Parametric influence-based landslide hazard mapping in constant geological conditions the Nepal Himalaya

Key words: GIS, deep-seated landslides, Nepal Himalaya

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Introduction:

This paper takes accounts of hazard assessment by tested in-situ most influencing terrain classes/factors in relation to non-uniform occurrence of deep-seated landslides in constant geological surroundings. The slope, relief energy, drainage density, and, thrust-faults proximity are the parameters employed. To incorporate non-uniformity in landslide occurrence, unit square kilometer blocks (USKBs) are constructed covering the entire study area. The comparative influencing role of employed parameters is observed in different high and low zones of landslide density and the most influencing parametric classes/factors are identified in several highly-prone and less-prone geologies. Phyllite, slate, and schist are the most landslide prone geologies (Gerrard 1994) whereas other geologies come under less-prone category in Himalaya Regions. The landslide hazard map of the whole study area is prepared, but with use of only the most influencing parametric classes in respective geology. The geology-based landslide hazard map thus prepared accounts 70.45 % accuracy. The application of present study includes prediction of the possible sites of failure with use of identified most influencing classes in other similar geological conditions of the Himalaya Region. Due to lack of time herein, the prediction accuracy of these classes/factors is checked in the same study area.

Study area and geology

The study area covers for about 5075 km^2 in Lesser Himalaya and Siwalik zone of Mid Nepal (Fig. 1). It encompasses sections of Prithvi Highway, Tribhuvan Highway and Narayanghat-Mugling Highway, all of which connect the Capital area of Kathmandu with rest of the nation. Physiographically, the study area lies in Midland group (Upper Precambrian to late Paleozoic). Bedrock geology is composed of 14 main types of lithological units (Fig. 2) (high grade to low weathered metamorphic rocks such as metagabro, limestones, quartzite, gneiss, phyllite, slate, schist etc) that have been folded and faulted (MCT, Main Central Thrust, MBT, Main Boundary Thrust), resulting steep slopes deeply dissected by an actively eroding drainage network.

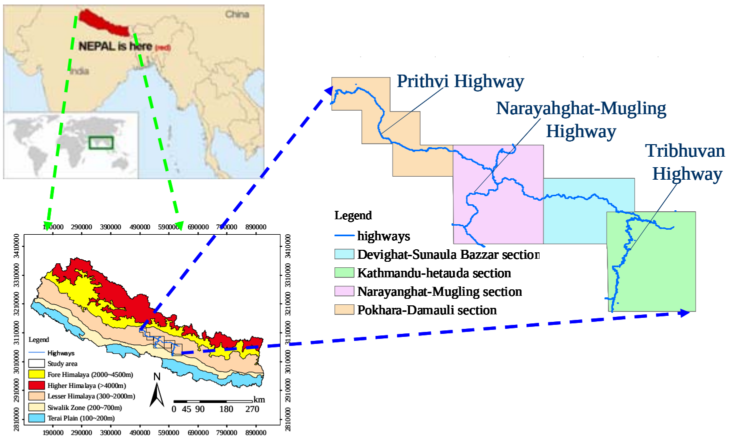

Fig. 1 The study area

Methodology

The collection of major landslide controlling factors, identification of existing landslides on the study area, analysis for the most influencing parametric classes/factors and, landslide hazard assessment by the most influencing parametric classes/factors are the main steps taken in methodology. The non-uniform distribution pattern of landslides, significance of construction of USKB, landslide density map (Fig. 3) and, the detailed procedure for identification of the most influencing parametric classes/factors can be seen in Acharya et al. 2010. In this particular paper, the hazard assessment is to be done by employing only the most influencing parametric classes/factors in respective geologies. Each of the USKB in each landslide density zone is to be multiplied by the parametric influence coefficient of the most influencing class in respective zones (Table 1). The actual and normalized values of landslide densities in different geologies are given in Table 2. The USKBs which contain pixels of the most influencing parametric class get multiplied with parametric influence coefficient, thus exhibit their parametric influence whilst the other blocks, which lack the most influencing parametric class pixels, are supposed to have no landslide risk and thus fall under very low hazard category.

