KATHMANDU UNIVERSITY

SCHOOL OF ENGINEERING

DEPARTMENT OF GEOMATICS ENGINEERING

FINAL REPORT

AHP FOR LANDSLIDE SUSCEPTIBILITY AREA

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List of Abbreviation

AHP	Analytical Hierarchy Process
DEM	Digital Elevation Model
GIS	Geographic Information System
ICIMOD	International Centre for Integrated Mountain Development
Km	Kilometer
M	Meter
MCDA	Multi Criteria Decision Analysis
MCDM	Multi Criteria Decision Making
WGS	World Geodetic system

A)ABSTRACT

Landslide problems are abundant in the mountainous areas of Nepal. This study aims to prepare landslide susceptibility map (LSM)using Analytical Hierarchy Process (AHP) method of BUTWAL-PALPA, Nepal. Five factor maps : slope, aspect, distance to stream/river, precipitation, and distance to road were used for preparing thematic layers. Weight for each factor was assigned using AHP depending on its influence on the landslide study revealed that higher slope (>30 deg)occurrence. The LSM was obtained with combination of weighted thematic layers and reclassified into five susceptible classes namely, very low(1), low (2), moderate (3), high (4) and very high(5)..The result showed that about % of the study area is highly susceptible for landslide occurrence. The) with combination of many factor has higher effect on landslide occurrence. Similarly, South facing slopes were found to be more susceptible to landslide occurrence in comparison to other aspects. The majority of the landslides were found near proximity of roads and streams/rivers. Finally, the landslide hazard zonation map was crossed with the landslide distribution map and the model applicability was confirmed by determining the per hazard class percent of area covered by the landslide. The LSM can be useful for the decision-makers and planners in choosing suitable locations for the development works like road network, drainage network, drinking water, etc.

1. Introduction

Landslide is the most damaging geological disaster all around the world causing loss of lives and damage to both man-made and natural structures (Petley et al., 2007; Froude & Petley, 2018).Nepal falls in tectonically most active zones on earth at the center of 2400km long Himalayan mountain range(Petley et al., 2007). Since this region is tectonically very unstable with rugged topography, unstable geological structures, soft and fragile rocks, common earthquakes, along with heavy and prolonged rainfalls during monsoon periods (Devkota et al., 2013), landslides holds significant phenomena among the various land degradation process prevalent in the country (Ahmad & Joshi, 2010). In Nepal, landslide disaster has been accelerated because of the impact of artificial structures and human interventions on mountain slopes followed by expansion of agricultural land, large scale deforestation, unplanned settlements and infrastructure developments as rural roads, hydro-dams, irrigation canals and so on without considering proper engineering plans, geological and geographical investigation (Rajbhandari et al., 2002). Deeply weathered and fractured rocks and greatly incisedrivers and streams contribute to excessive mass wasting in the mountainous terrain. Besides, high precipitation during the monsoon season (June–September) is another detrimental factor, which causes landslips, debris flows and flash floods. Consequently, natural land man-made disasters are increasing, which are often resulting in substantial economic and environmental losses and causing a great suffering to many people (Ministry of Home Affairs, 2018). In this context, the identification of probable landslide hazard zone and an early prediction of such events might be boon for saving millions of life properties and, mitigating the impacts or situation from being worse and serious. Several methods have been used for assessing landslide susceptibility mapping, hazard mapping and risk evaluation (Chauhan et al., 2010; Kayastha et al., 2013; Pardeshi et al., 2013). Inventory, historical records, satellite images and aerial photo interpretation have helped Experts to evaluate inducing factors, and identify sites that have similar geological and geomorphological feature (El Jazouliet al., 2019). Generally, the methods applied for landslide susceptibility mapping can be divided into (1) qualitative method (Kayastha et al., 2013; Sharma and Mahajan, 2018) (2) quantitative method including bivariate and multivariate modeling methods for statistical evaluation of landslides occurrences (Devkota et al., 2013; Sharma and Mahajan, 2018; El Jazouliet al., 2019).Qualitative models are the simplest methods which are entirely based on the expert knowledge and experiences of the persons carrying out the susceptibility or hazard assessment (Kaur et al., 2017).With Bist et al. Agric. For. J. Vol. 4, No. 2 (2020) © 2020 Agriculture and Forestry Journal This is an open access article distributed under the terms of the Creative Commons Attribution-Non Commercial 3.0 International License 81 incorporation of ranking and weighting, some qualitative methods become semi-quantitative method (Ayalew et al., 2005), such as Analytic Hierarchy Process (AHP) (Saaty, 1980; Mandal and Mandal, 2018; Abay et al., 2019) and the weighted linear combination (WLC) (Ayalew et al., 2005; Akgun et al., 2008).The limitation of these qualitative methods is their subjectivity associated with empirical ranking. However, the heuristic method is not necessarily bad when it is based on an expert opinion (Van Westen, 2000).Based on inventorying and heuristic analysis, qualitative or semi-quantitative methods define the risk zones in descriptive terms and are often used for small-scale regional studies (Van Westen, 2000; Zumpano et al., 2014; Sharma and Mahajan, 2018).AHP method is widely used in landslide susceptibility analysis (Kayastha et al., 2013). Using this method, each layer used in landslide susceptibility zoning is broken into smaller factors, then these factors are weighted based on their importance, and eventually the prepared layers are assembled and the final map is realized (Yazdadi& Ghanavati, 2016). In this study, AHP method was used to produce landslide hazard zone that will help to find proper and effective strategies in land use planning and management and also fore casting and finding measures to mitigate sub sequent losses to future landslides

1.1 Problem Statement

This project focuses on landslide risk areas inside Butwal-Palpa region which is a unique terrain in Nepal and a economic place.This region is known for most of the landslide case and is a burning topic. Hence, the objective of this study is to identify region which is risky for landslide using a combination of GIS (Geographic Information System) and MCDA (Multi-Criteria Decision Analysis) techniques.

