International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-6, April 2020

Long Term Vegetation Health Monitoring in Dibru-Saikhowa National Park using Remote Sensing & Gis

Sujata Medhi, Sourav Chetia, Syeda Fahima Shahnaz Sultana, Kasturi Borkotoky, Ashok KumarBora

Abstract: Remote sensing and GIS based vegetation monitoring offers lot of potential for ecosystem studies. This study utilized freely available moderate resolution Landsat images to quantify the changes in vegetation dynamics in Dibru-Saikhowa national park, India. A wide range of vegetation indices and temperature indices such as normalized difference vegetation index (NDVI), land surface temperature (LST), vegetation condition index (VCI), temperature condition index (TCI) and vegetation health index (VHI) was utilized for the purpose of the study. Results reveal that the study area has gone through changes in vegetation and temperature pattern affecting the land surface balances. The maximum NDVI value for the year 1996 was recorded between 0.5-0.8 whereas the maximum LST values ranged between 17.240C-34.850C. In 2019, the maximum NDVI values reduced to the range of 0.14-0.6 while LST increased to 18.950C-38.910C. Consequently, the VHI classes showed a negative trend. In 1996, healthy vegetation covered a total area of 14564.6 ha which reduced to 9872.1 ha in 2019. Conversely, the no vegetation class showed a significant positive trend from 951.3 ha to 3015.99. Such alteration in vegetation dynamics in the study area is affecting the local climate and regional ecosystem services and require instant attention of conservationist and policy makers.

Keywords: Lst, Ndvi , Tci , Vci, Vegetation Dynamics, Vhi.

I. INTRODUCTION

Understanding of vegetation dynamics is very essential for vegetation plays a decisive role in enhancing the structure of the ecosystem and at the same time reduces the global warming effects (Zhang et al., 2019). Functions of vegetation are manifold as it plays a crucial role in retaining the water cycle, stabilization of the soil, maintaining carbon balance, checking surface runoff pattern, altering the land surface conditions, assisting land surface processes, land-atmosphere interactions, reducing global climate change effects and in aiding human activities at local, regional and global levels (Pei et al.,2017; Qu et al.,2019; Zhang et al.,2019).

Revised Manuscript Received on April 30, 2020.

***** Correspondence Author

Sujata Medhi, Department of Geography, Gauhati University, Guwahati, India. Email: sujata@gauhati.ac.in

Sourav Chetia*, Department of Geography, Gauhati University, Guwahati, India. Email: schetia@gauhati.ac.in

Syeda Fahima Shahnaz Sultana*, Department of Geography, Gauhati University,Guwahati,India. Email: shehnu014@gmail.com

Kasturi Borkotoky, Department of Geography, Gauhati University, Guwahati, India. Email: kasturi@gauhati.ac.in

Ashok Kumar Bora, Department of Geography, Gauhati University, Guwahati, India. Email: akbmrp@gmail.com

Vegetation, therefore, can be deemed as one of the most important components of the biosphere. However, vegetation cover goes through frequent changes as it is affected by both, natural and anthropogenic factors. The magnitude in which anthropogenic disturbances is affecting vegetation communities has increased manifold (Qu et al.,2019). In many regions of the world, particularly developing countries like India,China, there has been rapid conversion of natural land into cultivated land. Such conversions make the vegetation ecology very fragile and possess a threat to the environment (Qu et al.,2019; Dhing,2003). The disturbances, whether natural or manmade, affect the vegetation activity which is the interaction of vegetation with its surrounding environments (Pei et al., 2017). For instance, proper carbon dioxide concentration during photosynthesis, sufficient mineral concentration, stabilized climatic conditions, sufficient surface runoff, balanced food chain, etc., increase the vegetation activity whereas deforestation, high incidences of flood occurrence, drought, infrastructure development, etc. leads to a reduction in the vegetation activity (Ji and Peters, 2003; Piao et al.,2012; Pei et al., 2017). Therefore, there is a need to identify and monitor the vegetation activity at multiple time scales including annual, interannual, interdecadal and long term trends, as the vegetation resources strengthen the national economy through maintaining a rich and balanced ecosystem and promote sustainable environment development (Qu et al., 2010; Qu et al.,2019; Zhang et al., 2019; Binod et.al., 2019).

