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Spatial Modeling in Forest Resources Management

Rural Livelihood and Sustainable Development

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Chapter 23
Transformation of Forested Landscape in Bengal Duars: A Geospatial Approach

Koyel Sam and Namita Chakma

Abstract The Bengal Duars, a landscape of foothill ecology in Eastern Himalaya asherb of rich biodiversity with unique physiography and climate. This landscape is now tremendously under threat disrupting by natural as well as anthropogenic activities. The recent phase of transformation of forest cover caused by illegal felling, encroachment, mining, quarrying activities, further enhancing flood and its associated vulnerability in such landscape. We assess the level of transformation of an area under deforestation, reforestation within forest boundary by using geospatial technology. Landsat imageries of two different periods has been used to find out zonal transformation of different land cover. The study also reveal that the rate of deforestation is more than rate of reforestation and major transformation has observed from dense forest to open forest within 20 years (1990–2010). The recent conversion and disturbances are highlighted through high resolution overview and field observation.

Keywords Bengal duars · Eastern Himalaya · Transformation · Deforestation

23.1 Introduction

Forest as the lungs of our mother earth, purifying air, water, soil and providing a life of billions of people. Transformation of the forested landscape and deterioration of the habitat causes loss of biodiversity and decrease primary productivity (Laurance et al. 1997; Debinski and Holt 2000; Li et al. 2009). Moreover, it also has a significant impact on the local and global environment and climate change (Xiao et al. 2004). Measuring, monitoring and mapping of spatio-temporal dynamics of forest cover using geospatial technology plays a vibrant role for the management and restoration of forest ecosystem (Rikimaru 1999). As traditional monitoring methods are time consuming, labour intensive, and uneconomical. Therefore, satellite data are often considered by several conservation agencies, governmental and non-government

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organizations for monitoring, mapping of vegetation as it rapid and cost effective by using free source imagery (Kumar et al. 2010; Pringle 2010; Madin et al. 2011).

Remote sensing technique has widely used by several researchers for monitoring deforestation and periodical change of land use and land cover. Specially to study the up to date dynamics of reserve and protected areas, satellite data are the important source to solve complex and current environmental issues (Andrieu and Mering 2008; Baldyga et al. 2007). Park and Lee (2016) identified the deforested area by comparing high and medium satellite imageries. The periodical change of forest cover from 1988 to 2010 in Khadimnagar National Park, Bangladesh has studied by Redowan et al. (2014). Bonilla-Bedoya et al. (2014) systematically quantified transition of forested landscape in Ecuadorian Amazon Region (EAR). Since 1987, Forest Survey of India (FSI) has been periodically observing the changes of forest cover with the help of remote sensing techniques. It was reported that forest cover of India from 1987 to 2003 has nearly stabilized and increased marginally over the years (FSI 1987, 1989, 1991, 1993, 1995, 1997, 1999, 2001, 2003). FAO estimates a yearly loss of 3.37 million hectares in India and claims that today most of the Indian forests are 'degraded forest' (Agarwal 1996). According to state forest report of India (2019), forest and tree cover of India has increased around 5188 km^2 across the country. However north-east region witnesses continuous decrease of forest cover since 2009. Saikia (2014) has studied a brief analysis of "Over-Exploitation of Forest: A case study from North-East India". This study not only highlighting the status of forest but also give emphasis on underlying factors and processes behind fragmentation under the pressure of Anthropocene.

