INDIAN JOURNAL OF GEOGRAPHY & ENVIRONMENT 19 (2022)
Indian Journal of Geography 19 (2022) 106-124
Vidyasagar University, West Bengal, India
(http://vidyasagar.ac.in/journal) **ISSN:0972-7388**

VIDYASAGAR UNIVERSITY
Dept. of Geography

Assessment of Land Use/Land Cover Changes in the Industrial Area of Bandel Thermal Power Plant of Eastern India Using Remotely Sensed Data and Statistical Analysis

Somnath Mandal[1*], Suman Paul[1]

Department of Geography, Sidho Kanho Birsha University, Purulia, WB

Article History:
Received 01 October 2021
Received in revised form 20 April 2022
Accepted 17 June 2022

ABSTRACT

The dynamic system of land use and land cover alteration is a vital condition around the world, suggesting global environmental changes, from an eco-friendly standpoint. To build a thermal power plant, a large amount of land is required. The foundation must be built in order to establish the primary station, as well as subordinate offices such as the ash pond, ash storage, debris storage, and staff convenience. As a result of the introduction of thermal power stations, changes in the surrounding LULC can be observed. This work uses a Landsat multitemporal dataset to look at the LULC situation in and around BTPS from 1989 to 2019, utilizing maximum likelihood classification techniques and multinominal logistic regression analysis to look at the effect of distance on changing phenomena (MLR). After the installation of BTPS, settlements and built-up areas with vegetation have expanded more than other features, whereas open forests and plantations have transformed more in this research region. After the establishment, a small percentage of crops and fallow land was turned both indirectly and directly. The LULC transformation depending on distance is only slightly affected by BTPS. The change of cropland to fallow land has largely been seen in response to distance. After the establishment, a large section of the land remained untouched.

Keywords:
Thermal Power Plant, LULC, distance, Multinominal logistic regression, Bandel

Introduction:

From an environmental standpoint, the dynamic system of land use/ land cover change is a critical condition around the world, suggesting global environmental changes (Showqi et al, 2014), which has been seen as the most significant local atmospheric harm caused by people (Lambin et al., 2003; Garai & Narayana, 2018). The fundamental financial exercises of individuals happen in any place or country. In this sense, the land is the dwelling place of man and the entire local area utilized for different purposes like the development of houses, horticulture, setting up of enterprises, exchange and trade, managerial exercises, transportation, setting up of different sporting offices, strict foundations, and development of supplies and burrowing of canals (Manna & Maiti, 2016). The nature or sort of landuse relies upon the reason for which the land is to be utilized. Be that as it may, it possesses changed over the energy for human intervention and requirements (Bisht & Kothyari, 2001) which wrecked the environment and bionetwork just as regular earth framework. Various sorts of global culmination identified with climate have been masterminded to forestall this issue all throughout the planet like Stockholm Conference, International Geosphere and Biosphere Program (IGBP) and International Human Dimension Program (IHDP) which primarily urged the scientist local area to lead research on it (Kumari & Sarma, 2017).

The nature and force of landuse and landcover (LULC) change has identified with the existence of development. The spatial impact of human

Correspondence to Somnath Mandal
Department of Geography, Sidho Kanho Birsha University, Purulia, WB
E-mail address : mandal.somu1@gmail.com

development remarkably affects the adjustment of the LULC throughout time. Basically, regular assets have switched up the world as LULC for continuous improvement measures that have unfavorably influenced the climate (Erener et al., 2012), and hence changing the environment and human life (Ruiz-Luna & Berlanga-Robles, 2003; Showqi et al, 2014; Kindu et al., 2016). Truly LULC change dataset assortment is additional tedious and costly, which is the reason distant detecting strategy can rapidly and precisely distinguish changes in LULC from little to huge scopes of the area (Joshi et al., 2011) and Geographical Information framework (GI Science) assists with reaching a resolution (Star et al., 1997). Not many specialists prior examined satellite information to comprehend the LULC change identification (Joshi et al., 2016), and sway on the climate (Dong et al., 1997).

Widespread land is needed to set up a thermal power plant. In request to fabricate the fundamental station, just as subordinate offices, for example, ash pond, ash storage, debris stockpiling, and staff convenience is needed to construct the foundation. Subsequently, changes in the encompassing LULC can be noticed normally as thermal power stations introduce. Notwithstanding, explicit laws have been authorized to secure the climate. As a developing nation, the energy compulsion in India is expanding day by day and the electricity enterprises are in the end expanding their creation to meet the prerequisite of energy creation through thermal power stations, where water is utilized for age of power. Fundamentally, set up away from touchy conditions and thickly populated regions. In this specific situation, Bandel Thermal Power Station (BTPS) obtained a broad region for its activity and partners, essentially a significant segment of the neglected and horticultural land.

The methodology of remotely sensed information made it conceivable to consider the spatio-temporal landcover in less time (Chatterjee et al.,1994), in a financially low cost manner with better precision (Kumari, & Sarma, 2017) in relationship with Geographical Information System (GIS) that give a reasonable stage to examination, apprise and recovery (Erener et al., 2012; Areendran et al., 2013). Space-borne satellite datasets detecting information might be especially valuable in agricultural nations where later and dependable spatial data is deficient with regards to (Dong et al., 1997). Remotely sensed dataset innovation and geographic data framework gives powerful techniques to the investigation of land use issues and devices for land use arranging and displaying. By understanding the main impetuses of land use improvement previously, dealing with the current circumstance with present-day GIS devices, and displaying the future, one can foster designs for numerous employments of normal assets and nature preservation. The adjustment of any type of land use is generally related either with the outer powers and the pressing factor developed inside the framework (Bisht & Kothyari, 2001). The assortment of distantly detected information works with the succinct investigations of Earth - framework work, designing, and change a nearby, territorial and worldwide scales after some time; such information likewise gives a significant connection between escalated, confined environmental examination and provincial, public, and global preservation and the executives of organic variety (Wilkie et al., 1996). Therefore, an endeavor was made to consider the situation with landuse/landcover around 5 Km buffer area in and around of BTPS transiently with a perspective on identifying the progressions that have occurred. The major goals of this study are to determine the changing phenomenon of LULC configuration after the BTPS was installed and in recent years. Along with this, an examination of the impact on LULC altering scenarios based on distance was conducted.

2. Materials and Method

2.1 Study area

The first thermal power project in the state of West Bengal was commissioned at Bandel under West Bengal power Development Corporation limited in 1965 with four units with total install capacity of 330 MW (82.5×4), however, generated as 240 MW (having 60 MW for each unit). In 1983, the fifth unit was commissioned with 210 MW. Thus, the total installed capacity has been turned into 450 MW. In recent times, Unit-2 and 3 have not functioning due to holding outdated machineries. Presently, the total installed capacity is 330 MW. Two 60 MW (unit-1 and 2) units and one 210 MW (unit-5) unit is running. In addition, 5 MW installed capacity has been enhanced after the compilation of renovation and modernization project of Unit-5 which was controlled by World Bank and turned the total installed capacity in recent date is 335 MW. That is why this power station has considered as study unit.

Bandel Thermal Power Plant located at Bandel near Tribeni, Hooghly (state of West Bengal) which is nearly 50 km far from Kolkata. The geographical location is

