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A Study on Relationship between NDVI and Precipitation over Kolong River Basin, Assam, India

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Abstract: *Vegetative productivity of any region is mainly dependent on meteorological parameters like precipitation and temperature of the region. The northeastern region of India has diverse vegetation, mainly controlled by its unique climatic as well as physiographic conditions. An index used for determining vegetative condition of an area is NDVI (Normalized Difference Vegetation Index). This study focuses on the relationship between precipitation and NDVI in regard to the Kolong Basin of Assam and attempts to evaluate the changing trend of NDVI values which in turn depicts the vegetative productivity of the region. The NDVI values were computed from multispectral images of LANDSAT(TM and ETM+) and IRS (LISS III) satellites and rainfall data were collected from the website of IMD for the years 1987, 1999 and 2008.Temporal changes of NDVI were related to rainfall patterns and the trend of NDVI was calculated. The critical changes of NDVI and the correlation-coefficients between NDVI and rainfall were examined for each pixel. The values of NDVI ranged between -0.95833 to +0.984, with highest positive value observed during 1987. The preliminary results indicate that overall negative trends in vegetation change occurred over most parts of the study area and these changes appear to be highly correlated with rainfall data and also that land cover transformations and modification of the surface flow regime especially that of Kolong River may be another major driving force behind the changes.*
Keywords: *Correlation-coefficient, LANDSAT, NDVI, precipitation, vegetative productivity*.

I. Introduction

Assam is one of the predominately vegetation rich states of India with a large percentage of agriculture dependent population in addition to large portion of geographical area under forest cover. It is known for its rich biodiversity. Favorable climatic conditions boosted by a strong southwest monsoon in combination with desirable soil conditions have transformed Assam into a mosaic of luxuriant greenery in the recent past. Furthermore, Assam is also endowed with the mighty river Brahmaputra, whose tributaries alongwith the oxbow lakes in the floodplain provide the region with a unique hydro-geomorphic and aesthetic environment. However, in long run it has been found that despite of all these favorable conditions, the overall area under forest cover of Assam has diminished with time, which is attributed to various demographic and developmental pressures (Acharjee et al., 2012). As per information available from the State Forest Department, the total area under forest cover in Assam which was 26,781.91 Km^2 (34% of total geographic area) at the end of March 2003 has diminished to 18530 Km^2 (24% of total geographic area) during 2011. Although the state of Assam receives plenty of rainfall during monsoon (usually for about six months i.e. from May to October), still a rain-shadow belt comprising Karbi Anglong, Nagaon and Golaghat district is prominent within the state receiving comparatively less rainfall. In this context, it is crucial to study the variation of rainfall and its influence on vegetation with a view to understand the trend of change of vegetation index with respect to precipitation. Out of all the available indices for ascertaining vegetation health, NDVI (Normalized Difference Vegetative Index) best serves the purpose. In this study, we analyze temporal patterns of NDVI in relation to precipitation in the Kolong basin of Assam which is spread over three districts namely Nagaon, Morigaon and Kamrup, using remote sensing data. Hence, this study is mainly focused on temporal variation of vegetation with relation to precipitation in the basin of a socially and environmentally significant river viz. Kolong River of Assam.

Development in the field of remote sensing and GIS has made it possible to get more information from multi-date and multi-spectral remote sensing data, which afford expert methods to study the vegetation distribution pattern and inter-annual changes in a given area (Glenn et al., 2008). Differential reflectance exhibited by green vegetation at different wavelengths is the basic principle behind the development of vegetation index in a GIS environment. Healthy green vegetation has distinctive reflectance in the visible and near-infrared regions of the spectrum. At visible and more precisely at red wavelengths, plant pigments strongly absorb the energy for photosynthesis, whereas in the near-infrared region, the energy is strongly reflected by the internal leaf structures. This strong contrast between red and near-infrared reflectance has formed the basis of various vegetation indices. When applied to multispectral remote sensing images, these indices involve numerical calculation of the sensor bands that record land surface reflectance at various wavelengths. NDVI is the example of the most common vegetation indices to explore the green cover of photosynthetic vegetation through image processing. The mathematical formula for deriving NDVI is given below:

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

Above formula indicates that the values of NDVI are unit-less and range in a scale having upper limit of +1 and a lower limit of -1; the higher the value on the NDVI scale, the more photosynthetically active the surface vegetation is. Non-vegetated areas like ice-cover, water bodies and rocks etc are expressed with negative values of NDVI (i.e. values less than 0). If the NDVI values are between 0 and 0.2, it is considered as low-vegetation; if the NDVI values lie between 0.2 and 0.4 then the area is under medium vegetation and if NDVI is more than 0.4, then the vegetation is assumed to reach mature stage (Kumar et al., 2013). Generally, NDVI of a region reaches its maximum during the peak of growing season which extends from April to October in case of Assam. The derived values of NDVI are often used as an indicator of vegetation health both spatially and temporally (Mingjun, 2007). Whether natural or cultivated vegetation, its growth pattern is always influenced by climatic factors like precipitation, temperature etc (Schmidt et al., 2000) and therefore it is essential to study the affect of precipitation on vegetation pattern. Detailed study on NDVI and its relationship with precipitation is accomplished from time to time by various workers abroad (Ghorbani et al., 2012; Davenport and Nicholson, 1993; Nicholson et al., 1990; Richard and Poccard, 1998; Wang et al., 2001 & 2003) as well as in India (Acharjee et al., 2012; Bhunia et al., 2012; Chandrasekar et al., 2006; Dubey et al., 2012; Dutta, 2006; Kumar et al., 2013; Milesi et al., 2010; Sarma and Kumar; 2006). In this research, satellite (LANDSAT and IRS) data and precipitation data were used to study the temporal change characteristics of NDVI in regard to the Kolong river basin, and the relationship between NDVI and precipitation is analyzed using statistics.

II. Materials And Methods

2.1. Study area

This study was conducted for the entire Kolong river basin which spreads in three districts of Assam viz. Nagaon, Morigaon and Kamrup (Figure 1). Kolong River is a south bank distributary of the mighty Brahmaputra having its origin from the Brahmaputra as well as outfall into it. Kolong river basin covering an area of about 5300 Km^2 lies between 26º36'26" and 26º02'20" northern latitude and 93º00'30" and 91º57'16" eastern longitude. The study area mainly comprises of alluvial plain with few hilly areas in the southern portion and the Kolong River is the main river of the region. Landuse pattern of the study area shows a total of 3111.589 Km^2 under vegetation cover i.e. agricultural land, forest cover and shrub/grassland during the year 2006 (Bora and Goswami, 2014). Out of the total geographical area of the basin, dense forest covers are mainly restricted to the hilly regions. The study area has subtropical climate highly influenced by the southwest monsoon having its onset mostly during the month of May. It is located in central Brahmaputra valley agro-climatic zone of Assam encircled by the Plateaus of Karbi-Anglong on the south, South–East and South–West along with Hilly ranges of Bura-Pahar in the east which creates barrier in the inflow of the moisture bearing winds turning the area (specially the part of Nagaon district) into a rain shadow zone that experiences mean annual rainfall varying from 1185.6 mm to 1621.2 mm. Like other parts of Assam, rainfall distribution in the Kolong river basin also follows a typical monsoon pattern with peak precipitation during monsoon and scanty rainfall in winter. Growing season in the study area mainly extends from April to October and thus the satellite images for the month of November/December were used for deriving NDVI maps in all the subsequent years (Figure 2).