In order to monitor the quantitative attributes of vegetation changes, different satellite data are used in accordance with different types of vegetation in many studies (Evans and Geerken, 2004; Kundu et al., 2016; Vilanova et al., 2019; Qu et al., 2019). Satellite borne remote sensing data provides a clear picture of the earth surface and therefore, it is used to monitor and evaluate the vegetation health conditions under different circumstances (Sholihah et al., 2016). Various vegetation indices such as VCI (Vegetation Condition Index), NDVI (Normalized Difference Vegetation Index), etc., are used in accordance with some additional dataset such as LST (land surface temperature), TCI (Temperature condition index) for such studies. VCI is derived from NDVI which indicates the short-term vegetation changes (Kogan, 1990; Vilonova 2019). TCI is derived from the LST Index and is used to determine temperature related vegetation stress (Kogan 1995). LST is calculated by conversion of the Digital Number (DN) into Radiance,

Radiance into the Top Atmospheric Brightness Temperature (Kelvin) and Top Atmospheric Brightness Temperature into Celsius which gives the LST. Thus, Vegetation Health Index is time series analysis that helps to evaluate vegetation condition stressed by temperature (Bhuyan et al., 2006; Sholihah et al., 2016; Tran et al., 2017). However, some researchers opined that the lower the NDVI and the higher the LST, the poor is the vegetation health (Bento el al., 2018). This assumption is based on researches widely conducted in the areas of Mongolia and in parts of the USA (Karnieli et al., 2006, 2010; Bento el al.,2018). To prove that this assumption is preferably applicable to almost all the vegetative regions of the globe, this study has been conducted by utilizing moderate resolutionLandsat 5 TM and Landsat 8 OLI images for a time span of 23 years (1996-2019) in Dibru-Saikhowa national park in Assam of Northeast India.

The Dibru-Saikhowa National Park itself serves as an important ecological hub in the region and thus maintain regional ecological balance (Qu et al., 2019). Both natural and anthropogenic disturbances in this ecological hub can significantly alter the ecosystem processes. Quantifying the vegetation changes of Dibru-Saikhowa can provide insights into the disturbance caused as a result of anthropogenic activities and its impact on the ecosystem structure and functioning. This study, therefore, aims to understand the changes in vegetation dynamics over a period of 23 years in the study area.

II. STUDY AREA:

The Dibru-Saikhowa National Park extends between the latitudes $27^0 30^{'}$N to $27^0 48^{'}$N and between $95^0 10^{'}$E to $95^0 45^{'}$E longitudes with an area of 350 km^2 (Purkayastha, 2004; Kalita, 2015) (Fig.1) It is situated on the southern bank of the Brahmaputra and the Lohit rivers in the upper Assam region of the state of Assam in the northeastern region of India and is considered as the nineteenth biodiversity hot spot of the world (Purkayastha,2004; Gogoi,2005). It lies in the Tinsukia and Dibrugarh districts of Assam. The average altitude of the national park is 118 m above the mean sea level (Sarmah,1998; Kalita,2015). The park features flat terrain with new and old alluvium, dense river network and abundant tributaries. It is characterized by typical tropical monsoon climate with a mean annual temperature ranging between 6^0 Celsius to 36^0 Celsius and has an annual rainfall of 2300 to 3800 mm (Sarmah, 1998; Gogoi, 2005). The vegetation of the national park is composed of semi-wet vegetation, tropical moist deciduous, littoral and swamp, savannah grassland and sand-cover along the banks of the rivers (Sarmah, 1998; Mahanta, 2002; Purkayastha ,2004). Despite having enormous potential, the study area is facing a lot of threats during recent years due to natural and anthropogenic causes. In many parts of the world, global warming is having an adverse impact limited to not only vegetation growth and changes but also upon the balanced ecosystem structure thereby, disrupting it. Such problems are slowly catching the remote places like Dibru-Saikhowa National Park and other remote parts of India.

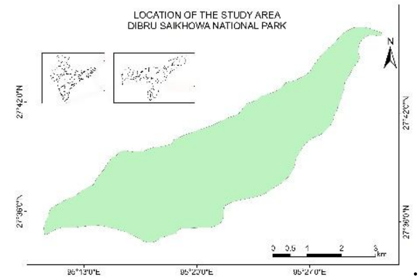

Fig1: Study area map

III. DATABASE AND METHODOLOGY:

The Landsat datasets were derived from USGS (United States Geological Survey). Landsat 5TM and Landsat 8 OLI images have been utilized for this study. Data for a duration of 23 years were considered i.e., from 1996 to 2019 to derive the changes in the vegetative cover of the study area.

The methodology involved in the study includes the calculation of the following indices-

NDVI

NDVI (Normalized Difference Vegetation Index) is calculated by using the following equation (Vilanova, 2019).