1.2 Objectives

Primary Objective

- To determine landslide susceptibilty in Butwal-palpa area.

Secondary Objectives

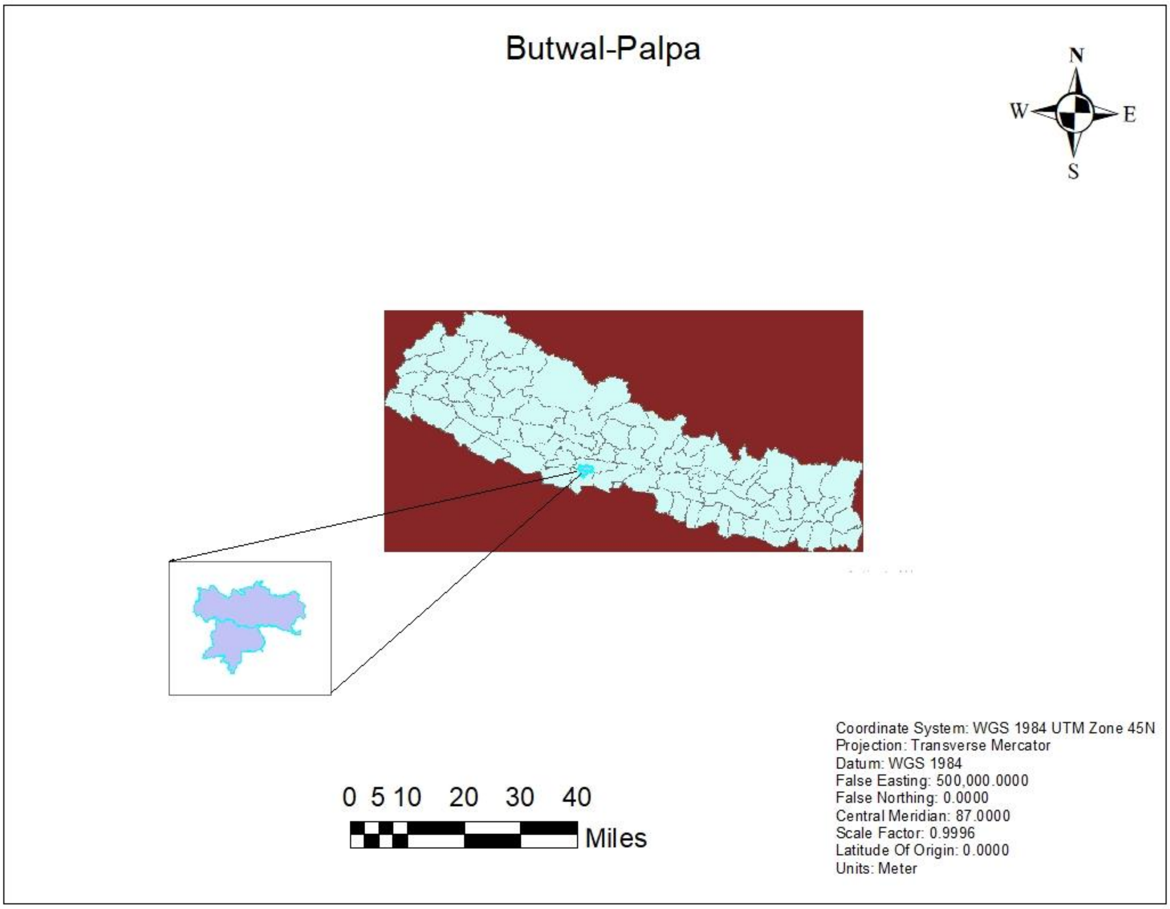
- To explore the Multi Criteria Decision Making (MCDM) as an analysis technique.

This research focuses on identifying optimal locations for landslide susceptibility in the Butwal-Palpa area. This area has the most unique terrain with slope varying from lowest to peak.Also By utilizing Geographic Information Systems (GIS) and a Multi-Criteria Decision Analysis (MCDA) approach, this study incorporates factors such as road networks, water networks, and settlement areas to identify landslide risk areas.

2. Materials and Methodology

2.1. Study Area

The study was done in the Butwal(Rupandehi) and Tinau(Palpa) of Nepal covering an area of 304.381 square kilometer extending from 83.433651 to 83.500038 Decimal Degrees latitude and 27.748235 to 27.766081 Decimal Degrees longitude. Besides, the main problem to indicate is SIDDHABABA area. Study area altitude ranges from 120m to 1700m above the sea level. Main stream namely Tinau flows throughout the study area



2.2. Data Collection and Preparation

A) Digital Elevation Model (DEM) :DEM of the study area was clipped in Arc GIS from freely available SRTM worldwide elevation data with 90 m resolution.Following derivatives were derived from the clipped DEM.

i) Slope(S): Slope gradient was derived from DEM using slope tool feature in Arc GIS. Then it was finally reclassified into 2 different classes as (0-30)degree and >30.

