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EVALUATION OF IMPACT OF EARTHQUAKE ON AGRICULTURE IN NEPAL BASED ON REMOTE SENSING

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ABSTRACT

The big earthquake happening in April 2015 killed over 9000 people in Nepal. The effect of earthquake affected not only safety of local people but also agricultural field. Agricultural economy dominates in income of local people. Therefore, restoration of agricultural areas is required for improving life of locals. However, lack of information about agricultural areas is the main problem for local government to assess and restore damaged agricultural areas. Remote sensing was applied to access damaged agricultural field due to its advantages in observing responds of environment without temporal and spatial restriction. Accordingly, the objective of the study is to evaluate disaster risks based on data from questionnaire survey, remote sensing and geographic information system (GIS) in agricultural areas of Nepal. Firstly, we conducted questionnaire survey about thirty indicators of agriculture-related issues. Moreover, based on USLE (Universal Soil Loss Equation), soil erosion risk was compared between before and after the earthquake. To clarify the relation between soil erosion risk and land-use, land-use map was created based on Worldview-3. Finally, statistical analysis was conducted based on the collected data. From the results of field survey and analysis, it turned out that there was little damage on agricultural areas but huge damage on houses and barns in the villages in the research site. It is attributed to the vulnerable house materials. Soil erosion risk, that has been little observed in agricultural area, decreased in forest area and increased in residential area compared to the pre-earthquake time. From the statistical analysis, multi regression analysis was applied and age of house and elevation was computed as dominant factors of building damage in the research site. It is suggested that it is important to improve house materials in the villages and increase vegetation cover to prevent from further soil erosion in the research site.

Keywords: *GIS, remote sensing, soil erosion, worldview-3.*

INTRODUCTION

An earthquake of magnitude at 7.8 occurred at Gorkha District in the northwestern part of Nepal on April 25, 2015. The earthquake caused an estimated death toll of 9,000 (Wilkes and Sharma, 2015). It triggered a number of human casualties, damages of buildings and landslides in Kathmandu and the surrounding rural areas. Although the situation of affected area became clear immediately, it has not been investigated sufficiently in rural areas. As most of people are engaged in agriculture in steep slope areas in Nepal, it is concerned about damage on agriculture and secondary or tertiary disasters such as slope failure, erosion or destruction of dams. Facing such issues, there is a strong need to clarify the disaster impact on the rural areas and identify safe place to live and resettle for their sustainable living and livelihood. However, lack of information about agricultural areas is serious problem for local government to assess and restore damaged agricultural areas (Ashalata and Dibya, 2015). As many agricultural areas are located in high elevation and remote area from the arterial highway, the access to that areas are difficult. In addition, the data that the local government has is limited. Therefore, the research requires the long field work to collect the necessary data. Remote sensing was applied for accessing damaged agricultural field due to its advantages in observing responds of environment without temporal and spatial restriction.
Accordingly, the objective of the study is to evaluate disaster risks based on data from questionnaire survey, remote sensing and geographic information system (GIS) in agricultural areas of Nepal. These results can contribute to suggest the Nepalese Government high resilience area to natural disasters.

MATERIAL AND METHODS

The research site is targeted at Panchkhal Municipality in Kavrepalanchok of Gorkha District (Nepal) where most of people are engaged in agriculture and suffered the immense damages (Figure 1).