Other than North-East India, forested landscape in Himalayan region and its surrounding foothills has experiencing disruption and different level of transformation explored by several researchers as Rawat and Kumar (2015), stated anthropogenic causes led to loss forest density in several districts of Uttarakhand. Dynamics of forest landscape of two protected areas in Himalaya Foothills was analyzed by Joshi et al. in (2014). They have explored two important protected areas in Himalayan foothills as Rajaji and Jim Corbett National Park. The used geospatial modeling tool to observe the land use dynamics from 1990 to 2005. They estimated that dense forests have high level of probability to convert into open forest. Quantitative analysis of forest cover changes in the Himalayan foothill of Dehradun forest division was attempted by Munsi et al. (2012). On the basis the previous data sets and anthropogenic disturbance Land Change Modeller (LCM) was used to predict status of forest cover in 2010 and 2015. They also demonstrated the potentiality of geospatial tool to understand the present and future scenario. Prokop and Sarkar (2012) were analysed land use transformation in the piedmont zone of Sikkim-Bhutan Himalaya over last 150 years (1930–2010). Stable and dynamic areas has identified through visual interpretation of toposheets and satellite images. The study reveal that the shifting from natural to human landscape causes enlargement of areas with monoculture cultivation of tea and paddy in between 1930–2010. Furthermore, human induced deforestation intensified the fluvial activities in piedmont. Deb et al. (2018) was addressed anthropogenic impacts on forest cover and future probability of changes in Himalayan Terai (foothills) of West Bengal. They had chosen Jaldapara

National Park and its surrounding area as an interest of study. They evaluated agricultural proliferation, human disturbances are the major cause behind the transition of LULC. The foothill landscape with rich forest resources is under threat due to population pressure, unplanned development, Illegal activities, climatic variability, socio-economic stresses and so on. Exploitation of natural resources increases level of physio-social vulnerability of the landscape. Ignoring the ecological importance, profit from commercial logging of forestry is a major issue in Duars region. This article assesses the spatio-temporal scenario of disruption took place in the forested landscape of Bengal Duars, by using satellite based remote sensing techniques and field observation. The goal of the study is to understand the changing trajectories in forest pattern and contribute relevant information to decision maker for biodiversity conservation.

23.2 Study Area: The Bengal Duars

The study area, Bengal Duars extends from 26°30′N to 27°11′20″N and 88°25′18″E to 89°52′40″E. At present, it covers a large portion of Jalpaiguri, Alipurduar, Kalimpong district and small part of Koch Bihar district (Fig. 23.1). The study area located in the foothill of Himalaya, the narrow strip of land with a width of 32.2–48.3 km and about 289.7 km in length aggregation of forest cover stretching between the river Sankosh in the east and the river Tista in the west, and Cooch Behar on the south forms the Bengal Duars or Western Duars and other parts in Assam is popularized as Assam Duars or Eastern Duars (Gruning 1911). The river Sankosh acts like a physical divider of Bengal and Assam Duars region. Bengal Duars region,

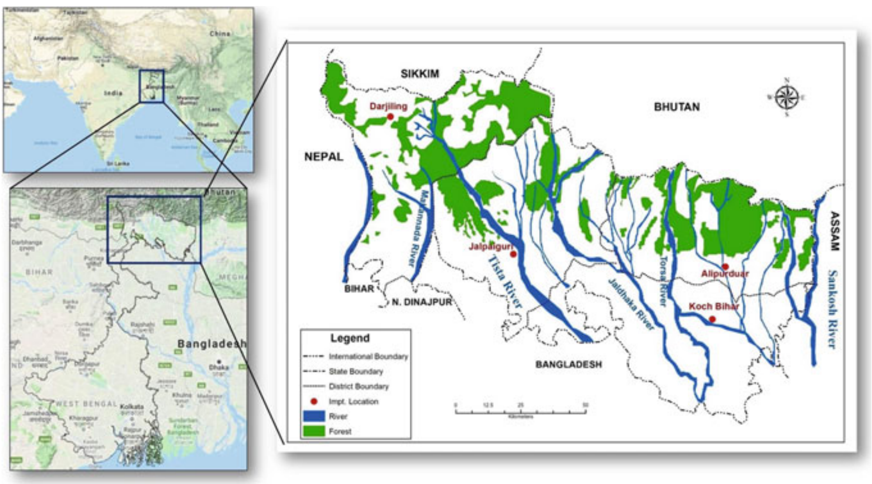

Fig. 23.1 Spatial distribution of Bengal Duars

Table 23.1 Descriptions of Landsat images used in the study

Year	Sensor	Resolution (m)	Path/Row	Date of acquisition
1990	TM5	30	138/042	14-11-1990
			139/041	23-12-1990
2010	TM5	30	138/042	05-11-2010
			139/041	30-12-2010