. ii) Aspect: Slopes with different aspects differ in solar radiation intensity, which affects a multitude of factors, including temperature difference, evaporation capacity, vegetation cover and slope surface, as well as slope and landslide stability. Aspects that favor landslide occurrence in the study area are 157.5◦–202.5◦ and 247.5◦–292.5◦

. B)River/ stream Network(Ri):

It was extracted from the data available freely in Arc GIS. The initial downloaded file format was in shapefile.After applying (Multiple ring buffer) tool the stream was divide to 20m , 50m, 100m , 200m .And later rasterized through polygon to raster feature.

C). Road Network(Rd): It was obtained from the free source of open street map by adding data from ArcGIS online named as Nepal roads. The vector data was clipped to study area. By using Multiple ring buffer the distance from road was divided into 20m,100m,150m and 200m. Later rasterized using polygon to raster.

D). Precipitation(P): The precipitation map was obtained from weather station data and further interpolated using kriging.

Here the datas represent the Risk of Landslide by values as:

- very low(1)

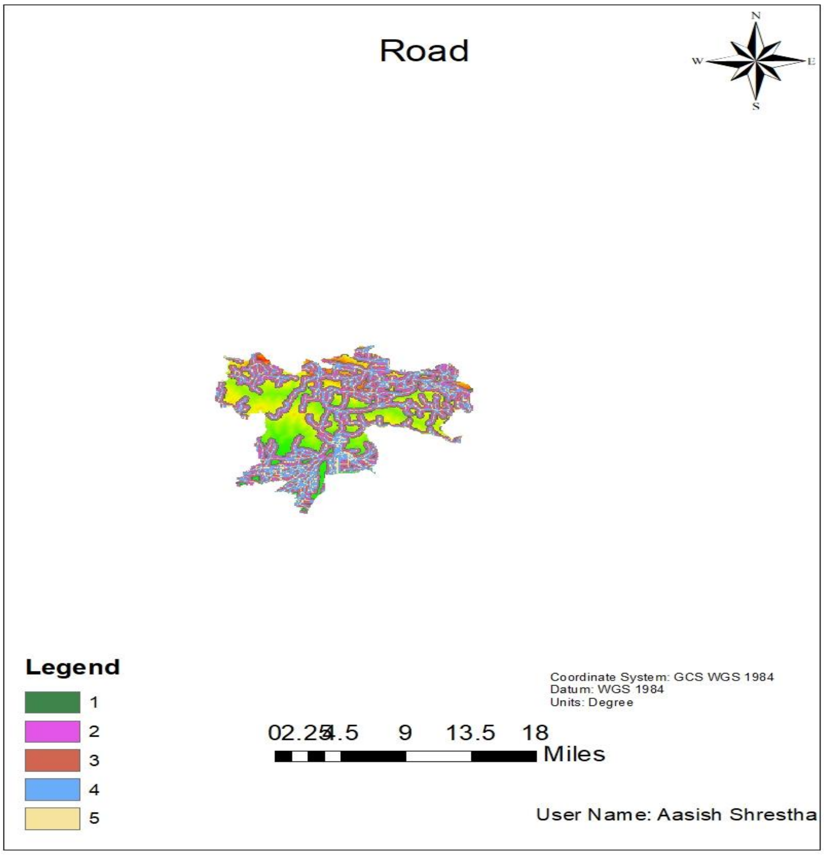
-low (2)

-moderate (3)

-high (4)

-very high(5)

A)


