

# Land use and land cover change-induced landscape dynamics: a geospatial study of Durgapur Sub-Division, West Bengal (India)

Sribas Patra\*, Kapil Kumar Gavsker

Ravenshaw University, School of Regional Studies and Earth Sciences, Department of Applied Geography, India

\* Corresponding author: sribaspatra2013@gmail.com

## ABSTRACT

This article examines the factors and process of change in the land use and land cover change-induced landscape dynamics in the Durgapur Sub-Division region of West Bengal in 1989, 2003, and 2018 by employing the satellite imageries of Landsat 5 (1989 and 2003) and Landsat 8 (2018). The images of the study area were categorized into seven specific land use classes with the help of Google Earth Pro. Based on the supervised classification methodology, the change detection analysis identified a significant increase in built-up land from 11% to 23% between 1989 and 2003 and from 23% to 29% in 2003 and 2018. The areas under fallow land and vegetation cover have mainly decreased, while the areas of industrial activities and urbanization expanded during the study period.

## KEYWORDS

change detection; geospatial; landscape dynamics; land use and land cover

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## 1. Introduction

Landscape of a region is subject to modifications and changes caused by various factors and processes occurring thereon. Almo Farina states that “[L]andscape dynamics involve properties of the landscape, such as stability, persistence, resistance, resilience, and recovery, that operate along a broad range of temporal and spatial scales, such as shifting mosaic steady-state, and equilibrium spatial properties” (Oxford Bibliographies 2017). Studying earth’s surface and environment has been one of the central themes of geographical research. Dynamics in landscape indicate to the fact that any land is not static forever; rather it is changeable at different scale and pace. Similarly, surface of the earth has been changing since its origin. Various types of external and internal factors play their role in such a change. The landscapes include the numerous features on the earth like forest land, water bodies, built-upland (all type of settlements, roads etc.), agricultural lands etc.

Land use and land cover are two separate terminologies which are often used interchangeably (Dimiyati et al. 1996). In particular, land use and land cover (LULC) changes in tropical regions are of major concern due to the widespread and rapid changes in the distribution and characteristics of tropical forests (Myers 1993; Houghton 1994). However, changes in land cover and in the way people use the land have become recognized over the last 15 years as important global environmental changes in their own right (Turner 2002).

Recent research on land use and land cover change detection has drawn attention of many researchers (Liang et al. 2002; Ayele et al. 2016). Change detection has emerged as a significant process in managing and monitoring natural resources and urban development mainly due to provision of quantitative analysis of the spatial distribution of the population of interest. There are a lot of available techniques that serve purpose of detecting and recording differences and might also be attributable to change (Singh 1989; Yuan et al. 1999).

The land use and land cover changes play an important role in the study and analysis of global changed scenario today as the data available on such changes is essential for providing critical input

to decision-making of ecological management and environmental planning for future (Zhao et al. 2004; Dwivedi et al. 2005; Erle and Pontius 2007; Fan et al. 2007). The accurate and timely land use and land cover maps derived from remotely sensed images are the keys for monitoring and quantifying various aspects of global and local climate changes, hydrology, biodiversity conservation, and air pollution (Sellers et al. 1995; Bonan 2008; Butchart et al. 2010; Schröter et al. 2010). Remote Sensing (RS) and Geographic Information System (GIS) are now providing new tools for advanced ecosystem management. The collection of remotely sensed data facilitates the synoptic analyses of Earth – system function, patterning, and change at local, regional and global scales over time; such data also provide an important link between intensive, localized ecological research and regional, national and international conservation and management of biological diversity (Wilkie and Finn 1996).

## 2. Objectives

The present study addresses the following major objectives: i) To study land use and land cover changes and their impact on landscape dynamics in the Durgapur Sub-Division by comparing three-time period of year 1989, 2003, and 2018; and ii) To examine and detect factors of change of land use and land cover during study period and resulting conditions in the Durgapur Sub-Division.