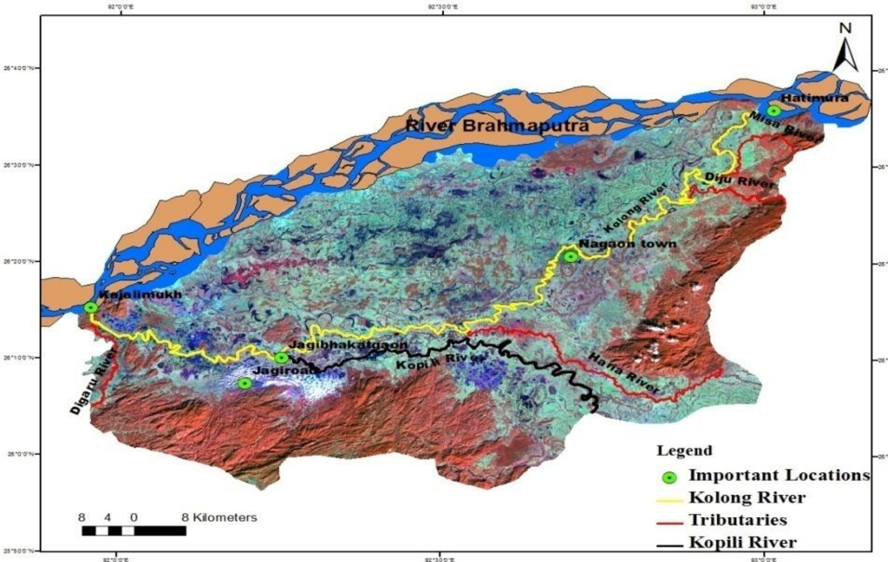

Figure 1: Location map of Kolong Basin

2.2. Data and methods

Satellite data used in the present study were of LANDSAT and IRS images. LANDSAT (TM and ETM+) images for the year 1987 (dated 26 Dec), and 1999(dated 19 Dec) and IRS (LISS III) image for 2008 (dated 19 Nov) were downloaded from GLCF website and Bhuvan website respectively and subjected to GIS environment. The formula $NDVI = (NIR - RED)/(NIR + RED)$ when applied in ArcGIS software can transmit the image to normalized difference vegetation indexes with values ranging between -1 to +1. Maximum and minimum NDVI values for each year were obtained from the year wise NDVI image generated and accordingly the changing trend of maximum NDVI value in the subsequent years were determined.

The data on precipitation were obtained from the IMD website. Considering that the growing season ends at the end of October and that precipitation after October has no influence on the vegetation NDVI of the current year, but has effects on vegetation of the next season, we counted the precipitation from November of the last year to October of the ensuing year as *annual effective precipitation* and precipitation from April to October as *growing season precipitation* respectively. Mean annual effective precipitation as well as mean growing season precipitation was calculated from monthly rainfall data for three districts i.e. Nagaon, Morigaon and Kamrup.

Finally, the correlation-coefficient between maximum NDVI and mean annual effective precipitation as well as between maximum NDVI and mean growing season precipitation were calculated with an aim to determine the effect of precipitation over vegetation health of the region.

III. Results

3.1. Temporal distribution pattern of maximum NDVI, minimum NDVI, mean annual effective rainfall and mean growing season rainfall (1987, 1999 and 2008)

Since negative values of NDVI represents overall non-vegetated areas, thus its variation is of less concern for the present study. However, variations in positive values demonstrate the difference in vegetation health of the region for each year and thus are very important. Maximum and minimum values of NDVI are derived from the NDVI maps generated for respective years (Figure 2) and are given in Table 1.

