International Journal of Geology, Earth & Environmental Sciences ISSN: 2277-2081 (Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jgee.htm
2016 Vol. 6 (1) January-April, pp. 1-11/Kafle et al.
Research Article

VEGETATION RECOVERY TREND ANALYSIS BY NORMALIZED DIFFERENCES OF VEGETATION INDICES (NDVI) DERIVED FROM LANDSAT IMAGES FOR DETECTING THE CHANGES IN FLOOD AFFECTED LAND OF KOSHI FLOOD 2008, NEPAL

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ABSTRACT
Earth observation techniques and remote sensing data are widely used for the Land cover and Land change evaluation and analysis. Amongst them, the Normalized Differences of Vegetation Indices (NDVI) is known for the vegetation change and types analysis in the land. A Koshi river flood 2008, largest in last few decades because of its severity on casualties mostly in Nepalese lower plain (Terai) and Northeastern part of Bihar, India were affected badly. The affected agricultural land was reported about 74% because of the flood sedimentation. Recovery of vegetation on the affected agriculture land is the focus of study with the help of Landsat 5 and Landsat 8 images from 2005 to 2015 specially on the based on dry (May) and wet (October) seasons generated by image analysis of NDVI values. NDVI mean value changes are 45.73% in dry and 29.36% in wet seasons during pre and post disaster and respectively. Similarly, average sum of NDVI change are 33.70% and 31.17% during these seasons respectively. The averages difference of mean NDVI (32.87%) and sum NDVI (29.57%) are shown similar in both seasons. The analysis of vegetation reclamation shows the rate is about 10% per year in natural way in the affected land without intervention of technology.

Keywords: *Flood, Images, Landsat, NDVI*

INTRODUCTION

On 18th August 2008 at 12.55 pm the Koshi River diverted its 100 years old course towards the eastern side by breaking its embankment with 95% flow of water (Kafle *et al.*, 2015a) (Figure 1). This flood is considered as one of the most disastrous natural events of the last decade in terms of the number of people affected and the loss of properties.

The flood completely destroyed three Village Development Committees (VDC) whereas two VDCs were partially affected. The flood deposited large amounts of sand and silt on 74% agricultural land (Kabir and Shrestha, 2011) affecting millions of people in Nepal and India including 65000 in Nepal (MoHA, 2009). About 700 ha of fertile land was uncultivable (THT, 2011) because of the inundation of the land with flood sediments filled with sand and silt till today (as of August 2015). Most of the severely affected VDCs are still in desert like conditions even after 7 years of the event.

Remote Sensing (RS) technology is known as an important tool for getting geographical information including land cover and changes on the ground (Maxwell *et al.*, 2004; Oetter *et al.*, 2000). In addition, the Geospatial Information systems (GIS) can also be effectively used in gathering, analyzing and presenting spatial and non- spatial data at any location (Alesheikh *et al.*, 2005; Longley *et al.*, 2005) for temporal variation analysis.

Earth observation techniques or remotely sensed data can make accurate mapping easy for flood hazards and agricultural crops issues (Kabir and Shrestha, 2011; Evans and Geerken, 2006; Langley *et al.*, 2001; Nordberg and Evertson, 2003) and also support pre-disaster, response, monitoring and post disaster phases (Jayaraman *et al.*, 1997).

The RS data for GIS particularly for the measuring the land use as well as land cover analysis (Maxwell *et al.*, 2003; Oetter *et al.*, 2000) is becoming significant and effective for temporal variation analysis. Although a number of methods are available for detecting of Land use-land cover (LULC) for analysis in different environmental issues; the common method in practices are land cover classification, band arithmetic, vegetation index differencing, change vector analysis and multidate classification (Jomaa and Kheir, 2003).

Generally multi date RS data is useful for measuring the LULC changes (Coppin *et al.*, 2004; Lu *et al.*, 2004). This has been made more efficient by the advancement of Landsat images and program than traditional air photo studies (Lillesand and Kiefer, 2000; Haack & Jampoler, 1994; Mundia and Aniya, 2005; Yuan *et al.*, 2005).

The main objective of this study is to assess vegetation recovery trend on the sediment deposited land during the post disaster phase using Landsat TM imagery.

Study Area

The study was conducted in the Koshi flood-affected area in Nepal as specified in (Figure 1), though Indian area was also severely affected. The Koshi has an average discharge of 2,166 cu. m/s (Jain *et al.*, 2007).

It is also reported that the river increases its volume to as much as 18 times of average during the high flood time. The highest ever recorded flood was 24, 200 m^3/s on August 1954 and the river barrage near to Indo-Nepal boarder has been designed for a peak flood of 27,014 m3/s (Sharma, 1996).