## 3. Study Area

The study area of Durgapur Sub-Division lies in the eastern part of the Paschim Barddhaman District of West Bengal (shown in Figure 1). It lies between 23°26' N to 23°48' N and 87°8' E to 87°32' E. The area of Durgapur Sub-Division is 771.28 km<sup>2</sup>. The total population of the region is 1,209,372 as per the Census of India 2011. In this area the major city is Durgapur. This is an industrial city of eastern India and the second planned city (1955) of India after Chandigarh. It consists of four Community Development Blocks: Durgapur–Faridpur; Kanksa; Andal; and

**Tab. 1** Showing administrative units and demographic profile of Durgapur Sub-Division.

Region	C.D. Block / M.C.	Panchayat			Mouzas	Inhabited Village	Population
		Samity	Gram	Gram Sansad			
Durgapur Sub-Division	Andal	1	8	146	14	12	186,915
	Faridpur-Durgapur	1	6	88	54	48	115,924
	Pndabeswar	1	6	112	17	14	161,891
	Kanksa	1	7	132	86	77	178,125
	Durgapur (MC)	–	–	–	–	–	566,517

Source: <http://www.sdodurgapur.org/blocks.php>; and Census of India, 2011.

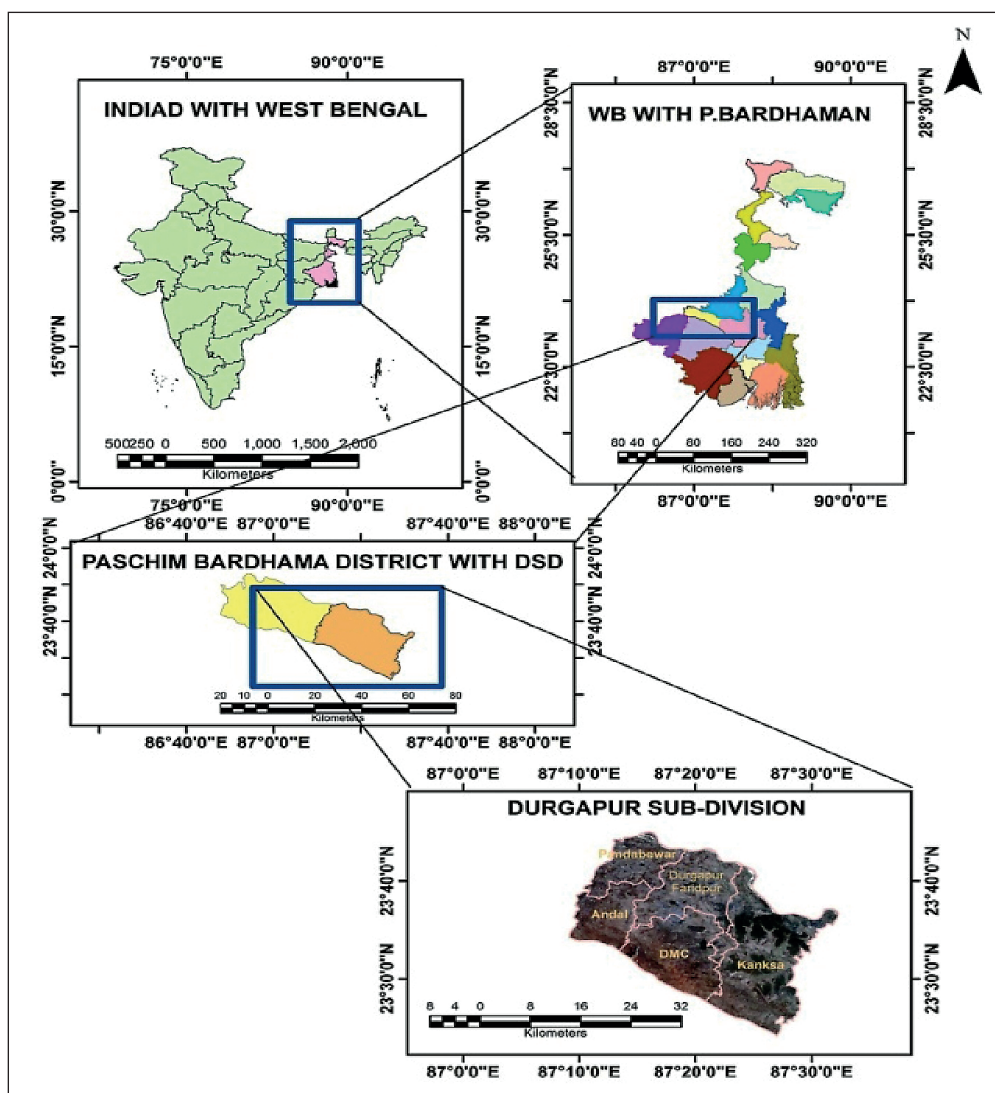


Fig 1 Location map of the study area.

Pandabeswar and a Durgapur Municipal Corporation as shown in the Table 1. In Durgapur Subdivision, Durgapur Municipal Corporation is the only statutory urban area that comes within the ambit of the Asansol-Durgapur Planning Area (ADPA).

