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Assessing the Adverse Impacts of Climate Change: A Case Study in the Philippines

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Climate-induced disasters, such as floods and landslides, have negative impacts on agricultural sustainability and food security worldwide. Our aim was to promote awareness of climate change, evaluate some of its adverse effects, and suggest methods that could help enhance agricultural production in two areas in the Philippines. Soil erosion was examined in Bukidnon province and a flood assessment was conducted in the Metro REINA (Real, Infanta and General Nakar) area in Northern Quezon. In Bukidnon, spatial dataset analyses were implemented using GIS and remote-sensing techniques. The corresponding factor values of each parameter were computed and encoded to spatial datasets before calculation. The extent of soil erosion was then classified into different categories. About 37% of the total land area of Bukidnon suffers from very high to very severe erosion. Many farms in this area are located on slopes, therefore soil conservation measures and the use of suitable crops enumerated in a previous paper authored by Adornado and Yoshida (2008) were recommended. The effects of flooding in the REINA area were evaluated by using multi-temporal satellite and elevation data. About 4,600 ha, including rice fields, in REINA were covered by more than 39 million m^3 of sediments ranging from 0.017 to 1.5 m thick. We recommend basket farming and the use of deep-rooted plants in areas heavily covered by sediments. Crops that thrive in sandy soil should be planted in areas with shallow sediment deposits to re-establish farming in those areas. A better understanding of climate change and its effects could increase the chances of developing appropriate strategies to abate the negative impacts of climate change, thereby enhancing both food security and agricultural sustainability.

Key words: Climate-induced, Erosion rate, Sediment, Food security, Agricultural sustainability

Introduction

The Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC, 2007) revealed that climate warming is unequivocal and it increases in global air and ocean temperatures, widespread melting of snow and ice, and rising global average sea levels have all been observed. Global sea level rose at an average rate of 1.8 mm/yr from 1961 to 2003 and an average of about 3.1 mm/yr from 1993 to 2003. Temperature increases are widespread over the globe and greater at higher northern latitudes. Average Arctic temperatures have increased at almost twice the global average rate in the past 100 years. The Pacific Economic Cooperation Council, (PECC, 2008) notes that impact of climate change will vary according to latitude of economy with increase in northern part of the region and decrease in tropical/equatorial areas. They also averred that agricultural production will increase in United States and Canada but declined in Southeast Asia, South America and parts of China over the next century. Similar findings have been reported by the International Food Policy Research Institute (IFPRI, 2009), which concludes that Agriculture is extremely vulnerable to climate change. South Asia will experience much larger decline in crop yields and production especially irrigated fields. Food prices will rise even without climate change, but the problem will be even worse with climate change.

In early September 2009, the U.N. Secretary-

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General said that, as a result of global warming, sea levels could rise by 50 cm to 2 m this century, which is higher than most experts have previously predicted (Doyle, 2009). The new findings based on satellite images as published online (AFP-Paris, 2009), show that 85% of the 33 largest delta regions in the world have experienced severe flooding over the past decade, affecting 260,000 km^2. Under moderate climate change scenario, the areas vulnerable to flooding will expand by 50% this century if ocean levels increase as expected. Asia will suffer the most but heavily populated and farmed deltas on every continent except Australia and Antarctica are in danger.

Indeed, Asian countries have been particularly hard hit by frequent typhoons coupled with landslides and soil erosion. The Philippines is a prime candidate for these types of climate-related calamities, which damage lives, infrastructure, property, and agriculture; and hinder the country from achieving its desired goals of agricultural sustainability and food security. In the Philippines, the agriculture and fishery sector contributed at least 18% to the Gross National Product (BAS Report, 2008), but climate change has placed the country's food security in doubt. A BSWM Agriculturist study showed that almost 90% of losses and damage to rice production from 1991 to 2007 was caused by flashfloods, typhoons, and drought (BSWM, DA-Philippines, 2009).