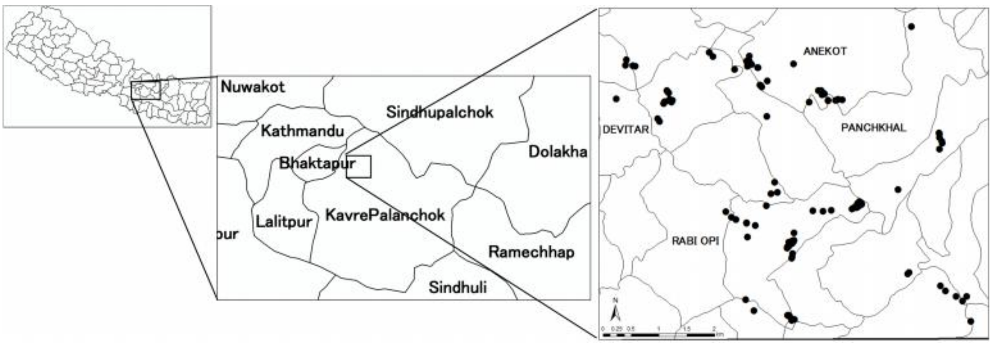


Figure 1. Research area in Nepal

The research consists of data collection not only from the governmental offices but also from the field survey including questionnaire survey, soil erosion risk analysis, land-use mapping and statistical analysis to reach the research objectives. The methods of each study are explained below.

Field survey (Questionnaire survey and soil sampling)

The research team conducted questionnaire survey from November 2015 to May 2016 in the research site. The survey targeted 136 households in thirteen villages and the questionnaire contained about thirty indicators such as building (house and barn) damage, building materials, main crops, water source, agricultural productivity and other agriculture-related issues, comparing the current situation to the one in the pre-earthquake time. The respondents were given scales to answer each indicator. In case of building damage, three-point scale such as partial, half and total collapse was provided. Soil sampling was conducted at nine spots in total in the research site in February 2016.

Soil erosion risk analysis and land-use mapping

Based on USLE (Universal Soil Loss Equation), soil erosion risk was compared between before and after the earthquake as seen in the formula (eq 1). Soil Loss Equation (USLE) have been used to calculate annual soil erosion rate (Wischmeier and Smith, 1978). USLE is empirical model, originally developed to predict soil erosion rate, mainly in agricultural land. Vegetation cover conditions before the earthquake were taken on June 14, 2014 and that after the earthquake on June 1, 2015. The calculation of soil erosion risk was based on the following equation.

$$\text{Soil erosion risk (SER)} = K * LS * C \quad \ldots \text{ eq 1}$$

where K is soil erodibility factor, LS topographic factor and C cropping management factor. The soil erodibility factor was extracted from physical condition of sampled soils, topographic factor was from land slope degree calculated from ASTER GDEM, and cropping management factor was calculated from the Normalized Difference Vegetation Index (NDVI) generated by LANDSAT8 (pre-earthquake on June 14, 2014 and post-earthquake on June 1, 2015). In cropping management factor, although empirical value is used in general, this research applied NDVI instead. Regarding this, it has been confirmed that NDVI has sufficient accuracy based on an experiment which used spectroradiometer which has the same sensor as satellite. Based on the factors, soil erosion risk map was created which normalized the value gap of soil erosion risk between pre- and post-earthquake. To clarify the relation between soil erosion risk and land-use, land-use map was created based Worldview-3. The map was classified into houses, forest, agricultural land, water and road.

Statistical (multi-regression) analysis

Statistical analysis was conducted based on the collected data, such as the results of questionnaire survey, land slope degree, soil erosion risk map, etc. It aimed to clarify the causal (dominate) factor of earthquake damages in the research area.

RESULTS AND DISCUSSION

The results of each analysis are discussed into three parts as field survey, soil erosion risk analysis and land-use mapping and statistical analysis shown as follows.

Field survey (Questionnaire survey and soil sampling)

As results of questionnaire survey, most of the farmers mentioned that soils became dry after the earthquake, although its cause could not be identified. For the loss of water source and the lack of precipitation after the earthquake, it was causing them poor harvesting and living. The houses and barns were significantly damaged in most of the villages. Besides that, the relief has been insufficient to repair them. By the time of the survey, they had made quite temporal and simple repair on their houses. Therefore, many of them sleep outside of their houses because of fear of house collapse and suffer from cold during nights. Although some houses were mainly built by bricks and woods, most of houses were built only by muds, rocks or unbaked bricks (Figure 2). Thus, the building damages were more significant in houses built only by muds, rocks or unbaked bricks.