The study area covers about 50 Sq. Km. within Bhantabari (26° 31' 45.07''N, 86° 58' 13.68'' E) in the south-western part, Pashim Kushaha (26° 39' 00''N, 87° 04' 11''E) in the north-western part, Laukahi (26° 35' 13'' N, 87° 03' 21''E) in the South-Eastern part and National Highway (26° 35' 56'' N, 87° 04' 40''E) in the North-Eastern part.

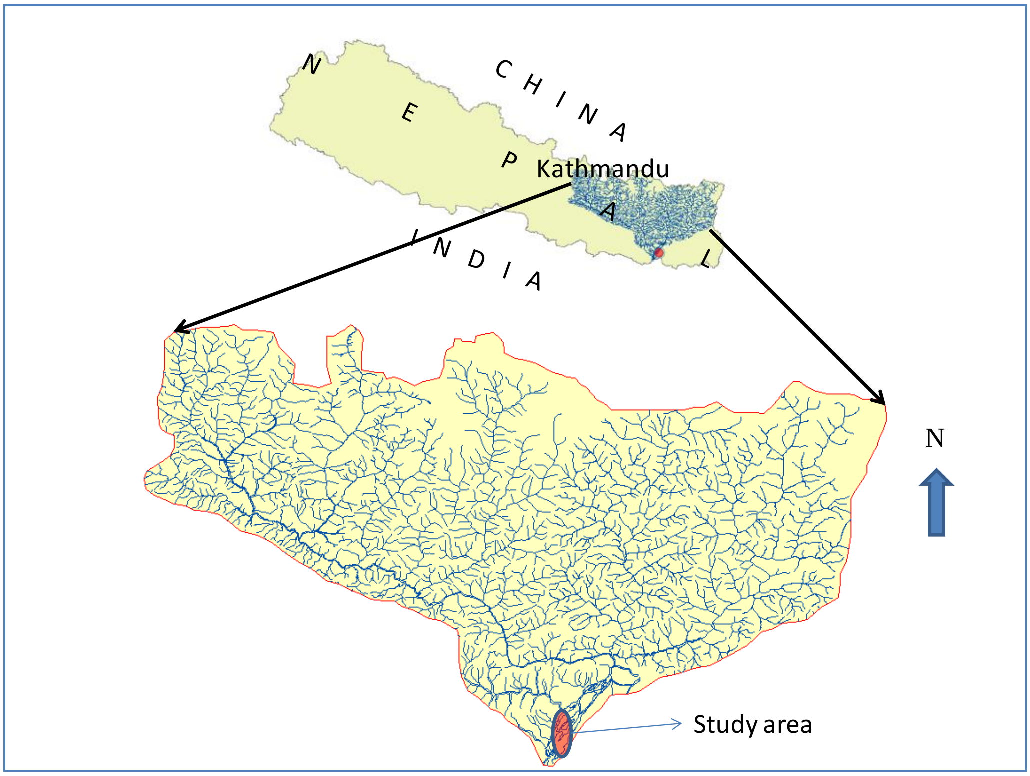

Figure 1: Study Area

MATERIALS AND METHODS

Normalized Difference Vegetation Index (NDVI) was used to assess vegetation change as it is an appropriate tool to study periodic vegetation changes (Pettorelli *et al.*, 2011). NDVI images can be used to find the vegetation changes during certain period of time.

Its accuracy and uses are more efficient for the vegetation analysis (Joshi 2011; Jacobberger and Hooper; 1991, Geerken *et al.*, 2005; Du Plessis, 1999). It has several advantages over the other types of vegetation indices Lyon *et al.*, (1998).

NDVI is a standardized vegetation index which allows us to generate an image showing the relative biomass (Fang *et al.*, 2001; Beget and Di Bella 2007).

The NDVI indicates the plant "greenness" or photosynthetic intensity and it is based on the absorbance of the most red lights that strikes it with reflecting the near infrared light. Thus, photosynthesis by plant is the key object to active vegetation for the measuring the NDVI.

Basically the pigment in plant leaves, chlorophyll, strongly absorbs visible light (0.4 µm to 0.7 µm) for use in photosynthesis and the cell structure of the leaves strongly reflects near infrared light (0.7 µm to 1.1 µm).

Therefore, the dead vegetation reflects more red light and less near infrared light however non- vegetated surfaces reflect more across the light spectrum.

The chlorophyll absorption in Red band and relatively high reflectance of vegetation in Near Infrared band (NIR) are used for calculating NDVI. Increase in the positive NDVI value indicates greener the vegetation or high density of vegetation.

The NDVI is calculated as: NDVI= (NIR-R) / (NIR+R)

Where, NIR represents the spectral reflectance in near infrared band and R represents red band. The NDVI values range between -1 and +1. Increasing positive values indicate increasing green vegetation surface and negative values indicate non-vegetated surface.

