International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 08, August-2019

Temporal Response of NDVI to Climatic Attributes in North East India

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Abstract: **NDVI (Normalized Difference Vegetation Index) is designed to estimate the amount of above ground vegetation cover from measurements of red and near-infrared reflectance. It has been widely used to monitor vegetation changes. This paper used 10-day SPOT-Vegetation NDVI time-series data from 1998 to 2013 in Northeast India, to illustrate vegetation changes during 16 years and to examine the relationship between vegetation indices and climatic attributes the (Climatic Research Unit- time series) CRU TS3.1 data from East Anglia was used for 31 study sites, using the GLC 2009 landuse categories. The framework of this analysis is the use of correlation and coefficient and Coefficient of determination (R^2) to determine the temporal changes in NDVI during the 16 year period and enables productivity changes under different climatic scenarios. We examined responses of remotely sensed NDVI to precipitation and temperature during a sixteen year period (1998-2013) in Northeast India. A set of 300 spatially distributed NDVI values was analyzed to investigate significant divergence of vegetation growth from the 10 year period in the study area. From the analysis of NDVI value in different times, it is found that there was some fluctuation in the vegetation growth during the wettest months of each year. And from the analysis between precipitation and NDVI during 1998-2013, the correlation between NDVI and precipitation showed a negative correlation. Thus from the analysis it emerged that the negative correlation between NDVI and rainfall was accentuated during the growing season particularly when the monsoon was prevalent in the study area.**

Keywords: NDVI, SPOT-vegetation time series, Correlation, Coefficient of determination, Rainfall, Temperature, Northeast India

I. INTRODUCTION:

In tropical Northeast India, the latent benefits of high precipitation and healthy vegetation are balanced. The region lies under high rainfall region with subtropical type of climate. The annual rainfall mainly from south-west monsoon from middle of May and continues till October prevails in this region. The average rainfall Northeast region receives about 2450 mm. The Cherrapunji-Mawsynram range receives rainfall as high as 11,500 mm, annually. Rainfall is the key source of water for vegetation growth in the entire world. It is important for growth of vegetation in the tropics and tropical areas where plentiful water in the form of high precipitation is available are infrequent (Camberlin et al., 2007). This study uses normalized difference vegetation index (NDVI) data produced by Systeme Pour l' Obsevation de la Tere (SPOT) Vegetation data and PROBA-V with 1 km resolution and precipitation data derived from CRU TS 3.1 from 1998-2013. CRU TS 3.1 comprises monthly values of station-observed meteorological data from the beginning of the 20th century, gridded at 0.5o resolution (Mitchell and Jones 2005). Monthly temperature values since January 1998 till 2013 were used in this analysis.

The remotely sensed normalized difference vegetation index (NDVI) has been shown to be linked with biophysical variables that control vegetation productivity and land/atmosphere change (Hall et.al 2006) such as: leaf-area index (Myneni et.al 1997), the fraction of photosynthetically-active radiation absorbed by vegetation (Asrar et.al 1984), and NPP . It has also been used to evaluate vegetation change, either as an index (Anyamba & Tucker 2005, Olsson et.al 2005) or as one input to lively vegetation indices (Nemani et.al 2003, Seaquist et.al 2003, Fensholt et.al 2006).

II. METHODS

2.1 NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI)

The Normalized Difference Vegetation Index (NDVI) is the difference between the near-infrared and visible bands divided by the sum of these two bands (Tucker 1980; Sellers 1985; Sellers et al. 1994). In this study the NDVI time series data comprised 576 raster images at 10 day intervals spanning 16 years from 1998 – 2013. Using random sampling method based on the major land use categories identified by the regional GLC 2009 data-set that was imported into the Geographical Information System (GIS), the monthly pixel values of NDVI were extracted, following a previous study (Saikia, 2009), although the previous study used a different and more coarse data. The raster maps of 10 day time-series NDVI, precipitation and temperature (maximum, minimum and average) were stratified according to land use categories and correlation coefficients were calculated between each of the factors and NDVI for the entire pixels for each land use category. In recent years, many scholars in their studies have analyzed the relationships between NDVI, temperature and precipitation for different vegetation types at a regional scale.

