Journal of the Institute of Engineering
Volume 16, No. 1 Published: April 2021
ISSN: 1810-3383

Printed in Nepal

A Report on GIS Based Analysis of Landslides in Myagdi District

Sumit Thapa

Disaster Risk Management Program, Department of Civil Engineering,
Pulchowk Campus, Institute of Engineering, Tribhuvan University, Nepal
Corresponding Author: sumitsaya09@gmail.com

Received: 2020-08-25 Revised: 2021-02-09 Accepted: 2021-02-19

Abstract:
Lanslide have become a routine event during monsoon in Nepal which accompanies a huge social, physical and economical loss. As the number of landslide event is in increasing order each year but their proper study is still limited, this assessment is an example of simple step in landslide study. Also, the developmental activities disturb the topology and hence increase or bring new form of landslide in the region. This report is mainly a preliminary study of existing landslide in Myagdi district which is generally carried out using QGIS software and remote sensing data available from http://earthexplorer.usgs.gov and recent Google satellite image. From the analysis carried out by using the inbuilt features in QGIS, relationship between various terrain, hydrological and anthropogenic parameters with landslide was driven. Based on this approach a simple precautionary measures in development activities, disaster preparedness and mitigation activities can be carried out.

1. Introduction

Nepal lies in the South Asian region between China and India. It has a unique landscape which differs with the rise in altitude. So, from plain agricultural land in the southern belt to the high Himalayas in the northern belt, makes Nepal geology different. As the Himalayas were formed 50 million years ago due to the collision of the Indian Plate and Eurasian Plate, the process is continuous and is responsible for different natural disasters[1].

As you look at the hilly and mountainous region of the country, due to geologically young and tectonically active landscapes, this region is highly susceptible to landslide, earthquake, erosion, flood, etc. Every year during monsoon season these catastrophes mark their presence with devastating outcomes resulting in huge human, material, economic and environmental losses.

Varnes [2]has classified landslides based on the type of material and type of movement. Landslide is simply the downward movement of earth material due to external forces under the direction of gravity. A landslide can be natural or human-induced. In the case of Nepal, both types of landslides are found. As mentioned earlier, the landslides are mostly active in the rainy season, most of the landslides are rainfall triggered landslides. About eighty percentage of the landslides in Nepal are shallow type, which moves very fast and are of destructive nature. Generally intense rainfall for short duration is responsible for shallow landslides. As an impact of climate change, there is an increase in the number of short intense rainfall. So, there is an increase in number of disasters related to it.

The parameters like slope, aspect, rainfall characteristics, soil characteristics and landscape influence the type and coverage area of landslides. Landslide is affected by various factors which can be time-invariant or dynamic in nature. The surface and the subsurface geomorphological characteristics of the earth differ spatially. Also, the climatological, hydrographical and environmental conditions may differ from time to time. So, even if the instability factor leading to slope failure are identified, its complex interactions is a subject of discussion if we consider a large region [3]. All methods proposed and tested to evaluate landslide hazard fall into different categories; direct geomorphological mapping, analysis of landslide inventories, heuristic or index-based models, functional or statistical models, physical and geotechnical models. As landslide varies in scale from local to regional, its study is very complicated [3].

For this study we are using Geographic Information System (GIS) to map the landslides in Myagdi district and work out its relationship with various parameters. So, GIS approach is simply a statistical approach which considers multiple variables for its study. It is simply a preliminary investigation carried out based on the satellite image, different relevant data and extensive use of inbuilt tools in QGIS.

1.1 General Information of the Study Site (Myagdi District)

Myagdi District, a part of Gandaki Province, is one of the seventy-seven districts of Nepal with the coverage area of 2297 km2.The district has one municipality and five rural municipality. The Dhorpatan Hunting Reserve also lies in this region. Beni Municipality is the district headquarter.

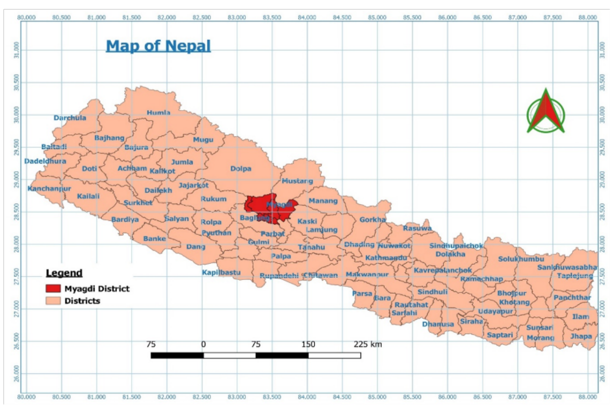

Figure 1: District Location (Source: Extraction from QGIS)