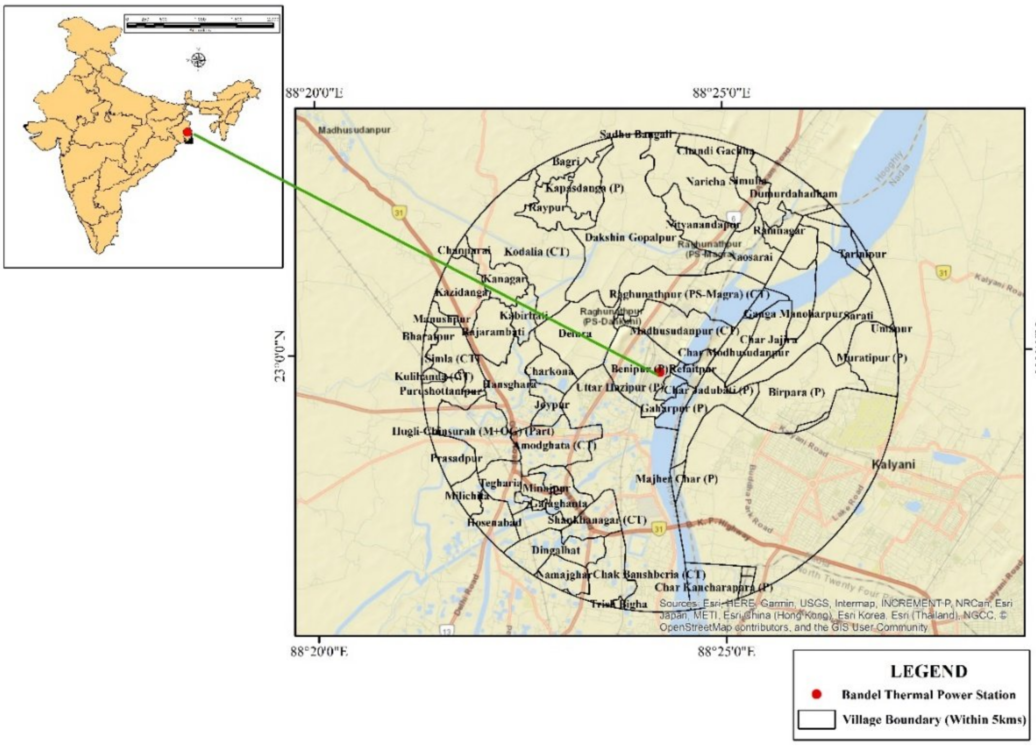

Fig. 1: Location of the Study Area

$22^0$54’N and $88^0$24’E (**Fig. 1**). It is located in the Gangetic plain of Bengal and seismic-III zone. The nearest railway station is Kuntighat on Bandel-Katwa branch line of Eastern Railway. The nearest highway is Assam road joining NH-2, about 500 metres away. Triveni Tissue Township, BTPS Township, Bansberia Municipality, Chandrahati-I and II Gram Panchayats (GPs), Kuntighat, Benipur, Raghunathpur, Triveni and Mogra is the neighbourhood urban and rural bodies of the power station. It is located just near the western bank of Hugli River. No National park or Sanctuary and forest land has been found within the radius of 10 km. Location of BTPS pursuit an appropriate site selection for study of the changing pattern of landuse/ landcover. Generally, coal-based power plants have been encompassed 3 to 4 acres of land for generation per megawatt power generation (Wadhwa, 1989). Thus, a large area is required to installed plant as well as dispose of the fly ash. The 5 km radius region around Bandel thermal power stations has been considered as the study area as this project is surrounded by several manufacturing industries, brick kilns and urban area in the present day. Therefore, the combined effect of such on the environment is present.

2.2 Data acquisition and preprocessing

Optical multispectral data derived from Landsat satellite image have used for land use and land cover classification which were obtained from the earth explorer (https://earthexplorer.usgs.gov) which are freely downloadable. **Table 1** appearance the subtleties of acquisition date, spatial resolution, path and row, and sensor types of various satellite images. The imagery from 1989 was used to analyse the LULC configuration after the establishment of BTPS, and the imagery of 2019 was used to determine the current state of the land layout. Such a dynamic phenomenon aids in comprehending the impact of effluent and pollution on the ecosystem. For instance, a contaminant turned an agricultural region into a wasteland. Several researchers have previously found similar phenomena in the vicinity of thermal power plants. In the pre-processing stage, geometrical and radiometric correction has improved representation and understanding the land design. Dark object removal techniques were used to reduce the histogram’s zero or small surface reflectance and minimum DN value. The haze was also removed.

Table 1: Details information of satellite imagery

Satellite and Sensor	Acquisition date	Spatial resolution (m)	Bands	Path/ Row	Data Source
Landsat TM 4 (LT04)	25/04/1989	30	4, 3, 2	138/44	https://earth explorer.usgs.gov
Landsat 8 OLI (LC8)	20/04/2019	30	5, 4, 3	138/44	https://earth explorer.usgs.gov

Source: Arranged by authors

After the adjustment, the individual groups are stacking and arranged FCC pictures on the ERDAS 2014 stage. The ground truth information has been determined in the period of May 2019 with the assistance of the Geographical Positioning System (GPS). This information has been utilized for the characterization and by and large exactness appraisal of the arranged pictures. Utilizing multi-dated satellite dataset collections of BTPS region, different digital image processing techniques were customary to get ready LULC guides of the examination region.

2.3 Image processing

Subsequent to stacking and cutting of pictures further proceed for LULC order by the supervised classification techniques dependent on Maximum likelihood method. At last the landuse/ landcover of the study area have been classified into nine classes. After the classification done, change location has performed to comprehend the change situation of various land highlights. Table 2 shows the detailed class portrayal in beneath.

Landsat MSS and TM data were imported in ERDAS Imagine and used layer stack option under the Spectral tool box to create false colour composite images (FCC). Necessary various types of errors in satellite images have been fixed by the radiometric tool box. All the images were clipped for extracting study area by 5 km buffer area from the selected thermal power plant as Area of Interest (AOI) and then proceed for image classification. Image classification refers the process of categorizing all pixels in an image or raw remotely sensed satellite data to obtain a given set of labels or land cover themes (Lillesand et al., 2015) which helps to transfer the pixel value into a particular class according to their characteristics. Image has been classified by supervised classification method with the help of maximum likelihood algorithm (MLC) technique which is based on Bayes theorem. A discriminant function is used to assign pixels to the class with the highest likelihood. The function's primary inputs are the class mean vector and covariance matrix, which may be calculated from a class's training pixels. Each class in ML classification is contained within a multispectral space region in which its discriminant function is greater than that of all other classes. Decision boundary separates these class regions. With good agreement with the reference map, ML classifies the classes that exist in the research area. One of the primary variables that lead to ML's

Table 2: Details information of LULC classes in the study area

LULC class	Description
Cropland	Paddy fields, harvested cropland in the agriculture fields
Plantation	Standalone trees
Open forest	Canopy density more than 10 per cent but less than 40 per cent
Settlement	Buildings, roads, and different concretized surface
Homestead plantation	Homestead plantation that mainly indicates settlement with trees/ vegetation which is mainly planted by human
Fallow	Agricultural fallow land, open and vacant land
Water bodies	River, ponds, and wetland
Char	Deposition in mid channel
Brick kiln	Brick kilns

Source: Arranged by authors

high classification accuracy is the separation between the mean of the classes in the decision space (Ahmad & Quegan, 2012) All the satellite data were classified on the basis of the specific Digital Number (DN) values in different classes with the help of ground truth points. Doubtful areas were verified by collected training sample points and Google Earth images. Different types of land have been delineated according to land characteristics within the study area from satellite images like: fallow land, vegetation, settlement, water bodies etc. Some of the pixel value have been visually interpreted due to presence of mixed pixels (like: built up area) because of low spatial resolution of satellite images (Jensen, 1996). The visually interpretation is mainly depending on the differences in tone, texture, shape, size and pattern of the features of satellite images (Singh & Dubey, 2012).

2.4 Accuracy assessment

Accuracy assessment assists with understanding the adequacy of order of various pixels into LULC classes by utilizing confusion matrix ' and 'kappa coefficient' (Lea & Curtis, 2010). In addition, 90 points have created in the arranged picture and count with the satellite symbolism and Google earth picture for precision appraisal (**Fig. 2**). The relations between ground truth information and comparing grouped information have been checked through a blunder grid. In the error matrix, the inclining shows the remedied characterized pixels. In this investigation, the precision has evaluated through commission and exclusion mistake and kappa measurements which is an attentive multivariate examination. The overall accuracy, user accuracy, producer accuracy and kappa co-efficient has calculated by the following equation (Congalton, 1991):

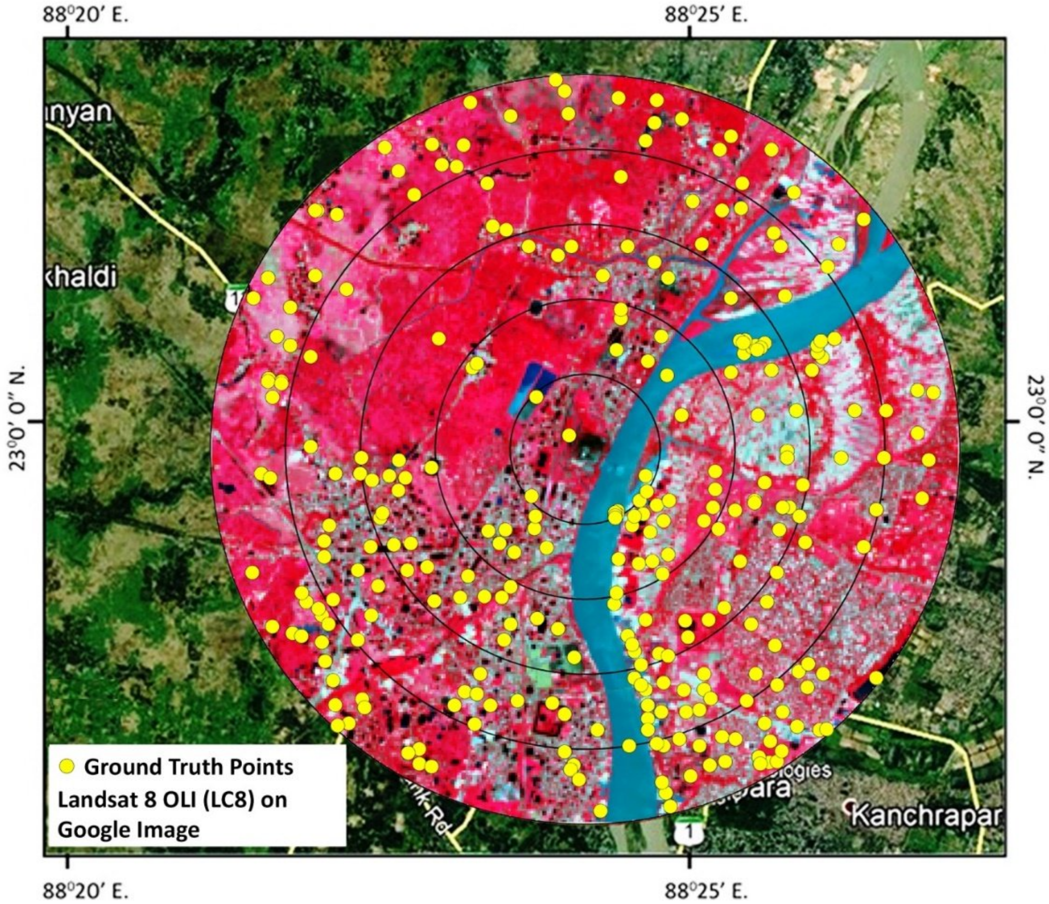

Fig. 2: Ground truth points collected from Google Earth Engine merging with Landsat Image for accuracy assessment

