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Land use changes, landslides and roads in the Phewa Watershed, Western Nepal from 1979 to 2016

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ABSTRACT

This paper details an investigation of land use/land cover changes (LULCC) for the period 1979–2016 in the Phewa Lake area watershed in Western Nepal based on an analysis of aerial photos, satellite images and ground-based observations. The main objective is to document LULCC with regards to forest, agriculture, built-up areas and roads in order to understand how sources of erosion have evolved during the investigated period. Results demonstrate that LULCC have led to a shift of active erosion areas from grazing zones around streams and forests in the northern part of the watershed to a much greater number of small failures along unplanned earthen rural roads, which have hugely increased in the watershed. The extreme rainfall event that occurred in July 2015 trigged a large number of small and large landslides, as prior to this date only 14 landslides were observed in the watershed compared with 174 after the event. More than 40% of newly triggered landslides intersect a road and 84% of them are located within a distance of 40 meter from a road. Roads are thus influencing slope stability through slope cutting, concentrating surface water, thus changing hydrological patterns, which are destabilizing upper slopes. This study quantifies observable trends of erosion in Phewa watershed, which are important for more sustainable management of rural road construction. Greater enforcement of regulations on road construction and more sustainable land management practices are required to reduce further environmental and economic impacts in Phewa Lake watershed.

1. Introduction

Nepal is one of the most vulnerable countries in the world in the context of climate change impacts and disasters (INFORM, 2016). Due to its steep topography and situation as part of the South Asian Monsoon cycle and the Main Central Thrust fault line, the country is naturally prone to flooding, landslides, glacial lake, outburst floods, hail storms and earthquakes. The country is still recovering following the 2015 Gorkha earthquake (7.6 M Richter scale), which killed 8856 people, injured 22,309, left thousands homeless and led to a mass movement of the population (MoHA, 2016). The earthquake also created greater slope instabilities, especially during the monsoon season (Collins & Jibson, 2015).

The 147,000 square kilometers of this landlocked mountainous country are divided into five physiographic units from north to south: the high Himalaya, high mountains, the middle hills region, the Churia or Siwalik range and the Terai region in the plains (Agrawala et al., 2003). About 80% of Nepal is mountainous or hilly and 20% is the plains area of Terai, which is located in the northern Ganga Basin. The plains area of Terai (south) occur at 60 meters above sea level (m.a.s.l.) and rise to the high Himalayas (north) (> 8000 m.a.s.l), over 200 km exhibiting the greatest altitude variation on earth and great topographic diversity. Intense rainfall patterns during the monsoon, coupled with the huge increase in road construction, has led to increasingly high occurrence of landslides and flooding in the past decade, especially in the middle and lower mountains (Siwaliks) (Petley, 2010).

The Government of Nepal has placed a great emphasis on developing the roads and the transportation infrastructure as a real means of development for the rural population (World Bank, 2013). Construction of roads throughout the country, but in particular in the high and middle mountain areas, is placing more pressure on highly fragile ecosystems. The rural Nepali road network has rapidly expanded from 4740 km in 1998 to 12,494 km 2014, of which 6368 km were blacktop, 4173 km were earthen and the rest were gravel roads (DoR, 2015).

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Earthen roads correspond to the greatest increase in new roads and most often constructed by communities themselves with few engineering designs.

Construction of roads and railroads are perhaps the most common way that humans cause landslides by undercutting slopes, altering slope morphology and hydrology and by adding unstable materials along roadsides (Jaboyedoff et al., 2016; Walker& Shiels, 2013). In areas with high rainfall, such as Phewa Lake Watershed, roads create pathways for sediment transport and the accumulation of water along roads can easily create gullies and trigger landslides, making drainage management especially important (Montgomery, 1994; Sidle & Ziegler, 2012). Proximity to a road can have a high influence on landslide occurrence. Larsen and Parks (1997) noted that landslides in Puerto Rico were 2.5 times more frequent and six times more severe within 100 m of a road compared to a distance of 350 m of a road. These failures can lead to high costs as even the best constructed and maintained roads can fail (Sidle & Ochiai, 2006).

