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Impacts of long-term flood-induced sedimentation on agricultural land: case study of the 2008 Koshi flood in Eastern Nepal

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Abstract

Flood of August 2008 in eastern lowlands of Nepal affected around 2.64 million people in India and Nepal, including 65,000 people and 700 ha fertile land in Nepal. It was estimated that 20% of land was still barren even in 2016 (eight years after the flood). The long-term effect of flood fed sedimentation in context of agriculture practices is the focus of this research. Information from questionnaire survey, field measurement and lab analysis are the adapted methods for the assessment. The affected area is divided into four zones with respect to the depths from 0.10 m to 5.0 m. The area where sedimentation thickness is less than 0.5m is in manageable condition within a year and in between 0.5m to 1.5m thickness could not be suitable for traditional crop even after 8 years. The thickness existed more than 2m is not suitable for any crop even after the 8 years because of its long-term impact on cultivation in context of flood fed sedimentation and recovery. From Normalized Difference Vegetation Index (NDVI) analysis also indicated that the recovery with vegetation trend is about 10% per year in less than 2m of thick sedimentation zones. Size of sediments and sedimentation thickness are the significant parameters to recover flood fed sedimentation zone.

Keywords: flood; sediment

1. Introduction

The Koshi is the largest river in the eastern part of Nepal and also one of the largest tributaries of the Ganga river. The Koshi river is known as "sorrow of Bihar" because of its unpredictable nature on channel dynamics. The dynamic oscillation of channel with high sediments carrier is its distinctiveness. High gradient Himalayan range has made high velocity river with high rate of denudation in Himalayan area that accumulates heavy sediments in low land areas that lies on Nepal and India. The tributaries that originate from middle mountain are also contributors for the sediment and flooding to the southern low land areas. In this regard, flood and sedimentation are driven by monsoon pattern that results the anomalous variations in channel avulsion, suspended sediments dynamics, channel migration, and the unexpected floods [1]. During the monsoon, influence of sedimentation as bed load and suspension load eventually impact on the lowland agriculture area.

The Koshi is also known as the highest silt yielding (estimated 118 million cum /year) river in the world [2, 3] which accounts 50% soil erosion of the country however runoff is only about 25 % [4]. This value shows the significant sediment load of the river.

The river channel system of the river has shifted 115 km westwards during the last 200 years [5, 6] and deposition covering 770 km2 with sand [4]. The dynamism includes extensive bank erosion, lateral shifting, frequent flooding "piggyback" thrusting sequences, tilting, neotectonics, sedimentological adjustment in its basin [7-15, 5]. This shifting dynamics because of climatic and tectonic variation that eventually impact on the floodplains and the agricultural lands [16, 17].

The flood fed infertile sedimentation stand as a challenge of its impact on a farmland though only small quantities can be used as construction materials [18]. Dynamism of hydrological system in Gangetic rivers is therefore vulnerable because of flood sediments that affects the people of the basin [8]. On other hand, the data availability of the Koshi basin is still scanty even though the studies have been carried out for several decades [18, 19].

Thus, there is a need to assess consequences of long-term impact in agriculture land because of sedimentation as a flood- induced disaster especially in agricultural land as post disaster productivity and management. In this regards, this study attempts to assess the sedimentation impact on the agriculture land on the base of sediment characteristics and cultivation practices on the 2008 flood affected areas as post disaster management.

1.1. Koshi flood of 2008

On 18th August 2008 afternoon, the Koshi River changed its 100 years old course with 95% flow of water eastwards breaching [20] the embankment. This flood has been considered most disastrous flood during the last decade in terms of the number of people affected and the loss of properties. The flood deposited huge amounts of sand and silt as a sedimentation on 74% agricultural land [21] affecting 65000 people in Nepal and millions of people in India [22].

Existing 4-5m higher level of river bank to the agriculture land poses flood sedimentation hazards for recurring devastations. On other hand, Sinha and Kommula [23] had also reported that other several critical points for breaching in the near future as of 2008 event.

