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Assessment of the Landslides triggered by Gorkha Earthquake 2015: A case study of Shivapuri Nagarjun National Park, Central Nepal

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ABSTRACT

The Gorkha earthquake (25 April 2015, Mw 7.8) Nepal caused a large number of casualties and serious property losses, and also induced numerous landslides. Landslides are recognized as the third type of natural disaster in terms of worldwide importance. Due to natural conditions or man- made actions, landslides have produced multiple human and economic losses. After the devastating Gorkha earthquake, Shivapuri National Park area has been affected as there has been rise in number of landslides within the area. This paper presents the landslide occurrences in Shivapuri Nagarjun National Park area by using Google Earth images, conducting interaction with the local people as well as national park staff members and direct field observation. Landslide validation, types of landslides and the landslide volume were calculated from the field study. Due to the unmanaged construction of the road through loose soil, potentiality of landslide occurrence was high in the presence of any triggering factors; Gorkha Earthquake 2015 did this job This result shows that the earthquake has increased the number of landslides within the national park area. It is found that the Gorkha Earthquake 2015 triggered altogether 13 small sized landslides in the study area, among them debris flow is the major type.

Key words: Gorkha Earthquake 2015, landslide, Shivapuri Nagarjun National Park

INTRODUCTION

Due to natural conditions or man- made actions, landslides have produced multiple human and economic losses (Fleming 1980, Guzzetti 2007). Earthquakes are one of the main triggering factors of landslides and rapidly changes of surface with generate landslides. Largest earthquakes have capable to trigger thousands of landslides throughout areas of more than 100,000 km2 (Keefer, 1984). Earthquake induced landslides have been documented from at least as early as 1789 BC in China (Hansen and Franks, 1991) and 372 BC in Greece (Seed, 1968). The first scientific identification of earthquake induced landslides and their systematic documentation was undertaken in the Calabria region of Italy after the 1783 earthquake swarm and first basic inventory for earthquake induced landslides accomplished in 1957 for Daly City after the California earthquake (Keefer, 1994). On the other hand the first large inventory attempt done by Harp et al. in 1981 for Ms 7.5 Guatemala earthquake (1976). According to the results of distribution and statistics based studies, the type and locality of landslides caused by earthquakes are affected by the differences in seismic parameters and distribution of geological characteristics and topographic factors. Therefore, it is prerequisite to have a comprehensive understanding of seismic parameters, geological and geomorphologic dynamics and the relations between them for better understanding of landslide distribution induced after the earthquakes. Earthquake-induced landslide hazard zoning known to have experienced earthquake-induced slope failures during historical earthquakes, or areas identified as having past landslide movement including both landslide deposits and source areas, or areas where the geological materials are susceptible to earthquake-induced slope failure (Varnes, 1984).

The Geographic Information System (GIS) is "a powerful tool for collecting, storing, retrieving, transforming and displaying spatial data from the real world for a particular set of purposes" (Burrough,1986). Wasowski et al. (2002) investigated the factors that control seismic slope susceptibility in the Slopes of Valley Sele. It was denoted that most of the slope failures were caused by 1980 Irpina Earthquake. It was also noted that hydrological conditions and differences in slope gradient are two important parameters that cause difference in the distribution of reactivated landslides that are caused by seismic effects. Capolongo et al. (2002), used a GIS-based analysis for the slope deformation model that was induced from a seismic effect in the Southern Apennines, Italy. Del Gaudio and Wasowski (2004), studied landslide hazard in Irpina, southern Italy caused by a seismic activity in order to map the landslides that were triggered by the earthquakes using the model of Newmark over a regional scale. Ingles et al. (2006) carried out a research on the displacements of earthquake induced landslides using Newmark model, in which the effect of the vertical component of ground shaking was investigated.