The impact of rural roads to landslides in Nepal is subject to controversy. Three decades ago Laban (1979) analyzing a landmark inventory of landslides in Nepal, concluded that only 5% of all landslides above 50 m^2 were attributed to roads and trails. At the time, he also noted that "since the percentage of the land surface covered by roads is infinitesimally small, this figure must be considered as a serious warning to Nepal's future development" (Laban, 1979). The present study draws upon several years of research on erosion, landslides (Sudmeier-Rieux, Jaquet, Derron, Jaboyedoff, & Basyal, 2013) and the impact of road construction in Phewa Lake Watershed (Leibundgut et al., 2016) in Western Nepal in relation to project activities related to the Ecosystems Protecting Infrastructure and Communities (EPIC) project 2013–2017 in the Panchase region. The main objective is to document land use/land cover changes (LULCC) occurred between 1979 and 2016 in the Phewa Lake area watershed in Western Nepal with regards to forest, agriculture, built up areas and roads. Secondly, the study seeks to understand how sources of erosion have evolved, considering recent urbanization, land abandonment and road construction. It quantifies observable trends of erosion, which are important for developing evidence-based recommendations on the need for greater enforcement of road construction regulations, bio-engineering, as well as more sustainable land use management in Phewa Lake watershed.

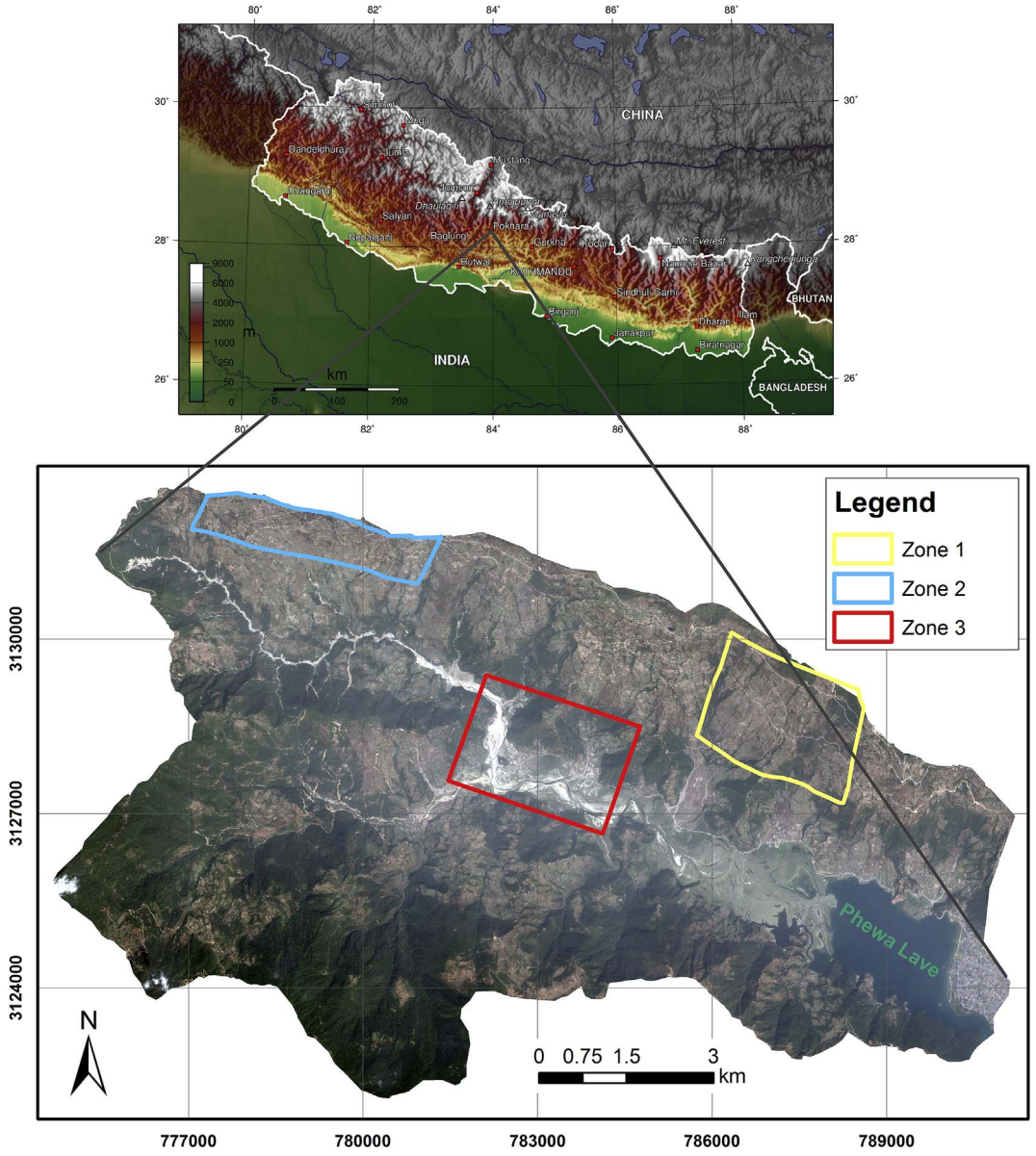

Fig. 1. Map of Nepal (above) and, map of the Phewa Lake Watershed (below) with the identification of the three case study areas (i.e. Zone).