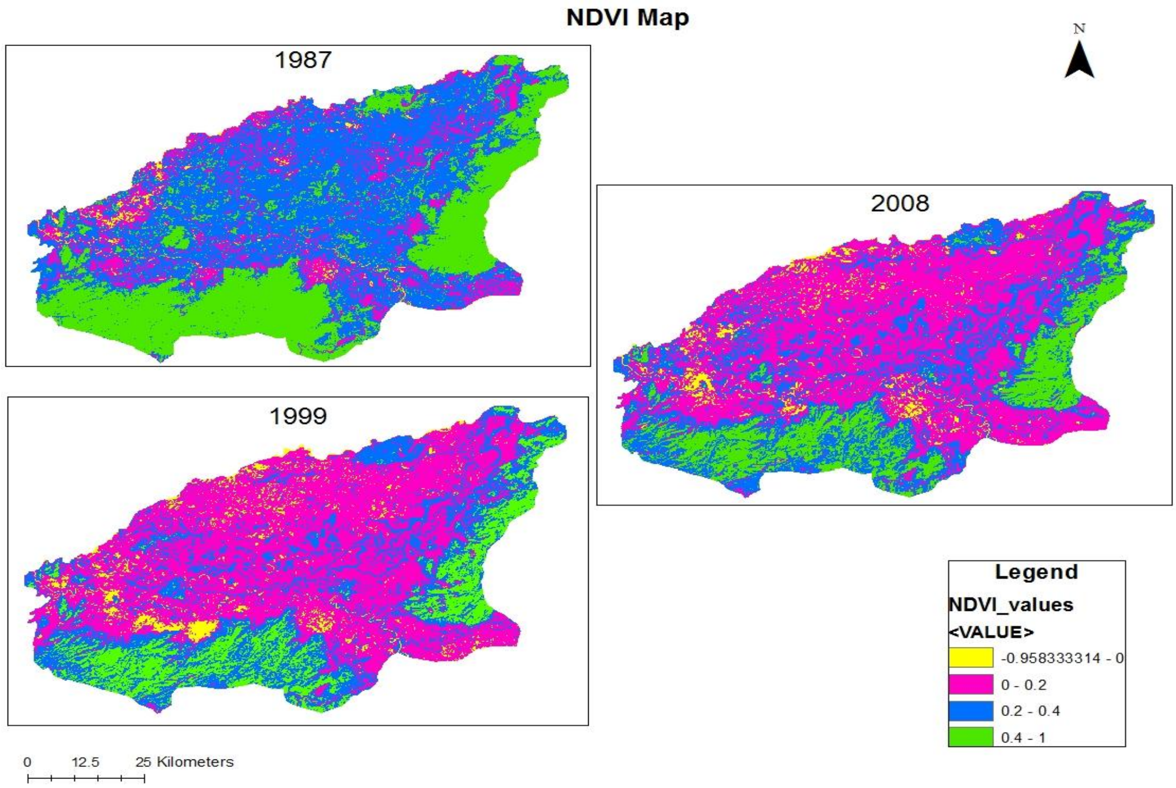

Figure 2: Temporal variation of NDVI in Kolong basin

Figure 2 shows spatial variation of NDVI in a given year. NDVI values were high at southwest and southeast while it decreases gradually towards north. In the southern parts of the basin, NDVI reaches the highest (+0.984), but in the northern and middle portion, it is low. Ground-truthing and local knowledge also supports the above result as the southern portion of the basin is covered by three reserve forests viz. *Swang* reserve forest, *Sonai Kuchi* reserve forest and *Kholahat* reserve forest. Table 1 clearly indicates that maximum NDVI values have a decreasing trend from 1987 to 2008.

Table 1: Temporal variation of Maximum & Minimum NDVI

Years	Max. NDVI	Min. NDVI
1987	0.984127	− 0.95833
1999	0.726316	− 0.90476
2008	0.715976	−0.50769

Monthly rainfall for each studied year alongwith immediate preceding years were considered to calculate average effective rainfall as well as average growing season rainfall and the results are depicted in Table 2 given below. During investigation, it has been found that average during growing season rainfall is higher than the average effective rainfall during all the studied years. Moreover, both 'average effective rainfall' and 'average growing season rainfall' showed a decreasing trend with highest values (297.822mm and 513.6712mm respectively) during 1987 and lowest values (128.447mm and 206.614mm respectively) during 2008. This result is analogous to the trend of change of Maximum NDVI.

Table 2: Temporal variation of Average Effective rainfall and Average Growing Season rainfall

Years	Average Effective Rainfall (mm)	Average Growing Season Rainfall (mm)
1987	297.822	513.67
1999	268.838	447.757
2008	128.447	206.614

3.2. Relationship between maximum NDVI and rainfall

3.2.1. Maximum NDVI vs. average annual effective rainfall: In order to determine relationship between average annual effective rainfall and maximum NDVI, correlation-coefficient among them was calculated. Result indicated (Table 3) a positive correlation between the two parameters with a correlation-coefficient of 0.65811.

Table 3: Correlation between maximum NDVI and average annual effective rainfall

Years	Max. NDVI	Average Effective Rainfall (mm)	Correlation-coefficient
1987	0.984127	297.822	0.65811
1999	0.726316	268.8376	
2008	0.715976	128.447	

3.2.2. Maximum NDVI vs. average growing season rainfall: As in the case above, correlation-coefficient was calculated between maximum NDVI and average growing season rainfall and it was also found to have a positive correlation with a correlation coefficient of 0.69106 (Table 4).

Table 4: Correlation between maximum NDVI and average growing season rainfall

Years	Max. NDVI	Average Growing Season Rainfall (mm)	Correlation-coefficient
1987	0.984127	513.6712	0.69106
1999	0.726316	447.757	
2008	0.715976	206.614	

IV. Discussion

The results of temporal variation of NDVI exemplify the fact that, with the passing time vegetation health has deteriorated in the study area with an overall decrease in maximum NDVI value. The map showing NDVI (Figure 2) demonstrates that, during 1987, majority of the study area was under the category of moderate vegetation health i.e. 0.2 to 0.4 (blue color), while, in contrary to this majority of the areas were under the category of low vegetation health i.e. 0 to 0.2 during the latter two years viz. 1999 and 2008.