Overall Accuracy =

$$\frac{\text{Total number of correctly classified pixels (diagonal)}}{\text{Total number of reference pixels}} \times 100$$

Users Accuracy =

$$\frac{\text{Number of Correctly classified pixel in each category}}{\text{Total number of classified pixel in that category (the row total)}} \times 100$$

Producer Accuracy =

$$\frac{\text{Number of Correctly classified pixel in each category}}{\text{Total number of reference pixel in that category (the column total)}} \times 100$$

Kappa Coefficient (K) =

$$\frac{(\text{Total Sample} \times \text{Total corrected Sample}) - \sum(\text{Column total} \times \text{Row Total})}{\text{Total Sample}^2 - \sum(\text{Column total} \times \text{Row total})}$$

The result of kappa values lies between 0 and 1. The value 1 implies the prefect or strong agreement and less than 1 reflects the less perfect agreement.

2.5 Effect of distance on LULC transformation

Categorical (nominal) variables are the result of the LULC transformation. The LULC changes were treated as dependent variables, whereas the distance from the BTPS was treated as an independent variable. Distance variable informed the direct and indirect impact of BTPS; primarily, the changing scenario of the LULC surrounding thermal power plants is purely dependent on emission and effluent and the growth and development of operation-related activities. As a result, the distance variable provided a straightforward explanation for such a case. Researchers have already discovered the rationale for LULC transition around thermal power plants using the distance variable. They stated that the most significant alterations occurred near the operational unit and the wind's downward direction (Kumari & Sarma, 2017). In this case, multinomial logistic regression analysis (MLR) was used to figure out how distance affects LULC changes. MLR is a technique for predicting the likelihood or explicit positioning of a categorized membership in the case of dependent variables based on multiple individual variables. It is similar to binary logistic regression in that it allows for more than two categories of dependent variables. It's a particularly appealing regression analysis for categorical variables because it doesn't require any assumption like normality, linearity or homoscedasticity. Discriminant function analysis is a more powerful alternative to MLR, but it must meet the aforementioned assumptions before it can be used (Starkweather & Moske, 2011).

Positive estimate values represented positive changes in land characteristics as distance increased, whereas negative values represented changes in land

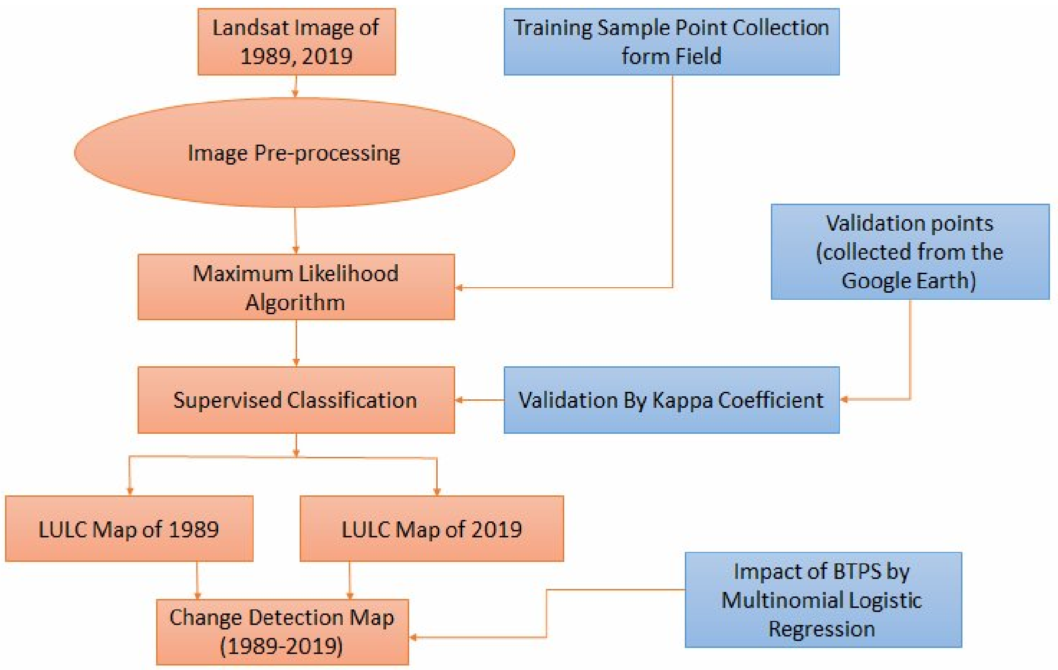

Fig. 3: Flow chart of the analysis

features close to BTPS. If the odds ratio is greater than one, there has been more land transformation than there have been no changes, and vice versa. As a reference, the model depicts the changing phenomenon, whether it has transformed or not, as a function of increasing distance. Fig. 3 shows the flow of the whole analysis.

3. Results and Discussion

3.1 LULC in and around BTPS and its changing nature

Nine substantial landuse/landcover classes – cropland land, fallow, homestead plantation, plantation, settlement, open forest, water bodies, char and brick kiln - were documented in the study region. The land use/land cover guides of the research area for two diverse time-frames are presented in Fig 4a & 4b. Spatial annexation and class-wise measurements of nine land use/land cover classes have been displayed in Table 3. Rate of change of different LULC classes are additionally displayed in Table 3. Table 3 portrays the magnitude of alterations in various landuse/ landcover classes in 30 year time frame from 1989 to 2019. The accuracy and Kappa analysis of the LULC classes during the time frame is displayed in Table 5. Table 6 also gives the landuse transformation complexes for the examination time frame from the year 1989 to 2019.

3.2 Areal extent of LULC during 1989-2019

Areal arrangements of various LULC classes during 1989-2019 have been presented in Table 3 and Fig. 4a & 4b. In the year 1989, the utmost land surface covered by cropland, i.e. 2042.08 hectare which establish close around 26 per cent of all out land while open forest covered by 1690.86 hectare region, close about 21.57 percent of all out land. The plantation has covered 1228.01 hectare region and establishes about 15.66 percent of complete land. The fallow land covered 911.53 hectare region and covered about 11.63 percent of all out land. Below 10 per cent of land surface have covered by the settlement (9.58 per cent) and water bodies (8.95 per cent). The settlement covered 751.19 hectares region and water bodies covered 701.92 hectare region. Insignificant land shrouded has seen on account of brick kiln and char. brick kiln and char covered about 84.23 and 1.89 hectare region respectively. The homestead plantation or settlement with vegetation has covered 428.76 hectares are which establish about 5.47 per cent of the all-out land surface. As a matter of fact the examination region situated at the flood plain of Hooghly River, reason the yield is most extreme. The regular shifting of the river also generated lots of ponds in this area.

In the 2019, cropland has covered greatest segment of land surface, i.e. 2009.07 hectares, about 25.62 per cent of complete land with negative growth rate of 1.62. The open forest has covered 1163.65 hectares, close about 14.84 per cent of absolute land with 31.18 per cent of negative growth though the plantations covered 864.66 hectares, and close about establish 11.03 per cent (-29.59 per cent). Tremendous turn of events and movement has demanded to develop settlement during this study period, 1071.38 and

Table 3: Areal distribution of LULC classes in the BTPS area during 1989 – 2019

LULC class	1989 Area (in hec.)	1989 Area (in %)	2019 Area (in hec.)	2019 Area (in %)	Growth rate (in %)
Cropland	2042.08	26.05	2009.07	25.62	-1.62
Fallow Land	911.53	11.63	885.82	11.30	-2.82
Homestead Plantation	428.76	5.47	1012.06	12.91	136.04
Plantation	1228.01	15.66	864.66	11.03	-29.59
Settlement	751.19	9.58	1071.38	13.68	42.62
Open forest	1690.86	21.57	1163.65	14.84	-31.18
Water bodies	701.92	8.95	736.78	9.40	4.97
Char	1.89	0.02	5.04	0.06	166.67
Brick kiln	84.23	1.07	92.01	1.17	9.24
Total	7840.49	100.00	7840.49	100.00	

Source: Computed by authors

1012.06 hectares region covered by the settlement and homestead plantation respectively. This gives a clear indication of anthropogenic impact having a positive growth of 42.62 per cent and 136.04 per cent for settlement and homestead plantation separately. Both establish close about 13.68 and 12.91 per cent of land surface individually. The fallow land covered 885.82 hectares region, comprise close about 11.30 per cent of all out land with a negative growth of -2.82 per cent. The shifting of river increases of width of channel which results the increase of areal coverage by water bodies in the study region. The water bodies covered 736.78 hectares region which comprises 9.40 per cent which nearly 5 per cent growth during last 30 years. The brick kiln and char land contains 92.01 and 5.04 hectares region separately. The pith of land use by distance examination offers a straightforward image of how various types of land use have been found at different buffer distance from the BTPS during 1989 to 2019. Table 4 shows the buffer wise areal coverage of various LULC classes. Buffer–wise analysis of LULC change gives us a clear image of changing pattern of land utilization and the impact of BTPS on surroundings. Five buffer zones consisting of 1 km each have been delineated for this study.