Available Landsat images for dry and wet seasons have been used for the NDVI analysis in this study. Landsat Thematic Maps are appropriate for the mapping of vegetation, and soil moisture (Jensen 2009). Landsats-4 and -5 were equipped with an Multispectral Scanner System (MSS) and an improved version of the Multi- (MSS), the Thematic Mapper (TM) with 30m spatial resolution.

Images of Landsat-5 and Landsat-8 dated from 2005 to 2015 acquired from USGS Earth Explorer have been used for the analysis.

These images were further classified into two phases for pre and post disaster. These were further classified into two seasons of the year; dry season (May) and wet season (October). The image data is in Geo Tiff format with 16 bit radiometric resolution (ranges from 0-65535).

Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) images consist of nine spectral bands with a spatial resolution of 30 meters for Bands 1 to 7 and 9. The Landsat-5 data were acquired for the years 2005 to 2011 and Landsat-8 for the years 2013 to 2015. The Landsat image 2012 couldn't be derived due to unavailability of the data. All together 20 images have been selected for the NDVI analysis for different years.

RESULTS AND DISCUSSION

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 is increasing during the post disaster phase.

Results

NDVI Value during Pre Disaster Phase

The images are derived from October (considered as wet season) and May (considered as dry season) of the each year of the phase. Seven images of three years of pre disaster phase from 2005 to 2008 show that the average mean value and average sum are 0.24789 and 13547.88 respectively.

