Geographical Information Systems and Analysis – A Case Study of Landslide in Adelaide Hills

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Abstract：The previous presentation described the process of finding landslide susceptibility zonation based on GIS, which contained four parts. Firstly, according to read journals and articles, we applied similar methodology which has been used by some scientists in previous researches or journals to confirm the potential hazard areas and then this presentation indicated what types of areas that are more susceptible to trigger landslide and the scope of our study area. Next, how to divide the different landslide hazard level has been introduced. Lastly, three main criteria such as slope, soil types and water course have been applied to filtrate the highest risk landslide area.

Landslide, defined as the mass movement of rock and one of the devastating geological process.Besides, Landslide as one of the major natural hazards, which causes huge property damage and even the loss of life almost every year in mountainous areas (Rawat et al. 2015; Huabin et al., 2005). For example, the landslide cause 1573 people dead and more than 10000 people injured and 500000 houses ruined in China mountainous areas in 1988(Huabin et al., 2005). Moreover, according to a declaration of United Nations, it is estimated that, landslide cause the economic losses about two to five billions US dollars per year (Schuster, 1994). Hence, there is a need for identification of landslide-prone areas and landslide-prone areas usually defined as a place where the under-soil is unstable and is more susceptible due to external factors such as sub-ground soil type, slope angle, water course and other geomorphology features (Chung and Fabbri, 1995). Also, our study area Adelaide Hill is mountainous area and nearby a lot of watercourse, a lot of houses built in this area and some roads, walk trails go through this area. Therefore, this research report will classify this area in different hazard level and label the highest risk area to prevent local residents and properties from the damage of landslides.

1. INTRODUCTION

The purpose of this research project is to analyse the landslide susceptibility by GIS. A case study in Adelaide Hills is provided and the high hazard roads are identified so that the hazard markers and sign boards can be posted to warn people. There are three parts of this research project paper. Firstly, the literature review provides the existing works that similar to our research project. Furthermore, the differences between methodology in our case study and the methodologies in the journals are explained. Secondary, the methodology in the articles can be used in our project. This session also includes the problems and difficulties we have found in this research project, the methodologies we used to solve the problems and the knowledge we have gained in this research project. In order to find the hazard road instead of classifying the hazard zone levels, the transport information is collected as the additional data. Then, the data analysis lists the required data in this research project and introduces the source of data. Lastly, the methodology for the research project is explained. It introduces the original ideas, the development of argument and the critical standard for analyzing with convincing arguments.

2. LITERATURE REVIEW

(1) Summary of literature review

Over the past few years, Geographic information system has been developed as an important meanof coping with natural catastrophes by integrating different data and information.Especially, GIS is not only a significant tool for landslide assessment but also a very efficient way to carry out the landslide-prone areas (Rawat et al. 2015; Huabin et al., 2005).Italy example. Moreover, due to the application of GIS techniques, a better opportunity could be provided for the International Decade for Natural Disaster Reduction to address the problems about control of natural catastrophes, including landslides, in an efficient and cost-effective way (Carrara et al. 1999). The earliest application that relates to GIS to analyse the landslide hazard zone was conducted by Alberto who used a multivariate model for landslide hazard evaluation in 1983. Also, Carrara (1983) described that the occurrence of landslide has a strong link with slope angle, drainage density, surface roughness and lithology (rock type). Meanwhile, a similar research about landslide hazard analysis also mentioned by Hansen (1984) that the stability of underground soil, steep slope and under water catchment are few of the important factors which could trigger a landslide. Due to the increasing number of institutes and individuals who are attempting to use GIS tool to evaluate and control landslides, we are able to refer to the previous researches and cases for our critical study methodology in terms of (1) classification of hazard zone level, (2) grade of slope, (3) effect of soil type and (4) water.