generally popularized for its rich forest resource and biodiversity. It covers around 36% of the total area of Bengal Duars. Physiographical, it is located in the foothill of Bhutan Himalaya which is fragile and erosion prone in nature. So, physically and socially forest plays an important role not only to maintain the sustainability of the ecosystem and climatic stability but also for the development of the local people per se.

23.3 Materials and Methods

23.3.1 Data Collection and Processing

Satellite images (Landsat TM) with 30 m resolution were downloaded from the USGS (https://earthexplorer.usgs.gov/) for the year of 1990 and 2010. The details of datasets in Table 23.1 were used in this study to detect spatiotemporal changes of forest cover from 1990 to 2010 in Bengal Duars. As spectral reflectance of vegetation varies from season to season, satellite data with similar sensors and same season are required in order to reduced spectral deviation. In the present study, the area covered by the cloud is treated as 'no-data'. Images were registered and geometrically rectified with the help of topographical sheet by Survey of India (SOI). The boundary of forest cover is obtained from toposheet and also verified with state forest map. The first order polynomial transformation has used in georectification of satellite images. After subset the boundary of forest cover on the images, a hybrid approach is applied in which NDVI transformation was performed in order to discriminate forest cover and non-forest cover area, using Erdas Imagine software (Fig. 23.2).

23.3.2 Accuracy Assessment

Accuracy is a measure of harmony between a standard one which is assumed to be a correct and classified image of unknown quality (Bhatta 2011). It is a feedback system for checking and evaluating the result. Ground information (GPS points) as well as high-resolution map were used to compare with classified maps. To evaluate