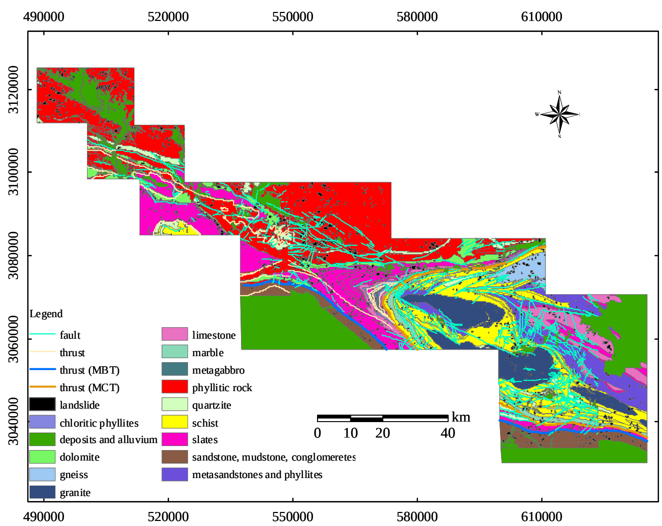

Fig. 2 Geological map of the study area

Thus hazard value of a single USKB is given as

$((HV)_i)_j = I_i * C_i$

where HV = Hazard value of each USKB

i = none, low, medium and high

j = analyzed zones (e.g. phyllite, slate, schist…..of geology)

I = Parametric influence factor

C = Number of parameter pixels of the most influencing parameter class occurring on each USKB

Results and discussion

Only the most influencing parametric classes/factors are used to recognize hazard level in respective geologies. The parametric influence coefficients of 0-0.5 km thrust-faults proximity (the most influencing class) in phyllite, 400-800 m relief energy (the most influencing parameter class) in slate, 4-6 km/km^2 drainage density (the most influencing parameter class) in schist, and 20-40 slope (the most influencing class) in remaining less landslide prone geologies are multiplied to the pixels of respective most influencing classes in respective landslide density zones thus getting the geology-based hazard score. Fig. 4 shows the clear representation of the hazard score in different high and low hazard zones. The hazard map shows 62, 368, 623 and 3336 number of blocks in high, medium, low and very low zones exactly in same position to that in landslide density map whilst the landslide density map subsumes 96, 583, 1140, and 2570 number of USKBs in respective zones. This clearly means that 64.58%, 62.26%, 54.64%, 100% USKBs are matching in both landslide density map and hazard map thereby overall accuracy accounts 70.45%. The accuracy does not seems to be much higher, but the integrated landslide hazard map obtained as the combination of geology-based, thrust-faults-based, and drainage density-based hazard maps accounts 86.77 % accuracy which could not be included in this paper. The USKB which are not covered by parametric influence fall under very low zone with zero hazard score. This is why very low hazard zone consists of increased number of USKB as compared to that of landslide density map.

Conclusion

The fidelity of hazard map to make prediction of landslides is seriously hampered by the quality/type of input data. Unnecessary use of less influential data results impractical and misinforming type of hazard map. In this study, the identification of landslide /landslide blocks in same high and low zones is done by the tested in-situ most influencing terrain classes/factors in relation to landslide occurrence. Each of the landslide density zones are directly multiplied by the parametric influence coefficient of respective zones in respective high and less landslide-prone geologies, thus producing the hazard score which governs accuracy of 70.45%. Due to lack of time, the competency of identified the most influencing parametric classes is tested in the same study area. The accuracy is far below the acceptable accuracy, but the integrated landslide hazard map obtained as the combination of geology-based, thrust-faults-based and drainage density-based hazard maps accounts 86.77 % accuracy which is beyond the scope of this paper.