(2) Literature review for classification of hazard zone levels

According to the research conducted by Rawat (2015) in Mandakini Valley, the methodology is compared against the historical landslide distribution and involved collection and selection of factors such as land-use, drainage, soil types, slope and aspects of data to generate numerical rating assessment by integrating with GIS, which divided the final landslide hazard zonation map into “very high”, “high”, “moderate”, “low”, “very low”, hazard zones. Another study organized by Saha, Gupta and Arora (2002) to classify landslide hazard level by using the similar rating or weighting evaluation method and also two extra elements such as photo-lineament(buffer) and relative relief have been considered in study case. For our study, we just consider the three key criteria soil type, slope and watercourse.

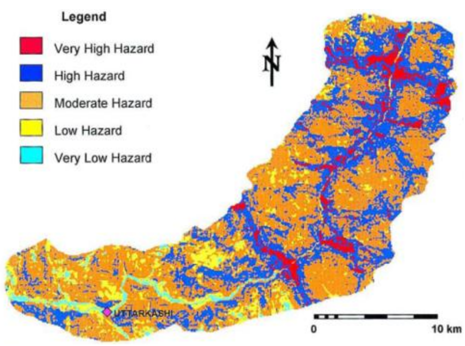

Figure 2.1.1: Classification of hazard zones

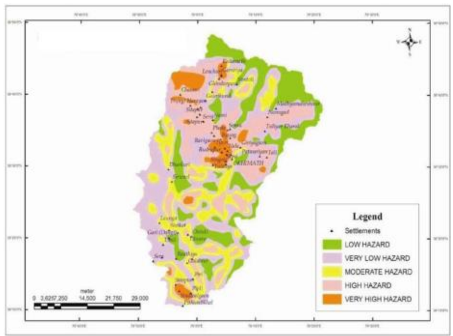

Figure 2.1.2: Classification of hazard zones

(3) Literature review for slope

The most common phenomena such as topples, falls, and slides are parts of consequence of landslide and also the outcome of hillslope erosion which is due to the over-steepening effect and increased weight on hillslope. In other words, the excessive steep hillslope angle is the main reason (Lansern& Parks, 1996). In Rawat's (2015) research, he applied the slope through a digital elevation model (DEM) to delineate slope degree and aspect for the study area and after integrating other factors such as aspect data and existing landslide location, he then classified the slope in six different intervals (Table 3). Dai and Lee (2002) also believed that slope degree or slope gradient has a huge effect on the susceptibility of a slope to landslide. They divided different slopes by considering the variations of soil thickness and strength (which has strong relation to soil type) and also the drainage, because slope can influence the direction of flow. In this study, the steeper the slope, the more landslide occurred (Table b) and the slopes were divided into seven intervals.

Table 3. Ranking and weightage of different thematic layers

Parameter	Rank	Category	Weight
Slope	9.5	0°–15°	1
		15°–30°	7
		30°–45°	9
		45°–60°	6
		60°–75°	5
		75°–90°	4
Lithology	9.3	Phyllite/quartzite	1
		Quartzite alternating with shale/slate/phyllite	6
		Quartzite alternating with schist	6
		Schist	7
		Schist with slate/phyllite	8
		Granites	2
		Gneiss	2
		Basic/metabasic/ulterabasic	3
Geomorphology	8.5	Low dissected hills and valleys	3
		Moderately dissected hills and valleys	6
		Highly dissected hills and valleys	8
		Alluvial fans	4
		River terraces	1
		Valley	1
		Escarpment	5
		Toe removal/erosion/cutting (by river)	9

