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Abstract

Remote sensing and GIS techniques were developed for identifying areas affected by landsliding, assessing landslide hazard, producing landslide hazard maps, and evaluating these maps. The methods developed were applied in the Kulekhani watershed (124 km^2), located in the central region of Nepal. Five change detection techniques were employed to evaluate their effectiveness in determining the landslide affected areas with Landsat thematic mapper (TM) data obtained prior to and after an event. The techniques applied were (1) spectral image differencing, (2) vegetation index image differencing, (3) tasseled cap transformation image differencing, (4) spectral change vector analysis, and (5) principle component analysis. Spectral image differencing was used with four TM bands (bands 1, 2, 3 and 7) to create four change images. The difference vegetation index, the ratio vegetation index, and the normalized difference vegetation index (NDVI) produced three change images. The tasseled cap transformation was used to create one image (change in brightness). Two spectral change vector analyses that used bands 1, 2, and 3, and bands 3 and 4 were employed. The bands 1, 2, and 3 from the two images were merged to create a single image with six data set and the principal component analysis was carried out. A third principal component image represented for the areas affected by landsliding.

A thresholding strategy was applied to change images to separate the pixels of change from those of no change. A GPS survey combined with large scale black and white photographs were used to generate reference data for the accuracy assessment. Two indices, overall accuracy and Khat accuracy were used to assess the accuracies of eleven change images. The spectral change vector using bands 1, 2 and 3 is found to be most accurate for detecting areas affected by landsliding with the overall and Khat accuracies of 88.3 percent and 75.4 percent respectively. The NDVI is most accurate for detecting areas affected in the vegetation areas with the overall and Khat accuracies of 86.2 percent and 53.3 percent. The change image of spectral change vector analysis (bands 1, 2 and 3) was further analyzed to detect the sediment deposition area, and landslides. It shows higher accuracy for detecting sediment deposition area compared to landslides. The producer's and user's accuracies for sediment deposition area are 80.9 percent and 90.3 percent, respectively, whereas that for landslides are 56.7 percent and 73.6 percent, respectively. Better results were obtained when the pixels interpreted as

landslides from the multitemporal Landsat TM data were evaluated in terms of landslide and non-landslide catchment units.

A distribution map of landslides produced from aerial photo interpretation and field checking were then used with GIS layers of topographic factors derived from a digital elevation model, geology, and land use/cover for the landslide hazard assessment. The site characteristics of landsliding were evaluated using multivariate statistical (Quantification Scaling Type II: Q-S II) and univariate statistical (Failure rate: FR) methods, and the results used for hazard mapping. Two failure rate analyses were carried out. The effects of different samples of landslide and non-landslide groups on the critical factors and classes, and subsequently on hazard maps were evaluated for Q-S II analysis. Simple random sampling was used to obtain samples of the landslide group and either an unaligned stratified random sampling or an aligned systematic sampling method generated the non-landslide group. For the analysis, one set of the landslide group was combined with each of five different sets of the non-landslide groups.

The geology is found to be the most important factor for landslide hazard. The scores of the classes of the factors quantified by the five Q-S II analyses and two FR analyses were used for the hazard mapping in the GIS, with four levels of relative hazard classes: high, moderate, less, and least. The evaluation of hazard maps indicates more accurate map with Q-S II analysis compared to that with FR analysis. The hazard maps produced from FR analysis and Q-S II analysis agrees 60 percent to 80 percent depending on hazard classes (two or four) in a hazard map. Within the Q-S II analysis, higher accuracy is found for the combinations in which non-landslide group was generated by the unaligned stratified random sampling method. The agreements in the hazard maps, produced from different sample combinations using unaligned stratified random sampling for selecting non-landslide group, are found to be acceptable for practical use in hazard mitigation and watershed management planning.

This study clears the appropriateness of satellite remote sensing data and aerial photographs at different stages of landslide hazard assessment and mapping. A better understanding is achieved for landslide hazard assessment methods employed in GIS for large areas. The application of remote sensing and GIS techniques described in this study should practically serve the hazard mitigation activities and the watershed management planning.