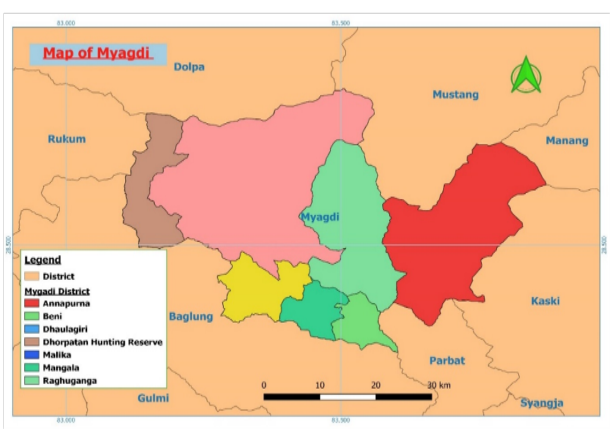

Figure 2: Administrative Division of Myagdi (Source: Extraction from QGIS)

The general information regarding different administrative unit of Myagdi district is listed in Table 1.

Table 1: General Demographic Information (Source-Census 2011)

Administrative Unit	Area (km^2)	Population
Beni Municipality	55.77	28,511
Annapurna Rural Municipality	556.41	13,315
Dhaulagiri Rural Municipality	1037	14,014
Mangala Rural Municipality	89	16,286
Malika Rural Municipality	147	19,458
Raghuganga Rural Municipality	379	15,753

1.2 Landslide situation

Each year Nepal is badly hit by landslide mainly in hilly region during monsoon season creating a havoc situation. Monsoon induced disasters are common in Nepal owing to country's mountainous topography and big rivers dissecting the landscape as they flow from the mountains to the plains in Terai. Since the beginning of monsoon, the number of floods and landslides highly affect the people living in the vulnerable region. Each year there is a rising tread in the number of landslides due to natural as well as anthropogenic causes. The explosion of informal road construction without proper geotechnical and scientific investigation have destabilize the slopes during monsoon season. As a result of this reckless development the risk and the rate of landslide is increasing in the hilly terrain. According to National Disaster Risk Reduction and Management Authority (NDRRMA) reports as of 31 July, 164 people have lost their lives due to landslides and floods, and many more are missing. The report also shows that within 23 days of active monsoon , a total of 256 water induced disaster took place in Nepal[4].

This year alone 700 people form 50 household have been displaced and 27 people have lost their life due to landslide in various regions of Myagdi district. Around 896 people from Beni Municipality and Dhaulagiri, Malika and Raghu Ganga rural municipalities have been transferred to safer locations. So the study of landslide and mitigation and preparedness activities is still not convincing. A detailed study and effective mitigation and preparedness plan is immediately needed to overcome the challenges of landslide.

2. Objectives of Study

The main purpose of this study is the Assessment of Landslides in Myagdi District. The objective of the study can be highlighted as:

- Identification and Mapping of Landslides in the district
- Analyze the relationship of Landslides with various topographical and hydrological characteristics and also analyze the influence of human activities

3. Methodology

For the following project Landslide mapping and identification was basically done by using the spatial data and using different features of QGIS to analyze the causes and extent of landslide in Myagdi District. At first 30m×30m resolution Digital Elevation Data (ASTER DEM) was downloaded from USGS website[5]. The data was then used accordingly to conduct different analysis (Terrain and Hydrological) and other relevant tasks in QGIS. Google Earth Software was used to identify the landslides in the area of our interest. So, the Google Satellite image was our prominent source of information to meet our objective. Recent Google Satellite image was used. Terrain analysis was done in order to analyze the relation between landslides and different parameters such as slope, aspect, profile and elevation. Similarly, hydrological analysis was done to extract channel network and delineate watershed. By doing so we can create river network, drainage basins, flow direction, flow accumulation and Strahler order. So, generally a base for analyzing the relationship with landslides and outcomes of hydrological analysis was then looked up carefully. Also, Vector Analysis tools (distance, buffer, and centroid) were used to find more information regarding the relationship of different layers (roads, rivers, drainage basins) with landslides.