For this reason, the loss of livestock was also significant because of the collapse of barns. Severe damage on agricultural facilities such as canals was not observed. Totally 136 houses were investigated and the damage scale among partial, half and total collapse was 21.3%, 12.5% and 65.4%, respectively. Thus, most of houses were totally collapsed (Figure 3). The valuable data such as the results of the questionnaire survey and location information of damaged buildings was obtained through visiting villages one by one.

In soil sampling, soil texture, permeability and structure were observed in agricultural soils. For this reason, it is able to maintain certain agricultural productivity if water management is conducted at certain level. On the other hand, forest soils contain a lot of clay, thus are hardly water permeable.

Figure 2. Difference of building damages between house materials
Bricks and woods (left) and Muds and rocks (right)

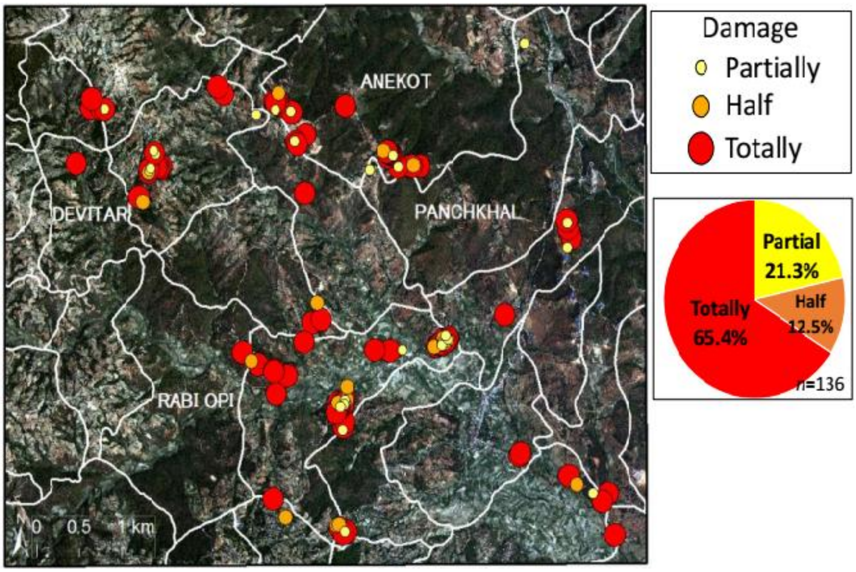


Figure 3. Distribution map of building damage scale and damage degree

Soil erosion risk analysis and land-use mapping

The changes in soil erosion risk between the pre- and post- earthquake was measured based on the relation of soil erosion risk (Figure 4) and land-use (Figure 5). The change value of soil erosion risk (VSER) was calculated by the following equation (eq 2).

$$VSER = SER(A) - SER(B) / SER(B) \quad \ldots \text{ eq 2}$$

where VSER is changed value of soil erosion risk, SER (A) soil erosion risk after earthquake and SER (B) soil erosion risk before earthquake.

From this, it was observed that the soil erosion risk was not changed in agricultural land averagely, but decreased in forest area and increased in residential area (Figure 6). Therefore, vegetation cover needs to be increased to avoid further erosion phenomena after the earthquake, and land reclamation is not encouraged for dwelling or agriculture from forests. Although soil erosion risk would be influenced by land slope degree, the correlation coefficient was low (R=0.08) between the risk and the slope degree generated from ASTER GDEM. As ASTER GDEM's spatial resolution is 30m, there might be the map was not sufficiently replicate the undulating and steep slopes in the research area. Therefore, there is a need to apply a DEM (digital elevation model) with higher resolution for the more accurate study.