The PECC (2008) reports that food production in developing economies in the Asia Pacific region will be most affected by climate change because the farmlands in this region are usually found in low-lying areas. Farmers in these areas will most likely have to move towards upland farming, which will increase pressure on sloped areas. In this study, we examined soil erosion and assessed the impact of flooding in two areas in the Philippines to promote awareness and understanding of climate change, and its adverse impacts. We also suggest strategies to increase food production and encourage agricultural sustainability.

Materials and Methods

Description of the Study Areas

The study was consisted of two parts. Soil erosion was examined in Bukidnon province, and a flood assessment was conducted in the Metro REINA (Real, Infanta, and General Nakar) Quezon, Philippines.

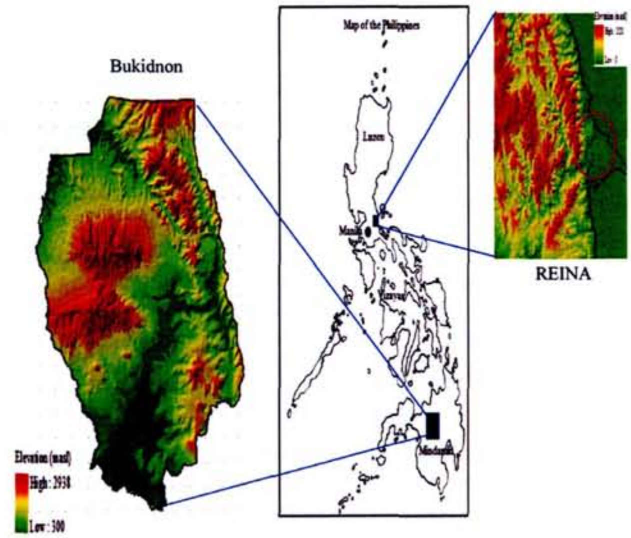

Fig. 1. Map of the two study areas.

Bukidnon is a landlocked province in the heart of Mindanao, Philippines (Fig. 1). The prevailing climatic pattern based on the Coronas classification (PAGASA-DOST Philippines and PPDO, 2003) is Type III in the northern part of the province and Type IV in the south. Type III areas are characterized by a relatively dry period from November to April and a wet period during the rest of the year, whereas Type IV areas are characterized by evenly distributed rainfall throughout the year. The province has about 1.2 million residents (NSO-Philippines, 2007). Because of the generally fertile soil and other favorable factors, many crops are grown in the province. Bukidnon is home to the world's largest pineapple plantation and the biggest producer of cattle in the Philippines. Agriculture is the main source of income for the residents of Bukidnon (PPDO, 2003).

The REINA area is in Quezon province (Fig. 1). The eastern portion is coastal area, whereas the west is mountainous. The eastern part of the study area falls within the Type IV climatic pattern, and the western side falls within the Type III pattern (PAGASA-DOST, Philippines). The annual average rainfall from 1994 to 2003 based on the obtained rainfall data from PAGASA-Philippines was 4131.85 mm. The REINA area was selected because previous flooding has done a great deal of damage in these municipalities.

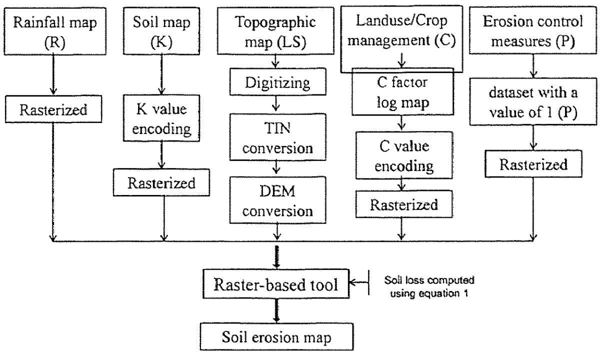

Fig. 2. Flow diagram for erosion evaluation in Bukidnon.