4. Results and Discussion

Various tools in QGIS have been used to study the existing landslide in order to find its relationship with different terrain and hydrological parameters. The results of terrain and hydrological analysis is elaborated in following subsections:

4.1 Landslide Inventory

Landslides were identified by introducing new layer in QGIS and identifying the landslide based on the Google satellite images. Apart from the natural landslide there were few which were human driven, as a result of reckless rural road development. The Landslide No. 33 covers a huge area of 585085.04 m^2 and it lies in Dhaulagiri Rural Municipality. In Myagdi district total 71 landslides were identified and based on the area covered by landslide, Raghuganga rural municipality is highly affected followed by Dhaulagiri and so on.

The ranking of the administrative unit based on the landslide coverage area is shown in the Table 2.

Table 2: Landslide Distribution in Myagdi (Source-Extraction from QGIS)

Administrative Unit	Number of Landslides	Rank	Area (Sq. km)
Beni Municipality	4	5	0.278
Raghuganga Rural Municipality	32	1	1.314
Malika Rural Municipality	8	3	0.558
Annapurna Rural Municipality	8	4	0.197
Mangala Rural Municipality	7	6	0.062
Dhaulagiri Rural Municipality	12	2	1.187
Total	**71**		**3.596**

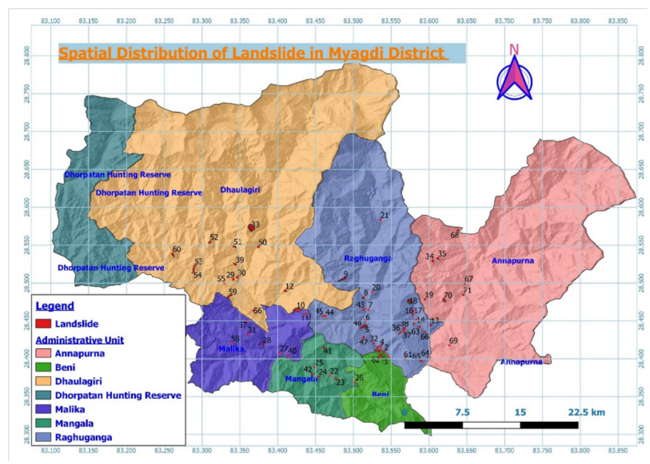

Figure 3: Spatial Distribution of Landslide (Source: Extraction from QGIS)

4.2 Terrain Analysis

Terrain analysis includes the use of a (Digital Elevation Model) DEM to model the landscape. It helps to describe, analyze and interpret any topographically related features. Here generally the primary attributes (Slope, Aspect, Profile Curvature, Tangential Curvature, and Hill Shade) of terrain analysis are calculated directly from elevation data[6]. So, a DEM file after attribute calculation gives different terrain attributes. So at first an ASTER GTM (DEM) data was downloaded (Source: earthexplore.usgs.gov) and work was carried out on it. Also, this elevation data was used to distinguish the landscape of Myagdi district into different regions based on elevation. (Refer: Table 3). From the figure below we can notice that landslide prone region in hilly region like Myagdi, lies in upper climate zones. The result may be due to soil characteristics, rainfall characteristics, and other phenomenon.

Table 3: Topology of Myagdi (Source: Wikipedia)

Climate Zone	Elevation Range	% of Area
Upper Tropical	300 – 1000 m	0.1
Subtropical	1000 – 2000 m	17.5
Temperate	2000 – 3000 m	28
Subalpine	3000 – 4000 m	21.1
Alpine	4000 – 5000 m	17.8
Nival	above 5000 m	13.9
Trans-Himalayan	3000 – 6400 m	1.6

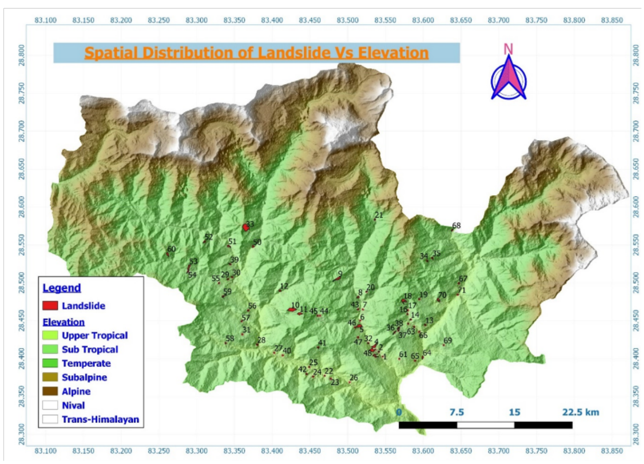

Figure 4: Spatial Distribution of landslide Vs Elevation (Climate Zones)
(Source: Extraction from QGIS)