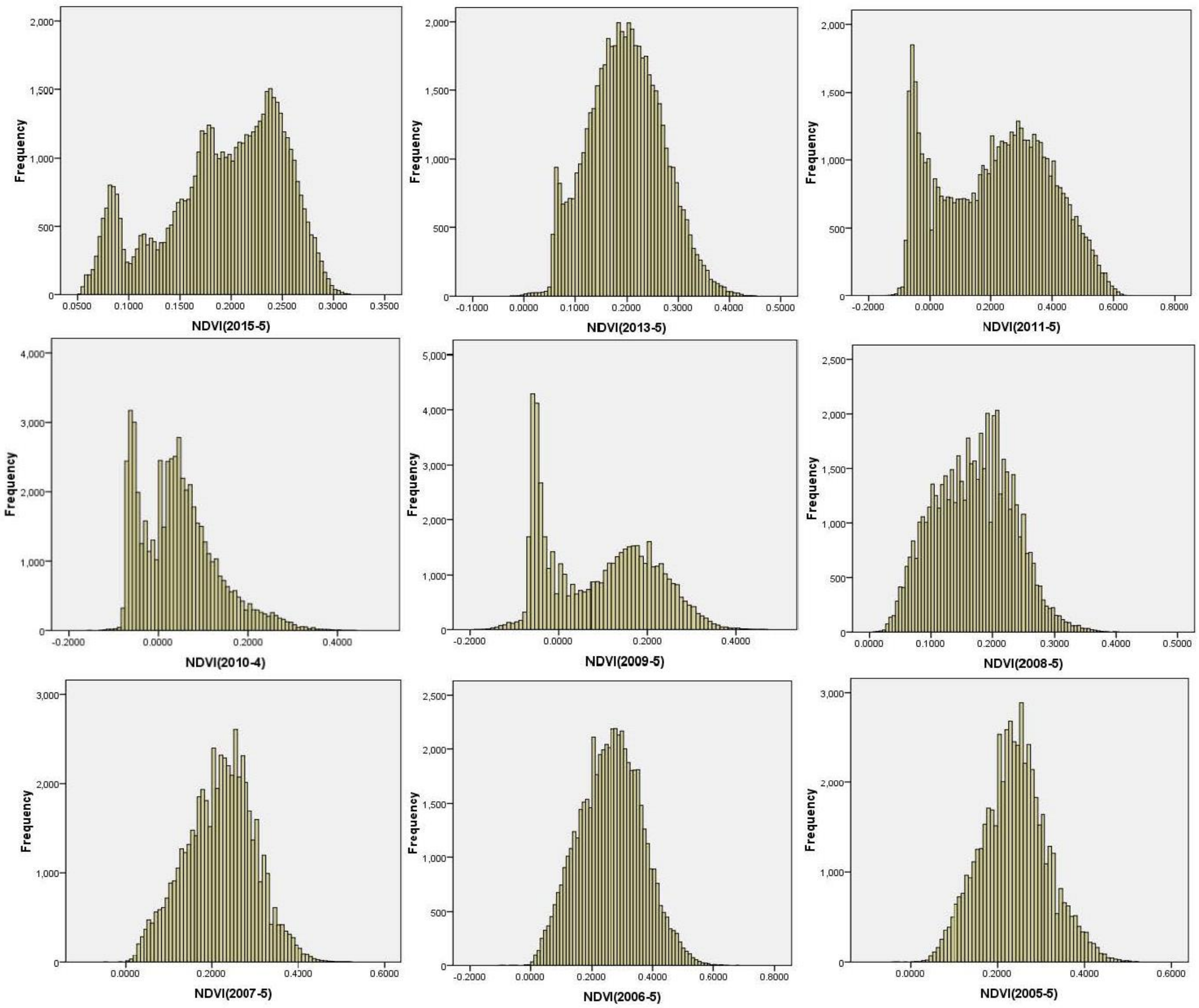

Figure 2: NDVI Histogram for Dry Seasons

Similarly, the average mean value of wet season 0.059257 is greater than that of dry season. In addition, the average sum of NDVI value 3239.45 is greater in wet season with compared to the dry season.
Standard Deviation (SD) is lower during the pre-disaster period compare to post disaster phase. It varies from 0.06 to 0.10.
The NDVI Skewness indicates the balancing value during the period. The Skewness varies from -0.309 in 2006 to 0.024 in 2007 during the period. The negative value indicates the high NDVI with high frequency during the pre-disaster period.
Similarly, the NDVI Kurtosis is max in June 2008 that reaches to -0.506, means the highest NDVI frequency the year during the pre-disaster period (Figure 2 and Figure 3).
NDVI Value of Post Disaster Phase
NDVI values are analyzed during post disaster phase for a period of 2008 to 2015. All together 12 images have been taken for the analysis including 7 images for wet season and 5 images for the dry season. The average NDVI values are found 0.199019 and 0.
120429 in wet and dry seasons respectively. Similarly the average sum of the NDVI value are found 10597.81 and 8061.22 in wet and dry seasons respectively.