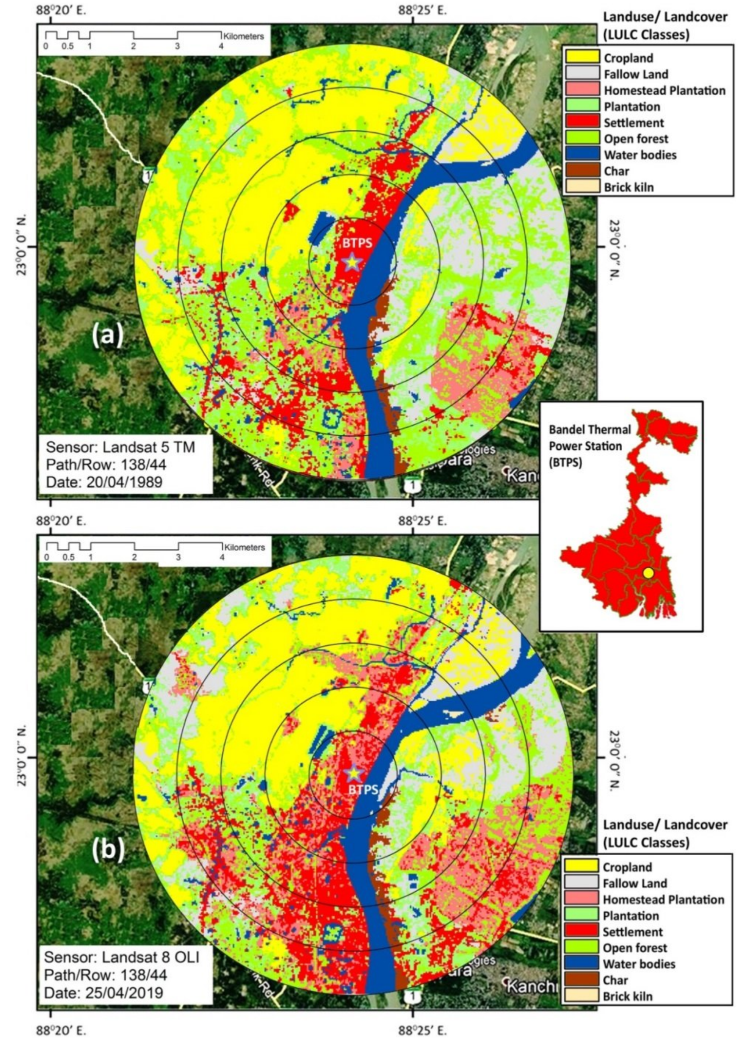

Fig. 4: The maps depicting the LULC changes in the BTPS area (within 5km buffer) during the study period from 1989 to 2019. (a) LULC cover extents in 1989 (b) LULC cover extents in 2019

Table 4: Areal distribution of LULC classes in the Five Buffer areas of BTPS during 1989 – 2019

Class	Distance (km)	Area (in hec.)		Total area (in hec.)		Change (%)	Change (%)
		1989	2019	1989	2019	1989-2019	1989-2019
Cropland	1.0	7.3	7.88	2042.08	2009.07	7.99	-1.62
	2.0	270.58	314.95			16.4	
	3.0	369.14	474.11			28.44	
	4.0	578.48	594.26			2.73	
	5.0	816.58	617.88			-24.33	
Fallow land	1.0	9.77	16.57	911.53	885.82	69.57	-2.82
	2.0	105.43	72.68			-31.06	
	3.0	190.26	116.92			-38.55	
	4.0	262.39	242.19			-7.7	
	5.0	343.68	437.46			27.29	
Homestead Plantation	1.0	12.28	72.08	428.76	1012.06	486.95	136.04
	2.0	52.17	106.77			104.66	
	3.0	94.17	247.55			162.88	
	4.0	139.08	313.35			125.29	
	5.0	131.05	272.31			107.79	
Plantation	1.0	28.98	11.68	1228.01	864.66	-59.69	-29.59
	2.0	111.45	85.58			-23.21	
	3.0	222.97	144.45			-35.22	
	4.0	387.6	284.05			-26.72	
	5.0	477.02	338.9			-28.95	
Settlement	1.0	126.65	105.2	751.19	1071.38	-16.94	42.62
	2.0	102.47	125.46			22.44	
	3.0	159.34	227.3			42.65	
	4.0	208.31	300.64			44.32	
	5.0	154.42	312.77			102.54	
Open forest	1.0	31.33	17.73	1690.86	1163.65	-43.4	-31.18
	2.0	150.14	82.63			-44.96	
	3.0	388.96	207.2			-46.73	
	4.0	435.47	335.44			-22.97	
	5.0	684.97	520.65			-23.99	
Water bodies	1.0	96.53	83.19	701.92	736.78	-13.82	4.97
	2.0	134.78	136.03			0.92	
	3.0	139.67	166.64			19.31	
	4.0	158.12	161.33			2.03	
	5.0	172.82	189.6			9.71	
Brick kiln	1.0	3.16	3.28	84.23	92.01	3.93	9.23
	2.0	34.61	29.96			-13.45	
	3.0	13.24	19.54			47.58	
	4.0	24.96	28.48			14.1	
	5.0	8.26	10.75			30.1	
Char	1.0	0	0.51	1.89	5.04		166.67
	2.0	0	0.03				
	3.0	0	4.5				
	4.0	1.89	0				
	5.0	0	0				

Source: Computed by authors

Figure 5 clearly stated the nature of growth of each LULC class during the study period as a whole. From Table 4, it is clear that, the cropland has covered by 7.30, 270.58, 369.14, 578.48 and 816.58 hectares within 0-1, 1-2, 2-3, 3-4 and 4-5 km buffer region during 1989 whereas the results depicted 7.88, 314.95, 474.11, 594.26 and 617.88 hectares separately in 2019. A clear higher degree of change for cropland

land has been estimated in 2nd and 3rd buffer zones depicting an areal alteration took place in eastern portion of BTPS. On account of open forest, 31.33, 150.14, 388.96, 435.47, and 684.97 hectares region found inside 0-1, 1-2, 2-3, 3-4 and 4-5 km buffer region separately in 1989 while it turn to 26.01, 82.63, 207.20, 327.16 and 520.65 hectares individually in 2019. In the 2nd, 3rd and 4th buffer region showing a negative change in the western portion of BTPS which is basically happened due to anthropogenic activities. In the year 1989, plantation has covered by 28.98, 111.45, 222.97, and 387.60, 477.02 hectares in the buffer of 0-1, 1-2, 2-3, 3-4 and 4-5 km and change into 11.68, 85.58, 144.45, 284.05 and 338.90 hectares individually in 2019.

zones clearly showing the negative growth during study period though 4th and 5th buffer area have a clear positive growth which specify that the, land utilization is not regulated as the distance increases from Bandel Thermal Power Station. In the study region water bodies is a great resource as BTPS demand a huge amount of water for run the plant. In the year 1989, water bodies covered 100.53, 132.78, 139.67 and 170.82 hectares within 5 buffers while it changed into 100.01, 136.03, 156.82, 161.33 and 182.60 hectares separately in 2019. Except in the extreme buffer (i.e. 4-5 km buffer region) no such deviation have been witnessed which is an exhibition of balanced development for the region. For settlement in study region, 126.65, 102.47, 159.34, 208.31 and 154.42

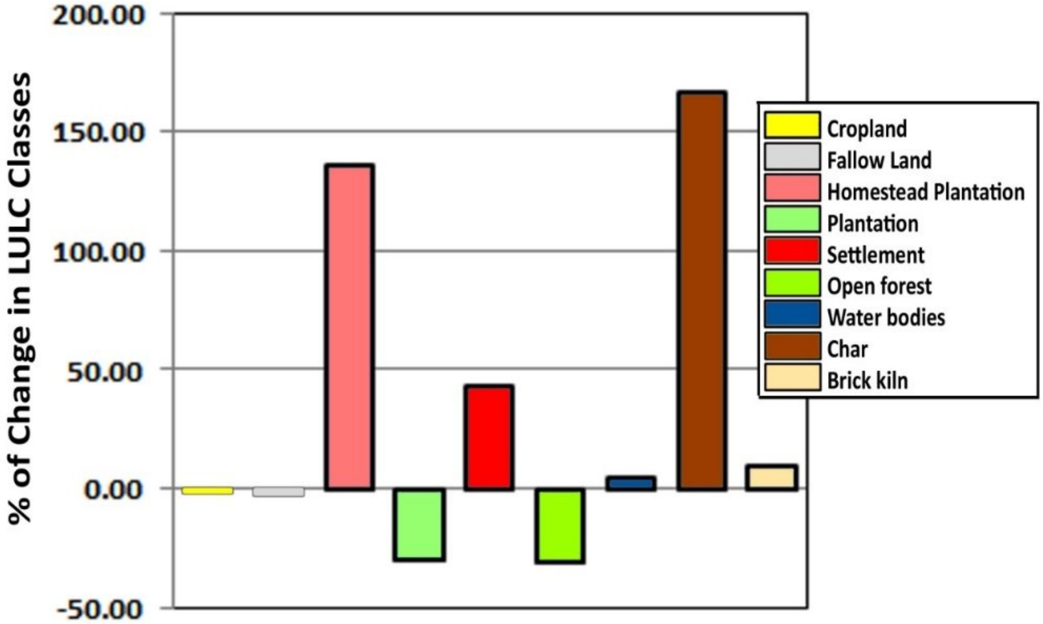

Fig. 5: Change in land use/ land cover classes of the BTPS area (change expressed in %)

A sharp change has been prominent in each buffer during the study period. Besides, in the underlying year (i.e. 1989), homestead plantation covered by 12.28, 52.17, 94.17, 139.08 and 131.05 hectares five buffers individually and transformed into 72.08, 106.77, 247.55, 313.35 and 272.31 hectares separately in 2019. This huge change (136.04 per cent as a whole) is designates the growth of built-up area and the surroundings of their place of living.