Figure 2.2.1: Table for classification of Slopes

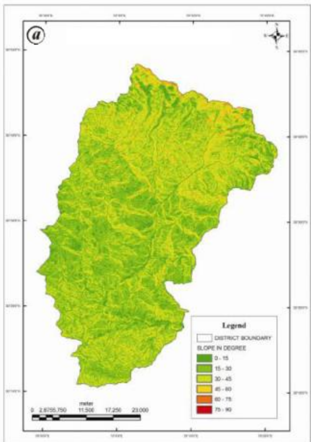

Figure 2.2.2: map for classification of Slopes

(4) Literature review for soil type

The different surface and underground soil types have resulted in different effects on the susceptibility of areas (Rawat 2015). In his study, the weaker rocks usually consist of schist and phyllites, white quartzite, and gneiss. According to Ayalew's (2005) study, the study area Sado Island consisted of sixteen different types of soil and some soil or rock is easier to be weathered and eroded such as dacitic and rhyolite rocks which covered most east and southeast part. Moreover, South Australia Government research data provided criteria about the different types of soil that could cause the landslide. (1). Soils unconsolidated and slowly permeate substrate materials. The clays of the old glacial valleys of Fleurieu Peninsula are in this category. Susceptible soils include deep clays and sand to sandy loam over clay types on slopes are as low as 12%. (2) Soils on sodic shales and quartzite. The mass movement of loam over clay soils on these formations is common in the Barunga Range and the Willunga Escarpment (our study area) where slopes exceed 20%. 3. Soils on strongly laminated shaly bedrock. On slopes where the laminations in the rock are parallel to the ground surface, lubrication of these planes of weakness by water can cause slippage of the overlying soil. Occurrences are widely distributed, although not common, on slopes steeper than 20%.clay soils on these formations is common in the Barunga Range and the Willunga Escarpment (our study area) where slopes exceed 20%. 3. Soils on strongly laminated shaly bedrock. On slopes where the laminations in the rock are parallel to the ground surface, lubrication of these planes of weakness by water can cause slippage of the overlying soil. Occurrences are widely distributed, although not common, on slopes steeper than 20%.

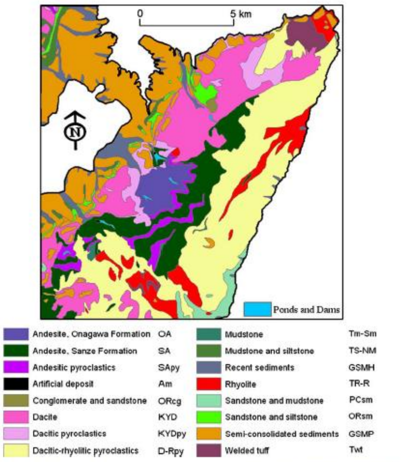

Figure 2.3.1: map for classification of soil types

(5) Literature review for watercourses and wetlands

As another important factor could affect the susceptibility of landslide, water such as watercourse, wetland and waterbodies usually generate a constant supply of moisture through basin effect that leads to the weathering of soil and rocks (Ayalew&Yamajishi, 2004). Also, according to Hadji and Demdoum (2014), there is a saturation effect that comes from flow regime of drainage lines, which could increase pore water stress to soil and lead to sliding in areas connecting water channels. Thus, the distance from drainage lines to having an effect on landslides is considered. In Dai and Lee's (2002) research, they use GIS buffer tool to limit the distance from the steam was calculated at a value of 0 – 100, and more than 100 meters from the stream. Another classification is that Buffer zones along drainage lines were set at 200 m, and divided into six classes: 0–200, 200–400, 400–600, 600–800, 800–1000, and >1000 m.

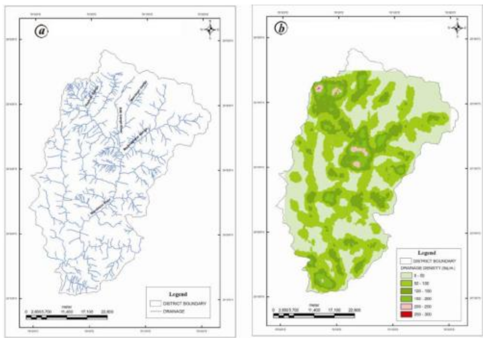

Figure 2.4.1: map for buffering of watercourses and wetlands

(6) Literature review for water bodies

Water bodies (without watercourses and wetland) are one of the factors that could influence the susceptibility of areas where can cause landslide. Due to the green vegetation and shallow water on the ground surface, the moisture level of underground has been emphasized than of the normal underground soil. Usually, the water bodies such as ponds, small water pool and water hole are analysed by applying density of water bodies (Clevenger et al. 2002). In their study area Cachoeira, the density of water bodies was calculated as area, for example, the area of water bodies in their study is 936.7KM2, the density of water bodies is 1.06 waterbodies per KM2. In our study, we only considered the high-density area which included more water bodies.