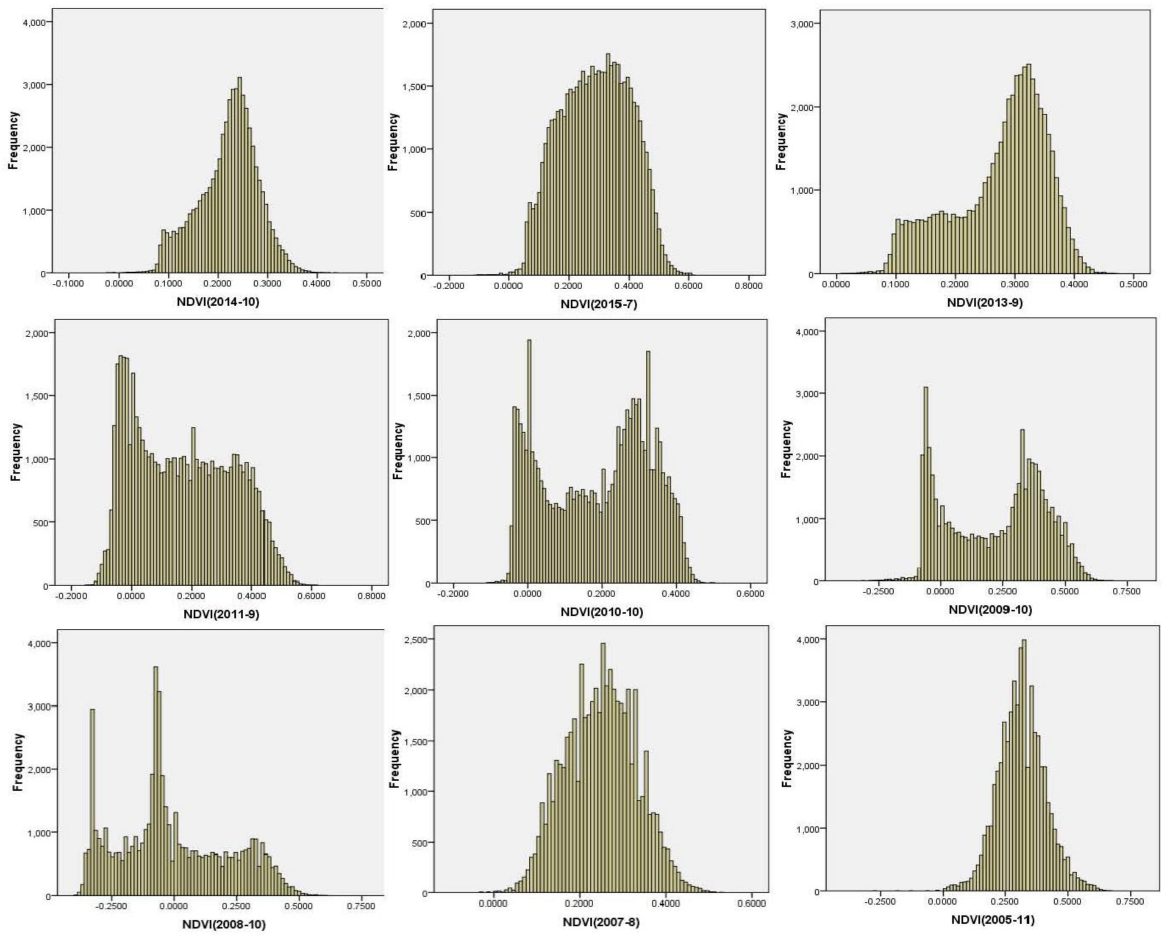

Figure 3: NDVI Histogram for Wet Seasons

The difference of NDVI value is analyzed for the both dry (May) and wet (October) seasons. The average mean value in wet seasons 0.078290 is greater than that of dry seasons. Similarly the average sum of NDVI value is 2536.594 which is greater in wet seasons with compared to the dry seasons.
Standard Deviation (SD) is higher during the following years of the event for 5 years, then after the SD is decreasing in trend for the following years. It is observed that 5 years has taken in the both season to revive on SD of NDVI during the post disaster phase. It is observed that NDVI Skweness in post disaster phase is higher for 5 years.
That indicates that greenery hadn't been developed during the post disaster phase around for 5 years. However the Skewness is negative (towards the higher value of NDVI) after few years of flood means reviving on vegetation is on process during the succession of the post disaster period (Figure 2 and Figure 3).
Ndvi Change
The mean percentage change in NDVI in dry seasons during pre and post disaster period is 45.73% similarly 29.36% in wet seasons. The sum of NDVI percentage change in dry seasons during pre and post disaster period is 33.70% similarly 31.17% in wet seasons.
The difference of average of mean NDVI and sum NDVI in both seasons are 32.87% and 29.57% respectively shows the similar difference for average mean and average sum NDVI in pre and post disaster period.