Fallow land covered by 9.77, 105.43, 190.26, 262.39 and 343.68 hectares region respectively for five buffer region and altered as 16.57, 72.68, 116.92, 242.19 and 437.46 hectares in 2019. When 2nd and 3rd buffer

hectares areal coverage has been found in the 5 buffers respectively and changed into 105.20, 125.46, 227.30, 300.64 and 312.77 hectares individually in 2019.

Except the first buffer, rest four exhibits a genuine positive change clearly posing the fact of concentration of population in the study region due to the impact of industrial activity. In case of brick kiln, 3.16, 34.61, 13.24, 24.96 and 8.26 hectares within different buffer distance respectively and turned to 3.28, 29.96, 19.54, 28.48 and 10.75 hectares respectively in 2019 which does not make any great impact in the study region. The char land has observed only within 3-4 km buffer area in 1989 and covered by 1.89 hectares. But during

1989-2019 a change of 0.51, 0.03 and 4.50 hectares within 0-1, 1-2, and 2-3 km buffer area has been found as a result of river dynamics.

3.3 Accuracy Assessment

Statistically evaluating for accuracy assessment involves the assortment of some in situ information or deduced information about certain pieces of the landscape, which can then measure up to the with the evaluated LULC map in remote sensing platform. The error matrix in the Table 5 demonstrates a general precision of 83.92 per cent in year 2019. In any case, users' accuracy found from 73.33 per cent (open forest) to 100 per cent (char) and producers" precision went from found from 61.36 per cent (fallow land) to 100 per cent (char) in the year 2019. This error matrix depends on training dataset. On the off chance that the outcomes are acceptable it shows that the preparation tests are frightfully distinguishable and the characterization functions admirably in the preparation regions. Here the overall accuracy found as 83.92 per cent for this analysis.

Discrete multivariate methods have been utilized to assess the accuracy of remotely sensed data derived outcomes and error matrix by several researchers since 1983 (Congalton, 1991). These strategies are well enough as the remotely sensed statistics are discrete instead of continuous and are likewise binomially or multinomially in nature. Kappa investigation is a discrete multivariate method for exactness evaluation. Kappa coefficient reflects a discrete multivariate measurement that is the proportion of arrangement of accuracy. The Kappa measurement of the year 2019 shows the most extreme understanding of accuracy with 0.82 (Table 5).

3.4 LULC changes during 1989-2019

Overall areal change in land use/ landcover (LULC) pattern has been shown in Table 6 and change matrix in Tables 7 which determine the nature and amount of change of area from one LULC class to another. During 1989-2019 the settlement and homestead plantation has increased huge i.e. 321.45 and 583.30 hectares respectively. Moreover, areal coverage of water bodies, char and brick kiln has also increased significantly, by 34.85, 3.15 and 7.78 hectares. On the other hand, maximum open forest has decreased by 527.21 hectares whereas plantation has decreased by 363.35 hectares, fallow by 25.71 hectares and cropland by 33.01 hectares (Tables 6). Therefore, brick kiln, homestead plantation, settlement, water bodies and char has increased by 9.23, 136.04, 42.62, 4.97 and 166.67 per cent respectively. Meanwhile, cropland, fallow land, plantation and open forest have decreased by 1.62, 2.82, 29.59 and 31.18 per cent respectively (Tables 4).

The buffer wise changes have cleared the image all the more obviously. The greatest areal inclusion of cropland has expanded by 28.44 per cent inside 2-3 km buffer distance and most extreme decreased has found inside 4-5 km buffer distance that is 24.33 per cent. Moreover, it has expanded in remaining buffer distance. The most extreme reductions inside 4-5 km buffer distance mirror the decline picture. Fallow land inclusion has expanded inside 0-1 and 4-5 km buffer

Table 5: Classification Accuracy Assessment (Error Matrix) and Kappa coefficient

Landuse/ Landcover types	Cropland	Fallow Land	Homestead Plantation	Plantation	Settlement	Open forest	Water bodies	Brick kiln	Char	Total User	Users' accuracy	Producers' accuracy	overall accuracy	Kappa coefficient
Cropland	25	2	0	0	0	2	1	0	0	*30*	83.33	83.33	83.92	0.82
Fallow Land	1	27	0	1	0	0	1	0	0	*30*	90.00	61.36		
Homestead Plantation	0	5	24	0	0	0	1	0	0	*30*	80.00	85.71		
Plantation	3	3	0	24	0	0	0	0	0	*30*	80.00	88.89		
Settlement	0	2	1	0	25	1	0	1	0	*30*	83.33	89.29		
Open forest	0	4	3	1	0	22	0	0	0	*30*	73.33	88.00		
Water bodies	1	1	0	1	2	0	25	0	0	*30*	83.33	83.33		
Brick kiln	0	0	0	0	1	0	2	27	0	*30*	90.00	96.43		
Char	0	0	0	0	0	0	0	0	15	*15*	100.00	100.00		
Total producer	*30*	*44*	*28*	*27*	*28*	*25*	*30*	*28*	*15*	*255*				

Source: Computed by authors

Table 6: Areal deviation of LULC classes during 1989-2019 in hectares

Class	Total area (in hec.)		Deviation (in hec.)
	1989	2019	
Cropland	2042.08	2009.07	-33.01
Fallow land	911.53	885.82	-25.71
Homestead plantation	428.76	1012.06	583.3
Plantation	1228.01	864.66	-363.35
Settlement	751.19	1071.38	320.19
Shrub	1690.86	1163.65	-527.21
Water bodies	701.92	736.78	34.85
Brick kiln	84.23	92.01	7.78
Char	1.89	5.04	3.15

Source: Computed by authors

distance, by 69.57 and 27.29 per cent separately while it has diminished within remaining buffer distance, inside 1-2, 2-3, and 3-4 by 31.06, 38.55 and 7.70 percent individually, that is the reason complete figure has depicted negative development. In addition, homestead plantation has expanded inside all support distance, greatest expanded has found inside 0-1 km buffer distance. Be that as it may, the plantation has diminished inside all buffer distance and greatest has found inside 0-1 km support distance for example 59.69 percent. Moreover, settlement has expanded inside all buffer regions with the exception of 0-1 km buffer region for example 16.94 percent as it were. The most elevated expanded has found inside 4-5 km buffer region for example 102.54 per cent. That declining pattern of open forest resulted diminishing scenario inside all buffer regions. Close around 45 per cent and more areal inclusion has diminished inside 1-2 (44.96 per cent) and 2-3 (46.73 per cent) km buffer region. The least decrease has found inside 0-1 km buffer region for example 16.98 per cent. Then again, the water bodies have expanded inside all buffer distance with the exception of 0-1 km because of predominantly the dynamicity of river and change of land into lakes for water system source. The most elevated augmentation has occurred inside 2-3 km support region for example 12.28 per cent. The char area has expanded mostly inside 2-3 km buffer region and brick kiln has expanded because of the expansion of associate, greatest augmentation has occurred inside 2-3 km buffer distance for example 47.58 per cent and decay inside 1-2 km buffer region for example 13.45 per cent (Tables 4).

The augmentation and decrease of various land includes exclusively relies upon the transferred and transformed situation. Table **7** showed the overall change matrix in a network structure and Fig. 6 shows the spatial transformation of LULC features. The massive cropland region has held or unaltered 1680.55 hectares, in any case, 189.18, 20.61, 106.38, 11.70 and 33.03 hectares region have moved into fallow land, homestead plantation, plantation, settlement and water bodies individually. Additionally, 1.26, 119.34, 115.22, 151.39 and 29.70 hectares have changed from char, fallow, plantation, open forest and water bodies individually into cropland during 1989-2019.