2.2 TIME SERIES DATASETS FOR PRECIPITATION AND TEMPERATURE ASSESSMENTS

However to examine the relationship between vegetation indices and climatic attributes the (Climatic Research Unit- time series) CRU TS 3.2 data from East Anglia and which

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is also an updated version are used in this study. These are month by month variations in climate over the last century or so. These are calculated on high resolution (0.5x0.5 degree) grids which are based on an archive of monthly mean precipitation or temperature. This data-set refines previous methods and has climate grids that are constructed for nine climate variables for the period 1901–2015.CRU TS 3.2 datasets was used in this study to acquire precipitation and temperature data for the period of 1998-2013. The database is only available in the form of ASCII file which is extracted in ArcGIS 9.3 software. The station records were obtained from randomly selected landuse and landcover categories based on GLC 2009 dataset. The Global Land Cover's (GLC2009) Regional Land Cover data-set was used to select NDVI pixels related to specific land use categories (LUC), following previous studies (Camberlin et al., 2007; Balaghi et al., 2008). The regional GLC 2009 data-set for India enabled 26 land use and land cover categories; this study used only five categories. Thus (a) closed to open broadleaved evergreen or semi-deciduous, (b) closed to open grassland, (c) Irrigated cropland, (d) closed to open mixed broadleaved or needle leaved, and (e) mosaic cropland/vegetation of 31 sites were used in this study.

2.2.1 Assessing the correlation between NDVI and rainfall

The Pearson's product-moment correlation coefficient (or Pearson's correlation coefficient, for short) is a measure of the strength of a linear association between two variables and is denoted by r. Basically, a Pearson's product-moment correlation attempts to draw a line of best fit through the data of two variables, and the Pearson's correlation coefficient, r, indicates how far away all these data points are to this line of best fit. It is given.

$$r = \frac{\Sigma\left(x_{i} - \bar{x}\right)\left(y_{i} - \bar{y}\right)}{n.\sigma x\, \sigma y} \quad (1)$$

where r = co-efficient of correlation
x_i = values of the variates in one distribution
$\bar{x}$ = mean of the distribution
y_i = values of the variates of other distribution
$\bar{y}$ = mean of the above distribution
n = number of observation
σx = Standard deviation of x distribution
σy = Standard deviation of y

Here, x_i refers to monthly rainfall data and y_i refers to monthly NDVI data, $\bar{x}$ refers to averaged of the rainfall data and $\bar{y}$ refers to averaged of NDVI, σx and σy is the standard deviation of rainfall and NDVI. All the components were derived using a spreadsheet and thereafter pearson correlation coefficient was calculated and ploted in a graph.

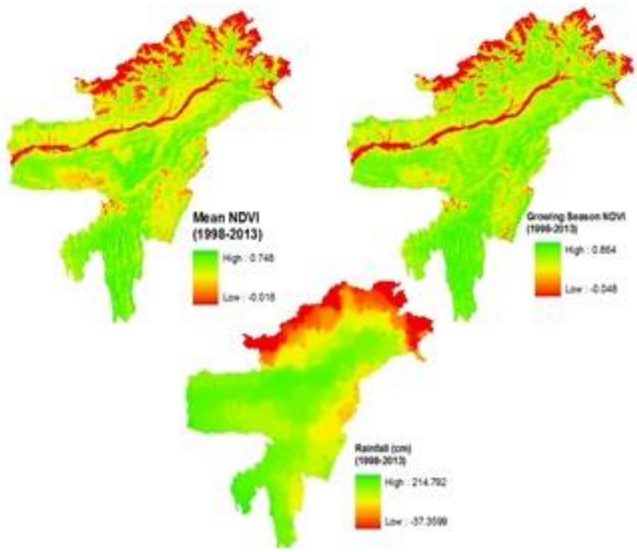
III. RESULTS AND DISCUSSIONS

3.1 CORRELATION BETWEEN RAINFALL AND NDVI

To analyze the spatial pattern of NDVI as they relate to precipitation maps of mean NDVI and growing season NDVI were compared with the interpolated rainfall maps (see fig-1.1)
According to the figure highest rainfall was perceived in Meghalaya, Tripura, and Mizoram and in the western and central part of Assam.