NDVI=RED-NIR/RED+NIR (1)

Where, red is the red band and NIR is the near infra-red band of Landsat image

Landsat 5 TM LST retrieval

Two different approaches were adopted while calculating the LST for Landsat 5 and Landsat 8. Landsat 5 TM and Landsat 8 OLI thermal bands were used for retrieval of LST in both data sets. Retrieval of LST for Landsat 5 TM is acquired through the following equation(s)

1. Conversion of Digital number to Radiance

$$L\boldsymbol{\lambda} = ((\mathbf{LMAX}\boldsymbol{\lambda}\text{-}\mathbf{LMIN}\boldsymbol{\lambda})/(\mathbf{QCALMAX}\text{-}\mathbf{QCALMIN})) * (\mathbf{QCAL}\text{-}\mathbf{QCALMIN}) + \mathbf{LMIN}\boldsymbol{\lambda} \quad (2)$$

Here,

L$\boldsymbol{\lambda}$ = Spectral radiance at the sensor's aperture in (Watts/(m² * sr * µm))

QCAL=Quantized calibrated pixel value in DN.

LMAX$\boldsymbol{\lambda}$=Spectral radiance scaled to QCALMAX in (Watts/(m² * sr * µm))

LMIN$\boldsymbol{\lambda}$= Spectral radiance scaled to QCALMIN in (Watts/(m² * sr * µm))

QCALMAX=Maximum quantized calibrated pixel value (corresponding to LMAXλ) in DN.

QCALMIN=Minimum quantized calibrated pixel value (corresponding to LMINλ) in DN

2. Radiance into Brightness temperature (Kelvin)

$$T = \mathbf{K}2/In(\boldsymbol{K1}/\boldsymbol{Ln\lambda} + \mathbf{1}) \quad (3)$$

Here,

$\boldsymbol{T}$ = Effective at-satellite temperature in Kelvin

$\boldsymbol{K2}$ = Calibration constant 2

$\boldsymbol{K1}$ = Calibration constant 1

$\boldsymbol{L\lambda}$ = Spectral radiance in (Watts/(m² * sr * µm))

Retrieval Number: F4747049620/2020©BEIESP
DOI: 10.35940/ijitee.F4747.049620

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3. Kelvin into Degree Celsius

$$C=K-273.15 \quad (4)$$

Landsat 8 OLI LST retrieval

1. Conversion to TOA radiance

$$L\lambda=M_L*QCAL+A_L \quad (5)$$

Here,

$L\lambda$ = TOA SPECTRAL RADIANCE

ML = Band specific multiplicative rescaling factor from the metadata (radiance multiband x, where x is the band number).

AL =Band specific additive rescaling factor from the metadata. (Radiance add band x, where x is the band number).

QCAL = Quantized and calibrated standard product pixel value (DN).

1. Conversion to top Atmospheric brightness Temperature

$$TB=K2/\ In\ (K1/L\lambda+1)-273.15 \quad (6)$$

Here**,**

T= Top of atmospheric brightness temperature(k).

K1= Band specific thermal conversion constant from the metadata (K1 constant band x, x is the thermal band).

K2 =Band specific thermal conversion constant from the metadata (K2 constant band x, where x is thermal band number).

2.Conversion from At-Satellite temperature to LST

$$T=TB/\{1+(\lambda*TB/C2)*\ In(\ e)\} \quad (7)$$

Here,

λ= wavelength of emitted radiance.

C2 =143288mm(constant)

h = Plank's constant =6.626*1023Js

s=Boltzmans constant =1.38*10 23 J/K

c= velocity of light =2.998*106m/s.

e=0.0048*pv+0.98

PV or the proportion of vegetation is derived by the following formula:

$$Pv=((NDVI-NDVI\ MIN)/(NDVIMAX-NDVIMI))^2 \quad (8)$$

VCI calculation

Following (Kogan, 1997; Bento, 2018); VCI is computed by considering each pixel in a given year.

$$VCI=NDVI-NDVIMIN/NDVIMAX-NDVIMIN \quad (9)$$

$$TCI=LSTMAX-LST/LSTMAX-LSTMIN. \quad (10)$$

VHI calculation

VHI is calculated by using the following equation (Kogan, 1995)

$$VHI=\alpha*VCI+(1-\alpha)*TCI \quad (11)$$

Here,

α is constant i.e,0.5 (Kogan, 1997; Kogan, 2001)