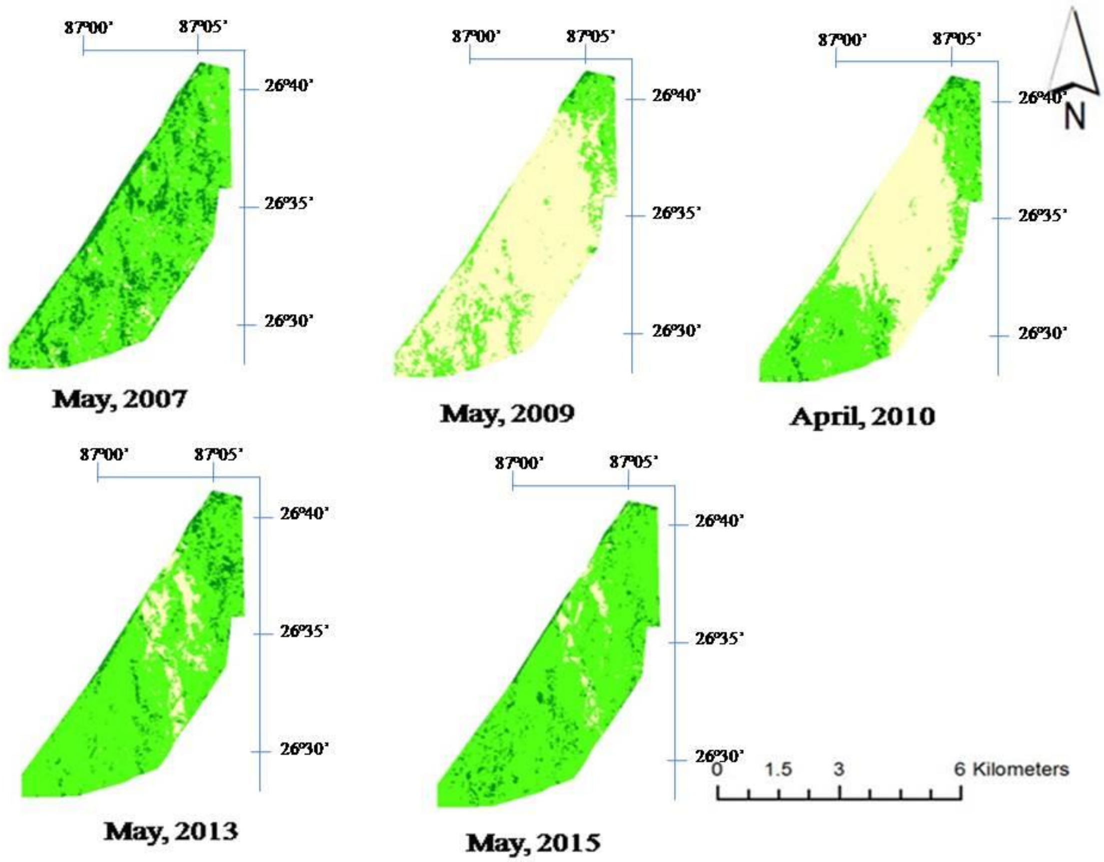

Figure 4 Vegetation Reviving Trend in Dry Season on the Basis of NDVI Value

Histogram analysis clearly indicates the changing pattern of NDVI after the flood. The pattern of frequency of the NDVI is symmetrical during pre-disaster period in the both dry and wet seasons. After the flood disaster, the Skewness has great variation towards the positive side means the lower NDVI value, that is dominant with high frequency for about 4-5 years after the flood. After the 4-5 years of disaster, the Skweness seems to be shifted towards in negative side means the higher NDVI value with high frequency is increasing after 5 years of the disaster.

NDVI on Classified Map

The NDVI value is classified for barren land and the vegetation land in white color and green color (Figure 4 and Figure 5).

The greenery is almost same as in dry and wet period during the pre disaster phase. When disaster occurred in 2008 August, then the area is filled with sand and silt. The NDVI images clearly distinguished the differences of both landforms from 2008 Nov to 2015 July.

Immediate after the flood, the central area is filled with the flood sediments in the agriculture land. The area has not significantly change in first two years after the flood. However, after two years from the event, the land is recovering with vegetation from northeastern side and southwestern side (Figure 4 and Figure 5).

The recovering trend is continuous till the date (July, 2015), however, the central part or the new river channel made by flood is remained as barren even after 7 years of event. The images of NDVI in dry and wet season have shown the land barrenness in present in central part particularly the new channel of the diverted river during the flood time.

The NDVI recovery trend shows quantitative duration of the post disaster phase for the agriculture land recovery.