Similarly, Nepal is a country consisting of many high mountains and high hills. It is also a prone country to earthquake due to its tectonic position. Hence it is very important to know

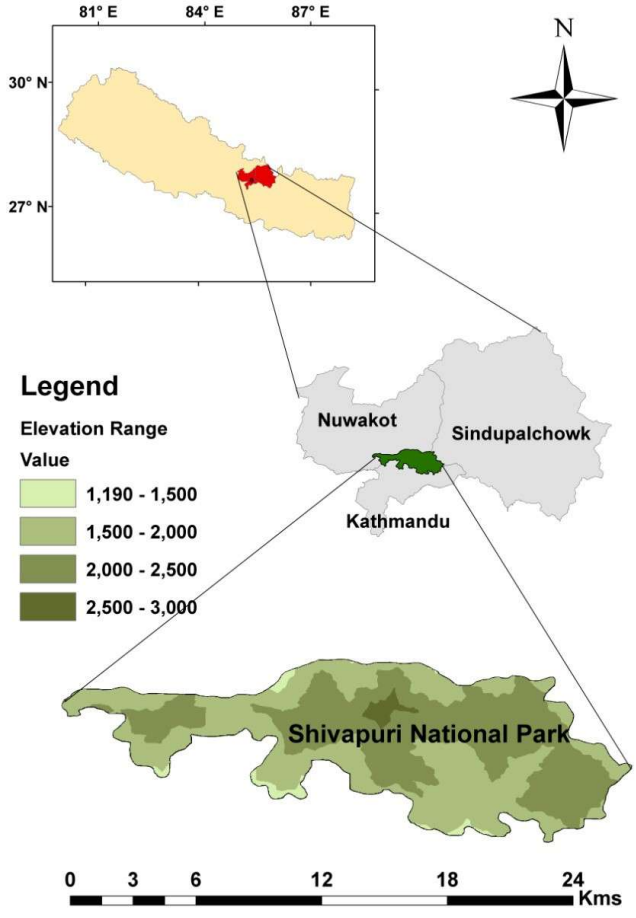

Fig. 1: Study area, Shivapuri Nagarjun National Park

the pre and post occurrence of landslide in hilly areas of Nepal that might occur due to the earthquake. This study emphasis on assessing the impact of Gorkha Earthquake 2015 on landslide events in Shivapuri Nagarjun National Park Area by identifying the number, types, materials present and volume of the land mass swept down.

METHODODLOGY

Study Area

Shivapuri National Park is the ninth national park of Nepal and was established in 2002 with an area of 159 km^2. It is located in country's midhills on the northern fringe of the Kathmandu Valley (Fig. 1) and named after Shivapuri peak of 2732 m altitude. The national park was upgraded to protect the valley's main water sources, as well as 177 species of birds and rare orchids.

Primary Data Collection

Questionnaire Survey

For the primary data collection questionnaire related to the landslide occurrence, the effect due to the landslide, etc was developed. The questionnaire was asked to the National Park staffs and the local people residing near the landslide area.

Direct Field Observation

For the visualisation of the landslide in the area direct field visit was done during the month of January, 2016. The types of landside were identified observing the way how the mass has been slide down and the classification was done using the "types of landslides and the Abbreviated version of Varnes' classification of slope movements (Varnes, 1978)". Also the materials in the mass were observed and identified. The breadth of the mass which has slide down along with its height measured and noted. This measurement was taken in order to calculate the volume of landslide. The coordinates of each site was noted in order to site the landslide area in the google map.

Data Analysis

The measurement of the length and breadth of mass were entered in excel sheet (Microsoft Office, 2013) in order to find the volume of mass of each landslide. For the depth, DEM 2011 was used through which the previous elevation of the site and the present elevation was compared and the difference was calculated for the depth of the mass. The study area map, aspect and slope of the national park were created using ArcGIS version 9.3.

Secondary Data Collection

Secondary information (literature review)

Different reports, papers, thesis and literatures were reviewed along the study period. The reference data and information were referred through the literatures of the global and local landslide and earthquake relations.

RESULTS

From the field study, altogether 13 landslides were encountered at different elevation points (Table 1, Fig. 2). Landslides were found mostly in the slopes greater than 300. The types of landslide were noted classifying in the basis of Varnes' classification of slope movements (Varnes, 1978). The materials present in the mass was analysed in the field and noted (Table 1).