There was inverse relationship between NDVI and rainfall in these states though for other areas the relationships were not distinct. The northern edge of the study area i.e the Arunachal Pradesh a part of Himalayas where rainfall was specifically lower, a positive relationship existed with areas which had low mean and growing season NDVI values. This could be due to higher elevation, alpine meadows and temperate coniferous vegetation predominated (GLC, 2009).

On the other hand Assam did not follow to the general inverse of relation between rainfall and NDVI. This may be due to dominance of irrigated agricultural land and low percentage of forested landscape.



Fig(1.1): Rainfall, growing season NDVI, and mean NDVI are shown clockwise. Rainfall during the growing season (May, June, July, August, September, October) which were interpolated using kriging, based on values of the 3000 randomly selected points.

But in some part of Assam where densely forested area around upper and middle Assam, an inverse rainfall and NDVI relation occur. Thus the relationship between NDVI and precipitation is lower which means that the impact of precipitation is weaker.

International Journal of Engineering Research & Technology (IJERT)
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During the sixteen years (1998-2013), there was considerable year-to-year variation in precipitation and NDVI. Here, linear Correlation coefficients between NDVI and precipitation in in Northeast India were revealed. NDVI was more intensely related to the sum of monthly precipitation between1998-2013. With this (see table 1.1) approach, the correlation coefficient trend of NDVI range values and growing season rainfall (GSR mean) from 1998-2013 shown in Fig-1.2. By assuming that NDVI response to rainfall might be reaching a when either the NDVI range or growing season rainfall were high.

Table 1.1

Shows Mean Growing Season Rainfall and Minimum and Maximum NDVI and NDVI range in 31 sites (Fig-6.5) in NE India (1998-2013)

Year	NDVImin	NDVImax	NDVI Range	GSR mean (mm)
1998	0.0406	0.7033	0.6626	203.01
1999	0.065	0.7213	0.656	218.94
2000	0.04	0.7353	0.6953	214.7
2001	0.09	0.758	0.668	209.92
2002	0.0853	0.75	0.6646	194.41
2003	0.0826	0.778	0.6953	189.5
2004	0.0706	0.7393	0.6686	225.48
2005	0.0824	0.7255	0.6431	193.07
2006	0.0852	0.7262	0.6409	168.93
2007	0.0928	0.7247	0.6319	216.27
2008	0.0931	0.7266	0.6335	196.25
2009	0.089	0.7367	0.6476	182.47
2010	0.0897	0.7279	0.6382	167.87
2011	0.0897	0.7279	0.6382	173.51
2012	0.0909	0.7284	0.6374	171.51
2013	0.0918	0.7287	0.6368	168.67

The NDVI range was plotted over Growing Season mean in a scatter diagram which shows co-relation between rainfall and NDVI (see fig: 1.2).It is indicated that NDVI significantly increased at a rate of 0.0005 over GSR mean (R2= 0.2253, p= 0.0632) from 1998-2013. This low P value and low R2 combination indicates that changes in the precipitation are related to changes in the NDVI variability. The NDVI range value is from 0.631 to 0.69 and the GSR mean value is from 169 (mm) to 225 (mm). The highest rainfall i.e. 225.48 mm occurred in 2004 and its NDVI value is 0.668 and the lowest rainfall is 163.87mm occurred in 2010 and its NDVI value is 0.638. Therefore it is specify that even when R-squared is low, low P value still indicate a relationship between significant predictors i.e the rainfall and response variable i.e the NDVI. The correlation and coefficient was computed for NDVI and rainfall using monthly value during 1998-2013 (see table 1.2)