4.2.1 HILLSHADE

Hill shade is one of Raster Analysis function which is used to output the raster with a nice shaded relief effect. Relief refers to the highest and lowest elevation points in an area. Mountains and ridges are typically the highest elevation points, while valleys and other low-lying areas are the lowest. We can specify the azimuth and altitude of the light source, a vertical exaggeration factor and a scaling factor to account for the difference between the horizontal and vertical units. Here we have taken azimuth of light 315 degree and altitude of light as 45 degree. Similarly, vertical exaggeration factor and Z- factor (ratio of vertical and horizontal units) were taken as 1. Generally, for hills the distribution of rainfall is affected on the orientation (leeward and windward). Windward side receive more rainfall than leeward side and is rich in vegetation as compared to the later one. Also, the profile, soil characteristics, rainfall characteristics differs from region to region. These features definitely, influence the spatial distribution of landslide in the region

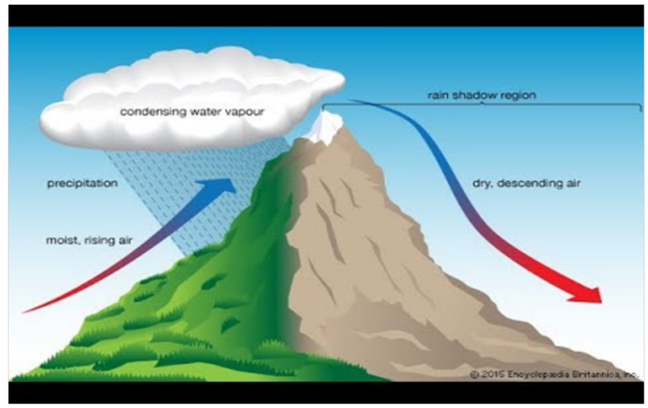

Figure 5: Leeward Side and Windward side of a hill
(Source: cimioutdoored.org)

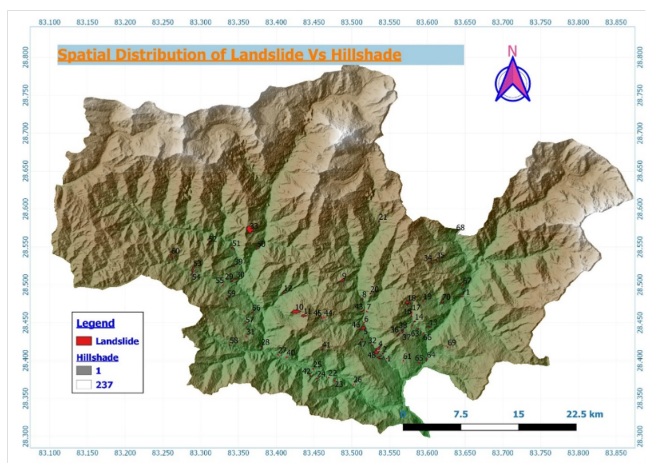

Figure 6: Spatial Distribution of Landslide vs Hill Shade
(Source: Extraction from QGIS)

4.2.2 Slope

Slope is one of the prominent primary attribute of terrain analysis. It basically shows how steep the hill is. Slope analysis quantifies the maximum rate of change in value from one cell to its neighbors. Slope has direct correlation with water as water always flow downhill. So, it generally shows which way the water is moving with aspect and describes overland and subsurface flow velocity and runoff rate. Among the 71 identified landslides, the spatial distribution of landslide based on slope can be summarized as shown in Table 4.

Table 4: Slope Vs Landslide (Source: Extraction from QGIS)

Slope in Degree	Landslide_id	Number of landslide(s)
0-15	25, 63, 64	3
15-30	1, 4, 5, 6, 8, 14, 15, 17, 19, 21, 24, 31, 32, 36, 38, 39, 44, 45, 46, 49, 51, 53, 54, 55, 57, 58, 61, 62, 66, 68	30
30-45	3, 12, 13, 20, 22, 23, 26, 27, 28, 37, 40, 42, 43, 48, 50, 56, 60, 65, 67	19
45-60	2, 7, 9, 10, 11, 16, 18, 29, 30, 33, 34, 35, 47, 52, 59, 69, 70, 71	18
60-75	41	1
75-90		

So basically, landslides are higher in number for mild slope as compared to high and low slope values.