2. Materials and methods

The study was carried out between 2008 September to 2017 April on affected area of Nepal only however the flood affected area was

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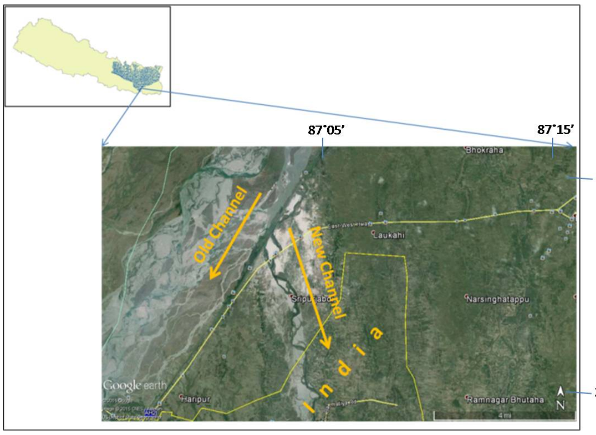

Figure 1: Study area

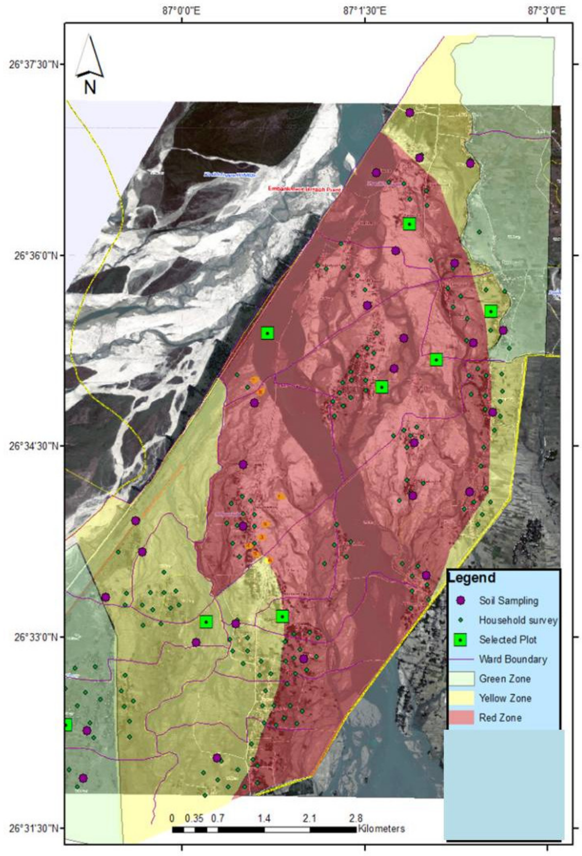

Figure 2: Study area with locations of samplings and surveys (Image from OCHA, 2008) [20]

large in India in spatial context. The major tools of the method were soil sampling, observation plots, lab plots, questionnaire survey, and collection secondary data with the standard method. All together 150 semi-structured questionnaires were sampled with reference to available literature [24-30] with the Stratified Random Sampling (SRS) method. The study area (about 50 Sq km) shown in Figure 1 was divided into seven clusters of settlement in different zones on the sedimentation land including severely affected land to lightly affected land.

Similarly, sediment samples were collected by manual hand auguring, digging the pits and from existing canal trench. All together 31 samples were taken from different locations from both sides/banks of the new channel with Stratified Random Sampling Method (SRSM) including two from natural unaffected area. The collected samples were carried out with standard American Society for Testing and Materials (ASTM) method for grain size analysis, textural analysis and composition analysis.

Eight observation plots (18225 sq. ft. each) were selected in different locations (Figure 2) on the sedimentation zone and continuous data of yield and productively has been collected during the following years. The yields were converted to the annual income in term of the monitory value. That data was compared to the difference on income from agriculture land during the pre and post disaster phase.

LANDSAT-5 and LANDSAT-8 dated from 2005 to 2016 from United States Geological Survey (USGS) Earth Explorer have been used for the analysis. All these images were further classified into two seasons dry (May) and Wet (October) for pre and post disaster phases. All these LANDSAT images are selected for the vegetation changes after the flood as a long-term vegetation recovery trend as vegetation analysis [31-34]. Therefore, NDVI was used to analyze for the periodic vegetation recovery trend on the flooded land in post flood period.

3. Results and discussion

All collected data from field and lab have been analyzed on the issue of sedimentation especially on depth and compositions, productivity and land management, vegetation recovery trend and adaptation on the impacted area.