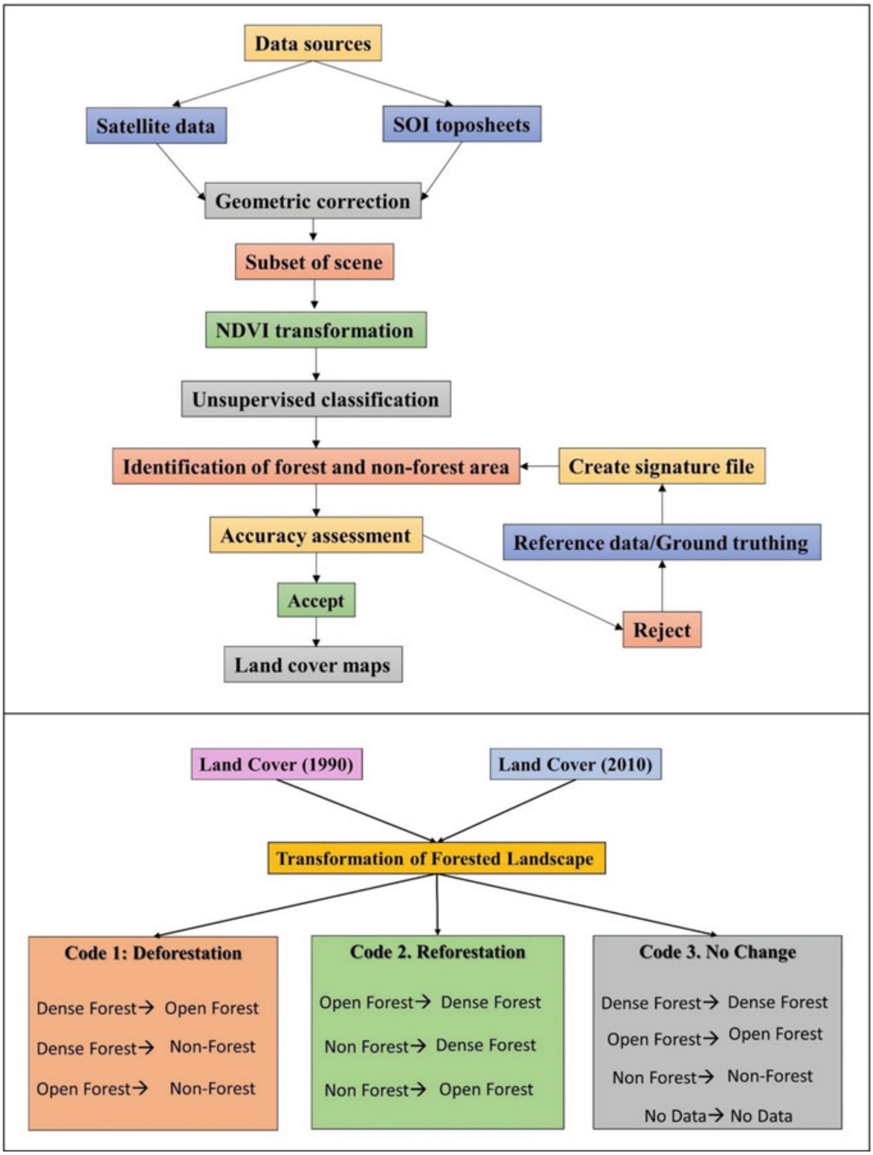

Fig. 23.2 Methodology followed in this study

the classification errors, confusion (contingency) matrix was generated. Individual land cover map was prepared for the year of 1990 and 2010 then change matrix was executed to work out the area under reforestation, deforestation and no change. The accuracy of the classified image is checked using equalized random sampling. Overall user's and producer accuracies are derived from the confusion matrix. The user's and producer accuracies are ranges from 62 to almost 92 percentages. User's accuracy of dense forest and non-forest are relatively high in both years (1990 and 2010) ranges from 84 to 92% (Tables 23.2 and 23.3). In the case of open-forest, user's accuracy is relatively less because open-forest area sometime intermixed with dense forest and non-forest cover.

Table 23.2 Contingency Matrix: Accuracy assessment for land cover classification (1990)

Year 1990		Reference image					
		Dense forest	Open forest	Non-forest	No data	Row total	User's accuracy
Classified image	Dense forest	146	24	3	0	173	84.39306358
	Open forest	13	44	7	0	64	83.01886792
	Non-forest	0	2	26	0	28	92.85714286
	No data	5	0	0	0	5	0
	Column total	164	70	36	0	256	
	Producer's accuracy	89.02	62.85	72.22	0		
	Kappa coefficient 0.81		Overall accuracy 84.37				

Table 23.3 Contingency Matrix: Accuracy assessment for land cover classification (2010)

Year 2010		Reference image					
		Dense forest	Open forest	Non-forest	No data	Row total	User's accuracy
Classified image	Dense forest	126	17	3	0	146	85.13513514
	Open forest	22	54	5	0	81	68.35443038
	Non-forest	2	0	25	0	27	92.59259259
	No data	2	0	0	0	2	0
	Column total	152	71	33	0	256	
	Producer's accuracy	82.89	76.05	75.75	0		
	Kappa coefficient 0.74		Overall accuracy 80				

23.4 Results and Discussion

Eastern Himalaya itself popularized as a biodiversity hotspot (Brooks et al. 2006). The foothill landscape of Himalaya had gone through abounded changes from pre-British to post British period and still continuing. Satellite-based observation and monitoring plays a pivotal role to provide real-time information about forest cover.