#### 4. Material and Methods

The present study is based on a secondary source of database. The research database here involves the use of various methods, techniques and tools for the study of land use and land cover to make a wider sense of landscape dynamics of the region. Geographic Information System and Remote Sensing tools are used to collect, organize and analyze the spatial data. Remote Sensing has greatly opened new vistas in deriving factual information on natural and human resources by virtue of its synoptic overview, multi-spectral and multi-temporal coverage of the earth's surface. The Table 2 and Table 3 show the types of data, sources,

satellite imageries and data sensors used in the present research.

The matter of the fact is that remote sensing platforms is a system used for collecting and analyzing space features. It includes space-borne (satellite imagery), air-borne (aerial photographs, thermal, radar images, etc.) and ground-based techniques as tools for the location and identification of the

Tab. 2 Showing data types and sources for the study.

Category	Data type	Data source	Time period
Secondary	Spatial	Satellite data	USGS 1989, 2003, 2018
		Administrative map	Durgapur Sub-division website 2018
	Attribute	Statistical	District Census Handbook, A-series – General Population Table 2011

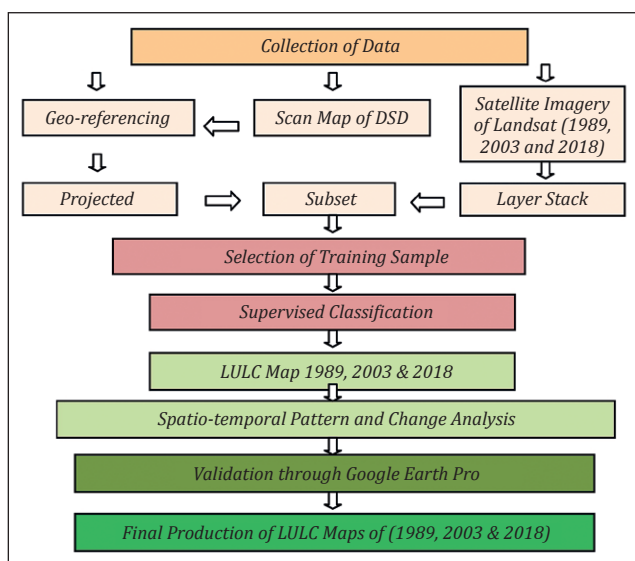
Source: Prepared by the authors, 2019.