Using ArcGIS, the total percentage of the study area (Shivapuri Nagarjun National Park having area of 106.7 sq. km) with the slope area greater than 300 (23.9 sq. km) was calculated in order to quantify the prone slope area for landslide. The area with slope exceeding 300 was 22.4%. The map was developed showing the aspect (Fig. 3a), elevation and slope greater than 300 (Fig. 3b) and aspect and slope greater than 300 (Fig. 3c), which helps in identifying the mostly prone areas of landslide.

Table 1: Different landslides triggered by Gorkha Earthquake (2015)

Landslide no.	Triggered by earthquake?	Materials available	Elevation (m)	Types of Landslide
1	Yes	Loose soil with big rocks.	2090	Debris Flow
2	Yes	Loose soil with big boulder of rocks.	2140	Debris Flow
3	Yes	Loose soil with mixed small boulders and disintegrated rocks.	1436	Debris Flow
4	Yes	Loose soil high content of lime, small rocks.	1447	Debris Flow
5	Yes	Loose soil with small boulders.	1424	Debris Flow
6	Yes	Loose soil with small boulders.	1431	Debris Flow
7	Yes	Loose soil with small boulders.	1416	Debris Flow
8	Yes	Loose soil with small boulders.	1406	Debris Flow
9	Yes	Loose soil with small boulders.	1474	Debris Flow
10	Yes	Loose soil with small boulders.	1574	Debris Flow
11	Yes	Loose soil with small boulders.	1546	Rock Fall
12	Yes	Loose soil with small boulders.	1535	Rock Fall
13	Yes	Loose soil with small boulders.	1528	Rock Fall

DISCUSSIONS

This study provides a rapid assessment of landslide triggered by the April 2015 Gorkha earthquake and its aftershocks. Within the study site all the 13 encountered landslides were triggered by the earthquake. Although the Google image was used for the screening of the landslide number, due to the vegetation cover (tree cover area) and also due to the small size landslide, clear visualization was not available. The information was more available by face-to-face interview with the local people residing within and around the park.

The aspect and the slope of the national park were found using the ArgGis 9.3. The elevation of the study site was calculated using DEM where the highest elevation was 2702 m and the lowest elevation 1178 m. The National Park has different slope angle and with the help of ArcMap, it was found that the slope with greater than 30° are high in number. Here slope angle of 30° or greater is considered to induce more landslides. The calculated total area of Shivapuri National Park is 106,724,724 sq. meters (107 km2 as calculated). The total area of slope greater than 30° is 23,941,318 sq. meters (23 km2). So the percentage of slope greater than 30° would be 22.4%. This determines that this area is more prone to the landslide in respect to the slope angle but due to the vegetation cover over the National Park this has positive point regarding the resistance of the ground against the landslide that may be triggered by the earthquake.

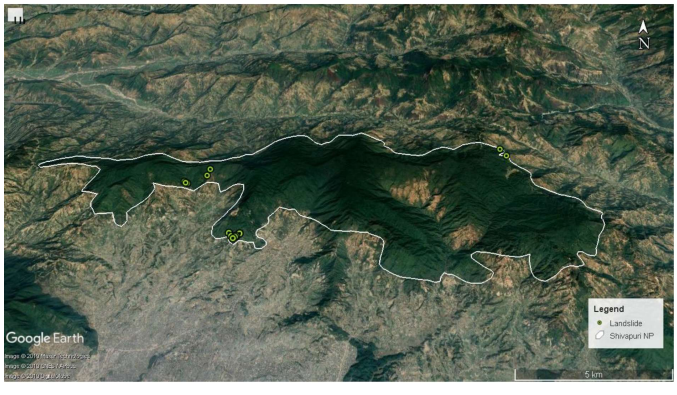

Fig. 2: Different sites showing the landslides occurred after the Gorkhal earthquake 2015. Landsides extracted from Google Earth 2016.

The overall landslides area are seen within the boundary area of the national park, this is due to the road construction in many areas at the boundary area and the road constructed for the transportation of the materials to the places like Chisapani, for the dam at Sundarijal and for house construction within the National Park area. This construction has added positive impact for easy landslide during the earthquake as well as erosion during heavy rainfall. But due to the high vegetation cover in other part of the National Park, there is low to no landslide seen. DEM, ArcGIS and Google Earth were used to identify if there were previous landslides seen before Gorkha earthquake 2015, but they could not be identified. Hence, face-to-face interview with the National Park authority, staff and local people were taken and proved from the interview that the landslide had occurred only after the Gorkha Earthquake 2015.