23.4.1 Spectral Characteristics of Forest Cover

The reflectance of vegetation covers in the near infrared region (0.74–1.3 µm) is high and strong absorption is found in 0.35–0.5 µm and 0.6–0.7 µm. Hence, the ratio in near-infrared and red is a good indicator of health of the vegetation. Systematic and extensive signature measurement has carried out in two different years in order to investigate the nature of change in forest cover. However, a place where forest cover is degraded, the range between NIR and RED bands also decreases. e.g. in case of Dumchi forest from 1990 to 2010, variation in spectral signature of reflects the same (Fig. 23.3). Hence remote sensing is a powerful tool for better analyzing the scope and scale of deforestation. Course to high-resolution data can provide a detail view of clear cut depletion and degradation of forest.

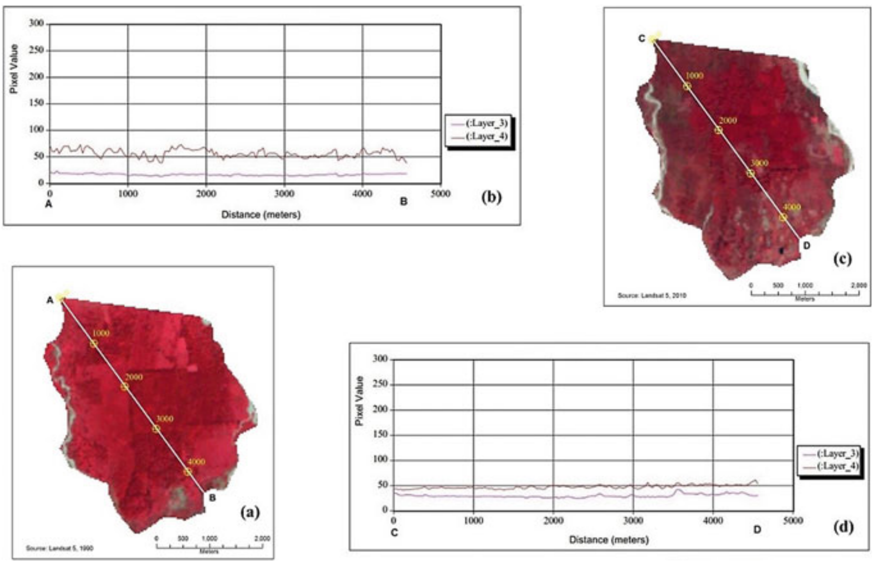

Fig. 23.3 Changing spectral characteristics in Dumchi Forest (1990–2010) **a** landsat TM satellite image 1990. **b** Spectral cross section along AB. **c** Landsat TM satellite image 2010. **d** Spectral cross-section along CD

23.4.2 Change Matrix

The NDVI is a widely used transformation for the enhancement of vegetation information (Nogi et al. 1993; Huete et al. 1997; Runnstrom 2000). The temporal dynamics of NDVI is very useful to detect changes in land cover characteristics, but season plays a vital role for spectral details. Figure 23.4a, b shows spatiotemporal variation of NDVI in 1990 and 2010. In 1990 NDVI value ranges from 0.96 to (−0.89) but in 2010 NDVI value decreases from 0.70 to (−0.80). Ground truth and high-resolution image further help in the identification of dense forest, open forest and non-forest areas. Whereas scarp lands, grasslands are included in open forest class and water bodies, bare lands, croplands in forest villages are considered as a non-forest area. After identification of individual land cover classes, the land cover map of 1990 and 2010 has prepared. Figure 23.5a, b shows the classification results of multi-temporal images for 1990 and 2010.

The change matrix represents the area in transition between two periods. In a simple way, diagonal box in the matrix represents that area remained the same class in both periods of time. On the other hand, non-diagonal values represent changes from one class to another class. Pixels that undergoes a change from non-forest to forest cover and open forest to dense forest are treated as 'reforestation'. Pixels which are changed from dense forest to open forest, dense forest to non-forest and open forest to non-forest are combined as 'deforestation'. Pixels that remained open forest and dense forest in both years are considered 'no change'. Following the above principles, a land cover change trajectories map 20 years has been prepared (Fig. 23.5c) in order to identify the spatial vulnerability of this landscape. However, the rate of deforestation is more than afforestation (Table 23.4) that's serious concerning issue in Bengal Duars landscape. Within 20 years' deforestation took place around 26% and afforestation has occurred around 15% (Table 23.5). Thus, the major transformation has taken place between dense forest to open forest cover from 1990 to 2010 (Table 23.4). The maximum transformation of deforestation has noticed in those forest cover located in Alipurduar district.