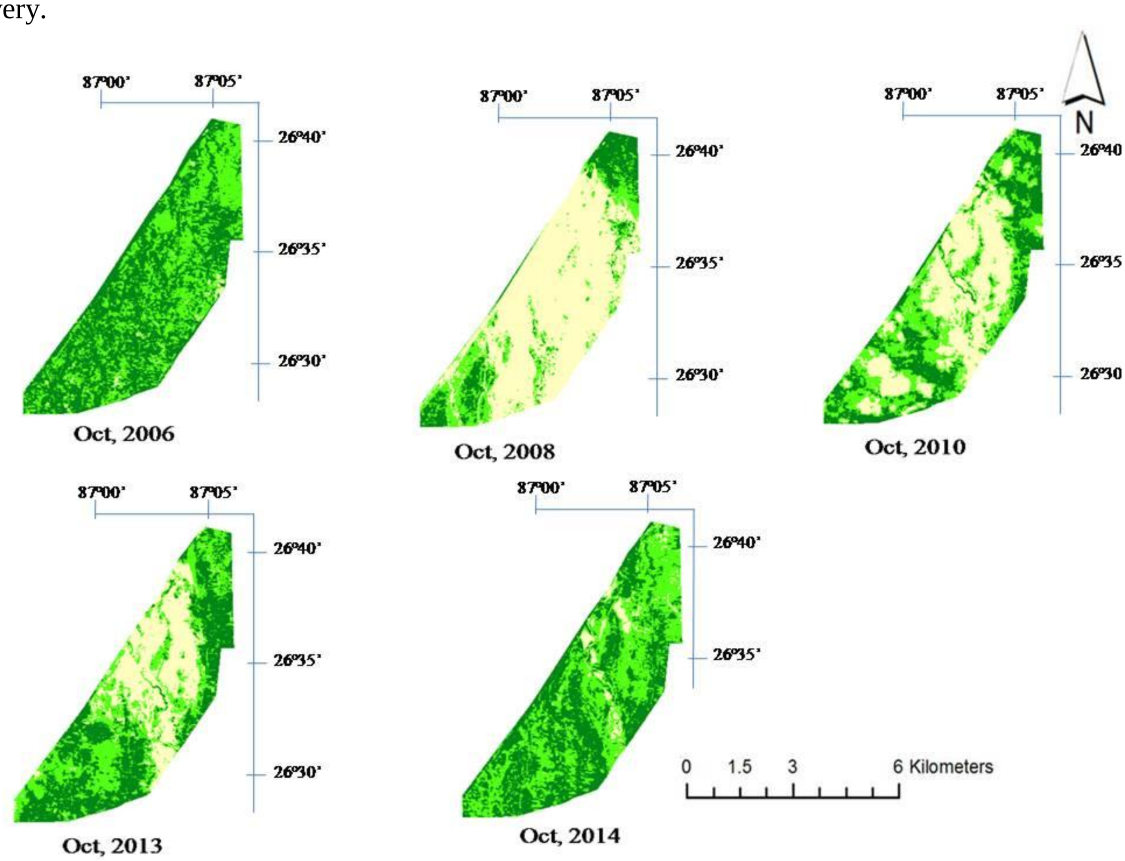

Figure 5 Vegetation Reviving Trend in Wet Season on the Basis of NDVI Value

Discussion

Kale (1997) indicated that the Gangatic plain has occurrences of the most frequent floods during the last 30 years. The disastrous Koshi flood entered the agriculture land of the adjoining area by breaking a embankment. The lateral shifting due to the river sediment deposition made the river diverted towards the bank. The major activities of denudation are the channel changes including bank accretion, cutting and bank erosion as of natural processes for an alluvial river (Kummu *et al.*, 2008). Basically, the lateral movements result in the destruction of floodplains and the agricultural lands (Moench, 2010).

NDVI analysis from image processing always describes the large area information about the vegetation change and vegetation cover. On this prospective, Koshi flood area had been using as agricultural land for the rice and wheat the most. The Koshi river flood filled sand and silt during the event affected the land of eastern bank areas of Nepal as well as India.

The NDVI value is analyzed from statistical tools. The images are classified into two major group pre-disaster and post-disaster period. Then again it has been divided into two groups for vegetation in dry and wet periods. The negative Skewness with high frequency of NDVI indicates greater vegetation density. In this aspect, the NDVI value greater than 0.25 presence towards the negative Skewness that indicates greater vegetation. Just immediate after the flood, the NDVI values are drastically decreased and presence on Skweness positive side until the 4-5 years. Then after the 5 years, the NDVI values are greater with high frequency. The NDVI trend shows the the vegetation is reviving during the successive years of post flood period.