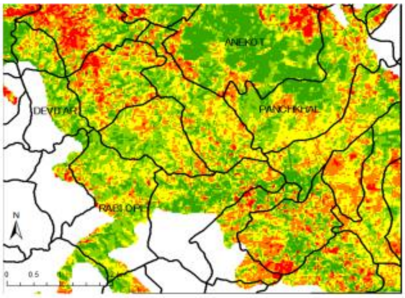
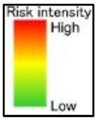


Figure 4 Changed value of soil erosion risk map



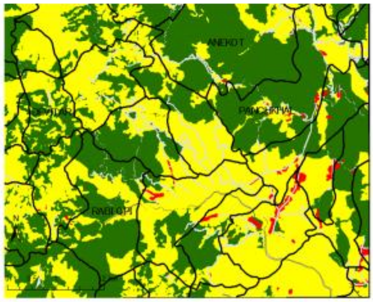


Figure 5 Land-use map based on Worldview-3

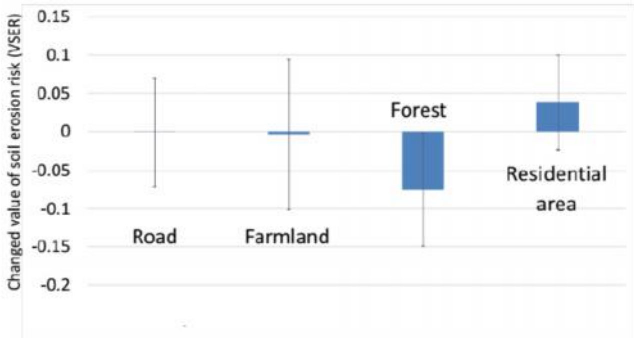


Figure 6 Changed value of soil erosion risk (error bar shows standard deviation)

Statistical (multi-regression) analysis

It was observed from the field survey that there was little damage on agricultural land because most of the farmers do not own them in large scale. However, houses which also play a role of granary are the most important in this case for their living and agricultural activities. For this reason, multi regression analysis was conducted by making intensity of damage as an objective variable, and age of house, building material type, soil erosion risk, cropping management factor, soil erodibility factor, land-use type, irrigation type, slope in degree, crop type, farmland productivity, elevation and so on as explanatory variables. As the consequence, 'age of house' and 'elevation' was computed as dominant factors for building damage in the research site with 95% confidence interval (Table 1). The both factors are considered to have affected on damage on buildings. It is considered as valid that age of house is a factor because of its vulnerability. In case of elevation, it is considered that vulnerable house materials are used more in the research site. However, because 'house materials did not emerge as a dominate factor, there is doubt on this result. Therefore, it is necessary to analyze further with more details to make a conclusion. The data and results obtained from this research, such as land-use map and soil erosion risk map have been compiled on GIS database.

Table 1. Result of multi-regression analysis

Explanatory variables	P Value
Age of house	$^{*}0.0257$
Farmland productivity	0.0519
Irrigation type	0.1036
Elevation	$^{*}0.0464$
K factor	0.1386
Land use	0.1865
C factor	0.0608
Soil erosion risk	0.1369
Constant	$^{**}0.0047$

$^{*}P \leqq 0.05 \quad ^{**}P \leqq 0.01$

CONCLUSION

From the overall research results, the followings are the concluding remarks corresponding to the research objectives.

- Agricultural land was not damaged directly by the earthquake in research area.
- Building structures such as houses and barns were significantly damaged and caused a large number of livestock losses.
- Most of collapsed houses were made by unbaked bricks, stones or muds. Because of that fact, it is important to improve house materials in villages.
- Based on USLE (Universal Soil Loss Equation), soil erosion risk was compared between before and after the earthquake. In farmlands, the changed value of SER (VSER) was small. However, there were tendencies for VSER to increase in residential area and decrease in forests in the research area. Accordingly, it was concluded the vegetation cover is important to eliminate further erosion phenomena.
- From the results of multi regression analysis, the dominate factors were 'Age of house' and
'Elevation' at 95% confidence interval. However, there is a tendency that in the higher in elevation the smaller in the damage occurred, and in the lower in elevation the larger damage occurred in general. Therefore, analysis that is more detailed is necessary to conclude it.

From above conclusions, it suggests that it is necessary to promote the use of more resilient house materials for houses and barns to aim for sustainable agriculture and livelihood for the locals. In this research analysis, it applied damage on buildings and erosion phenomena. However, because productivity of crops is significantly important for farming, there is the need to continue observing agricultural productivity to suggest high resilient area for resettlement.

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