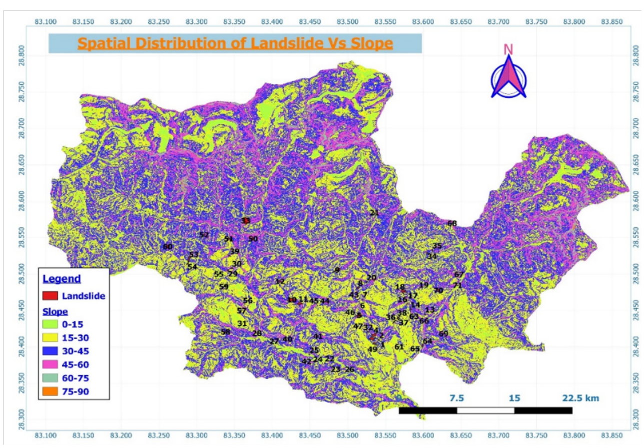

Figure 7: Spatial Distribution of Slope Vs Landslide

4.2.3 Aspect

Aspect defines the cardinal direction (0 – 360°) a surface is facing. It shows which way the landscape is facing. So, Aspect defines the direction of flow. Among the 71 identified landslides, the spatial distribution of landslide based on aspect can be summarized as:

Table 5: Aspect Vs Landslide (Source: Extraction from QGIS)

Aspect	Interval	Landslide_id	Number of landslides
N	0 – 22.5		
NE	22.5 – 67.5	23, 31, 36, 37, 38, 48, 51, 54, 57, 62, 63, 64, 66	13
E	67.5 – 112.5	5, 8, 15, 19, 32, 49, 55, 69, 70, 71	10
SE	112.5 – 157.5	9, 16, 17, 18, 21, 24, 26, 28, 33, 35, 39, 42, 43, 46, 47, 50, 52, 56, 59, 60, 67, 68	22
S	157.5 – 202.5	10, 12, 13, 25, 29, 30, 34, 40, 41, 45, 61, 65	12
SW	202.5 – 247.5	2, 3, 4, 6, 11, 14, 20, 27, 44, 53, 58	11
W	247.5 – 292.5	1, 7, 22	3
NW	292.5 – 337.5		
N	337.5 – 360		

As we can see that most of the landslides is facing from North East to South West (22.5-247.5°) in Myagdi. It may be one of the factors influencing landside in this region.

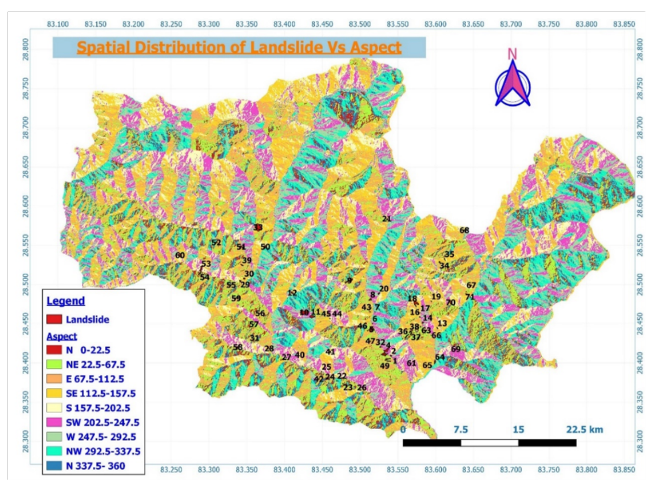

Figure 8: Spatial Distribution of Landslide Vs Aspect

All the result can be summarized as shown in Table 6.