CONCLUSIONS

This study completed the study of landslides triggered by the Gorkha earthquake 2015 at Shivapuri National Park. Most of the areas were found to contain loose materials i.e. mixture of soil, small rocks and sand. Most of the landslides seen more or less near the boundary areas of the national park, the main reason is the excavation for road construction at those area where the vegetation cover are less and the loose soil are exposed. It is found that the the Gorkha Earthquake 2015 triggered altogether 13 small sized landslides. The landslides are small with highest breadth of 40 m and lowest of 4m causing some property to animal life and vegetation damage but no human casualty occurred. This result shows that the earthquake has increased the number of landslides within the National Park area. Hence, further study in such areas are required in order to protect the vegetation, human property, animal life, stabilize

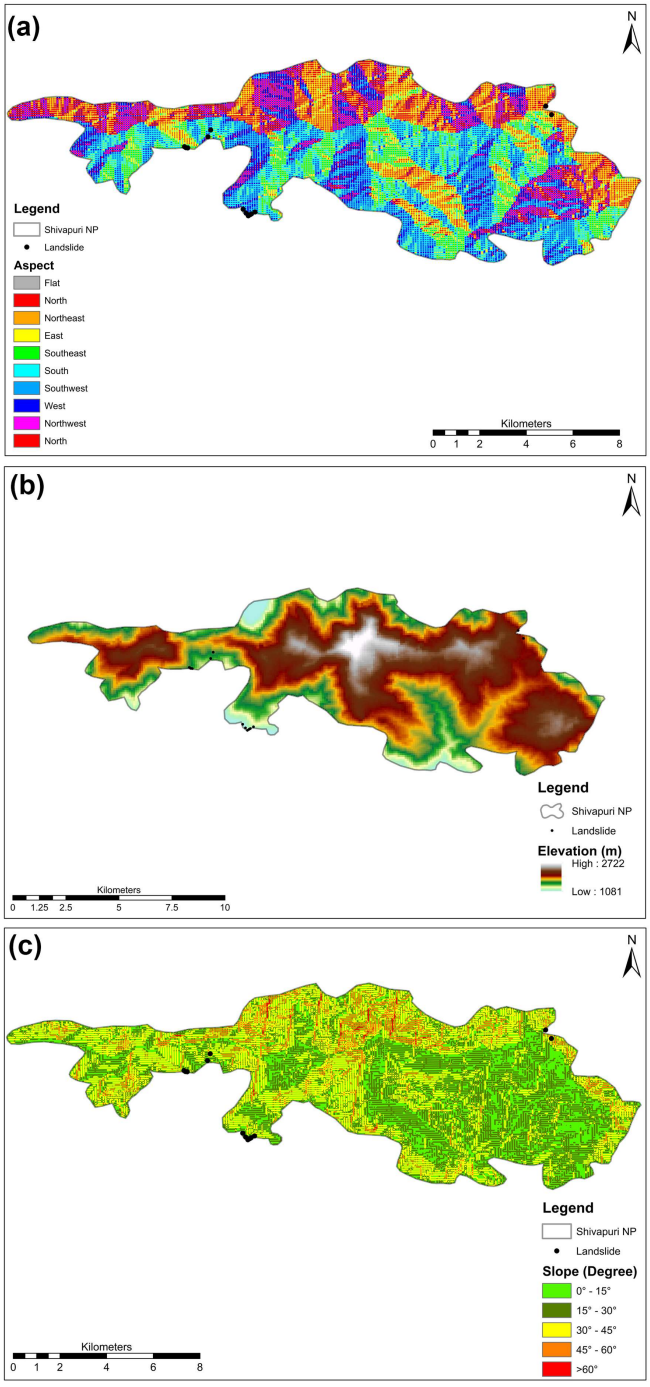

Fig. 3: (a) Map of Shivapuri National Park showing the slope aspect, (b) Map showing the different elevation range and the slope greater than 30°, and (c) Map showing the slope aspect and the slope angle greater than 30°.

the landslide areas and minimize the damage and to protect the national park.

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