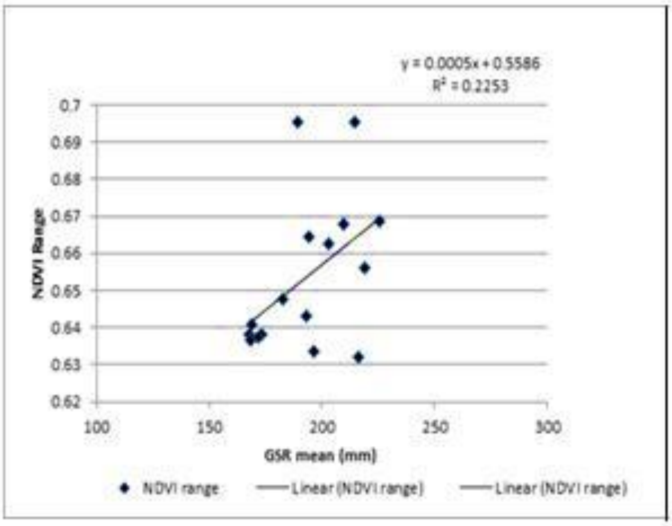

Fig 1.2: Linear relationships between mean growing season rainfall and Averaged monthly NDVI. The X axis shows mean growing season rainfall in Millimeters while the vertical Y axis shows NDVI range.

orrelation coefficients was figured for NDVI and rainfall using monthly values during 1998-2013 exhibited a negative correlation in 24 of the 31 sites of which 7 showed significant results (see table- 6.2). These 7 sites comprised of mosaic vegetation, closed to open mixed broadleaved or needle leaved, closed to open grassland, and closed to open broadleaved evergreen or semi-deciduous landuses. Following the previous studies in comparatively lower rainfall regimes found good correlation between NDVI and rainfall lags (Wang et al., 2003; Chamaille- Jammes et al., 2006; Piao et al., 2006), and such a lag was obvious in north east India, although the relationship was negative on account of the high precipitation.

Similarly when growing season correlations were sought, 29 sites reflected the negative effect of high precipitation on NDVI with significant negative coefficients at (*0.005 P-level*) in 5 sites. These 5 sites comprised of closed to open broadleaved evergreen or semi-deciduous and closed to open grassland landuses. Only two sites comprising irrigated cropland and mixed vegetation landuses showed positive correlation. The irrigated cropland sites would be benefit from higher precipitation, because wetland paddy cultivation increases in drenched conditions during the growing season. Thus it emerge that the negative correlation between NDVI and rainfall gets emphasized during the growing season i.e from June to October where

International Journal of Engineering Research & Technology (IJERT)
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monsoon exist in the study area. According to the previous studies in arid areas where too little rainfall prevails is a constraint to vegetation growth but in the

Table.1.2

Coefficient of determination (R^2) for the correlations between NDVI and rainfall in the 31 sites. The numbers in the column header indicate the investigated relationships listed below the table.

Sl No	Landuse/landcover	states	District	1	2
0	closed to open broadleaved evergreen or semi-deciduous	Arunachal Pradesh	East Kameng	-0.253	-0.006
1	closed to open broadleaved evergreen or semi-deciduous	Arunachal Pradesh	Upper Subansiri	-0.3	-0.594**
2	closed to open broadleaved evergreen or semi-deciduous	Arunachal Pradesh	Upper Dibang Valley	-0.403	-0.342
3	closed to open grassland	Arunachal Pradesh	Lohit	-0.397	-0.337
4	Irrigated cropland	Assam	Tinsukia	-0.002	-0.207
5	closed to open mixed broadleaved or needle leaved	Assam	Karbi Anglong	-0.447	-0.36
6	Irrigated cropland	Assam	Kamrup	-0.176	-0.504
7	Irrigated cropland	Assam	Kokrajhar	-0.153	-0.343
8	closed to open grassland	Assam	Nalbari	-0.451	-0.293
9	Irrigated cropland	Assam	Goalpara	-0.128	-0.367
10	closed to open broadleaved evergreen or semi-deciduous	Meghalaya	West Khasi Hills	-0.185	-0.628**
11	mosaic vegetation/ cropland	Meghalaya	West Khasi Hills	-0.391	0.081
12	mosaic vegetation/ cropland	Meghalaya	Jaintia Hills	0.206	-0.155
13	closed to open mixed broadleaved or needle leaved	Assam	Karbi Anglong	0.477	-0.164
14	closed to open grassland	Assam	North Cachar Hills	-0.307	-0.451
15	closed to open broadleaved evergreen or semi-deciduous	Manipur	Tamenglong	-0.39	-0.286
16	closed to open grassland	Nagaland	Mokokchung	0.075	-0.568
17	closed to open broadleaved evergreen or semi-deciduous	Nagaland	Tuesang	0.124	-0.501
18	closed to open grassland	Nagaland	Phek	0.008	-0.46
19	closed to open grassland	Nagaland	Kohima	-0.134	-0.504
20	closed to open broadleaved evergreen or semi-deciduous	Manipur	Ukhrul	-0.115	-0.601**
21	mosaic cropland/vegetation	Manipur	Senapati	-0.213	-0.321
22	closed to open broadleaved evergreen or semi-deciduous	Manipur	Chandel	-0.331	0.659
23	closed to open grassland	Manipur	Churachandpur	0.192	-0.587**
24	closed to open grassland	Mizoram	Kolasib	-0.002	-0.387**
25	Irrigated cropland	Assam	Karimganj	-0.148	-0.423
26	mosaic cropland/vegetation	Tripura	Chalai	0.427	-0.548
27	Irrigated cropland	Tripura	West Tripura	-0.382	-0.19
28	closed to open grassland	Mizoram	Mamit	-0.128	-0.377
29	closed to open grassland	Mizoram	Lunglei	-0.364	-0.004
30	closed to open broadleaved evergreen or semi-deciduous	Mizoram	Lawnglei	-0.53	-0.247