Table 1: Satellite data used in the study

Sensors	**Date**	**Path/Row**	**Source**
Landsat 5 TM	1996-04-15	135/041	Earthexplorer.usgs.gov
	1996-01-10	135/41	Earthexplorer.usgs.gov
	1996-02-11	135/41	Earthexplorer.usgs.gov
	1996-06-18	135/41	Earthexplorer.usgs.gov
	1996-12-11	135/41	Earthexplorer.usgs.gov
Landsat 8 OLI	2019-01-25	134/41	Earthexplorer.usgs.gov
	2019-03-14	134/41	Earthexplorer.usgs.gov
	2019-04-24	134/41	Earthexplorer.usgs.gov
	2019-10-17	134/41	Earthexplorer.usgs.gov
	2019-11-02	134/41	Earthexplorer.usgs.gov
	2019-12-04	134/41	Earthexplorer.usgs.gov

IV. RESULTS AND DISCUSSIONS

The study area of Dibru-Saikhowa National Park with different vegetation cover were classified based on the vegetation indices and climatological parameters such as temperature, solar radiance, etc. The long-term average Land Surface Temperature (LST) for the year 1996 ranged between 15.58^{0}C - 23.09^{0}C . The minimum LST were recorded within the range 11.40^{0}C -17.93^{0}C-, whereas the maximum LST ranged between 17.24^{0}C -34.85^{0}C-. For 2019, the LST average ranged between 14.38^{0}C -25.96^{0}C-, with the minimum lying between the range 14.33^{0}C -20.16^{0}C-and the maximum between 18.95^{0}C -38.31^{0}C-. High LST value is detected for the year of 2019 as a result of increased CO_2 emission caused as a result of deforestation, an increase in sedimentation load from Brahmaputra river and Lohit river, increased land use in the adjacent forest reserve i.e, a higher concentration of human activities (Fig.2)

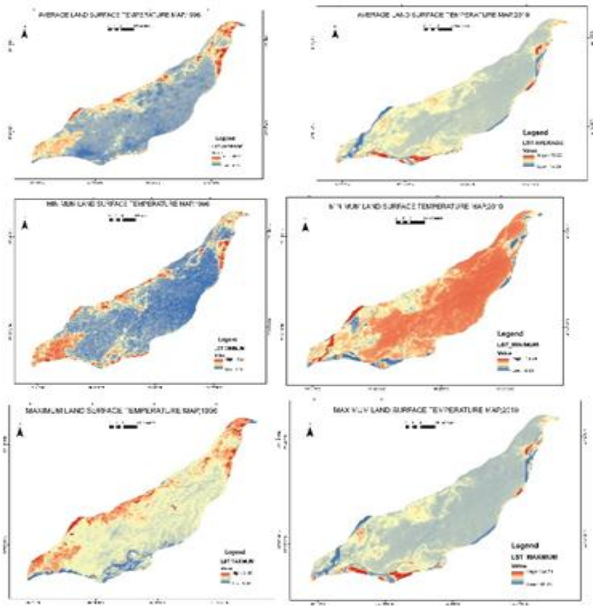

Fig.2 Land surface temperature map.

NDVI is a standardized indicator to measure the photosynthetic activity of vegetation. The NDVI variable showed a significant variation for the years under consideration, i.e., 1996-2019 respectively. The year 1996 represented average NDVI value within the range of 0.22-0.35. The minimum and maximum values for 1996 ranged between 0.10-0.72 and0.56-0.85. While for the year 2019, the NDVI value ranged within 0.12-0.42, with the minimum value lying between the range of 0.18 -0.30-and maximum value within the range 0.14 - 0.60 (Fig.3). The spatial distribution and concentration of NDVI for duration of 23 years of the study area shows moderate vegetation activity in the area. The vegetation activity is closely related with the precipitation cycle of any area. As the study area falls under the monsoon climatic regime, precipitation ought to have a greater impact upon the vegetation of the area but due to changes in the seasonal shift and less pronounced annual cycle of rain, moderate vegetation activity is seen.