3. METHODOLOGY

(1) Study area

The study area for the case study of Adelaide Hills includes 26 suburbs. The slope interval in the study ranges from 0 to 56 degrees and there are ten domination soil types. Two of the domination soil types are unconsolidated soil type. Moreover, the unconsolidated soil type combines with large amount of watercourses or wetlands which increases the susceptibility of landslides to some extent (Rawat 2015).However, there are only a few water bodies and a variety of roads, streets, tracks and some other road types in our study area. The detailed map for study can be referred to Appendix A.

(2) Original ideas

The original idea for this case study is to identify the hazardous road and implement hazard markers or the signboards to warn people of the threat. According to literature reviews, Rawat's (2015) have classified the hazard zone levels in his journal. The aim of our case study is to identify the high hazard zone. Throughout the case study, we have added the roads on a map and identified two high hazard roads.

(3) Standard of critical analysis

From recent knowledge, it is apparent that slope, soil types, watercourses and wetlands are all critical for analysing the susceptibility of landslides. Firstly, we identified the overlapping of areas with unconsolidated soil types and buffered watercourse or wetlands. From the research, we found out that the overlapping areas are the landslides hazard areas on Adelaide Hills. Furthermore, the susceptibility of landslides in this area increases when it is combined with the nature of their steep slopes. Next, we created a new layer that has slope intervals from 20 degrees to 50 degrees.After that, we continued to locate the roads across the overlapping areas with steep slopes and mark them as high hazard roads. As a result, only two private roads have been identified as high hazard roads (detailed map refer to Appendix B). However, some walk trails and tracks are also present in the high hazard zones. This report indicated one of them and the detailed map information can be referred to Appendix C.

(4) Classification of slopes

According to the collected data, the DEM file can be masked to our study area. After that, the slopes can be analysed by slope analysis in toolbox. As a result, the slopein Adelaide Hills can be classified from 0 to 56.8 degrees.For this study case, our interest is between 20-50 degrees as illustrated in Figure 4.4 below. At first, a slope interval of 30-45 degrees was chosen, which has the highest contribution to the susceptibility of landslides in slope (Rawat et al. 2015; Huabin et al., 2005). However, we could not find any overlapping areas with unconsolidated soil types and watercourses or wetlands. In this case, we changed the slope interval to 20-50 degrees. Furthermore, we found that "Clip" is not working with raster data. The clip tool damaged the raster data and as a result, we had to use a mask in raster analysis tool.

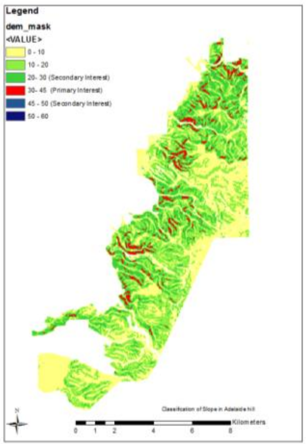

Figure 3.4: Classification of slope

(5) Classification of soil types

Table 4.5 shows the soil types for the soil code in Figure 4.5 below, the unconsolidated soil type is 13 and 15 as selected in Figure 4.5. The problem we faced during this session is to identify the unconsolidated soil types in our study area. The soil can have multiple layers and we did some research on geotechnical engineering(BUSSCHER 1994). The result is that grey sandy surface on quarzities and granular structure are not compact and dense in structure.