1 monthly rainfall versus monthly NDVI
2= Growing season rainfall versus growing season NDVI
**= values significant at 0.05 P-level

high precipitation belt of Northeast India where rainfall is very high play a similar constricting effect (Saikia,2009). In conformity with previous studies which show that above certain rainfall verge the relationships between rainfall and NDVI were insignificant (Saikia, 2009; Nicholson & Farrar, 1994; Piao et al., 2006).

3.2 CORRELATION BETWEEN TEMPERATURE AND NDVI

Based on SPOT vegetation NDVI data a vegetation map and annual mean temperature map is prepared. In recent years few studies have examined NDVI and its relationship with temperature in different region.

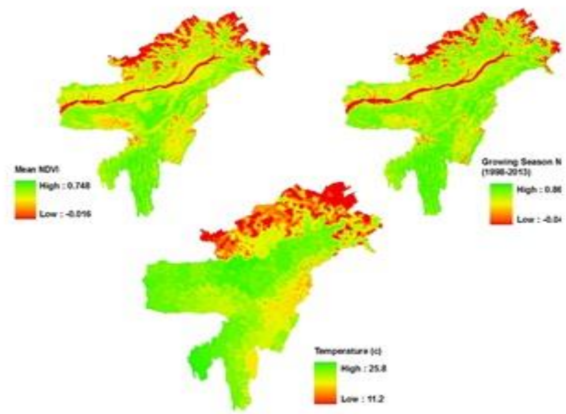

Fig 1.3: Mean NDVI, growing season NDVI, and temperature, are shown clockwise. Temperature shows growing season (May, June, July, August, September and October) values, which were interpolated using kriging, based on values of the 3000 randomly selected points.

According to Luo et al. (2009) there were strong correlations between NDVI, precipitation and temperature for different vegetation forms in northeast China, where the influence of temperature on NDVI was more obvious than that of precipitation. This study analyzed changes in NDVI and temperature and also investigated the correlations between NDVI and temperature for different vegetation types during the growing seasons of the period 1998-2013 in Northeast India. The growing season was defined as May–October in Northeast India.

Maps comparing growing season NDVI, mean NDVI and temperature (see figure) show positive relations in northeastern and western part of Meghalaya, Tripura, Mizoram and Nagaland while in rest of the states like some parts of Assam and Manipur, southeastern and western parts of Arunachal Pradesh where negative relations seems to be activate.