**Tab. 3** Showing satellites and sensors data acquired for the present study.

Sl. No	Satellite	Sensor	Date
1	LANDSAT 5	Thematic Mapper (TM)	Dec 17, 1989
2	LANNDSAT 5	TM	Nov 15, 2003
3	LANDSAT 8	OLI-TIRS	Nov 18, 2018

Source: Prepared by the authors, 2019.

biological, ecological and cultural characteristics of various features of the earth surface. In order to identify the spatial pattern and the rate of change, it all requires data analysis over a considerable time period or of sometime junctures. For data analysis purpose the important software and tools used in the study include ARC-GIS and ERDAS imagine 14. The ARC-GIS software is used to complement the display and processing of the acquired data. The ERDAS Imagine 14 is used for ‘image processing’ (layer stack, subset, classification) purpose. For verification and accuracy purposes of satellite images used in the research, the Google Earth system also has been very useful in the present study. Through this, images are used for location identification and classification. The method adopted in the present study for a detailed analysis of the land use and its mapping is given in the flow chart as shown in Figure 2. The methodology of the present study comprises the use of Landsat-5 (TM), Landsat-8 (OLI-TIRS) data from USGS (The United States Geological Survey, <https://earthexplorer.usgs.gov>). Here supervised classification method is used with maximum likelihood algorithm for Operation Image Classification. In the supervised classification approach, select groups of training pixels are adopted to represent seven land use and land cover units of the study area. Supervised classification is more or



**Fig. 2** Flowchart of methodology. Source: Prepared by the authors.

less controlled by the analyst. In this process, the analyst selects training pixels that are representative of the desired land use classes. In the present study, for each class around 40 training samples are taken into account. SPSS 22 is also used for analysis particularly Pearson’s product-moment correlation coefficient (r) and Multiple Linear Regression to understand the relationship among the classes.

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}} \tag{1}$$

$$y_i = \beta_0 + \beta_1x_{i1} + \beta_2x_{i2} + \dots + \beta_px_{ip} + \epsilon \tag{2}$$

where, for  $i = n$  observations,  
 $y_i$  = dependent variable,  
 $x_i$  = explanatory variables,  
 $\beta_0$  = y-intercept (constant term),  
 $\beta_p$  = slope coefficients for each explanatory variable,  
 $\epsilon$  = the model’s error term (also known as the residuals).

The description of classified seven land use and land cover categories and their properties are provided in the below given Table 4. It provides a features description of the concerned classes.

The interpretation keys are chosen based on the classification of Landsat-5 and Landsat-8 images. Bhatta notes that “the criterion for identification of an object with interpretation elements is called an interpretation key” (Bhatta 2011). The seven major land use and land cover classes identified; the interpretation keys used for them are mentioned below in the Table 5.

**Tab. 4** Land use and land cover classes of Durgapur Sub-Division.

Land use / Land cover classes	Features description (Based on National Remote Sensing Centre, India, 2019)
1. Built-up Land	Residential, Commercial and services, Industrial, Transportation, Communication and Utilities, Mining – Active, Mining – Abandoned, Quarry.
2. Crop Land	These are the areas with standing crop as on the date of Satellite overpass. Such as Cultivated Land, Plantation, Garden.
3. Fallow Land	Without Crop Land which are taken up for cultivation but are temporarily allowed to rest.
4. Vegetation	Deciduous Forest Land, rivers in the buildings, in the agricultural fields and gardens, Mixed Forest Land, Shrubs vegetation along the roads.
5. Barren Land	Gullied, Ravinous, Barren Rocky/Stony Waste
6. Water Bodies	River/Stream/Canals, Ponds, Reservoirs
7. Sandy Areas	Riverine or inland areas. Riverine sands are those that are seen as accumulations in the flood plain as sheets which are the resultant. Due to river flooding.

Source: Prepared by the authors, 2019.