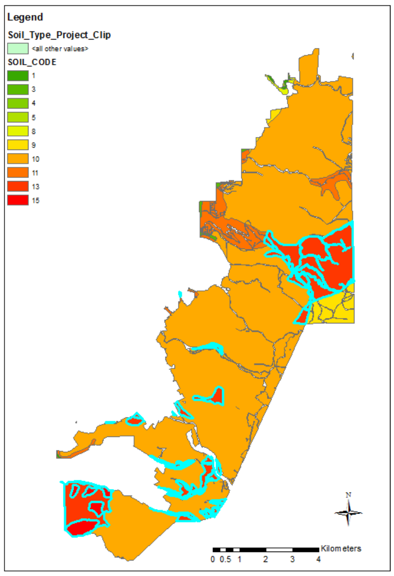

Figure 3.5: Classification of soil types

(6) Buffer for watercourse and wetlands.

We used 20 meter buffer for the water course and wetlands as shown in Figure 4.6 below. However, the journal article (Ayalew&Yamajishi, 2004)in sub point 2.4 used 0-50m, 50-100m, 100-200m and 200-300m buffer respectively. Even though we did try to use 50 meter buffer, this was inapplicable because it includes a huge area on the map due to the size of our study area. As a result, we had to change the buffer distance to 20 meters.

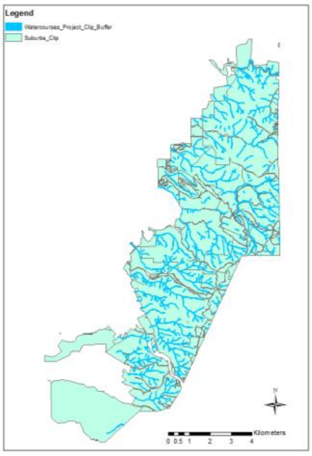

Figure 3.6: Buffer for watercourses and wetlands

(7) Dot density for water bodies

As we can see from the dot density of water bodies in Figure 4.7, there are only a few water bodies in our study area. In this case, we are not able to find any overlapping areas for water bodies and unconsolidated soil types. Thus, we use the union tool to add areas of water bodies to the overlapping areas.

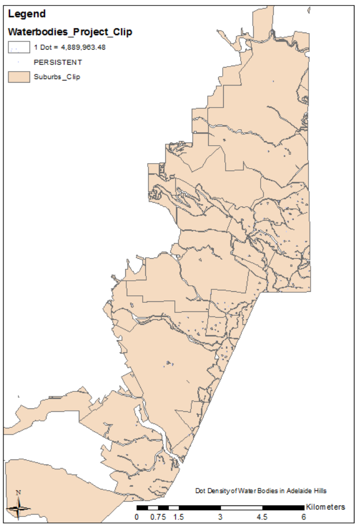

Figure 3.7 Dot density for water bodies

(8). Analysis existing layers

Firstly, we selected soil type 13 and 15 by selection of their attributes and used them to create layer throughdetailed selection. Secondly, we clipped the buffer watercourses and wetlands with the selected soil type layer. After that, we use the union tool to combine the overlapping areas with water bodies. The problem we have in this session is to analyse the slope data. Due to the nature of the slope obtained, which was araster data, we were not able to intersect or clip with other feature classes. We tried to use conversion tool to convert the raster data to polygon. However, convert tool only works to convert raster data to integer pixel type. The original raster had a pixel type of 32bit float. The pixel type can be changedby using the copy tool in toolbox and select 32bit signed in the dropdown box of pixel type. After that the raster data can be converted to polygons and we later used selection by attributes to highlight areas with slope 20-50 degrees. The high hazard zone has been found as shown in Figure 4.8 below and the detailed map referred to Appendix A. The Marble Hill Road has been indicated in Appendix C for orientation.