References

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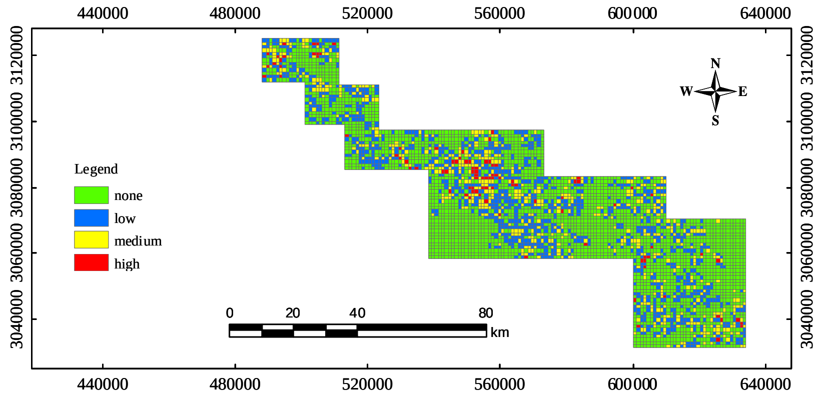

Fig. 3 Landslide density map

Zone	Analyzed class	Influencing parameter class	USKB (%) none	USKB (%) low	USKB (%) medium	USKB (%) high	Parametric influence coefficient (Normalized value of USKB (%)) none	low	medium	high	Most influencing Parameter
Geology based-analysis	phyllite	20-40 slope	42.0	49.7	61.1	68.0	0.000	0.297	0.733	1.000	
		400-800 m relief energy	33.6	39.5	48.8	50.0	0.000	0.360	0.927	1.000	0-0.5 km thrust-
		2-4 km/km^2 drainage density	8.2	12.5	19.1	23.4	0.000	0.283	0.717	1.000	faults proximity
		0-0.5 km thrust-faults proximity	28.1	32.2	36.7	49.6	0.000	0.208	0.431	1.000	
	slate	20-40 slope	61.5	74.5	81.0	100.0	0.000	0.338	0.506	1.000	400-800 m relief
		400-800 m relief energy	52.0	60.1	73.4	100.0	0.000	0.169	0.446	1.000	energy
	schist	4-6 km/km^2 drainage density	48.8	52.2	53.7	62.0	0.000	0.106	0.447	1.000	4-6 km/km^2
	Other rock areas	20-40 slope	43.1	50.8	64.2	78.1	0.000	0.220	0.603	1.000	
		400-800 m relief energy	35.3	49.7	56.3	65.6	0.000	0.475	0.693	1.000	
		0-0.5 km thrust-faults proximity	32.5	43.3	44.7	50.6	0.000	0.597	0.674	1.000	

Table 1: Showing normalized parametric influence coefficients

Zone	Analyzed class	Actual landslide density none	low	medium	high	Normalized value of Landslide density none	low	medium	high
Geology based-analysis	phyllite	0.000	0.040	0.160	0.420	0.000	0.095	0.381	1.000
	slate	0.000	0.040	0.160	0.400	0.000	0.100	0.400	1.000
	schist	0.000	0.030	0.110	0.200	0.000	0.150	0.550	1.000
Other less landslide- prone geologies		0.000	0.040	0.180	0.360	0	0.111111	0.5	1

Table 2: Showing actual and normalized values of landslide density

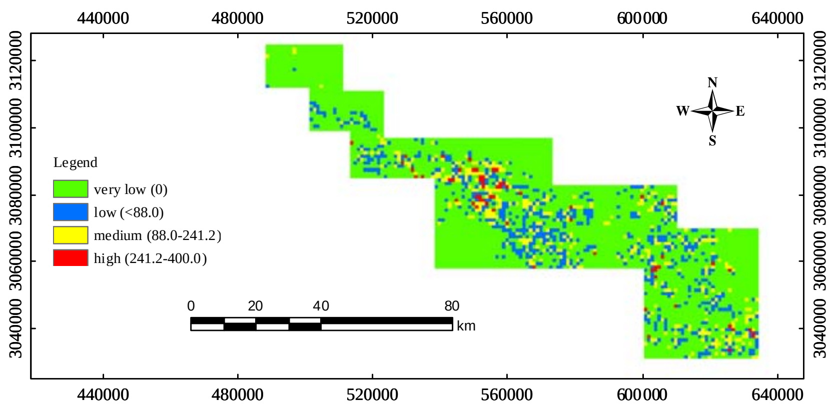

Fig. 4 Geology-based landslide hazard map