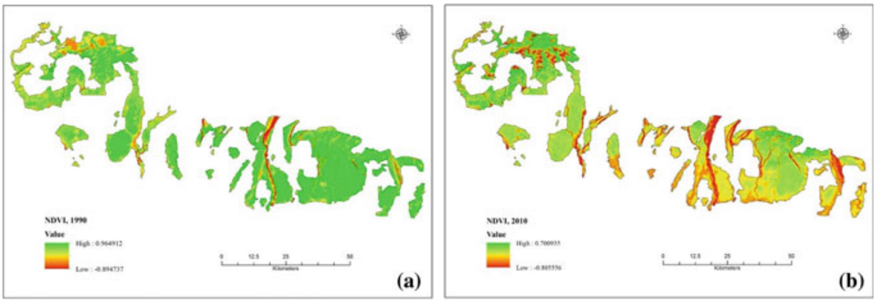

Fig. 23.4 NDVI detection of 1990 (**a**) and 2010 (**b**)

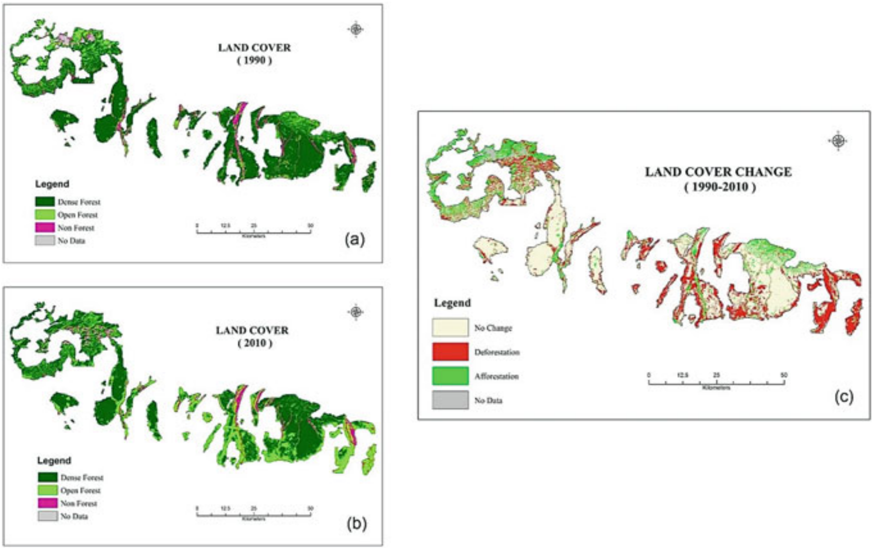

Fig. 23.5 Land cover map in 1990 (**a**), 2010 (**b**) and Change of Land Cover in between 1990–2010 (**c**)

Table 23.4 Change matrix of land Cover (1990–2010)

2010	Area (ha)				Total
1990	Dense forest	Open forest	Non-forest	No data	
Dense forest	94,368	47,754	3724	848	146,694
Open forest	20,213	16,111	3095	434	39,853
Non-forest	1930	8044	5477	21	15,472
No-data	1908	1208	618	44	3778
Total	118,419	73,117	12,914	1347	205,797

Table 23.5 Nature and rate of change of land cover (1990–2010)

Landcover status	Area (ha)	%	Rate of change
Deforestation	54,573	26.51	1.325893963
Reforestation	30,187	14.66	0.733416911
No change	116,000	56.36	2.818311248
No data	5037	2.44	