Moreover, the fallow land has held or unaltered 329.62 hectares region, be that as it may, 2.34, 119.34, 60.52, 134.64, 59.40, 143.93 and 61.74 hectares region have moved into char, cropland, homestead plantation, plantation, settlement, open forest and water bodies respectively. Also, 0.63, 189.18, 139.47, 151.39 and 75.53 hectares have changed from char, cropland, plantation, open forest and water bodies respectively into fallow during 1989-2019. In the meantime, homestead plantation has held 204.28 hectares region; notwithstanding, greatest region moved into settlement for example 157.78 hectares and 66.44 hectares into water bodies. One next to the other, 20.61, 60.52, 132.30, 316.32, 271.27 and 6.76 hectares have changed from cropland, fallow, plantation, settlement, open forest and water bodies respectively into homestead plantation. Besides, the plantation has unaltered 286.30 hectares, be that as it may, most extreme moved into open forest for example 265.88 hectares and 1.62, 115.22, 139.47, 132.30, 227.99 and 54.38 hectares region have moved into char, cropland, fallow, homestead plantation, settlement and water bodies respectively. In the

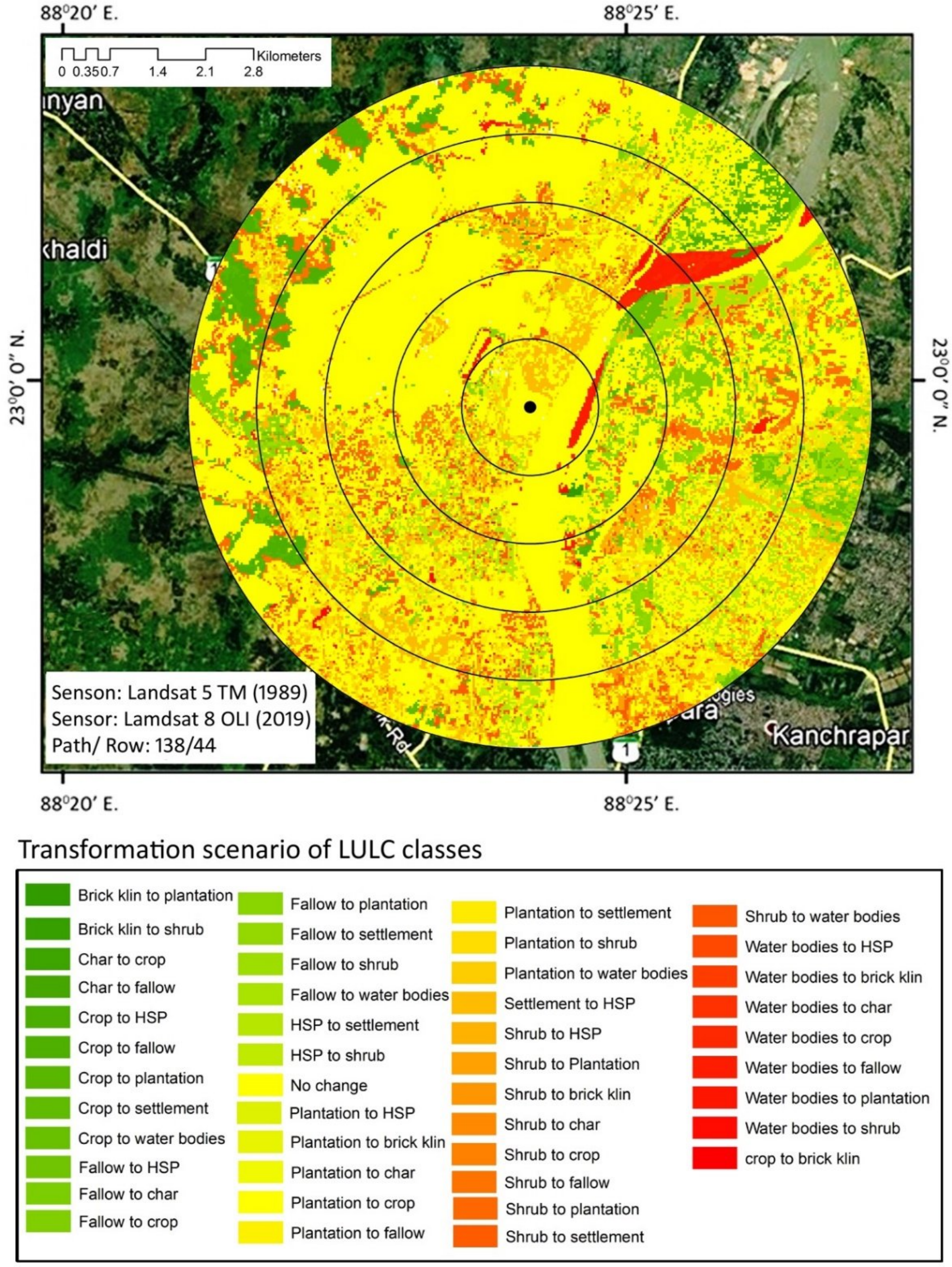

Fig. 6: Transformation scenario of LULC classes during 1989 – 2019 in and around BTPS

Table 7: Change matrix of LULC classes during 1989 – 2019 in hectares

	Cropland	Fallow	Homestead Plantation	Plantation	Settlement	Open forest	Water bodies	Brick kiln	Char
Cropland	1680.55	189.18	20.61	106.38	11.7	0.00	33.03	0.63	0.00
Fallow Land	119.34	329.62	60.52	134.64	59.4	143.93	61.74	0.00	2.34
Homestead Plantation	0.00	0.00	204.28	0.00	157.78	66.44	0.27	0.00	0.00
Plantation	115.22	139.47	132.3	286.3	227.99	265.88	54.38	4.86	1.62
Settlement	0.00	0.00	316.32	0.00	434.87	0.00	0.00	0.00	0.00
Open forest	63	151.39	271.27	313.38	179.65	671.6	32.85	7.47	0.54
Water bodies	29.7	75.53	6.76	20.26	0.00	14.44	554.51	0.18	0.54
Brick kiln	0.00	0.00	0.00	3.99	0.00	1.36	0.00	78.87	0.00
Char	1.26	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: Computed by authors

interim, 3.99, 106.38, 134.64, 313.08 and 20.26 hectares of brick kiln, croplands, fallow, open forest and water bodies have transformed into plantation. Also, just 434.87 hectares region have unaltered on account of settlement, be that as it may, 316.32 hectares region have moved into homestead plantation and 11.70, 59.40, 157.78, 227.99 and 179.65 hectares cropland, fallow land, homestead plantation, plantation, and open forest have transformed into settlement. The open forest has held 671.60 hectares of region. Nonetheless, greatest area of its alteration into brick kiln, char, cropland, fallow, homestead plantation, plantation, settlement and water bodies by 7.47, 0.54, 63, 151.39, 271.27, 313.38 and 32.85 hectares respectively and 143.93, 66.44, 265.88 and 14.44 hectares area of fallow, homestead plantation, plantation and water bodies have transformed into open forest. Additionally, water bodies have held 554.51 hectares region, nonetheless, its region has moved into brick kiln, char, cropland, fallow, homestead plantation, plantation, and open forest by 0.18, 0.54, 29.70, 75.53, 6.76, 20.26 and 14.44 hectares individually. In the meantime, 33.03, 61.74, 0.27, 54.38, and 32.85 hectares space of cropland, fallow, homestead plantation, plantation and open forest respectively have changed into water bodies. Little space of brick kiln has moved plantation and open forest, by 3.99 and 1.36 hectares individually. In any case, other land features have changed into brick kiln implies its encompassing space has changed not the fundamental creation unit. 0.63, 4.86, 7.47 and 0.18 hectares space of cropland, plantation, and open forest and water bodies transformed into brick kiln and hold 78.87 hectares region. Then again, char area has moved into the harvest by 1.26 per cent because of the good condition for agriculture and into decrepit by 0.63 hectares. Besides, 2.34 hectares of fallow land, 1.62 hectares of plantation and 0.54 hectares of open forest and water bodies have changed into char land because of the river avulsion.

Buffer wise land transferred and transformation situation obviously depicted the spatial changing phenomena of LULC in details (**see *Appendix-1***). Most extreme brick kiln area has moved into plantation inside 1-2 km by 3.45 hectares while 0.09 and 0.45 hectares inside 2-3 and 3-4 km buffer distance separately and into open forest by 1 hectare inside same support distance though 0.18 hectares inside 2-3 and 3-4 km buffer region. Char area has moved into harvest and decrepit inside 3-4 km support region by 1.26 and 0.63 hectares individually. Just cropland area has moved into brick kiln inside 2-3km buffer region by 0.63 hectares. Greatest changes from cropland to fallow land has occurred inside 4-5 km cushion region by 142.85 hectares though 2.02, 3.74 and 40.56 hectares have moved inside 1-2, 2-3 and 3-4 km buffer distance individually. The most noteworthy yield to homestead plantation occurred in same buffer distance and 0.36, 0.54, 4.87 and 3.91 hectare have up to 4 km moved buffer distance individually. Besides, the most noteworthy cropland to plantation and settlement additionally has occurred inside 4-5 km buffer distance for example 82.12 and 8.16 hectares separately and insignificant changes occurred inside 0-3 km buffer distance. The most noteworthy changes from cropland to water bodies have occurred inside 2-3 km buffer distance by 18.64 hectares though 7.91, 0.18 and 6.30

hectares inside 1-2, 3-4 and 4-5 km buffer distance separately. Just changes from fallow land to char land have occurred inside 2-3 km cushion distance by 2.34 hectares. The most extreme changes from fallow land to the cropland has occurred inside 4-5 km buffer distance by 32.4 hectares, though 14.16, 44.9, 27.5 hectares inside 1-2, 2-3 and 3-4 km buffer distance separately. Likewise most extreme fallow land region has moved into homestead plantation inside 4-5 km cushion distance by 37.63 percent while 0.54, 3.51, 18.84 hectares inside 0-1, 2-3 and 3-4 km support distance individually. Then again, the most extreme changes into plantation has recorded inside 3-4 km buffer distance by 46.38 hectares while 2.32, 31.38, 28.50, 26.07 hectares inside 0-1, 1-2, 2-3, and 4-5 km cradle distance individually, inside a similar buffer region fallow land has moved into settlement in tremendous sum for example 30.53 hectares while 1.80, 0.20, 7.95 and 18.92 hectares region changed inside 0-1, 1-2, 2-3 and 4-5 km buffer distance separately.