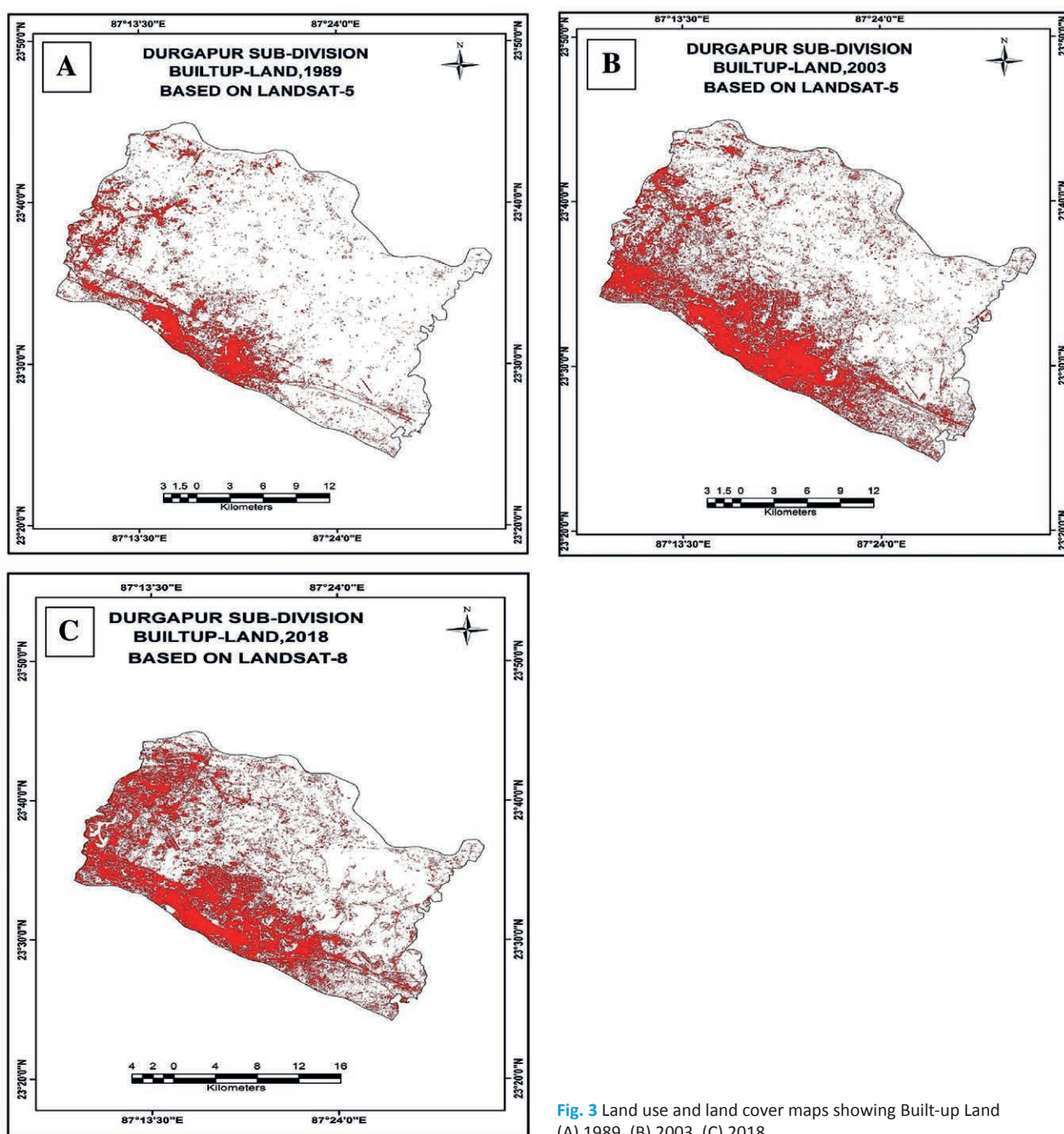
**Tab. 5** Showing interpretation keys for the study region.

Land use / Land cover classes	Characteristics of False Color Composite (FCC) of Landsat-5 Landsat-8
1. Built-up Land	Bluish
2. Cropland	Dull red and smooth appearance
3. Fallow Land	Grey with smooth texture
4. Vegetation	Dark red with rough texture, Dull red to Pinkish
5. Barren Land	Bluish/greenish grey with smooth texture and yellowish
6. Water Bodies	Dark blue to light blue, accordingly depth
7. Sandy Area	White with smooth texture

Source: Prepared by the authors, 2019 (Based on Document Control Sheet, NRSC, India).