23.4.3 Recent Conversion and Disturbance in Forested Landscape

The year after 2010, forested landscape is disturbed by both natural as well as anthropogenic activities continuing to degrade the whole biodiversity and landscape towards losing its identity.As this region located in the foothills of eastern Himalaya, the sudden change of slope and notorious character of river in pediment make the region prone to flood. Mostly, each and every year due to heavy rainfall within a short span of time causes bank failure of river. The deforestation in river catchment is an additional disturbance to increase the level of vulnerability. This region always came in front of us because of human encroachment, illegal felling and poaching activities (Prokop and Sarkar 2012; Das 2012; Bhattacharyya and Padhy 2013; The Telegraph 2006, 2008, 2018). The clear cut fragmentation and transformation of some areas in Buxa Tiger Reserve has still recognised in 2019 (Fig. 23.7).

Recent disturbance in forest cover is accelerated by clear-cut felling of trees, poaching of animals, encroachment, mining and quarrying activities that further enhancing flood vulnerability and decreases vegetation stabilized gravel bars. Riverside bolder mining and deforestation caused shifting of river course from straight to meandering and braided (Prokop and Sarkar 2012) (Figs. 23.6 and 23.8a). Frequently

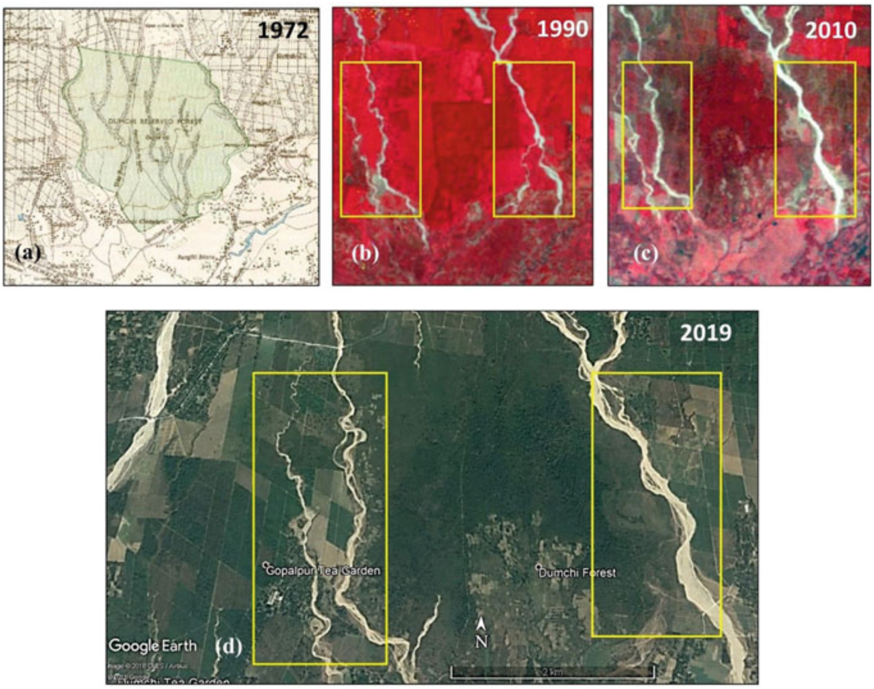

Fig. 23.6 Shifting course of river channel directed to cause by deforestation over time

reported illegal timber extraction, poaching of animal in local media and press reflects relatively poor enforcement and protection level that rises threat to the biodiversity hotspot. In north Bengal JFM is still evolving because the presence of tea garden in closeness to forest, presence of large protected area accompanist with forest villagers make things more complicated (Gupta 2005). Forest villagers are now also preferring to plant cash crops (betel nuts) around their surroundings rather than planning native trees (Fig. 23.8b).