On the other hand, greatest changes into open forest have occurred inside 4-5 km buffer distance by 73.39 hectares while 0.54, 12.89, 23.52 and 33.59 hectares inside 0-1, 1-2, 2-3 and 3-4 km buffer distance individually. Though into water bodies, the most extreme changes has occurred inside 3-4 km buffer distance by 24.03 hectares while 0.64, 4.67, 18.12, and 14.28 hectares inside 0-1, 1-2, 2-3 and 4-5 km buffer distance separately. The homestead plantation just moved into settlement and open forest. The most extreme changes have occurred inside 4-5 km if there should be an occurrence of settlement by 59 hectares just as 3-4 km support distance on account of open forest by 28.57 hectares. Inside the remaining buffer distance, 6.12, 24.18, 37.94 and 30.54 hectares region has moved in to settlement inside 0-1, 1-2, 2-3 and 3-4 km cushion distance, in the meantime, 0.81, 2.83, 8.08 and 26.16 hectares region has moved into open forest inside 0-1, 1-2, 2-3 and 4-5 km support distance separately. Negligible region from plantation to brick kiln and char has moved inside all buffer distance.

Most extreme changes into cropland, fallow and open forest have occurred inside 4-5 km buffer distance by 41.90, 72.53 and 110.45 hectares separately, in the interim, into homestead plantation and settlement have occurred inside 3-4 km support distance by 53.78, and 86.58 individually and water bodies inside 2-3 km buffer distance by 17.50 hectares. On account of remaining buffer distance, the fallow land has moved inside 0-1 km buffer distance while it steadily expanded with expanded distance besides if there should arise an occurrence of water bodies. It has expanded up to 2-3 km buffer distance after it has diminished steadily. Just the settlement region has moved into homestead plantation and most noteworthy occurred inside 3-4 km buffer distance by 92.86 hectares while 43.31, 42.54, 52.25 and 85.36 hectares inside 0-1, 1-2, 2-3 and 4-5 km buffer distance separately. The open forest has moved into various highlights as of now. Maximum area has transferred into brick kiln, cropland and homestead plantation inside 2-3 km buffer distance by 4.59, 36.45 and 98.12 hectares individually though into fallow land, settlement and water bodies inside 4-5km buffer distance by 79.24, 159.08 and 11.59 hectares separately. Here likewise tracked down the insignificant moved inside 0-1 km buffer distance region. Water bodies fundamentally have moved into cropland and fallow land inside 3-4 km buffer distance by 15.89 and 28.19 hectares individually.

3.4 Effect of distance on LULC changes

The general model test results there is a huge impact is available, the model is statistically significant at 99 per cent level (Table 8). Table 8 portrays that there is a significant role of distance from BTPS ashore change.

Table 8: Overall model test

Model	χ^2	df	p
1	3878	43	<? .001

Source: Computed by authors

The model shown that there are significant transformation have taken place in various form, however, the estimate value showing minimal effect of distance on LULC change (see appendix-2). That means BTPS has no direct effect on the LULC change, transformation of LULC only happened normally in due course of time. The surrounding areas of the BTPS enclosed with agricultural land and urban area which are mostly transformed due to the demand of the human beings. There is no evidence of land transformation due to the direct involvement of BTPS. Moreover, the negative estimate value of brick kiln to plantation, cropland to water bodies, fallow land to char, fallow land to cropland, fallow land to plantation, homestead plantation to settlement, plantation to homestead plantation, plantation to cropland, plantation to settlement, settlement to homestead plantation, open forest to homestead plantation, open forest to char, open forest to cropland, open forest to settlement, water bodies to homestead plantation, water bodies to fallow land, water bodies to plantation and water bodies to open forest have seen and the odd ratio approximately 1 for all transformation which reported that the aforementioned transformation have taken place near the BTPS. Moreover, the positive estimate value of the char to fallow land, cropland to homestead plantation, cropland to fallow land, cropland to plantation, cropland to settlement, fallow land to homestead plantation, fallow land to settlement, fallow land to open forest, homestead plantation to open forest, plantation to char, plantation to fallow land, plantation to open forest, plantation to water bodies, open forest to fallow land, open forest to plantation and open forest to water bodies have seen which indicates that aforementioned transformation have taken place according to the increases of distance from BTPS.

4. Conclusion

The discussion in this chapter aims to pinpoint the changing landuse/landcover phenomenon from 1989 to 2019. Settlements and built-up areas with vegetation have expanded more than other features after the installation of BTPS, while open forests and plantations have transformed more, which is a common phenomenon around the world in the modern and postmodern era. Due to data limitations, this study does not depict the situation prior to the foundation of BTPS. The BTPS, on the other hand, took mostly fallow land and a small amount of agricultural land that had been reported by locals. A little proportion of cropland and fallow land was transformed indirectly and directly after the establishment. Furthermore, due to the transformation into harvest, the maximum cropland has increased at 3 km while the highest drop has occurred at 5 km, with the maximum decline of fallow land and open forest occurring at 3 km. Furthermore, at a 5 km distance, the maximum settlement envelope has grown. Due to the extension of the associate and plantation programme, the maximum percentage of water bodies and plantation within 1 km of BTPS has dropped, while the maximum percentage of homestead planting with fallow land has grown. The maximum area under research has not changed, and the maximum static LULC characteristics have been detected at a distance of 4-5 km. The highest change from settlement to homestead plantation has been seen in this study area, with the maximum taking place within 3-4 km distance, which is a good sign in terms of environmental protection. According to the multinominal logistic regression analysis, BTPS has a minimal effect on the LULC transformation based on distance. Cropland to fallow land transformation has been observed mostly in relation to distance. BTPS has created economic opportunity for the nearby community as well as outstation residents through industrialization. As a result, the settlement has evolved and various vital infrastructure developments have occurred. Despite the fact that it has absorbed some vegetation and agricultural area, ongoing environmental work has resulted in a cleaner and healthier environment as well as a variety of economic prospects for the local population.

Acknowledgement:

The first author wishes to express his heartfelt gratitude to the University Grants Commission (UGC), Ministry of Human Resource Development (MHRD), Government of India, for awarding a 5-year PhD fellowship.

References:

Ahmad, A. & Quegan, S. (2012). Analysis of Maximum Likelihood Classification on Multispectral Data. *Applied Mathematical Sciences*, 6, 6425–6436.

Areendran, G., Rao, P., Raj, K., Mazumdar, S. & Puri, K. (2013). Land use/land cover change dynamics analysis in mining areas of Singrauli district in Madhya Pradesh, India. *Tropical Ecology*, 54(2), 239–250.

Bisht, B., & Kothyari, B. (2001). Land-cover change analysis of Garur Ganga watershed using GIS/remote sensing technique. *Journal of the Indian Society of Remote Sensing*, 29(3), 137–141.

Chatterjee, R.S., Bannerjee, D., Roy, J. & Bhattacharya, A.K. (1994). Landsat TM data processing techniques for identifying and delineating environmental impacts of coal mining, *ITC Journal*, 2, 155–162.

Congalton, R.G. (1991). A review of assessing the accuracy of classifications of remotely sensed data. *Remote Sensing of Environment*, 37(1), 35–46.

Dong, Y., Forster, B. & Ticehurst, C. (1997). Radar backscatter analysis for urban environments. *International Journal of Remote Sensing*, 18(6), 1351–1364.

Erener, A., Düzgün, S. & Yalciner, A.C. (2012). Evaluating land use/cover change with temporal satellite data and information systems, *Procedia Technology*, 1, 385–389.

Garai, D. & Narayana, A. (2018). Land use/land cover changes in the mining area of Godavari coal fields of southern India. *The Egyptian Journal of Remote Sensing and Space Science*, 21(3), 375–381.

Jensen, J. R. (1996). Introductory digital image processing: A remote sensing perspective, (Issue

Ed. 2). Prentice-Hall Inc.

Joshi, C., Leeuw, J.D., Skidmore, A.K., Duren, V. & Oosten, H. (2016). Remotely sensed estimation of forest canopy density: A comparison of the performance of four methods. *International Journal of Applied Earth Observation and Geoinformation*, 8(2) 84–95. https://doi.org/10.1016/j.jag.2005.08.004

Joshi, R.R., Warthe, M., Dwivedi, S., Vijay, R. & Chakrabarti, T. (2011). Monitoring changes in land use land cover of Yamuna riverbed in Delhi: A multi-temporal analysis. *International Journal of Remote Sensing*, 32(24), 9547–9558.

Kindu, M., Schneider, T., Teketay, D. & Knoke, T. (2016). Changes of ecosystem service values in response to land use/land cover dynamics in Munessa–Shashemene landscape of the Ethiopian highlands. *Science of the Total Environment*, 547, 137–147.