### 5. Results and Discussion

The study reveals that area is largely agrarian in character except few urban centers and industrial clusters located in the Durgapur Sub-Division. There has been accelerated spatial change under two prominent land uses i.e. built-up land and cropland. This pinpoints to the fact that the region being agriculturally prominent, the cropland has increased drastically more than the built-up area in the region. Therefore, spatial changes including surface organization of the land use and land cover and their inter-relationship with a focus on direction and spread are well explained.



**Fig. 3** Land use and land cover maps showing Built-up Land (A) 1989, (B) 2003, (C) 2018.

(i) **Built-up land.** It is covered 87.2302 km<sup>2</sup>, which constituted 11% of the total geographical area in the year 1989. What is importantly observed is that most of the built-up land area is found in the South Central and West, South-West portions in Figure 3. In the year 2003, in a span of fourteen years, the built-up land covered 174.5542 km<sup>2</sup> which accounted for 23% of the total area. During this period major built-up land areas are Durgapur Municipal Corporation, Andal, and Pandabeswar mining clusters. By the year 2018, the built-up area further grew to 221.4387 km<sup>2</sup> accounting for 29% of the total area of the region (Table 6). During this phase, major concentrations

are found in South Central and Western portions of the Sub-Division.

(ii) **Crop Land.** As seen from classification image cropland is found to be a dominant land use class in the area. It covered 203.3873 km<sup>2</sup> constituting 27% of the total area in 1989. Cropland covered 189.2033 km<sup>2</sup> constituting 24% of the total geographical area in 2003 (Table 6). Rice, wheat, vegetables, etc. are the main crops of the region. By 2018 the cropland is found to increase to 36% of the area. The cropland is seen all over the region, mostly in Central and Northern, South-East parts. There is the presence of a canal system in the Southern portion and along the Southern boundary flow the Damodar River