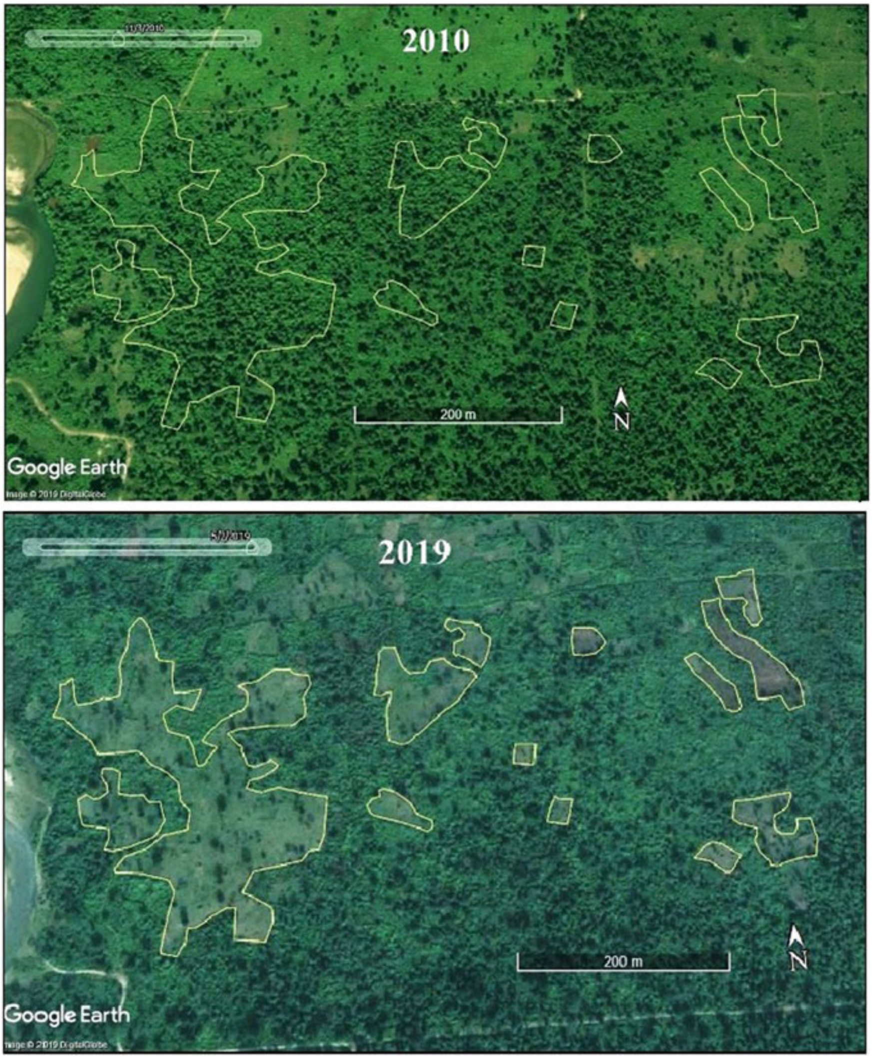

Fig. 23.7 New patches of forest fragmentation open up in 2019

Fig. 23.8 **a** River bed quarrying of boulder; **b** Betel Nut plantation at a forest village in Bengal Duars

23.5 Conclusion

The Eastern Himalaya is acknowledged as a ‘biodiversity hotspot’ and well identified as ‘eco-crisis’ zone. The major transformation has taken place during the British period, through the establishment of tea garden and expansion of settlement. The Recent phase of transformation carried out beyond shifting cultivation through illegal felling, encroachment, mining and quarrying activities that further enhancing flood vulnerability and decrease vegetation stabilized gravel bars. As well as riverside bolder mining, deforestation caused shifting of river course from straight to meandering and Braided. For conservation plans and policies, understanding of spatio-temporal disturbance is very crucial. The present study demonstrates the utilization of remote sensing data for the identification and monitoring of deforestation with proper methodology. This research can also help forest department to identify the vulnerable zones specially within inaccessible areas to restore the forest ecosystem. Further, quantification of carbon stock and estimation land surface temperature (LST) in Bengal Duars region can extend the scope of future research.

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