Road
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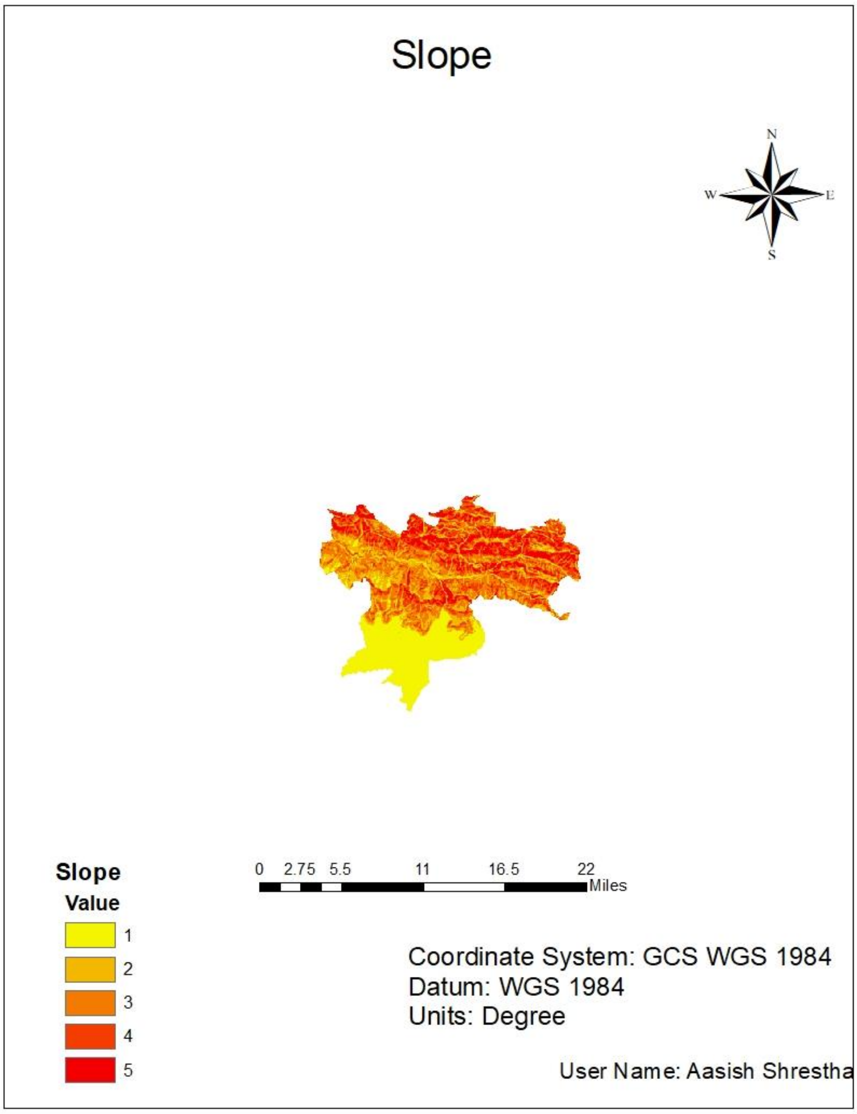
User Name: Aasish Shrestha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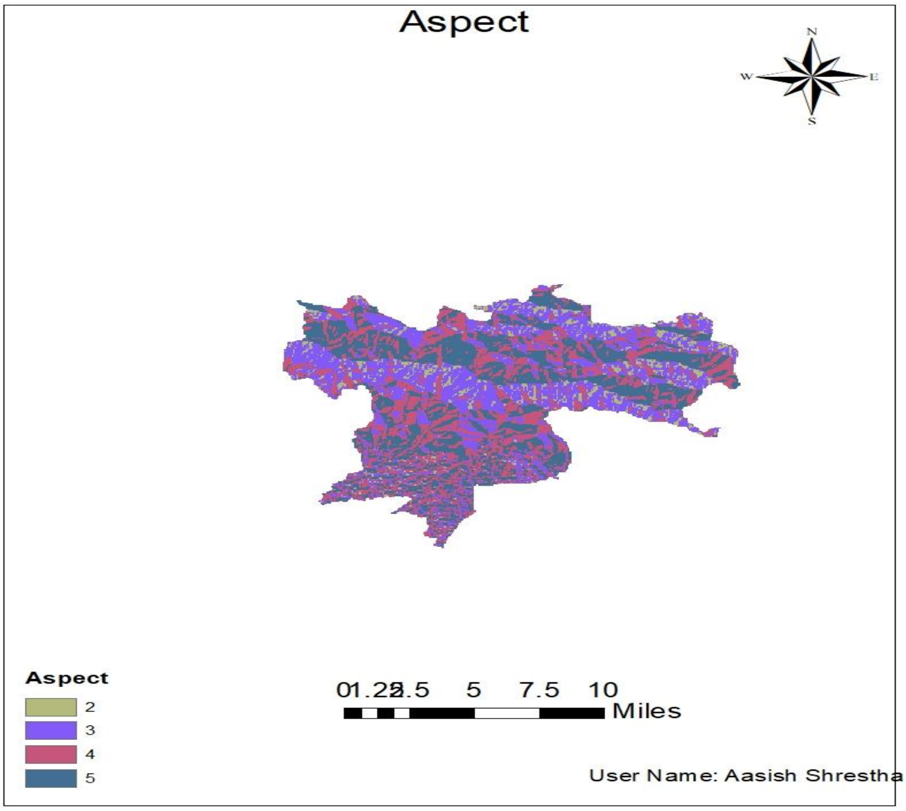