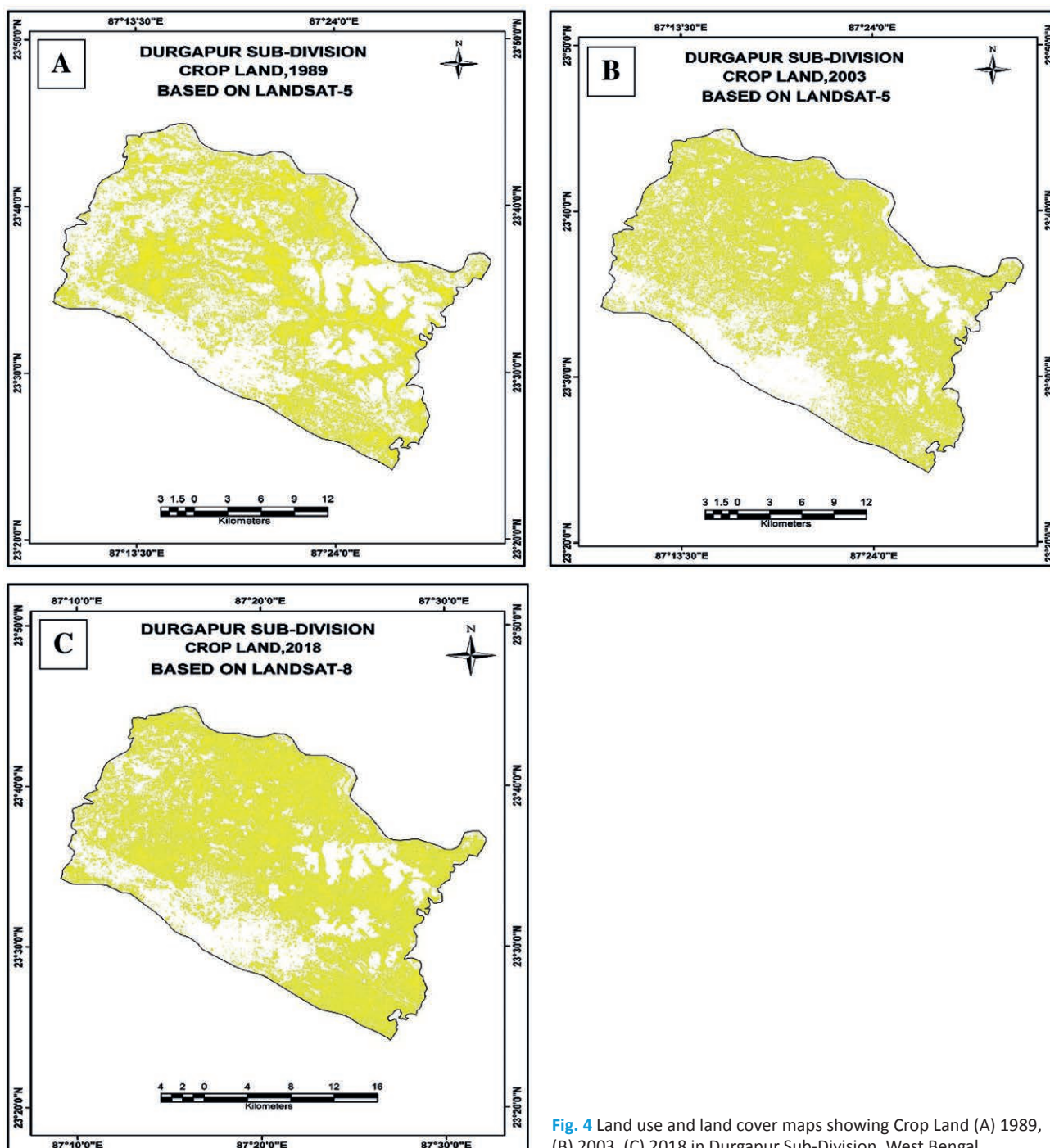


Fig. 4 Land use and land cover maps showing Crop Land (A) 1989, (B) 2003, (C) 2018 in Durgapur Sub-Division, West Bengal.

Tab. 6 Showing area profile of different land use and land cover of the study region.

Sl. No	Land use / Land cover classes	1989		2003		2018	
		Area (km <sup>2</sup> )	%	Area (km <sup>2</sup> )	%	Area (km <sup>2</sup> )	%
1	Built-up Land	87.2302	11	174.5547	23	221.4387	29
2	Crop Land	203.3870	27	189.2033	24	273.6386	36
3	Fallow Land	185.3955	24	195.9534	25	95.6295	12
4	Vegetation	207.3816	27	162.6660	21	119.0188	15
5	Barren Land	61.3674	8	27.9828	4	29.4435	4
6	Water Bodies	16.8129	2	15.6402	2	13.8159	2
7	Sandy Area	9.7254	1	5.3001	1	18.3150	2
<b>Total</b>		<b>771.30</b>	<b>100</b>	<b>771.30</b>	<b>100</b>	<b>771.30</b>	<b>100</b>

Source: Prepared by the authors, 2019 (Based on satellite imageries).