Like maximum NDVI, rainfall also showed a declining trend as shown in figure 3 and figure 4, where the black line is indicating the exponential trendline for maximum NDVI.

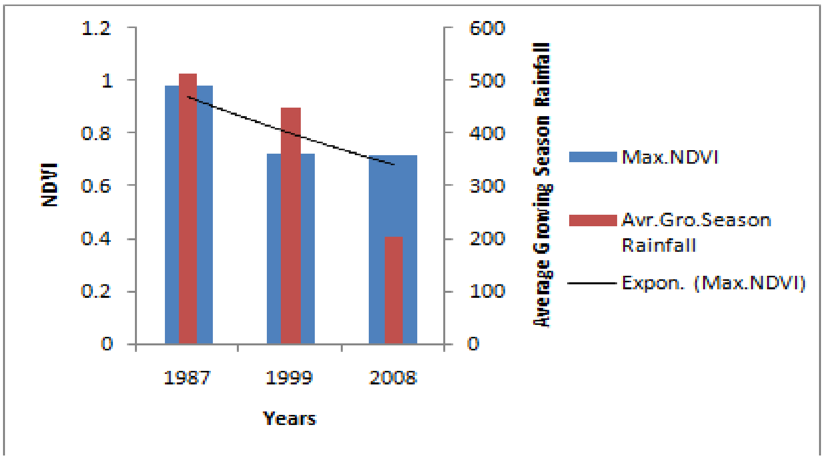

Figure 3: Temporal variation of Maximum NDVI and average growing season rainfall

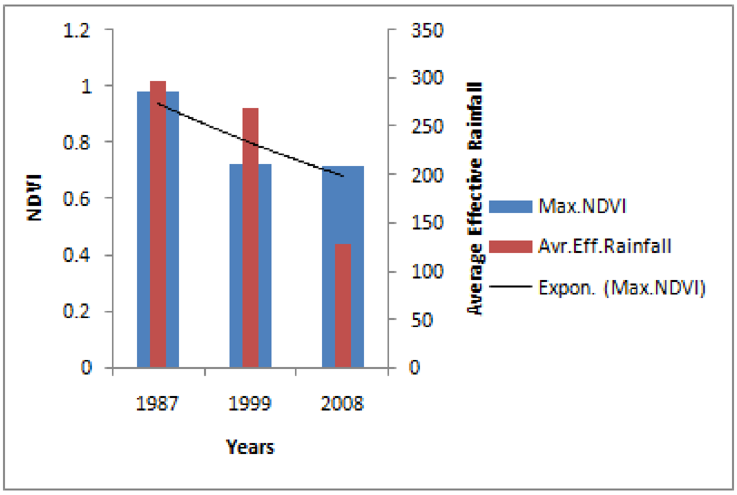

Figure 4: Temporal variation of Maximum NDVI and average effective rainfall

The figure 3 and figure 4 emphasize the fact that vegetation health of the region is greatly influenced by the rainfall pattern, i.e. when precipitation is high, NDVI values are also high and when there is a decrease in average precipitation, NDVI value also diminishes. The landuse/landcover mapping of the region is also found to support of the above result (Bora and Goswami, 2016) which showed a decreasing trend of vegetation cover in the area over the years.

V. Conclusion

For the study period, we conclude that NDVI demonstrates strong correlation with rainfall (growing season rainfall slightly higher than effective rainfall) in regard to the Kolong basin. Temporal response of vegetation to precipitation is found to have a linear relationship i.e. when there was an increase in precipitation, simultaneously the vegetation indices also showed elevated values and vice-versa.

This study helps us to better understand how vegetation growth is temporally affected by rainfall in the Kolong river basin. Moreover, as mentioned earlier, the main source of surface water of the region i.e. Kolong River is facing the problem of low flow, thus the vegetation health of the entire region is found to be completely dependent on rainfall. Hence, for this agriculture dependent region, government authorities must take some effective measures towards improving irrigation facilities as well as to improve the hydrological health of the prime river system of the region.

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