B)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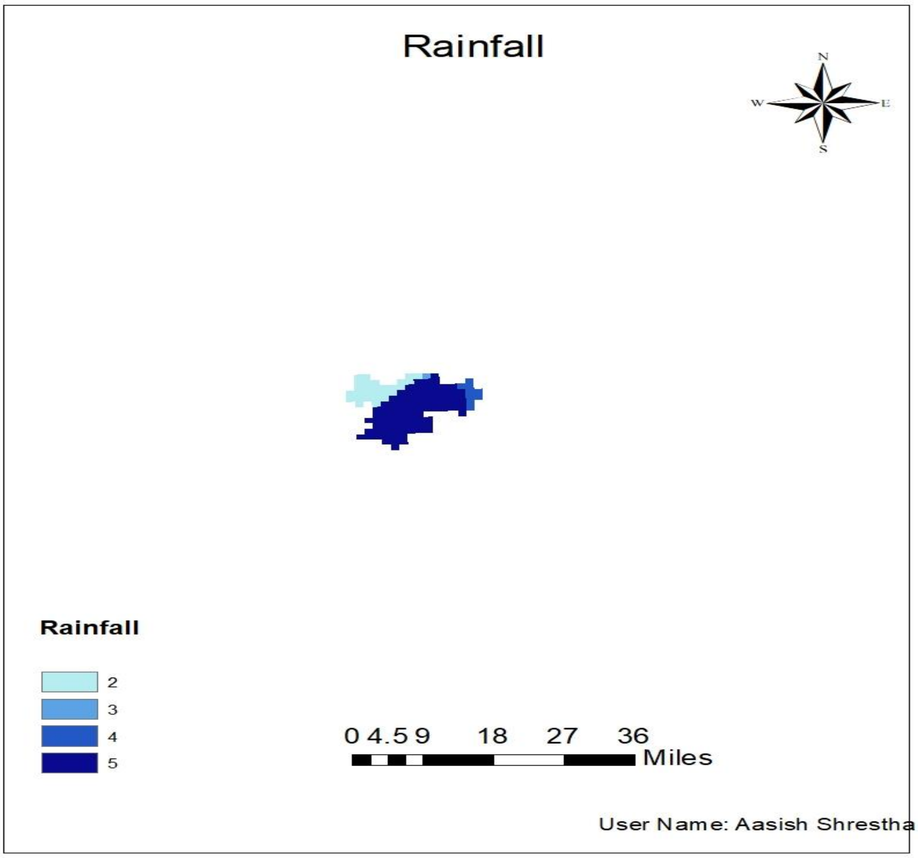
C)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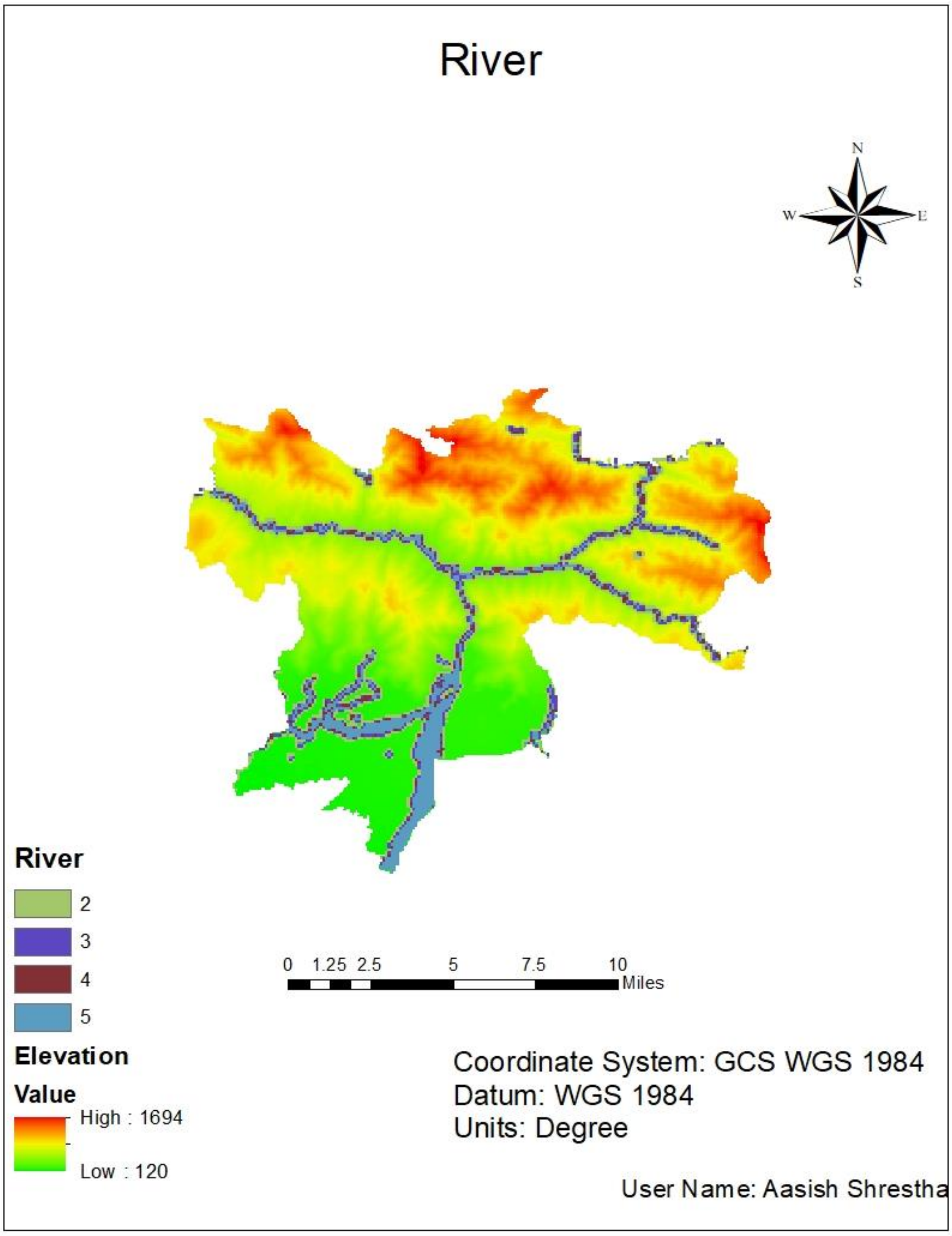
D)