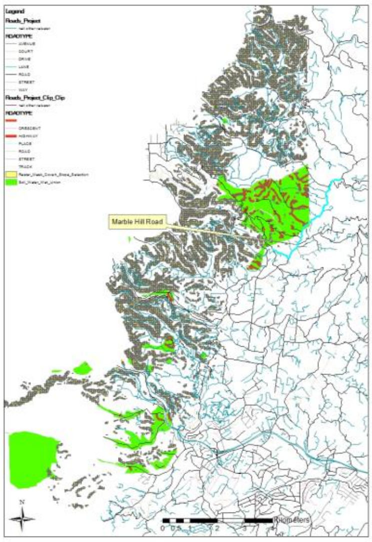

Figure 3.8 Overview map

(9) Roads and callout for high hazard road.

Lastly, two private roads have been identified as high hazard road as shown in Figure 4.9 below and detailed map can be referred to Appendix B.

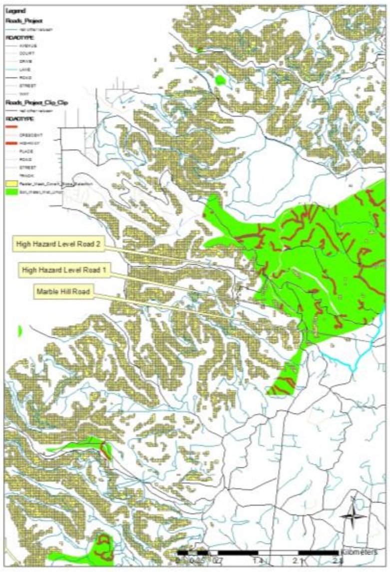

Figure 3.9 High hazard road 1 &2 callout

4. CONCLUSION

As a recurrent natural disaster every year, landslide leads to extensive damage in most mountainous areas of the world and thus analysing hazard landslide zone has become a hotspot subject for government and research organizations. Therefore, we did a GIS-based analysis to identify the high hazard zone and indicate high hazard roads in this case study. In addition, this case study can be used to set hazard marking. After studying the literature review, the methodology we used to find the high hazard zone is to analyse the factors that contribute to the susceptibility of landslides. The factors include slope, soil types, watercourses, wetlands and waterbodies. As a result, the analysis shows that most roads in Adelaide Hill have a low susceptibility of landslides. However, two private roads and some tracks are within the high hazardzone for landslides and the detailed map can be referred to Appendix A and B. Furthermore, we picked one track named “Chinaman Hut track” in the high hazard tracks. This study demonstrates a relatively simple methodology of identifying thehigh hazard roads on landslides. It is also recommended that engineers should avoid the constructions of roads with steep slope if possible. Moreover, the geotechnical survey for soil attributes should be carried out before the construction activities in high landslides hazard areas takes place. Lastly, a suitable drainage system is also important because water leakage could cause the stability of underground soil to deteriorate.

REFERENCES

[1] Ayalew, L. and Yamagishi, H. (2005). The application of GIS-based logistic regression for landslide susceptibility mapping in the Kakuda-Yahiko Mountains, Central Japan.Geomorphology, 65(1-2), pp.15-31.

[2] Ayalew, L., Yamagishi, H., Marui, H. and Kanno, T. (2005). Landslides in Sado Island of Japan: Part I. Case studies, monitoring techniques and environmental considerations. Engineering Geology, 81(4), pp.419-431

[3] Ayalew, L., Yamagishi, H., Marui, H. and 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), pp.432-445

[4] BUSSCHER, W 1994, "Fundamentals of Soil Behavior", in , Soil Science, vol. 158, no. 1, p. 74.

[5] Carrara, A., Guzzetti, F., Cardinali, M. and Reichenbach, P., 1999. Use of GIS technology in the prediction and monitoring of landslide hazard. Natural hazards, 20(2-3), pp.117-135

[6] Carrara, A., 1983. Multivariate models for landslide hazard evaluation. Journal of the International Association for Mathematical Geology, 15(3), pp.403-426

[7] Chung, C.F. and Fabbri, A.G. 1995: Multivariateregression analysis for landslide hazard zonation. InCarrara, A. and Guzzetti, F., editors, GeographicalInformation Systems in assessing natural hazards,Dordrecht: Kluwer, 107–42.— 1999: Probabilistic prediction models for landslidehazard mapping. Photogram Engineering and RemoteSensing65, 1389–99.