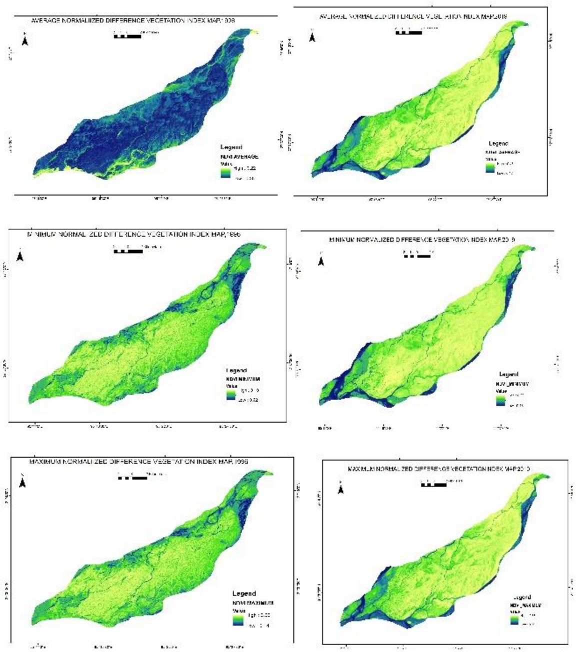

Fig.3 Normalized Difference vegetation Index map.

To examine the trends of vegetation dynamics in the past 23 years, VCI and TCI were utilized to obtain the VHI (Bento,2019). While comparing TCI values for the years 1996-2019, it is observed that the TCI is lower in 1996 than in 2019. On the other hand, the value of VCI in 1996 is higher than that in 2019(fig.4)

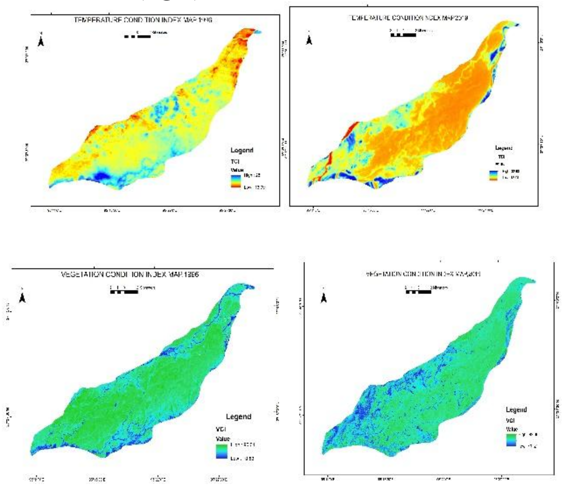

Fig.4 TCI and VCI map.

The VHI index helped to detect vegetation condition in the Dibru-Saikhowa National Park. VHI is based on a linear combination of two indices, namely, VCI and TCI, where VCI is derived from NDVI and TCI is derived from Land Surface Temperature (Bento et al., 2019). The study area is classified into healthy vegetation, moderate vegetation, sparse vegetation, and no vegetation based on VHI values. It is observed that the vegetation seems to have healthy growth in 1996 while sparse vegetation and no vegetation is more pronounced in 2019. Comparing the VHI for both the years, with the duration of study being 23 years, it can be concluded that VHI shows a negative trend(fig.5)

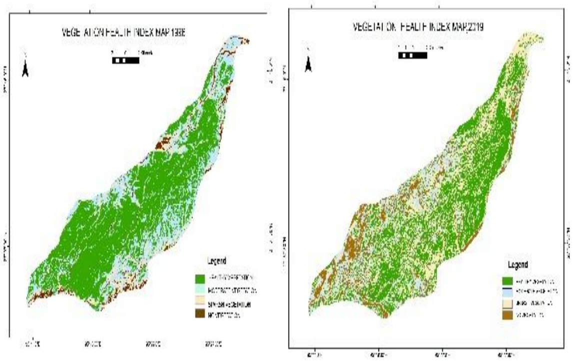

Fig.5 Vegetation health index map.

A graph showing changes in VHI classes is prepared to analyse area specific changes (fig.6). For the year 1996, the area under healthy, moderate, sparse and no vegetation covers were 14564.4 ha., 2225.16ha., 6785.1 ha. and 951.3 ha. respectively. For the above classes of vegetation, the area in 2019 accounted for 9872.19 ha., 3989.97 ha., 769.33ha. and 3015.99 ha. The study has thus, exhibit large scale shifts in the vegetation dynamics in Dibru-Saikhowa National Park over the 23 years period and it is quite visible that the ecosystem of the study area has taken a negative hit in these 23 years.