Kumari, M., & Sarma, K. (2017). Spatio–Temporal Dynamics of Land Use/Cover around a Thermal Power Plant in Singrauli District, Madhya Pradesh, India. *IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)*, 5(4), 08–13.

Lambin, E. F., Geist, H. J. & Lepers, E. (2003). Dynamics of land-use and land-cover change in tropical regions. *Annual Review of Environment and Resources*, 28(1), 205–241.

Lea, C. & Curtis, A. (2010). Thematic accuracy assessment procedures: National Park Service vegetation inventory. Version 2.0. *Natural Resource Report NPS/2010/NRR-2010/204. Fort Collins: National Park Service, US Department of the Interior*.

Lillesand, T., Kiefer, R. W. & Chipman, J. (2015). Remote sensing and image interpretation. John Wiley & Sons.

Manna, A., & Maiti, R. (2016). Alteration of surface water hydrology by opencast mining in the Raniganj Coalfield Area. India, *Mine Water and the Environment*, 35(2), 156–167.

Ruiz-Luna, A., & Berlanga-Robles, C.A. (2003). Land use, land cover changes and coastal lagoon surface reduction associated with urban growth in northwest Mexico, Landscape *Ecology*, 18(2), 159–171.

Showqi, I., Rashid, I., & Romshoo, S.A. (2014). Land use land cover dynamics as a function of changing demography and hydrology. *GeoJournal*, 79(3), 297–307.

Singh, V., & Dubey, A. (2012). Land use mapping using remote sensing & GIS techniques in Naina-Gorma Basin, part of Rewa district, MP, India. *International Journal of Emerging Technology and Advanced Engineering*, 2(11), 151–156.

Star, J.L., Estes, J.E., McGwire, K.C., Arvidson, R., & Rycroft, M. (1997). Integration of geographic information systems and remote sensing (Vol. 5), Cambridge University Press.

Starkweather, J., & Moske, A.K. (2011). Multinomial logistic regression.

Wadhwa, C.L., Generation, Distribution and Utilization of Electrical Energy, New Age International (1989).

Wilkie, D.S., Finn, J.T., & Finn, J. (1996). Remote sensing imagery for natural resources monitoring: A guide for first-time users. Columbia University Press.

Appendix

Appendix-1: Buffer wise LULC transformation during 1989-2019 in hectares

Transformation	0-1km	1-2km	2-3km	3-4km	4-5km	Total
Cropland to brick kiln	0.00	0.00	0.63	0.00	0.00	0.63
Cropland to fallow land	0.00	2.02	3.74	40.56	142.85	189.18
cropland to homestead plantation	0.36	0.54	4.87	3.91	10.93	20.61
Cropland to plantation	0.06	3.45	4.96	15.8	82.12	106.38
Cropland to settlement	0.36	0.67	1.49	1.02	8.16	11.7
Cropland to water bodies	0.00	7.91	18.64	0.18	6.30	33.03
Fallow land to char	0.00	0.00	2.34	0.00	0.00	2.34
Fallow land to cropland	0.00	14.66	44.99	27.25	32.44	119.34
Fallow land to homestead plantation	0.54	0.00	3.51	18.84	37.63	60.52
Fallow land to plantation	2.32	31.38	28.5	46.38	26.07	134.64
Fallow land to settlement	1.80	0.20	7.95	30.53	18.92	59.40
Fallow land to open forest	0.54	12.89	23.52	33.59	73.39	143.93
Fallow land to water bodies	0.64	4.67	18.12	24.03	14.28	61.74
Homestead plantation to settlement	6.12	24.18	37.94	30.54	59.00	157.78
Homestead plantation to open forest	0.81	2.83	8.08	28.57	26.16	66.44
No change	198.57	586.42	827.37	1190.57	1437.67	4240.6
Plantation to brick kiln	0.12	0.33	1.35	2.34	0.72	4.86
Plantation to char	0.00	0.00	1.62	0.00	0.00	1.62
Plantation to cropland	0.73	25.57	25.88	21.14	41.9	115.22
Plantation to fallow land	0.95	16.64	17.86	31.49	72.53	139.47
Plantation to homestead plantation	10.30	10.08	20.33	53.78	37.82	132.3
Plantation to settlement	8.19	17.68	34.88	86.58	80.66	227.99
Plantation to open forest	4.59	15.97	46.47	88.4	110.45	265.88
Plantation to water bodies	0.00	4.08	19.61	17.56	13.12	54.38
Settlement to homestead plantation	43.31	42.54	52.25	92.86	85.36	316.32
Open forest to brick kiln	0.00	0.09	4.59	2.79	0.00	7.47
Open forest to char	0.00	0.00	0.54	0.00	0.00	0.54
Open forest to cropland	0.34	15.29	36.45	9.22	1.70	63.00
Open forest to fallow land	0.00	10.97	10.93	50.24	79.24	151.39
Open forest to homestead plantation	12.18	30.11	98.12	70.87	60.00	271.27
Open forest to plantation	1.72	16.1	61.24	74.94	159.38	313.38
Open forest to settlement	4.85	22.09	37.14	50.24	65.34	179.65
Open forest to water bodies	0.00	1.62	8.59	11.05	11.59	32.85
Water bodies to brick kiln	0.00	0.18	0.00	0.00	0.00	0.18
Water bodies to char	0.51	0.03	0.00	0.00	0.00	0.54
Water bodies to cropland	0.02	2.21	9.41	15.89	2.16	29.7
Water bodies to fallow land	11.75	2.22	27.68	28.19	5.68	75.53
Water bodies to homestead plantation	0.09	0.9	4.47	1.21	0.09	6.76
Water bodies to plantation	1.45	7.43	2.53	4.32	4.54	20.26
Water bodies to open forest	0.09	2.41	4.69	1.69	5.55	14.44
Brick kiln to plantation	0.00	3.45	0.09	0.45	0.00	3.99
Brick kiln to open forest	0.00	1.00	0.18	0.18	0.00	1.36
Char to cropland	0.00	0.00	0.00	1.26	0.00	1.26
Char to fallow land	0.00	0.00	0.00	0.63	0.00	0.63

Source: Computed by authors

Appendix-2: Effect of distance from BTPS on LULC transformation by Multinominal Logistic Regression

Change	Estimate	p	Odds ratio
Cropland to homestead plantation - No change	0.0002	<? .001	1.000
Cropland to fallow land - No change	0.0011	<? .001	1.001
Cropland to plantation - No change	0.0009	<? .001	1.001
Cropland to settlement - No change	0.0005	<? .001	1.000
Cropland to water bodies - No change	0.0000	<? .001	1.000
cropland to brick kiln - No change	-0.0003	0.183	1.000
Fallow land to homestead plantation - No change	0.0010	<? .001	1.001
Fallow land to char - No change	-0.0007	<? .001	0.999
Fallow land to crop - No change	-0.0001	<? .001	1.000
Fallow land to plantation - No change	-0.0003	<? .001	1.000
Fallow land to settlement - No change	0.0005	<? .001	1.000
Fallow land to open forest - No change	0.0002	<? .001	1.000
Fallow land to water bodies - No change	0.0000	0.138	1.000
Homestead plantation to settlement - No change	-0.0009	<? .001	1.000
Homestead plantation to open forest - No change	0.0002	<? .001	1.000
Plantation to homestead plantation - No change	-0.0002	<? .001	1.000
Plantation to brick kiln - No change	-0.0003	0.477	1.000
Plantation to char - No change	0.0006	<? .001	1.001
Plantation to cropland - No change	-0.0002	<? .001	1.000
Plantation to fallow land- No change	0.0001	<? .001	1.000
Plantation to settlement - No change	0.0003	<? .001	1.000
Plantation to open forest - No change	0.0002	<? .001	1.000
Plantation to water bodies - No change	0.0001	<? .001	1.000
Settlement to homestead plantation - No change	0.0004	<? .001	1.000
Open forest to homestead plantation - No change	-0.0003	<? .001	1.000
Open forest to brick kiln - No change	0.0000	0.902	1.000
Open forest to char - No change	-0.0013	<? .001	0.999
Open forest to cropland - No change	-0.0006	<? .001	0.999
Open forest to fallow land- No change	0.0004	<? .001	1.000
Open forest to plantation - No change	0.0003	<? .001	1.000
Open forest to settlement - No change	-0.0004	<? .001	1.000
Open forest to water bodies - No change	0.0002	<? .001	1.000
Water bodies to homestead plantation - No change	-0.0005	<? .001	0.999
Water bodies to brick kiln - No change	-0.0004	0.714	1.000
Water bodies to char - No change	-0.0003	0.056	1.000
Water bodies to cropland - No change	-0.0003	<? .001	1.000
Water bodies to fallow land- No change	-0.0004	<? .001	1.000
Water bodies to plantation - No change	-0.0006	<? .001	0.999
Water bodies to open forest - No change	-0.0003	<? .001	1.000
Brick kiln to plantation - No change	-0.0014	<? .001	0.999
Brick kiln to open forest - No change	0.0001	0.419	1.000
Char to cropland - No change	0.0000	0.693	1.000
Char to fallow land- No change	0.0006	<? .001	1.001

Source: Computed by authors