3.1. Sedimentation depth (thickness) variation

The analysis from 120 places depth data showed that the thickness varied from 0.1 m to 5 m. Thicker than 2.5 m of sedimentation area could not be managed till the eight years of the event. This area was about 22.0% even after the eight years. The thickest area was around the breach point and the thickness was decreasing towards the downstream of the new channel. Similarly, the thickness was higher (>2.5m) on the main new channel and it was decreasing towards as apart as from the center of the new channel.

The outcomes from questionnaire survey analysis also exhibited that farmer could not do anything if the land had more than 2.5 m of thick sediment on their land. The sedimentation depth where the thickness was less than 1.5 m, they could manage on their effort on removal of the sediments by bulldozers and tractors that they could revive their cultivation on their original land. Similarly, the outcomes of the questionnaire survey revealed that their 20-25% of land was still uncultivated even after the eight years from the event. The income from agriculture product had been reduced by 95% immediately after the flood time. Whereas they had recovered their farm land by 75-80% after the eight years. For the adaptation, they had changed their traditional crop pattern from paddy-wheat to cash crop in most of the areas.

3.2. Flood Sediment size distribution and mineral composition

The sieve analysis found that the coarser grain is more prominent (Figure 3) on the new main channel where the land remains as uncultivated even after the eight years from the event. Similarly, the fine grain is prominent on the distant from the center of the new channel. The majority of the grain size was found medium fine to medium size sand with absence of gravel.

The observation plot shows that medium grain sediment are also suitable for the wheat whereas the paddy is not. Similarly, the fine grain area is suitable for the any crop. Therefore, the farmer has changed their traditional crop (wheat-paddy) to cash crop (vegetables, sunflower and sugarcane). The result from observation plot shows the income has also increase up to 300% if they have changed the crop pattern traditional to the cash (Table 1).

Table 1: Thickness of sediments in different zone with change in cultivation [20].

Zone	Previous	Current	Thickness of Sediments
Central Red (CR)	Rice, wheat	Water melon, parbar	< 1.5 m thickness of sediments
Central Red (CR)	Rice, wheat	Barren	> 2 m thickness of sediments
Right Bank Red (RBR)	Rice, wheat	Simal, sugarcane	< 1.0 m thickness of sediments
Left Bank Red (LBR)	Rice, wheat	Wheat	< 1.5 m thickness (After removing the sediments)
Right Bank Yellow (RBY)	Rice, wheat	Wheat	< 1.5 m thickness (After removing the sediments)
Left Bank Yellow (LBY)	Rice, wheat	Vegetables	< 0.30 m thickness of sediments
Right Bank Green (RBG)	Rice, wheat	Rice, wheat	< 0.20 m (No effect after 6 months)
Left Bank Green (LBG)	Gram, wheat	Vegetables	< 0.20 m (No effect after 6 months)

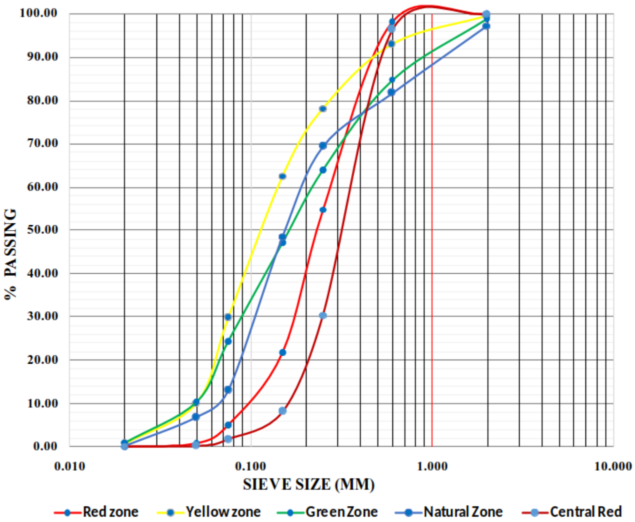

Figure 3: Grain size distribution in different zones [35]

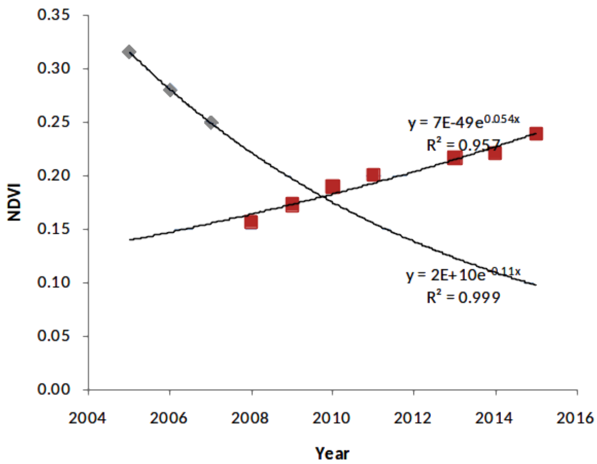

Figure 4: NDVI of wet period during pre and post disaster phases [36].