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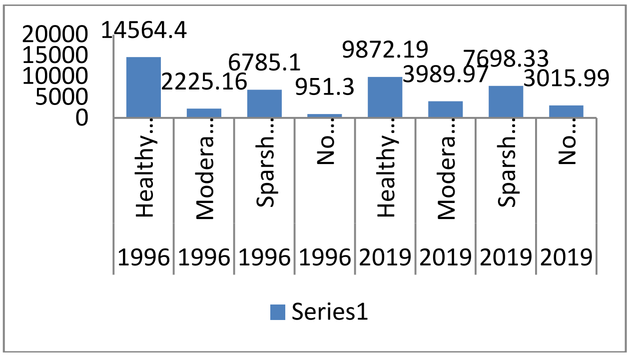

Fig.6 Graph showing changes in areas for 1996-2019

V. CONCLUSION

This study focused on the changes in vegetation dynamics in the Dibru-Saikhowa National Park using the Landsat 5 TM and Landsat 8 OLI datasets based on NDVI, VCI, TCI and VHI indices. It is found that VHI can be successfully used for identifying the temporal changes in vegetative cover as indicated earlier (Kogan, 2011). VHI is based on the linear combination of VCI and TCI. The results showed that the land surface temperature over the years has increased whereas, moderate changes occurred in vegetation activity. Consequently, VCI, TCI, and VHI showed a negative trend from 1996 to 2019. The large-scale shift in vegetation dynamics has mainly resulted from the disturbance caused by anthropogenic factors as-well-as and natural disasters like floods, erosion, etc. The changes in climatological parameters have their contribution in the temporal changes over the study area. Nevertheless, the changes in vegetation dynamics cannot be a good thing for the existing ecosystem. Therefore, there is a need of frequent monitoring of the area to assess the status of vegetation dynamics in order to identify the causes of damages to the vegetation which may provide greater insight for policymakers to come up with preservation policies to restore the vegetation status of the Dibru-Saikhowa National Park and also to have a meaningful positive impact upon the local climate.

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AUTHORS PROFILE

Sujata Medhi is a doctoral student of Department of Geography, Gauhati University, Assam, India. Before that, she worked as an assistant professor in Raha college, Assam in a contractual basis. She has successfully completed her master's degree in Geography with specialization in Geoinformatics. She has published a number of papers on land use land cover change,dwindling forest and their protection strategies for joint forest management in Assam, Jhum cultivation practices in west Garo hill, Meghalaya.

Sourav Chetia is a doctoral student of Department of Geography, Gauhati University, Assam, India. He has successfully completed his master's degree in Geography in 2016 with specialization in Geoinformatics. On top of that he has acquired a P.G. diploma in Geoinformatics. He has also completed M.phil. degree in Geography on impact of urbanization on land surface temperature. His primary field of interest is climate change, its impact on environment and mitigation approaches. Currently he is working on carbon forest sequestration. Before joining Geography department as a doctoral student, he worked as a junior research fellow in climate research cell of Tocklai Tea Research Institute, Assam.

Syeda Fahima Shahnaz Sultana is a doctoral student of the Department of Geography, Gauhati University, Assam, India. She has successfully completed her master's degree in Geography from Aligarh Muslim University in 2017 with Settlement Geography, Geography of Resources, Geography of Health and Industrial Geography as her optional courses under the CBCS pattern. She has also attended an off-campus outreach certificate programme conducted by IIRS in collaboration with ISRO on "Geospatial Technologies for Urban Planning". Her area of research interest is Social and Cultural Geography. She has co-authored papers on topics related to agriculture and river morphometry. She has recently participated in a national workshop conducted by ICSSR-NERC on "Research Methodology in Social Sciences".

Kasturi Borkotoky is a doctoral student of Department of Geography, Gauhati University, Assam, India. Before that she has successfully completed her master's degree in Geography with specialization in fluvial geomorphology. She has also completed M.phil degree in Geography on analysis of suspended sediment variation in the upper reach of Brahmaputra river, Assam. She has a post graduate diploma in Geoinformatics from North Eastern Hill University, Meghalaya. She has presented her works on river morphometry in a number of national and international conferences. She is currently working on riverine landscape dynamics of Noa Dihing river basin of Assam.

Ashok Kumar Bora is a professor and former head of the department of department of Geography, Gauhati University. He specializes in Fluvial Geomorphology, Hydrology, Remote Sensing, Environmental Geography, and Quantitative Methods. He is also a former director of Institute of distance and open learning, Gauhati University. He is also a coordinator of DRS SAP-III level. He also formerly held positions as executive council member, Gauhati University, Director, college development council, Gauhati University and member of IQAC, Gauhati University. His research areas include Geomorphology, fluvial geomorphology and hydrology, disaster management, health studies, wetland studies, resource studies, landscape dynamics and climate change.