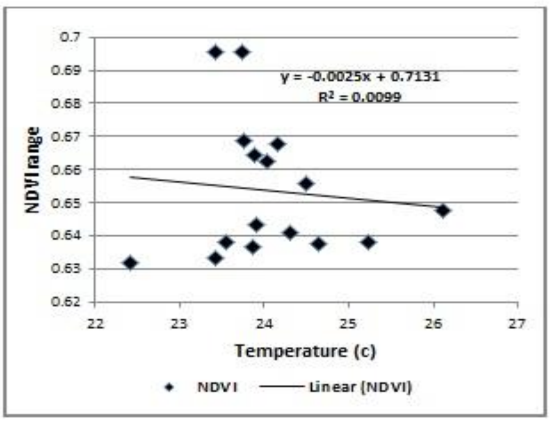

Fig 1.4: Linear relationships between averaged monthly temperature and monthly NDVI range. The X axis shows averaged monthly temperature in Celsius while the vertical Y axis shows NDVI range.

Table.1.3:

The Coefficient of determination (R^2) for the correlations between NDVI and temperature in the 31 sites are shown in this table. The numbers in the column header indicate the investigated relationships listed in the table.

Sl No.	Landuse/landcover	States	District	1	2
0	closed to open broadleaved evergreen or semi-deciduous	Arunachal Pradesh	East Kameng	0.114	0.144
1	closed to open broadleaved evergreen or semi-deciduous	Arunachal Pradesh	Upper Subansiri	0.24	0.176
2	closed to open broadleaved evergreen or semi-deciduous	Arunachal Pradesh	Upper Dibang Valley	0.115	0.379
3	closed to open grassland	Arunachal Pradesh	Lohit	0.397	0.279
4	Irrigated cropland	Assam	Tinsukia	0.564	0.148
5	closed to open mixed broadleaved or needle leaved	Assam	Karbi Anglong	0.499	0.136
6	Irrigated cropland	Assam	Kamrup	0.342	0.494
7	Irrigated cropland	Assam	Kokrajhar	0.118	0.443
8	closed to open grassland	Assam	Nalbari	0.315	0.406
9	Irrigated cropland	Assam	Goalpara	0.218	0.125
10	closed to open broadleaved evergreen or semi-deciduous	Meghalaya	West Khasi Hills	0.338	0.055
11	mosaic vegetation/ cropland	Meghalaya	West Khasi Hills	0.348	0.1
12	mosaic vegetation/ cropland	Meghalaya	Jaintia Hills	0.267	-0.16
13	closed to open mixed broadleaved or needle leaved	Assam	Karbi Anglong	0.5	0.11
14	closed to open grassland	Assam	North Cachar Hills	0.192	0.025
15	closed to open broadleaved evergreen or semi-deciduous	Manipur	Tamenglong	0.005	0.114
16	closed to open grassland	Nagaland	Mokokchung	0.612**	0.348
17	closed to open broadleaved evergreen or semi-deciduous	Nagaland	Tuesang	0.038	0.435
18	closed to open grassland	Nagaland	Phek	-0.109	-0.081
19	closed to open grassland	Nagaland	Kohima	0.444	0.077
20	closed to open broadleaved evergreen or semi-deciduous	Manipur	Ukhrul	0.309	0.411
21	mosaic cropland/vegetation	Manipur	Senapati	0.282	0.178
22	closed to open broadleaved evergreen or semi-deciduous	Manipur	Chandel	0.341	0.313
23	closed to open grassland	Manipur	Churachandpur	0.092	0.501
24	closed to open grassland	Mizoram	Kolasib	0.117	0.562**
25	Irrigated cropland	Assam	Karimganj	0.52	0.208
26	mosaic cropland/vegetation	Tripura	Chalai	0.044	-0.006
27	Irrigated cropland	Tripura	West Tripura	0.164	0.234
28	closed to open grassland	Mizoram	Mamit	0.183	0.663**
29	closed to open grassland	Mizoram	Lunglei	0.591**	0.175
30	closed to open broadleaved evergreen or semi-deciduous	Mizoram	Lawnglei	-0.454	-0.063

1= monthly temperature versus monthly NDVI
2= Growing season temperature versus growing season NDVI
***= values significant at 0.05 P-level*

Here, linear Correlation coefficients between NDVI and temperature in five landuse categories of 31 sites in Northeast India were revealed. NDVI was more strongly related to the sum of monthly temperature between1998-2013. With this approach, the correlation coefficient trend of Averaged monthly NDVI values and growing season temperature from 1998-2013 shown in Figure 1.4.

