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学 位 論 文 審 査 の 要 旨

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学 位 論 文 題 名

Flood risk mitigation by inundation mapping and socioeconomic analyses in two river basins of Nepal
（ネパールの2つの河川流域における浸水域予測地図作成と社会経済分析による洪水リスク軽減）

Floods often cause enormous damage to lives, property, and infrastructure. Sudden floods frequently occur in the Himalaya under changing climates. This study, focusing on flood issues in the mountains of Nepal, aimed to identify safe and at-risk houses and the availability of routes for emergency evacuation and to analyze the relationships between the inundation risk and socioeconomic situation. This study chose three settlements (Masinabagar, Laltinbazar, and KI-sing) in the Seti River basin (Kaski District) because these settlements are densely populated and situated in the sub-urban area along the river, and 11 settlements in the remote rural area in the Tamakoshi river basin (Dolakha District). Detailed hazard maps were created based on the results from aerial vehicle (UAV) photogrammetry and the Hydrologic Engineering Center River Analysis System (HEC-RAS). Agisoft Photoscan (v.1.4.0) and ArcGIS (v.10.2) were used for the mapping. For inundation mapping, the flood level (peak discharge) was assumed to be the same as that observed on May 5, 2012, i.e., 1450 m^3/s for the Seti River basin. In the Tamakoshi River basin, peak discharge from the Department of Hydrology and Meteorology (1940 m^3/s) was used for inundation mapping. The return period is expected to be 50 years for the Seti River and 10 years for the Tamakoshi river basin. Evacuation route mapping was done based on the UAV photogrammetry, toposheets, and field surveys. The questionnaire, focus-group, and key-informant surveys helped identify the socioeconomic situation in both basins.

In the Seti River basin, inundation maps showed a maximum depth of inundation water level of 13 m in Masinabagar, 17 m in Laltinbazar, and 21 m in KI-sing. In Masinabagar 268 among 466 households (population: 976 among 2303) are situated in the inundation area. Laltinbazar with 232 of 329 households (population: 1800) is located either on the floodplain or along the slopes with a small relative height to the river water surface. Similarly, 68 households are situated in the inundation zone in KI-sing (population: 786).

This study suggested that both the existing pedestrian routes and new pedestrian routes to be created can be used for emergencies. In Masinabagar, 27 new evacuation routes are suggested to be created, in Laltinbazar, 25 routes, and in KI-sing, 9 routes should be created. This study also found that all the Masinabagar, Laltinbazar and KI-sing areas are highly susceptible to future flooding.

The socioeconomical survey result highlighted that low-income residents, primarily migrants and laborers, were in the danger zone near the riverside. Highly impoverished and immigrant households were at the highest risk for both factors: income and migration ($p<0.001$). The locations of laborers' houses were also significantly correlated with inundation risk ($p<0.001$). The relationship between occupation and income was statistically not significant ($p<0.839$).

In the Tamakoshi River basin, the inundation maps showed that Gongar, Singati, Jagat, Bhorle, Jamune, Kattike and Tamakoshi are highly susceptible to future flooding. The maximum inundation depth was calculated as 19 m in Gongar, 10 m in Jagat, 6 m in Bhorle, 10 m in Jamune, 39 m in Singati, 14 m in Kattike, and 19 m in Tamakoshi. In Singati out of 659 houses, 220 houses are situated in the inundation zone. Of the 17 houses in Kattike (population: 61), 6 houses (population: 23) are situated in the inundation zone. In Tamakoshi all 6 houses (population: 17) are situated in the inundation zone. It was suggested that the number of evacuation routes that should be newly created was 9, 25, 3, and 2 in Gongar, Singati, Kattike, and Tamakoshi, respectively.

To evaluate the proposed evacuation routes, walking speed of 31 resident volunteers were measured on five experimental routes. The people walked on the routes were classified into four groups: <15-years, 15–40-years, 40–65-years, and >65-years old groups. The result showed that the average evacuation speed was 2.28 m/s for the elderly group (>65 years old), 1.95 m/s for middle-aged group (40-65), 1.09 m/s for adult group (15-40), and 1.22 m/s for child group (<15). Based on the results, the adequacy of the proposed evacuation routes was evaluated.

This study developed an evacuation system by considering short-term and long-term measures. Land located outside the inundation area and at a higher altitude was assumed as safe places for temporary evacuation; however, most such places do not have shelters. Establishing adequate evacuation routes and shelter houses is one of the most pressing needs. This study suggested an implementation of a mobile phone-based early alarming system, which is cost-effective and easy for all areas connected to the network coverage. Results in the Seti Khola basin showed that 98% of the interviewed households have mobile-phone handsets, indicating the realization of the mobile phone-based early alarming system. This study also found that most riverside residents in both river basins remain unaware of the preparation and risk associated with flood emergency evacuation; thus, adaptive capacity-building strategy programs, disaster preparedness training, and evacuation drills must be urgently incorporated.

This research contributes to flood-disaster mitigation, and the proposed evacuation system will help save lives. This study recommends applying a combined approach that uses flood modeling and socioeconomic surveys to other parts of the Himalayan region and impoverished areas around the globe.

In addition to the excellent academic knowledge in the research, her academic records throughout the Ph.D. course are outstanding. Based on these pieces of evidence, the committee concluded that Bhabana Thapa deserves to become a Doctor of Environmental Science.