaire survey in selected areas, nearly 55% of families live in high-risk areas and only 20% of the families are in a moderate risk while 25% families have low or no risk. Nineteen houses in the study area can be identified at high



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risk. 50% of them are distributed in Morawaka Kanda and Yati Horagala. The high-risk areas are approximately located in the high elevation and consists of higher slope angles while, low risk areas can be identified in low elevation areas with low slope angles. Most of the high-risk areas are occupied by tea or other cultivation and cleared areas as well as most of the previous landslides are reported in these areas. Most of the low-risk areas were identified in the settlement areas which have gentle slopes and undulating terrain. Further, the results revealed that, elevation, slope, aspect, land use, drainage pattern, soil and geology formation are important parameters for landslide risk in the region. The risk of landslides in the Morawaka Kanda area can be minimized by controlling informal constructions on higher slope areas, protecting and growing vegetation in the upper stream valleys, establishing suitable drainage systems in high risk areas to drain off excess water properly downward by the construction of drains, the broadening of permanent slope management systems and holding awareness programs.

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