The mean and growing season NDVI and Averaged monthly temperature when plotted in a scattered diagram showed a negative linear relationship. While linear relationship was explored it showed R^2 value 0.0099 which means negative correlation (see figure-6.4). It is indicated that NDVI significantly declining at a rate of -0.0025/year where (R^2 = 0.0099, P = 0.7137) . However a significant (p = 0.005) relationship existed when growing season correlations were explored in Northeast India negative relationships were found.

Correlation coefficients computed for NDVI and temperature using monthly values during 1998-2013 exhibited a negative correlation in 4 of the 31 sites out of which 4 showed significant results. These 4 sites comprised of closed to open shrub land. Following the previous studies the effects of precipitation and temperature on NDVI varied for different vegetation types (Chui.et.al 2013). The (figure- 1.4) shows that high temperature reveals a healthy vegetation growth and positive relation between NDVI and temperature. Here out of 31 sites only 4 sites shows negative co-relation and rest of the 27 sites shows positive co-relation. The 4 sites comprise Cropland and mosaic vegetation. The correlation and coefficient were highest in closed to open broadleaved evergreen or semi-deciduous, intermediate in grassland and lower in cropland area.

3.3 WITHIN SEASON RELATIONS BETWEEN NDVI AND PRECIPITATION

During the sixteen years (1998-2013), there was significant year- to- year variation in precipitation and NDVI (figure - 1.5). Correlation coefficients between NDVI and precipitation in Closed to open broadleaved evergreen or semi deciduous, Closed to open Grassland, Irrigated cropland, Closed to open mixed broadleaved or needle leaved and Mosaic Vegetation/ Cropland are high in precise combinations of time duration and lag. Correspondingly when monthly correlations were sought, out of 31 sites 25 sites reflected the negative effect of high precipitation on NDVI except 6 sites shows positive value (see table 1.4). These 6 sites comprised of closed to open broadleaved evergreen or semi-deciduous, closed to open grassland, irrigated cropland and mixed vegetation landuse showed positive correlation. There was significant correlation (*P <0.005*) in all the 31 sites The irrigated cropland sites would be benefit from higher precipitation, because wetland paddy cultivation increases in drenched conditions during the growing season.

When a 1 month rainfall lag was explored, negative relationship became more prominent as all the 31 sites showed negative significant correlations. On using a 2 month rainfall lag the result showed negative relationship in 19 sites and rest of the 12 sites showed positive relationships and the coefficients were significant.

Previously most of the authors' studies in comparatively lower rainfall regimes establish good correlation between NDVI and rainfall lags specially in drought region (Saikia, 2009, Wang et al, 2003; Piao et.al, 2006; Barbossa et.al, 2006 and 2016) and such a lag was marked in Northeast India, although the relationship was negative on account of high precipitation.

Table 1.5.

Coefficient of determination (R^2) for the correlations between NDVI and rainfall in the 31 sites. The numbers in the column heading indicate the investigated relationships listed below the table

	Station	1	2	3
1	closed needle leaved evergreen	-0.253	-0.642	0.028
2	closed to open broadleaved evergreen or semi-deciduous	-0.3	-0.659	0.077
3	closed to open broadleaved evergreen or semi-deciduous	-0.403	-0.545	0.071
4	closed to open grassland	-0.397	-0.351	-0.123
5	Irrigated cropland	-0.002	-0.677	0.057
6	closed to open mixed broadleaved or needle leaved	-0.447	-0.682	-0.11
7	Artificial areas	-0.176	-0.29	0.027
8	Irrigated cropland	-0.153	-0.531	-0.02
9	closed to open grassland	-0.451	-0.203	-0.19
10	Irrigated cropland	-0.128	-0.531	-0.129
11	closed to open broadleaved evergreen or semi-deciduous	-0.185	-0.203	-0.04
12	mosaic vegetation/ cropland	-0.391	-0.594	-0.177
13	mosaic vegetation/ cropland	0.206	-0.499	0.053
14	closed to open mixed broadleaved or needle leaved	0.477	-0.329	0.134
15	closed to open scrubland	-0.307	-0.23	-0.096
16	closed to open broadleaved evergreen or semi-deciduous	-0.39	-0.436	-0.046
17	closed to open shrubland	0.075	-0.508	-0.04
18	closed to open broadleaved evergreen or semi-deciduous	0.124	-0.595	0.111
19	closed to open shrubland	0.008	-0.565	-0.175
20	closed to open shrubland	-0.134	-0.541	0.0008
21	closed to open broadleaved evergreen or semi-deciduous	-0.115	-0.57	-0.114
22	mosaic cropland/vegetation	-0.213	-0.292	0.088
23	closed to open broadleaved evergreen or semi-deciduous	-0.331	-0.443	-0.032
24	closed to open shrubland	0.192	-0.443	0.07
25	closed to open shrubland	-0.002	-0.34	-0.046
26	Rainfed cropland	-0.148	-0.449	-0.134
27	mosaic cropland/vegetation	0.427	-0.501	-0.095
28	Irrigated cropland	-0.382	-0.287	-0.064
29	closed to open shrubland	-0.128	-0.583	-0.025
30	closed to open shrubland	-0.364	-0.328	0.131
31	closed to open broadleaved evergreen or semi-deciduous	-0.53	-0.502	-0.076