Table 6: Terrain Analysis Summary

Landslide_id	Latitude	Longitude	Area	Location	Slope	Aspect
1	28.40268	83.54637	4538.79	Beni	15-30	W
2	28.40889	83.54103	18848.63	Raghuganga	45-60	SW
3	28.41189	83.53635	6072.5	Raghuganga	30-45	SW
4	28.41608	83.53519	187698.5	Raghuganga	15-30	SW
5	28.44319	83.51552	202457.4	Raghuganga	15-30	E
6	28.45036	83.51649	5627.88	Raghuganga	15-30	SW
7	28.46502	83.51976	5536.71	Raghuganga	45-60	W
8	28.48134	83.51388	61502.42	Raghuganga	15-30	E
9	28.50583	83.48726	177808.4	Raghuganga	45-60	SE
10	28.46459	83.42486	359881.7	Malika	45-60	S
11	28.45927	83.43598	147040.6	Malika	45-60	SW
12	28.48968	83.41003	56175.63	Raghuganga	30-45	S
13	28.44432	83.60244	19205.21	Raghuganga	30-45	S
14	28.45158	83.58341	30873.83	Raghuganga	15-30	SW
15	28.44609	83.57999	11158.3	Raghuganga	15-30	E
16	28.4589	83.57915	6644.65	Raghuganga	45-60	SE
17	28.46391	83.57986	1612.84	Raghuganga	15-30	SE
18	28.47656	83.57359	189000.7	Raghuganga	45-60	SE
19	28.47844	83.59466	5521.78	Annapurna	15-30	E
20	28.48806	83.52464	22914.33	Raghuganga	30-45	SW
21	28.58344	83.53584	23844.61	Raghuganga	15-30	SE
22	28.37752	83.46935	8663.7	Mangala	30-45	W
23	28.37346	83.47751	5612.09	Mangala	30-45	NE
24	28.37632	83.45405	3058.82	Mangala	15-30	SE
25	28.38881	83.449	9032.22	Mangala	0-15	S
26	28.36889	83.50234	1743.27	Mangala	30-45	SE
27	28.40762	83.40263	3258	Malika	30-45	SW
28	28.41836	83.38002	9261.29	Malika	30-45	SE
29	28.50472	83.34151	28554.49	Dhaulagiri	45-60	S
30	28.50744	83.34686	34283.56	Dhaulagiri	45-60	S
31	28.43203	83.36039	487.85	Malika	15-30	NE
32	28.42052	83.5271	26366.56	Raghuganga	15-30	E
33	28.57129	83.36493	585085	Dhaulagiri	45-60	SE
34	28.52902	83.60495	23002.22	Annapurna	45-60	S
35	28.53283	83.61185	18610.55	Annapurna	45-60	SE
36	28.43478	83.56203	54558.59	Raghuganga	15-30	NE
37	28.43705	83.56698	27282.17	Raghuganga	30-45	NE
38	28.4406	83.56759	49809.95	Raghuganga	15-30	NE
39	28.52445	83.3444	31039.5	Dhaulagiri	15-30	SE
40	28.40431	83.41381	1858.63	Malika	30-45	S
41	28.41479	83.46073	20552.31	Mangala	60-75	S
42	28.37987	83.44543	13288.66	Mangala	30-45	SE
43	28.46513	83.5136	9327.59	Raghuganga	30-45	SE
44	28.45658	83.46319	1700.5	Raghuganga	15-30	SW
45	28.45665	83.46019	6295.74	Raghuganga	15-30	S
46	28.4413	83.50954	4113.57	Raghuganga	15-30	SE
47	28.42808	83.51358	5169.53	Raghuganga	45-60	SE
48	28.41185	83.53171	190722	Beni	30-45	NE
49	28.40262	83.5368	19873.59	Beni	15-30	E
50	28.54763	83.37458	64187.1	Dhaulagiri	30-45	SE
51	28.54858	83.34165	75454.51	Dhaulagiri	15-30	NE
52	28.55435	83.31033	36551.75	Dhaulagiri	45-60	SE
53	28.52227	83.29008	135266.9	Dhaulagiri	15-30	SW
54	28.51508	83.28856	33935.7	Dhaulagiri	15-30	NE
55	28.49971	83.32941	8616.6	Dhaulagiri	15-30	E
56	28.46358	83.36812	10466.57	Raghuganga	30-45	SE
57	28.44935	83.35947	9775.81	Malika	15-30	NE
58	28.42061	83.33838	26757.45	Malika	15-30	SW
59	28.48243	83.33503	54610.19	Dhaulagiri	45-60	SE
60	28.53855	83.26102	99498.92	Dhaulagiri	30-45	SE
61	28.39967	83.56806	6085.32	Raghuganga	15-30	S
62	28.40487	83.53502	62889.82	Beni	15-30	NE
63	28.44202	83.5878	14005.53	Raghuganga	0-15	NE
64	28.4015	83.5993	62794.96	Raghuganga	0-15	NE
65	28.39734	83.58903	4840.91	Raghuganga	30-45	S
66	28.43541	83.5945	4290.54	Raghuganga	15-30	NE
67	28.49935	83.64717	7411.49	Annapurna	30-45	SE
68	28.56947	83.6384	26843.65	Annapurna	15-30	SE
69	28.4178	83.62695	9585.19	Annapurna	45-60	S
70	28.4777	83.61961	99712.88	Annapurna	45-60	S
71	28.48438	83.64556	6115.29	Annapurna	45-60	S

4.2.4 Profile Curvature and Tangential Curvature

Profile Curvature is parallel to the direction of maximum slope. It affects the acceleration and deceleration of flow across the surface and therefore, influences the erosion and deposition. A negative value indicates upwardly convex surface at that cell, positive value indicated upwardly concave and zero value indicates that the surface is linear at that cell. Similarly, Tangential Curvature is perpendicular to the direction of maximum slope. It influences the convergence and divergence of flow. A negative value indicates sideward convex surface at that cell, positive value indicated sideward concave and zero value indicates that the surface is linear at that cell. So, both of this terrain attributes help us understand the topology.

