IMPLICATIONS OF A SPATIAL MULTI CRITERIA EVALUATION MODEL TO IMPROVE THE EXISTING LANDSLIDE HAZARD ZONES: WITH SPECIAL REFERENCE TO RATNAPURA DISTRICT, SRI LANKA

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INTRODUCTION

Landslides are one of the most frequent and prominent hazards in Sri Lanka. Out of twenty-five administrative districts in Sri Lanka ten districts are prone to landslides (Bandara, and Jayasingha, 2018). Many researchers find that the upward trend in landslides as a hazard within the country in the last decade is due to the increase in high intense rainfall, growing population, expansion of plantation and development (Perera et al., 2018; Karunawardena, 2021). As a result, many lands in central highlands of the country are converting to landslide prone areas.

Landslide hazard zonation and mapping are important methods to identify the landslide prone areas and to determine the level of susceptibility. Demarcation of landslide hazard zones with susceptibility can contribute to effective landslide risk management and mitigation (Perera et al., 2020; Shano et al., 2020). The National Building Research Organization (NBRO) has conducted landslide hazard zonation for Sri Lanka based on relatively static factors such as geology and geomorphology due to lack of dynamic data. However, in the current situation of increasing landslide occurrence, it's essential to redefine the landslide hazard zones considering both static factors and dynamic factors such as land use change, water table fluctuation etc.

In recent years, many GIS (Geographic Information Systems) based approaches have been used for landslide hazard zonation. However, many researchers claim that Spatial Multi Criteria Evaluation (SMCE) method is the most appropriate method for landslide hazard zonation due to its high predictive capacity (Perera et al., 2018; Bhat et al., 2019). Spatial Multi Criteria Evaluation (SMCE) has the ability to estimate the weight of landslide causative factors on the basis of their relative contribution to the occurrence of landslides (Bhat et al., 2019). Then GIS could map the spatial distribution of landslide hazard. The main objective of this study is to map the landslide hazard zones considering geology, slope, road network, stream network, land use and the rate of land use change to improve the existing landslide hazard zonation maps as a case study on Ratnapura District.

MATERIALS AND METHODS

This study was conducted in Ratnapura District due to its frequent occurrence of natural and human induced hazards. Ratnapura District has an area of 3,275km^2 and the total population is 1,088,007 (Department of Census and Statistics, 2012).

For this study, digital spatial data of landslide causative factors; geology, soil type, slope, road network, streams, land use were obtained from the survey department of Sri Lanka at 1:10,000 scale for the Ratnapura District. The land use change was acquired by analysing the satellite images obtained by Landsat 5 and Landsat 8 for the period of 2000 to 2020.

Landslide hazard zonation process was initiated with weighting causative factors according to their relative importance at the first pairwise comparison matrix was developed using equation based on 9-point intensity of relative importance scale proposed by Saaty (1994). Then the pairwise comparison matrix was normalized. Then the vector weights were estimated by simplifying the pairwise comparison matrix as shown in table 1.

Table 1: weighted pairwise comparison matrix

Factors	Slope	Soil	Geology	Land Use	Land Use Change	Proximity To Stream	Proximity To Road	**Weight (W)**
Slope	0.13	0.11	0.10	0.09	0.12	0.13	0.11	**0.10**
Soil	0.06	0.06	0.05	0.05	0.05	0.06	0.06	**0.13**
Geology	0.24	0.23	0.20	0.37	0.23	0.23	0.23	**0.35**
Land Use	0.06	0.04	0.03	0.05	0.06	0.06	0.06	**0.08**
Land Use Change	0.51	0.42	0.40	0.36	0.46	0.46	0.44	**0.22**
Proximity To Stream	0.03	0.02	0.02	0.02	0.02	0.02	0.02	**0.07**
Proximity To Road	0.03	0.02	0.16	0.02	0.02	0.02	0.02	**0.05**

Then the consistency ratio (CR) was calculated and obtained CR value is 0.062 which is lower than 0.1, which means that obtained weights are consistent. Then each causative factor was multiplied by its derived weight and resultant raster maps were composited to produce the landslide hazard map for Ratnapura District. Then the produced map was classified into four classes: Safe area, landslide not likely to occur, modest level of landslide hazard, and Landslide area to be expected as in National landslide hazard map prepared by NBRO. Finally, the developed hazard map was validated through the application of Kappa statistics.