E)

Here,

A-Road

B-Slope

C-Aspect

D-Rainfall

E-River

3)Data Analysis AHP and Weighted overlay method were used to prepare Landslide Susceptibility Map.

Analytical Hierarchy Process (AHP) :The AHP is a semi-qualitative, multi-objective, multi-criteria decision making (MCDM) method, which involves a matrix- based pair wise comparison of the contribution of the different factors which supply a flexible and easily understood way of analyzing complicated problems (Saaty, 1980). While applying AHP, factors were compared with each other to determine the relative preference of each other in accomplishing overall goal and numerical values were assigned to each pair using guidelines established in Fundamental Saaty's scale (Table 1).

Scales	***Degree of preferences***	***Descriptions***
1	Equally	Two activities contribute equally to the objective.
3	Moderately	Experience and judgment slightly to moderately favour one activity over another.
5	Strongly	Experience and judgment strongly or essentially favour one activity over another.
7	Very strongly	An activity is strongly favoured over another and its dominance is showed in practice.
9	Extremely	The evidence of favouring one activity over another is of the highest degree possible of an affirmation.
2, 4,6,	Intermediate	Used to represent compromises between the preferences in

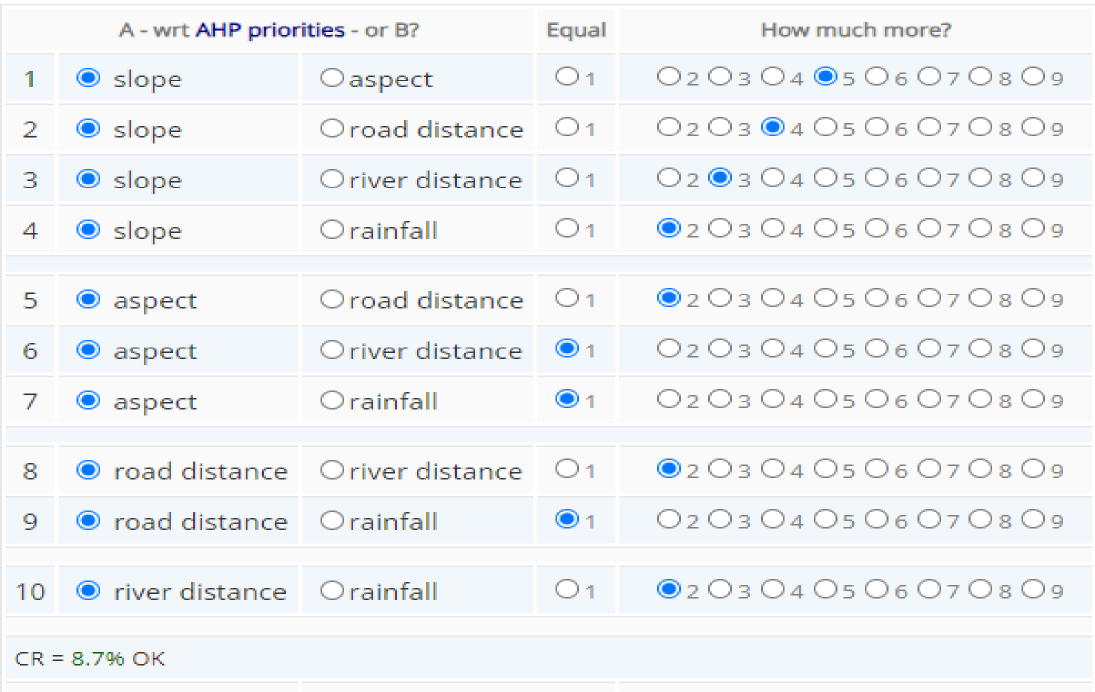
8	Values	weights 1, 3, 5, 7 and 9.

3.1 Establishment of pairwise comparison

The couple comparison method was used to determine the preference of the triggering factors. In this study 8 factors: Slope, Aspect, River, Road, Precipitation were used as triggering factors. In the construction of a pair- wise comparison matrix, each factor was

N	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

rated against every other factor by assigning a relative dominant value between 1 and 9 to the intersecting cell and numerical values assigned in the cell were summed up column wise



	A - wrt AHP priorities - or B?		Equal	How much more?
1	slope	aspect	1	2 3 4 5 6 7 8 9
2	slope	road distance	1	2 3 4 5 6 7 8 9
3	slope	river distance	1	2 3 4 5 6 7 8 9
4	slope	rainfall	1	2 3 4 5 6 7 8 9
5	aspect	road distance	1	2 3 4 5 6 7 8 9
6	aspect	river distance	1	2 3 4 5 6 7 8 9
7	aspect	rainfall	1	2 3 4 5 6 7 8 9
8	road distance	river distance	1	2 3 4 5 6 7 8 9
9	road distance	rainfall	1	2 3 4 5 6 7 8 9
10	river distance	rainfall	1	2 3 4 5 6 7 8 9

CR = 8.7% OK

$$\frac{\lambda_{max}-n}{1-n}$$

	1	2	3	4	5
1	1	5.00	4.00	3.00	2.00
2	0.20	1	2.00	1.00	1.00
3	0.25	0.50	1	2.00	1.00
4	0.33	1.00	0.50	1	2.00
5	0.50	1.00	1.00	0.50	1

Where, CI is the consistency index, which is expressed as

$$CI =$$

Where, λ max is the major or principal Eigen value of the matrix and it is computed from the matrix and n is the order of the matrix. In this study, the principal Eigen value was found to be 8.7. So, CR=(CI/RI) using values of RI as 0.89 and n=5, which indicates a reasonable level of consistency, that is good enough to recognize the factor weights.