1 Monthly rainfall versus monthly NDVI
2 Months lag averaged monthly rainfall with averaged monthly NDVI
3 Months lag averaged monthly rainfall with averaged monthly NDVI

The response time of diverse vegetation classes to rainfall is not discrete between land cover classes. Regarding the lag correlation there was very less significant difference. Only in the monthly and 2 month lag correlation shows positive correlation in few sites. The results of the 1 month lag correlation coefficient analysis for each landuse and landcover site revealed slight improvement while the dependency on lag 2 rainfall was strongest. Similarly when growing season correlations were sought, 29 sites reflected the negative effect of high precipitation on NDVI with significant negative coefficients at (0.005 P-level) in 5 sites.

Similarly when growing season correlations were sought in the previous analysis, 29 sites reflected the negative effect of high precipitation on NDVI with significant negative coefficients at (*0.005 P-level*) in 5 sites. Thus it appears that the negative correlation between NDVI and rainfall that existed during the growing season seems to be operating when the 1 and 2 months lagged NDVI and rainfall was considered.

IV CONCLUSIONS

In due consideration of the present situation in Northeast India, observing ecological balance through NDVI based change detection was used. Forest loss and improvement have been assessed by remotely sensed indicators of biomass productivity. NDVI transmits valuable information regarding vegetation change or biomass productivity can be most accurately identified by image differencing of NDVI data. The indicators show clear regional trends over the period 1998-2013, both decreasing and increasing, which may be interpreted as deforestation or improvement, respectively.

The temporal and spatial variation of NDVI by different vegetation types in Northeast India during the period 1998-2013 indicate that the value of vegetation indices slightly decreased slightly in some parts of Arunachal Pradesh, Assam, Manipur, Mizoram and Nagaland; possibly due to agricultural intensification.

The inter-annual variations in growing season NDVI for the Northeastern region of India shows that there is considerable variation in forest loss and gain in the region during the period of 1998-2013. Highly negative NDVI value appears in large parts of Arunachal Pradesh, Assam and Meghalaya and also in some parts of Manipur, Nagaland, Mizoram and Tripura.

The correlations between growing season NDVI and rainfall reveals that out of 31 study sites of land-use and land-cover, 29 sites reflected the negative effect of high rainfall. Only two sites comprising irrigated cropland and mixed vegetation land-use showed positive correlation. The irrigated cropland sites would benefit from higher rainfall, because wetland paddy cultivation increases in drenched conditions during the growing season. Thus it appears that the negative correlation between NDVI and rainfall gets emphasized during the growing season i.e from June to October where monsoon occur in the study area. Thus high rainfall plays a constricting role in vegetation health and greenness in Northeast India.

The correlations between temperature and NDVI results that out of 31 sites only 4 sites show negative correlation and rest of the 27 sites shows positive correlation. The 4 sites comprise cropland and mosaic vegetation. The correlation and coefficient were highest in closed to open broadleaved evergreen or semi-deciduous, intermediate in grassland and lower in cropland area.

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