[8] Cruden, D.M. and Fell, R. 1997: Landslide risk assessment.InProceedings of International Workshop onLandslide Risk Assessment, Honolulu, Rotterdam:Balkema,371

[9] Dai, F. and Lee, C. (2002). Landslide characteristics and slope instability modeling using GIS, Lantau Island, Hong Kong.Geomorphology, 42(3-4), pp.213-228

[10] Das, I., Sahoo, S., van Westen, C., Stein, A. and Hack, R. (2010). Landslide susceptibility assessment using logistic regression and its comparison with a rock mass classification system, along a road section in the northern Himalayas (India). Geomorphology, 114(4), pp.627-637

[11] Hadji, R., Limani, Y. and Demdoum, A., 2014, March. Using multivariate approach and GIS applications to predict slope instability hazard case study of Machrouha municipality, NE Algeria. In Information and Communication Technologies for Disaster Management (ICT-DM), 2014 1st International Conference on (pp. 1-10). IEEE.

[12] Hansen, A. 1984: Landslide hazard analysis. InBrunsden, D. and Prior, D.B., editors, Slope instability,New York: Wiley, 523–602.

[13] Larsen, M.C. and Parks, J.E., 1997. How wide is a road? The association of roads and mass-wasting in a forested montane environment. Earth Surface Processes and Landforms, 22(9), pp.835-848

[14] Mancini, F., Ceppi, C. and Ritrovato, G. (2010). GIS and statistical analysis for landslide susceptibility mapping in the Daunia area, Italy.Nat. Hazards Earth Syst. Sci., 10(9), pp.1851-1864

[15] Ohlmacher, G. and Davis, J. (2003). Using multiple logistic regression and GIS technology to predict landslide hazard in northeast Kansas, USA. Engineering Geology, 69(3-4), pp.331-343

[16] Rawat, V, Uniyal, A, Dobhal, D, Joshi, A, Rawat, A, Bartwal, A, et al 2015, 'Study of landslide hazard zonation in Mandakini Valley, Rudraprayag district, Uttarakhand using remote sensing and GIS', Current Science, vol. 109, no. 1, pp. 158-170.

[17] Saha, A, Gupta, R & Arora, M 2002, "GIS-based Landslide Hazard Zonation in the Bhagirathi (Ganga) Valley, Himalayas", in ,International Journal of Remote Sensing, vol. 23, no. 2, pp. 357-369.

[18] Saha, A, Gupta, R, Sarkar, I, Arora, M &Csaplovics, E 2005, "An approach for GIS-based statistical landslide susceptibility zonation?with a case study in the Himalayas", in , Landslides, vol. 2, no. 1, pp. 61-69.

[19] Schuster, R. L. 1978. ‘Introduction’, in Schuster, R. L. and Krizek, R. J. (Eds), Landslides, Analysis and Control, National Research Council, Transportation Research Board Special Report, 176, 1–10.

[20] WESTEN, C. and TERLIEN, M. (1996). An Approach Towards Deterministic Landslide Hazard Analysis In Gis.A Case Study From Manizales (Colombia).Earth Surf. Process. Landforms, 21(9), pp.853-868

[21] Wang, H, Liu, G, Xu, W & Wang, G 2005, 'GIS-based landslide hazard assessment: an overview', Progress In Physical Geography, vol. 29, no. 4, pp. 548-567.

[22] Yalcin, A. (2008). GIS-based landslide susceptibility mapping using analytical hierarchy process and bivariate statistics in Ardesen (Turkey): Comparisons of results and confirmations. CATENA, 72(1), pp.1-12