Soil Erosion in Bukidnon

We used the raster-based tool developed by Adornado *et al.* (2009) inside a Geographic Information System (GIS), because it offered the easiest calculations and had simple data requirements. The raster-based tool was developed by applying the Universal Soil Loss Equation, (Wischmeier and Smith, 1978) concept and used the equation 1 to compute soil loss.

$$A = R \times K \times L \times S \times C \times P, \qquad \text{Equation (1)}$$

where A is annual soil loss (ton/ha^{-1}), R is rainfall erosivity factor, K is a soil erodibility factor, L and S are slope length and steepness factors, respectively, C is cover and management, and P is the support practice factor.

Datasets Preparation and Processing

All datasets used were prepared by using a combination of remote sensing and GIS techniques (see Fig. 2). The corresponding factor values were encoded in each vector dataset generated before it was rasterized, except in the case of the topographic map, which underwent a Triangulation Irregular Network (TIN) process followed by Digital Elevation Model (DEM) conversions.

The R factor represents rainfall erosivity index, the capacity of rainfall to cause erosion. The average annual rainfall in the area ranges from 2,150 to 3,150 mm (Fig. 3a). The equation described by Eiumnoh (2000; reported by Thang *et al.*, 2005) was used because it has shown acceptable results for tropical and sub-tropical ecological zones: $R = 38.5 + 0.35P$, where R is the rainfall erosivity factor and P is mean annual rainfall in mm.

Using the soil information reported by Adornado and Yoshida (2008) and equivalent soil factor values described by Stewart *et al.* (1975), we generated the K factor. Values were encoded for each soil type except the areas covered by Mountain Soil Undifferentiated (MSU), because no soil information was available for that soil type. In this case, a value of 1 was used to indicate no data. K values ranged from 0.2 to 1 (Fig. 3b).

The LS factor refers to slope length and steepness and was calculated by the tool using empirical formula suggested by Mitasova *et al.* (1996) because it reflects the increased erosion in areas of concentrated flow and permits the identification of areas with potential gullies. We used a topographic map with a contour interval of 100 m because it was the only map available during data preparation. The map was scanned, georeferenced, and digitized. The Z values were encoded and underwent the TIN process and finally converted into DEM (Fig. 3c).

The C factor, representing cover and management was generated by using analog map and available ASTER image to update land use map. The values suggested by Wischmeier and Smith (1978) and Morgan (1995) were adopted. The C factor value is ranging from 0.002 to 0.377 (Fig. 3d).

We observed that farm owners were not practicing soil conservation measures, except on a small demonstration farm near the road heading to Mount Kitanglad. We therefore assumed that no conservation practices were implemented in the entire province and used a P factor of 1. The raster datasets with the corresponding factor values were rasterized and became inputs for evaluating the extent of soil erosion.

Flood Assessment in REINA

The flooding that occurred in 2004 was caused by abnormally high levels of precipitation in a short period of time. The weather station in this area recorded 342 mm of rainfall in just six (6) hr. during the typhoon. Based on the report of the local government of Infanta, among the three neighboring towns, Infanta was hard hit most by flooding that resulted to 176 people died. In this town alone, 14 villages were inundated. Damages to agriculture and fisheries, public infrastructure, were reached to 400 M pesos while damage to private properties/businesses