RESULTS AND DISCUSSION

According to the landslide hazard zonation map prepared by NBRO (figure 1) an area of 257km^2 was demarcated as landslide area to be expected but in the study it was expanded to 327km^2 showing 27% of expansion (figure 1).

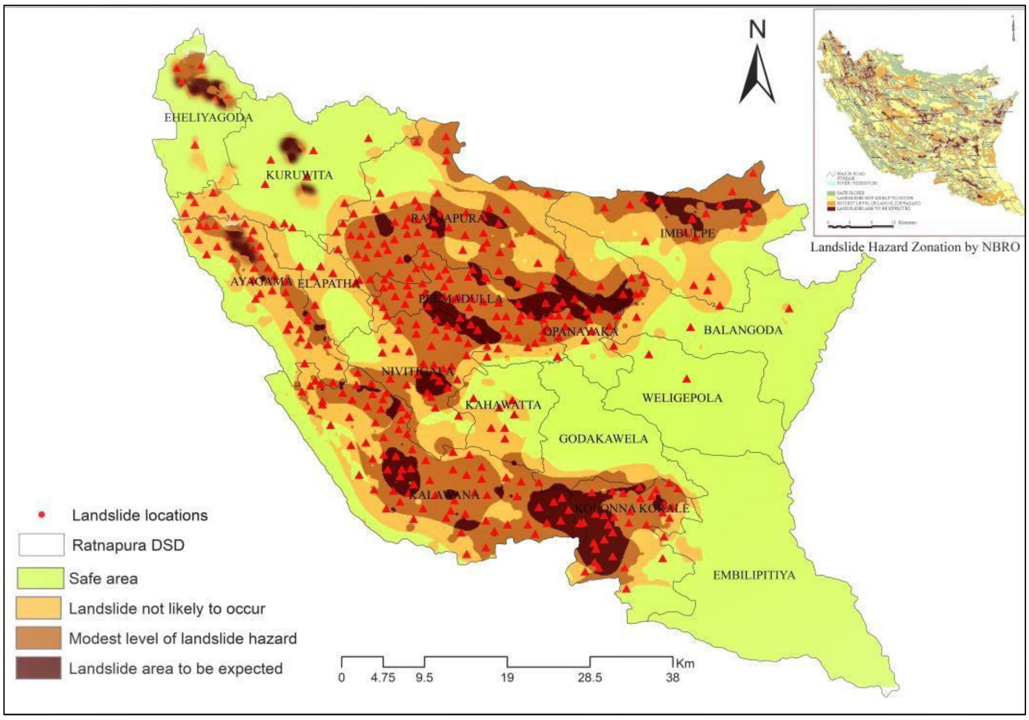

Figure 1: Improved landslide hazard zonation map

However, the extent of safe area does not change significantly in improved landslide hazard zonation map (figure 1). In contrast, spatial distribution of landslide not likely to occur area was contracted by 46% and this contracted area was transformed to modest level of landslide area. And 48% of the modest level of landslide hazard region merged to high hazard zones due to increase of planation activities and illegal constructions in moderately hazard slopes.

Model validation results show that 84% of the landslides fall under modest or high hazard zones, which shows that improved landslide hazard zonation map has higher prediction capacity compared to the hazard zonation done by NBRO.

Improved landslide hazard zonation map shows, 13% (327km^2) of high hazard area and 27% of modest hazard (885km^2) area. It means that totally 40% (1310km^2) of land area of the Rathnapura district can be demarcated as landslide prone area. These results showed that landslide-free zones have a tendency to become landslide-prone areas. Further analysis of the conversion of landslide free area revealed that the slope regions with 45^0-60^0 are more likely to be converted into a landslide prone area compared to flat and high terrain areas. The main reason is that slope areas are most vulnerable to anthropogenic activities.

CONCLUSIONS AND RECOMMENDATIONS

The existing landslide hazard maps should be improved considering the dynamic landslide causative factors at least once in a year. Improvement of landslide hazard zonation maps could contribute to effective landslide risk management. It is recommended to establish an automated mechanism to update the landslide hazard zonation digital maps using artificial intelligence.

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ACKNOWLEDGMENTS

This research was supported by the Accelerating Higher Education Expansion and Development (AHEAD) Operation of the Ministry of Higher Education funded by the World Bank.