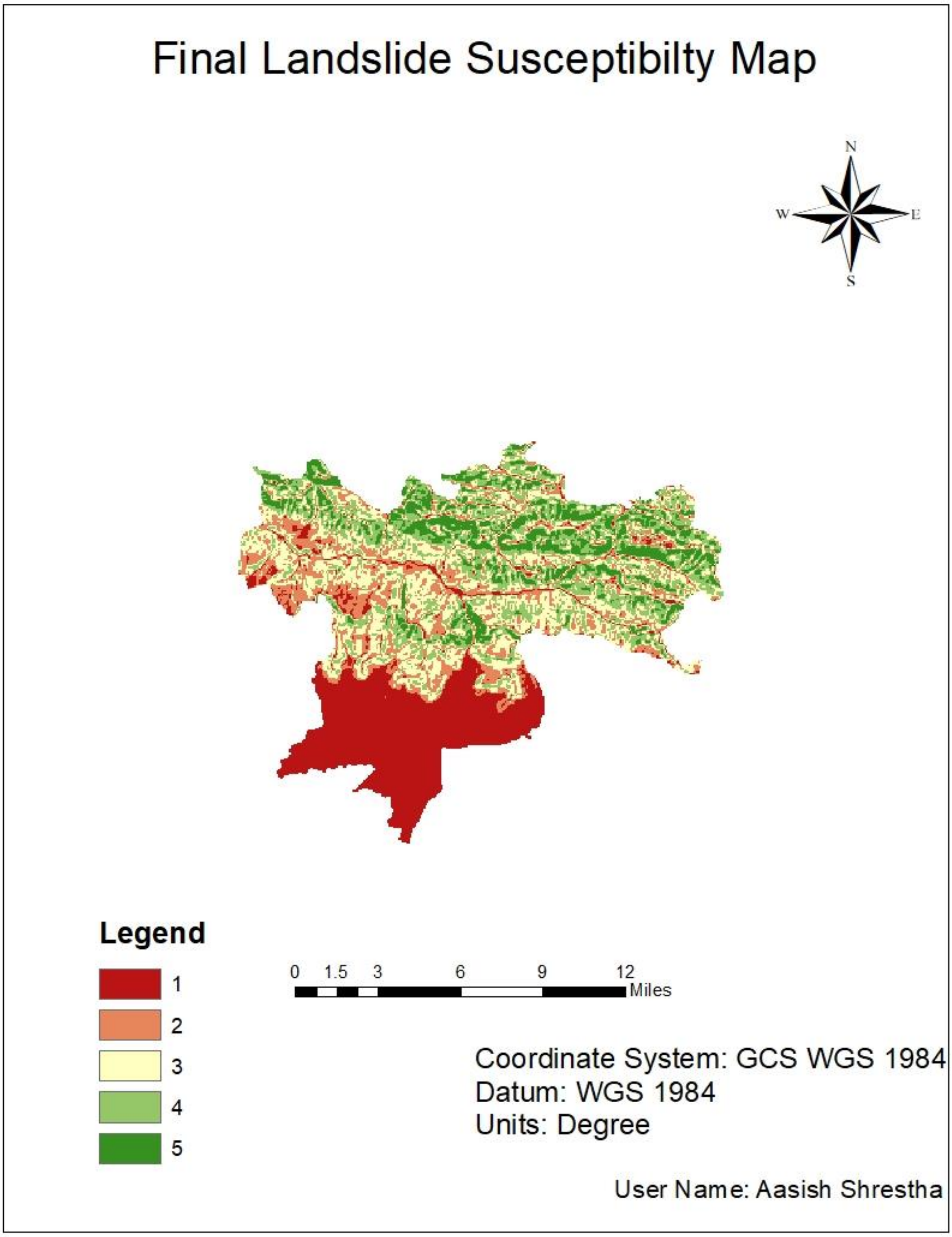
3.2 Assigning weight values to each class of factors

The weight values are given to each class of factors on the basis of the percentages of area covered by the landslide area in each of them. All the classes of the different factors were given values from 0-100. For this, firstly the percentages of area covered by the landslide in each class of different factors were determined. Then, in each class of respective factors the percentage of area covered by the landslide which given intermediate values on proportional basis. Finally, weight values of each class of factors was obtained with multiplication of the weight obtained by the percentage of LS covere area with the factor weight of respective factors

Cat		Priority	Rank	(+)	(-)
1	slope	44.6%	1	15.7%	15.7%
2	aspect	14.5%	2	6.4%	6.4%
3	road distance	13.6%	4	7.5%	7.5%
4	river distance	14.2%	3	6.4%	6.4%
5	rainfall	13.1%	5	5.0%	5.0%

4)Result and discussion

Once the layers were reclassified according to their suitability intervals and ratings, they were assigned weights based on their relative importance, as specified in above Tables. The Model Builderin ArcGIS was employed to utilize the Weighted Overlay tool, which facilitated the overlay of all thereclassified layers. This process aimed to identify and delineate the suitable areas for the selection ofa dumping site.This analysis provided valuable information on the spatial distribution and proportion of landslide susceptibilty areas.


Final Landslide Susceptibilty Map
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1.5
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12
Miles
Coordinate System: GCS WGS 1984
Datum: WGS 1984
Units: Degree
User Name: Aasish Shrestha

5) **Limitation**

Some of the limitations of the project are:

1.Data Sources: The reliance on secondary data from the internet introduces potential inaccuracies andoutdated information, raising concerns about the validity and reliability of the data.
2.Scope of Criteria: The analysis considered a limited number of factors, excluding important considerations such as economic and social factors, which may result in an incomplete evaluation ofdumping site suitability.
3.Data Authenticity: The reliability and authenticity of the data obtained solely from internet sources are questionable, emphasizing the importance of verification and validation from local authorities.
4.Data Integration Challenges: Heterogeneity in data formats, projections, and cell sizes posed challenge sduring data integration and processing, potentially impacting the accuracy of the results.
5.Limited Knowledge and Guidance: Initial difficulties arose due to a lack of expertise in GIS-integrated MCDA techniques, but efforts were made to overcome this limitation through group discussions and literature review.
It is important to acknowledge and address these limitations to improve the reliability and robustness offuture studies in this field.