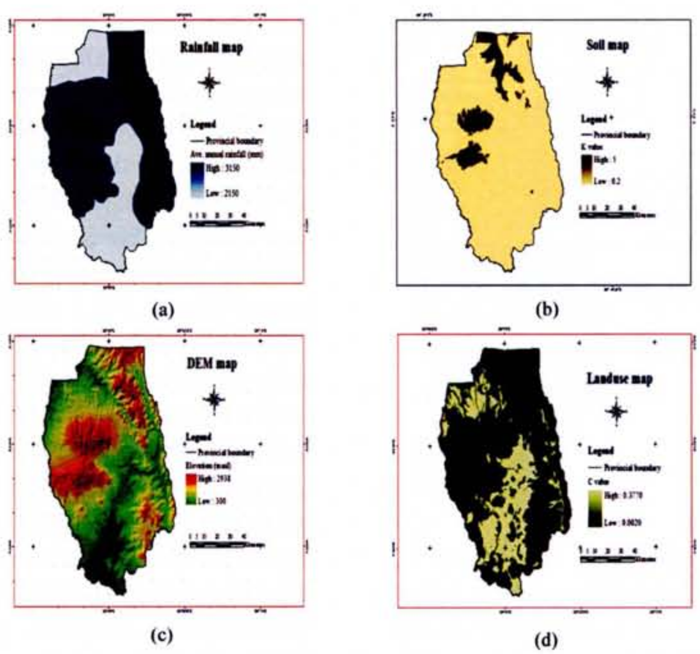

Fig. 3. Datasets used as inputs (a) rainfall, (b) soil, (c) DEM, and (d) landuse for the erosion evaluation in Bukidnon.

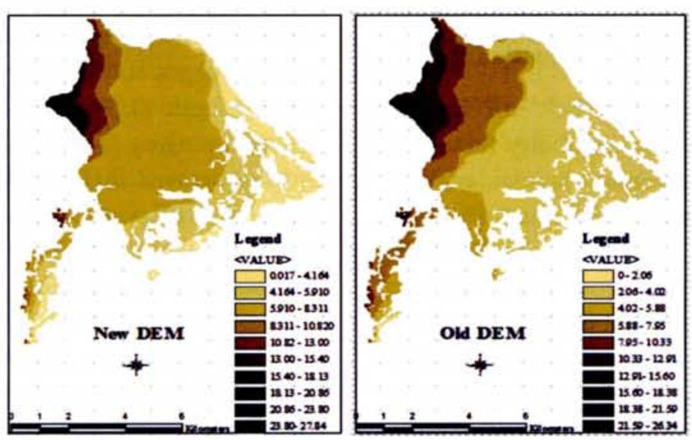

Fig. 4. Subsets of (a) new (2005) and (b) old (2002) DEM data for the REINA area.

and the environment were unaccounted for.

Delineation

Flooding commonly occurs in the Philippines during almost every heavy rain event. Along with the deluge of water come soil materials. As stated previously, the REINA area was strongly affected by the 2004 typhoon. We delineated the total area affected through a visual interpretation of multi-temporal satellite images from ASTER and other UNOSAT information.

Sediment Estimation

The vector output generated from the interpreted images was utilized to create a subset of the surface raster with elevation values. Elevation raster datasets were used from before (2002) and after (2005) the flooding (Fig. 4). The differences between the two surface rasters were used to determine the thickness of sediments deposits. Although deposits in some areas, especially the town proper, had already been removed by the time the data were acquired, the results overwhelmingly showed large amounts of

Table 1. Extent of soil erosion in Bukidnon

Category	Soil loss ($t\ ha^{-1}\ yr^{-1}$)	Area (ha)	%
None to slight	0-5	354,349	39.26
Moderate	5-15	64,247	7.12
High	15-50	146,702	16.25
Very high	50-150	140,095	15.52
Severe	150-300	60,083	6.66
Very severe	>300	137,152	15.19

%=area affected by erosion.

sediment deposited nearby and within farm lots. The total volume of sediment was calculated as the product of the area and the sediment thicknesses with the use of spatial analysis tools from ArcMap GIS software (ESRI, Japan).

Results and Discussion

Soil Erosion Evaluation

Six categories were used to rate the extent of erosion. About 39% of the total land area in Bukidnon fell into the none-to-slight category. The high, very high, and very severe categories covered about 15% to 16% of the total land area (Table 1; Fig. 5). Areas in the none-to-slight category were predominantly in the south and other parts of the province that are typically flat (slope < 8%; Fig. 5). The degree of erosion increased in areas with slopes of greater than 8%, especially those that were exposed to agricultural activities and had no soil cover for most of the year. High rate of erosion can be observed on eastern slopes of Mt. Kalatungan and Mt. Kitanglad, the two tallest mountains in the province, (Fig. 5).