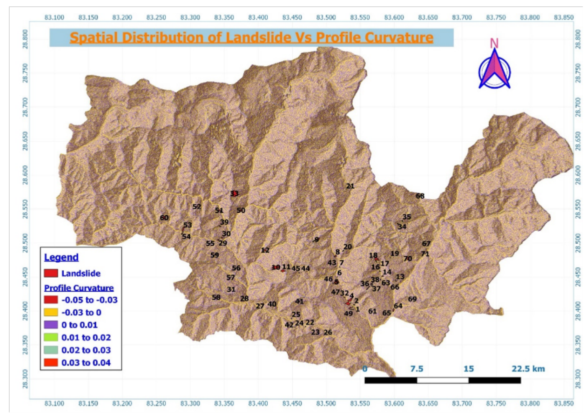

Figure 9: Spatial Distribution of landslide Vs Profile Curvature (Source: Extraction from QGIS)

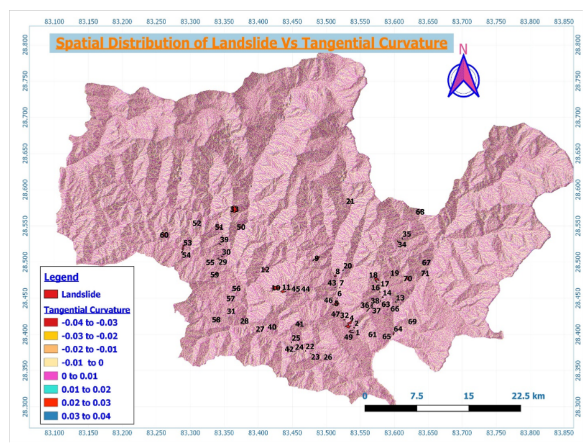

Figure 10: Spatial Distribution of Landslide Vs Tangential Curvature (Source: Extraction from QGIS)

From Figure 9, we can see that most of the landslide lies in the region having positive profile curvature value which indicated the surface is upwardly concave at the cell. So, we can assume that, such upwardly concave surfaces are susceptible to landslides. Similarly, from Figure 10 we can see that most of the landslide lies in the region having positive tangential curvature value which indicated the surface is sideward concave at the cell[7]. So, we can assume that, such sideward concave surfaces are susceptible to landslides.

4.3 Hydrological Analysis

Hydrological Analysis is done to extract channel network and delineate watershed. As water is the major reason for most of the disaster, so hydrological analysis is very important in understanding the landslide susceptibility and its spatial distribution.

At first, flow accumulation raster is created where every cell represents the number of cells from which it collects water. And if we join the cells which exceed the threshold value, it will create a river network. Similarly, watershed is created by joining the raster cells from which water flows to create point. So, in this way channel network and drainage basins can be created.

Each segment of a stream or river within a river network is treated as a node in a tree, with the next segment downstream as its parent. When two first-order streams come together, they form a second-order stream. When two second-order streams come together, they form a third-order stream and so on. Thus, in Strahler's ordering the main channel is not determined; instead the ordering is based on the hierarchy of tributaries. Similarly, a drainage basin is an area where precipitation is collected and drains off to a common drain such as river, bay or other types of water body. The region comprises of perennial rivers (Kali Gandaki, Myagdi) and due to the hilly terrain there are river which are active in monsoon season and are responsible for huge sediment transport to basins at lower elevation. And hence give rise to many shallow types of landslide in this region. The landslide distribution from the main channel was analyzed by using Buffer tool. The result can be summarized as shown in Table 7.

Table 7: Landslide Distribution Vs River Channel Buffer Zone (Source: Extraction from QGIS)

Buffer Zone	Landslide_id	No. of Landslides
20 feet	2, 4, 19, 33, 34, 36, 37, 38, 44, 48, 60	11
40 feet		
60 feet	50	1
80 feet	63	1