6)Conclusion and recommendations

Natural disasters are inevitable and it is almost impossible to fully recover from the damages, though can be mitigated the potential risks by preparing and implementing the disaster plans which could assist in rehabilitation. The preparation of landslide hazards map could be foremost and crucial for mitigation and early warning of such events by identifying landslide prone areas. For this, this study suggests that the landslide susceptibility map can be prepared with the help of possible landslide inducing factors using AHP techniques and GIS environment tools, as the results of which could be validated by use of the zonal histogram function andchi-square test. In the study area, majority of the areas falls under high hazards class followed by medium hazards class while few areas fall under very low hazards class depicting that the studied area needs to keep alarming for mitigating the future disaster to happen.. In addition, westernfacing slopes and nearby of river/stream and roads revealed high occurrence of landslide events. These maps can be considered as base map for landslide hazard evaluation when intending to avoid or reduce future hazard's impacts and improve decision prior to any development

References

1. Abay A., Barbieri G., Woldearegay K., 2019. GIS-based Landslide Susceptibility Evaluation Using Analytical Hierarchy Process (AHP) Approach: The Case of Tarmaber District, Ethiopia. *Momona Ethiopian Journal of Science*, 11(1): 14–36.
2. Abdul Rahamana S., Aruchamy S., Jegankumar R., 2014. Geospatial Approach on Landslide Hazard Zonation Mapping Using Multicriteria Decision Analysis: A Study on Coonoor and Ooty, Part of Kallar Watershed, The Nilgiris, Tamil Nadu. ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XL (8): 1417–1422.
3. Ahmad R., Joshi M.N., 2010. Assessment of landslide susceptibility on land degradation processes in Chamoli and surrounding area using RS and GIS technique. *Int Geoinf Res Dev J*, 1(3):
4. Akgun A., Dag S., Bulut F., 2008. Landslide susceptibility mapping for a landslide-prone area (Findikli, NE of Turkey) by likelihood-frequency ratio and weighted linear combination models. *Environmental Geology*, 54(6): 1127–1143.
5. Ayalew L., Yamagishi H., Marui H., Kanno T., 2005. Landslides in Sado Island of Japan: Part II. GIS- based susceptibility mapping with comparisons of results from two methods and verifications. *Engineering Geology*, 81(4): 432–445.
6. Bui D. T., Pradhan B., Lofman O., Revhaug I., Dick O.B.,2012. Spatial prediction of landslide hazards in Hoa Binh province (Vietnam): A comparative assessment of the efficacy of evidential belief functions and fuzzy logic models. *Catena*, 96, 28–40.
7. 7Chauhan S., Sharma M., Arora M.K., 2010. Landslide susceptibility zonation of the Chamoli region, Garhwal Himalayas, using logistic regression model. *Landslides*, 7(4): 411–423.
8. Devkota K.C., Regmi A.D., Pourghasemi H.R., Yoshida K., Pradhan B., Ryu I.C., Dhital M.R., Althuwaynee O.F., (2013). Landslide susceptibility mapping using certainty factor, index of entropy and logistic regression models in GIS and their comparison at Mugling–Narayanghat road section in Nepal Himalaya. *Natural Hazards*, 65(1), 135–165.
9. Earthxplorer, 2018. Earth Explorer. https://earthexplorer.usgs.gov/
10. El Jazouli A., Barakat A., Khellouk R., 2019. GIS-multicriteria evaluation using AHP for landslide susceptibility mapping in Oum Er Rbia high basin (Morocco). Geoenvironmental Disasters, 6(1): 3.

11. Froude M.J., Petley D.N., 2018. Global fatal landslide occurrence from 2004 to 2016. *Natural Hazards and Earth System Sciences*, 18(8): 2161–2181.
12. Kanwal S., Atif S., Shafiq M., 2017. GIS based landslide susceptibility mapping of northern areas of Pakistan, a case study of Shigar and Shyok Basins. *Geomatics, Natural Hazards and Risk*, 8(2): 348– 366.
13. Kaur H., Gupta S., Parkash S., 2017. Comparative evaluation of various approaches for landslide hazard zoning: A critical review in Indian perspectives. *Spatial Information Research*, 25(3): 389–398.
14. Kayastha P., Dhital M.R., De Smedt F., 2013. Application of the analytical hierarchy process (AHP) for landslide susceptibility mapping: A case study from the Tinau watershed, west Nepal. *Computers & Geosciences*, 52: 398–408.
15. Lee S., Min K., 2001. Statistical analysis of landslide susceptibility at Yongin, Korea. *Environmental Geology*, 40(9): 1095–1113.
16. Mandal B., Mandal S., 2018. Analytical hierarchy process (AHP) based landslide susceptibility mapping of Lish river basin of eastern Darjeeling Himalaya, India. *Advances in Space Research*, 62(11): 3114–3132.
17. Ministry of Home Affairs, 2018. Nepal Disaster Report, 2017: The Road to Sendai. Government of Nepal.
18. Pardeshi S.D., Autade S.E., Pardeshi S.S., 2013. Landslide hazard assessment: Recent trends and techniques. *SpringerPlus*, 2(1): 523.
19. Petley D.N., Hearn G.J., Hart A., Rosser N.J., Dunning S.A., Oven K., Mitchell W.A., 2007. Trends in landslide occurrence in Nepal. *Natural Hazards*, 43(1): 23–44.
20. Rajbhandari P.C.L., Alam B.M., Akther M.S., 2002. Application of GIS (Geographic Information System) for landslide hazard zonation and mapping disaster prone area: A study of Kulekhani Watershed, Nepal. *Plan Plus*, 1(1): 117–123.
21. Saaty T. L., 1980. The analytic hierarchy process McGraw-Hill. New York, 324.