Many of the mountainous areas fall in the high and very high erosion categories (Fig. 5). Although some of these areas remain forested, the results may be skewed higher because of a lack of soil information for these areas. As mentioned in the methods, a *K* factor value of 1 was assumed for MSU soils which are located on top of the mountain. Therefore, in these areas, the raster-based USLE tool calculated the soil loss by using only five parameters instead of the complete set of six.

In comparison with the results from a previous study of the RIENA area (Adornado *et al.,* 2009), erosion rates were higher, although similar trends were observed in areas having no vegetation and

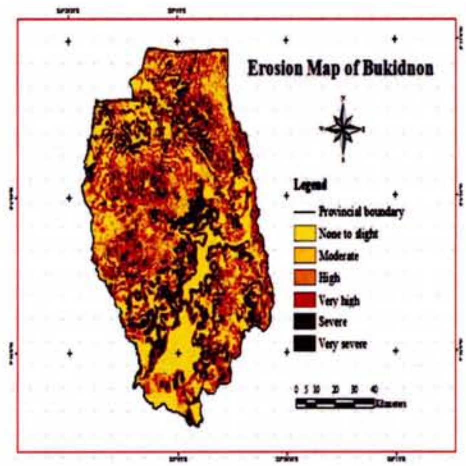

Fig. 5. Erosion map of Bukidnon.

high levels of rainfall. Soil erosion is directly affecting agriculture. According to the study conducted by Bakker *et al.* (2003), a yield reduction resulting from erosion has been estimated to be 4% per 10 m^3 of soil loss. This means that the crop yield in areas suffering a soil loss of 10 $t\ ha^{-1}\ yr^{-1}$ will decline by an average of 4% per decade. Higher rates of soil erosion could result in even greater yield reduction. Therefore, conservation of agricultural soil now could lead to increased production in the future.

Flood Assessment in REINA

The geospatial analysis showed that vast part of Infanta was inundated; and partly of Real and General Nakar with a combined area of around 4,600 ha. The Infanta town became a depository area for much soils brought by water current from the Sierra Madre Mountain during a 2004 deluge. The flooded area was covered by sediments ranging from 0.017 to 1.5 m thick (Fig. 4) and we estimated the total volume of sediments deposited to be about 39 million m^3. The satellite image of the place showed hundreds of eroded portions inside the mountain that may have contributed to the tremendous amount of sediment deposited in the REINA area. The sediments buried farm lots and left many uncultivable to common crops.

Conclusions and Recommendation

The availability of new technologies can be of great help in evaluating environmental problems and coming up with possible solutions. We were able to use available satellite images to find areas where the land surface had changed. In the case of the typhoon in 2004, the use of multi-temporal data like DEM and satellite images was an efficient way of determining the thickness of sediment deposits. The methods implemented helped to highlight and assess damage quickly and efficiently.

Determining the extent of erosion could help in designing strategies to restore forest cover and adopt erosion control measures, especially in sloping areas used for agricultural purposes in order to minimize erosion if not completely controlled. Information on erosion will become more important only as pressure increases in hilly areas as a result of agricultural expansion. Bukidnon is dominated by rolling to steep slopes. Its climatic condition and soil fertility varies as elevation changed, therefore we recommend the use of suitable crops in particular elevation range like Banana, Mango, Tomato, Potato Corn, Sugarcane, etc. (Adornado and Yoshida, 2008) to improve agricultural production and food security may increase. On the other hand, in the case of deluge affected area, (Real, Infanta and General Nakar-REINA), basket farming (BSWM and JICA, 1991) using deep-rooted plants (Tree crops and Fruit bearing trees) in areas with very thick sediment deposits and crops thrive in sandy soil with shallow sediments are recommended to re-establish farming in the area.

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