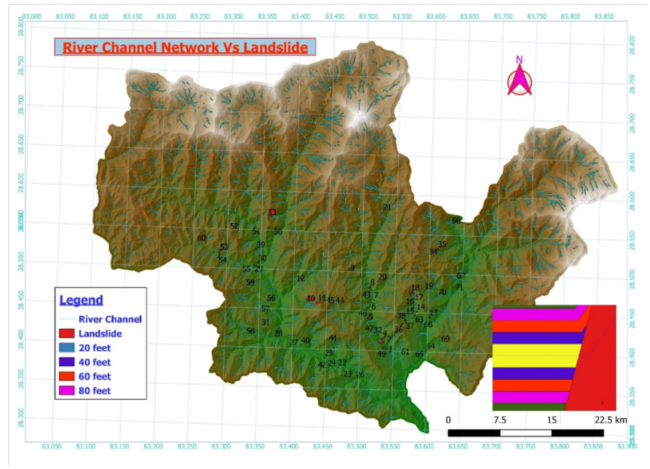

Figure 11: Spatial distribution of landslide Vs River Network with different buffer zones(Source: Extraction from QGIS)

4.4 Landslide and Road Development

Some vector analysis tools were used to better understand the distribution pattern of landslides and to clarify if the cause was actually artificial. Here different buffer zones around the road network were created to identify the landslide within its vicinity. Since the rural road construction is being done by using heavy machinery and without prior knowledge about the geology and meteorological study of the place, landslides are the consequence of this reckless acts. The result of vector analysis can be summarized in Table 8.

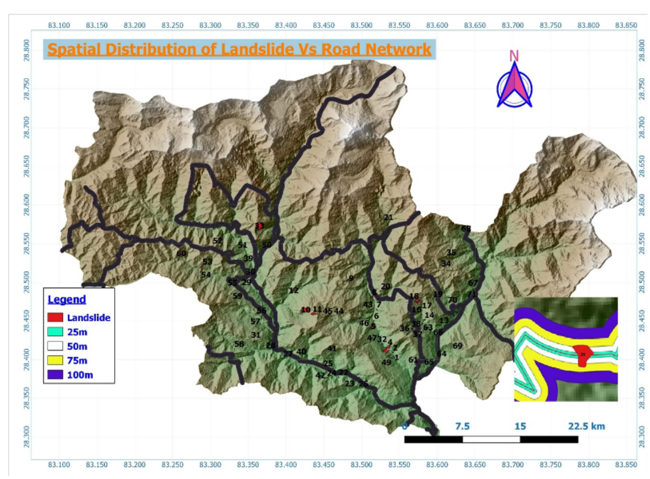

Figure 12: Spatial Distribution of landslide vs Road network with different buffered zones (Source: Extraction from QGIS)

Table 8: Landslide Distribution Vs Road Network Buffer Zone (Source: Extraction from QGIS)

Buffer Zone	Landslide_id	No. of Landslides
25 meter	26, 27, 29, 30, 55, 56	6
50 meter	50	1
75 meter	40, 25, 64, 39	4
100 meter	7	7

4.5 Limitation

Even though, all the above-mentioned analysis processes in methodology section requires less time and resources than field-based survey, it still does depend on some ground verification to make sure that the result of the assessment is authentic and reliable. So, some tangible information related to the district may add more authenticity and make this report more holistic and accurate. Since other tangible information related to the district was not available at this moment, this assessment was generally carried out based on the satellite images and DEM file and other relevant information found in different articles.

5. Conclusion

This assessment is generally based on the remote sensing data and the information which is generated is simply by using QGIS software. It can be considered as a preliminary study of landslide in Myagdi district. Although the study may seem informal as only some shape files, raster data and satellite image were under scrutiny to get information related to the landslide, this approach can be considered a powerful and effective tool for initial study landslide. This assessment thus highlights the key terrain, hydrological and anthropogenic parameters and their relationship with landslide in Myagdi district. The results of this study can be used for sustainable development planning and help in building efficient preparedness and mitigation measures to reduce the effects of landslide in this region.

From the terrain analysis we can notice that the landslide prone region lies in upper climate zones. Also, the windward side of hills receive more rainfall and are rich in vegetation, the landslides in this region are generally monsoon driven. If we study the leeward side which have comparatively less rainfall, dry landslides are common in this region and are activated due to various weathering actions.

Since the slope has direct correlation with water as water always flows downward, we can see from this study that the number of landslides is maximum in region where slope varies from 15 to 60 degrees. Similarly, if we consider the aspect which determines in which direction the land is facing, we can see that the region from North East to South West has higher susceptibility to landslide. And if we consider the profile curvature, we can notice that most of the landslide lies in the region having positive profile curvature value which indicates that the surface is upwardly concave. In case of tangential curvature, we can see that maximum number of landslides lies in the region having positive tangential curvature, which indicates sideward concave surface. Hydrological analysis result shows that there is maximum landslide in twenty feet buffer region from river channel. Also, we can see that the reckless road development without prior technical study can trigger landslide.

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