The major uncultivated thick sediment land is covered with quartz and feldspar dominant sediments as context of the mineral content. The total sum of percentage of quartz and feldspar all altogether is on range 75-85% excluding with other minerals. The higher percentage of quartz exhibits the toughness for the weathering due to its crystalline nature that eventually make the land unfertile because of its thickness and the less percentage of the fine and clay minerals. The source of the quartz from the higher crystalline rocks of higher Himalayan and the quartzite rock in the lesser Himalayan region.

Clay forming minerals like mica and feldspar are lesser in the main new channel area however it is higher in the both banks that are in distant from the central of the new channel. As distant from the central of new channel has fine grain clay minerals with less thickness. Therefore, the fertility and the recovery of greenness is higher rate in these areas. Soil pH has shown the mild acidic nature of the normal soil (on unaffected land), the flood sediments are alkaline in nature because of the carbonate minerals. The analysis shows that natural balancing the soil pH because of flood sediments.

3.3. Vegetation recovery trend

Twenty-five Landsat 5 and 8 images from 2005 to 2016 have been selected for the NDVI analysis for different years. A total 54651 pixels have been detected with 30m x 30m spatial resolution that covers a total area of 49.185 sq km. The results from the analysis shows that the trend of NDVI value has been drastically decreased after the Koshi flood in both dry and wet seasons in the following years.

Statistical analysis shows that Skewness is positive until the 4-5 years. After the 5 years, the NDVI values are increased with high frequency. The NDVI trend shows the vegetation is reviving in flooded land following years from the flood.

It is found that the mean NDVI value deficit on vegetation recovery is about 21.87% after the eight years. That outcomes can be correlated on about 80% of recovered land during the eight years (Figure 4 and Figure 5).

Similarly, 22.15% of deficit on NDVI sum of both seasons comes almost equal amount of the mean NDVI deficit. These correlation and comparison value show that vegetation recovery rate is almost 10% per year. The vegetation reviving trend has shown on the based on NDVI indicates the shallow depth of sedimentation with fine grain area has shorter time of recovery rate. Basically, the vegetation recovery immediately starts from fine sediments banks of the new channel. The remaining unrecovered land is situated on the main channel sedimentation area. Therefore, quartz mineral content sediments with great thickness has slower recovery trend because of absence of the clay forming minerals with great depth to the soil.

Finally all image analysis and statistical parameters have shown the vegetation recovery trend is about 10% per year without intervention of the new technology.

4. Conclusions

Flood sediments impact over the agriculture land is significant as in post disaster impact issues. The variation of thickness of the sediments, the mineral composition and the grain size also govern the productivity of the agriculture land. Shallow depth with clay minerals can be managed and recovered in short period of time whereas the thickness greater than 2.5 m took long duration to revive the land for the cultivation. Vegetation reclamation rate on the post disaster period on the sedimentation land is found 10% per year in a natural in context of long-term post flood impact. The

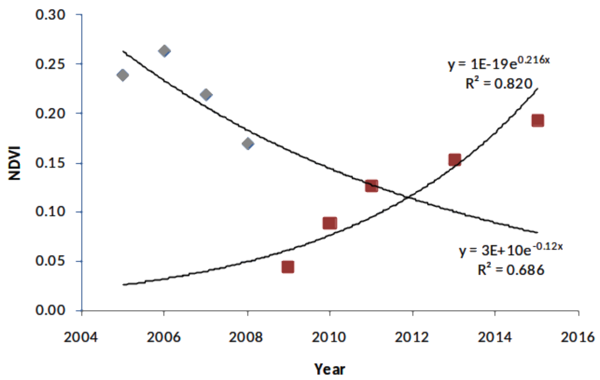

Figure 5: NDVI of dry period during pre and post disaster phases [36].

sedimentation impact can be minimized with changing the cultivation practices on flood sediment land with the new crops instead of the traditional crops.

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