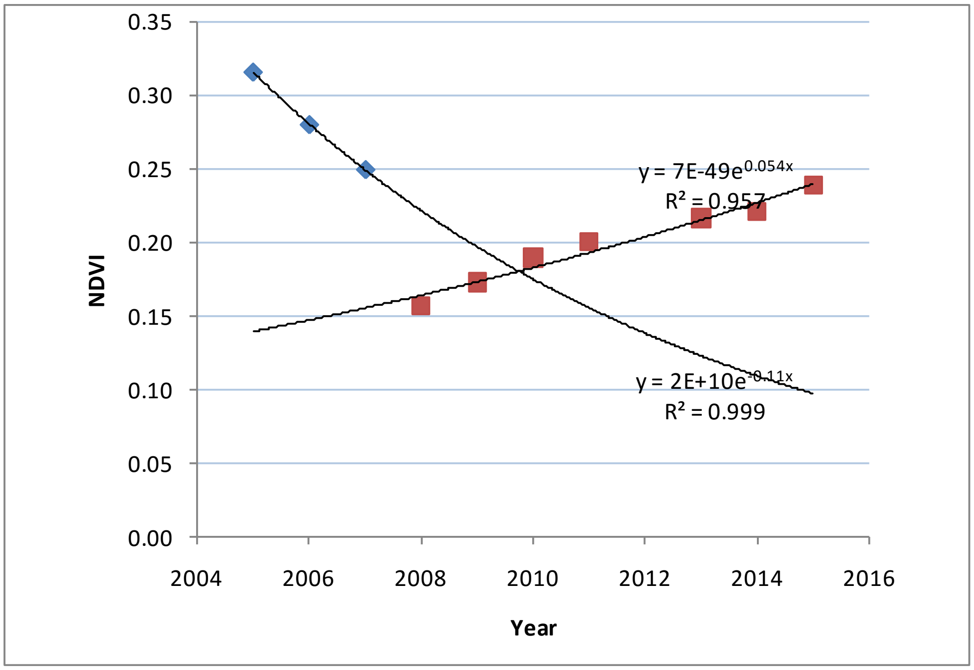

Figure 6 NDVI of Wet Period During Pre and Post Disaster Phase

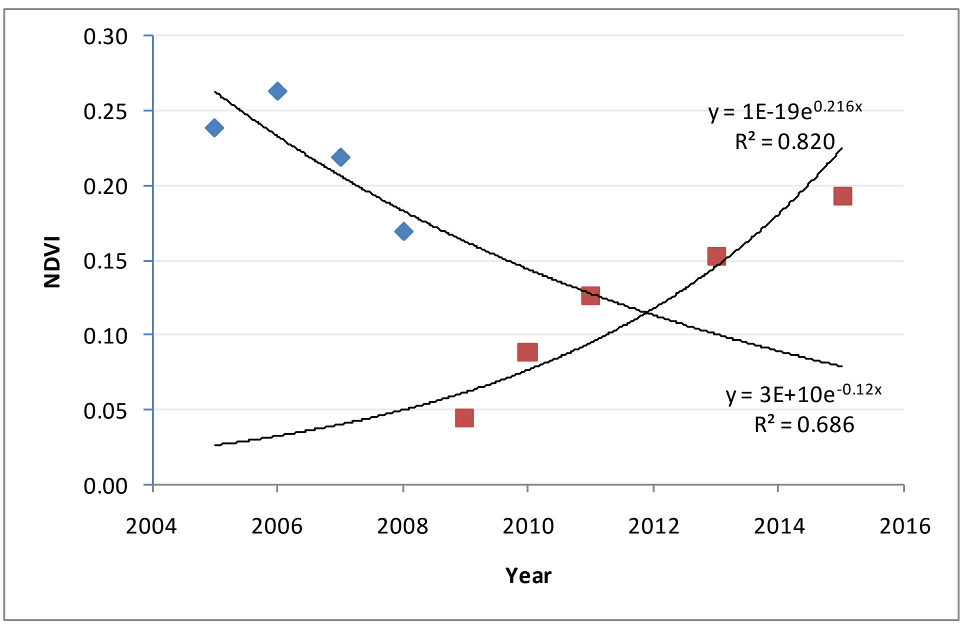

Figure 7 NDVI of Dry Period During Pre and Post Disaster Phase

The most of statistical parameters satisfy the recovery on vegetation an average of 4 to 5 years after the event to be similar to the pre disaster phase parameters. Despite above all recovery trends, new flood channel area remains uncultivated even after the 7 years (Kafle *et al.*, 2015 b) from the disaster due to the thickness and composition of the sediments.

The impact of flood will not always be negative in context of cultivation practices as the flood has increased the productivity in some of the areas of the inundation. On the other hand, the most affected area could be useable within the few years of the event and can generate income to recover the economic loss. The adoption of new cultivation practices sometimes makes positive impacts (Kafle *et al.,* 2015 b) for the productivity and income in context of the long term post disaster phase.

The classified NDVI images show the recovering trend after the flood event. The both seasons images demonstrate the vegetation covering trend is continued until the date (July 2015). Both seasons exhibit the drastic decrease in vegetation amount immediate after the flood and it has been in positive trend reviving with succession of the following years from the disaster (Figure 6 and Figure 7).

The mean NDVI analysis shows that the deficit of vegetation is about the 32.87% after the 7 years after the disaster. That indicates the about 70% of land has been recovered after the seven years of the event. Along the new flood channel has remained as barren for a long time.

The sum of the NDVI deficit 29.57% is about equal amount of the mean NDVI deficit. The both value concludes the recovering rate is per year 10% if we take 70% for the 7 years.

The resulting value indicates the positive development on vegetation on post disaster phase. The NDVI value has shown the recovering trend on vegetation in the flooded agriculture land. The images of NDVI shows the greenery has started from southwestern part and northeastern part. That indicates the inundation area besides the main channel can revive rapidly than adjoining area of the new flood channel. It is because of the fine sediments accumulation on the bank of the new channel. The study of depth of sediments has shown that, the high thickness (>4m) sediments (Kafle *et al.*, 2015 b) along the new channel area obviously takes time to be cultivated land as pre-disaster phase. The thickness contour made by Kafle *et al.*, (2015 b) has shown the barren land with high thickness and new cultivated land with low thickness sediments on the flooded land. The study has also shown the contours and the section of the deposited sediments. Lower thickness area with fine sedimentation has short time of vegetation recovery with greater NDVI value with compared to the higher thickness area. On other hand, the composition of the sediments in central thick area has quartz mineral dominance (>70%) that means it does not go immediately to the soil by the weathering process however other than the quartz may go to the form of clay with the weathering process. Therefore, the results from NDVI recovering area is filled with thin layer of sediments, fine sediments and clay minerals sediments.

Conclusion

The appropriate image processing method for the vegetation change and vegetation cover known as NDVI popularly. The NDVI in different seasons during the post disaster phase exhibits the slow recovery trend in the study area. According to the previous study by Kabir and Shrestha (2011) indicated that 74% of agricultural land had been destroyed by the flood. However, the recovery trend shows the 10% per year is the really very show process which has shown in NDVI analysis on the following years from the disaster. Recovery generally started from northeast and southwestern part of the flooded area. The reason behind the early recovery is the fine sediments presence due to the inundation on the areas. Then the recovery trend is expanding on the other side of the flooded area. Generally, all statistical and image analysis shows the parameter are seem to be the normal as pre-disaster phase is around 7 years excepts the new river channel of the area.

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