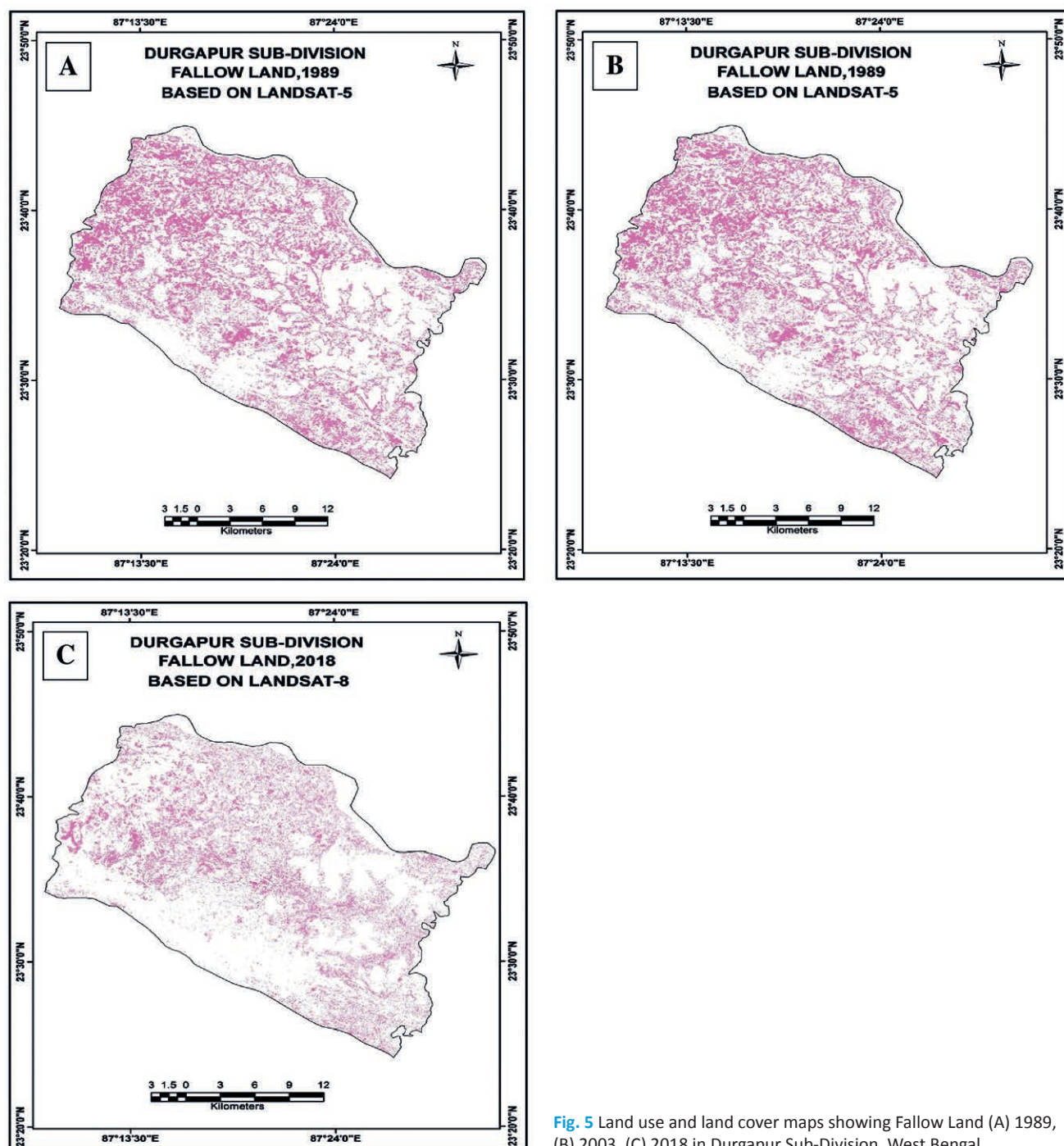


Fig. 5 Land use and land cover maps showing Fallow Land (A) 1989, (B) 2003, (C) 2018 in Durgapur Sub-Division, West Bengal.

which is the major source of irrigation in the region (Figure 4).

(iii) **Fallow Land.** In Durgapur Sub-Division the ‘fallow land’ is the area that is without any crops and it is mostly open land. It covered 185.3955 km<sup>2</sup> which accounted for 24% of the total area in the year 1989 and in 2003 it grew to 195.9534 km<sup>2</sup> accounting for 25% of the total geographical area. By 2018, the fallow land has decreased to 95.6295 km<sup>2</sup> area which is 12% of the total geographical area (Table 6). This sharp decline in the area is mainly observed in the middle portions along with agricultural land and

near the northern ends. Some patches are also seen in South-East, North-East parts, Western parts, and few dense patches are seen in the South- West, Central parts of the region (Figure 5).

(iv) **Vegetation.** Dense vegetation can be observed in the East, North-East, South-East parts of the region. Some patches of forest cover seen in the Central and North-West parts. The vegetation area was 207.3816 km<sup>2</sup> constituting 27% of the total area in 1989. In 2003, this was 162.666 km<sup>2</sup> which is 21% of the total geographical area. It is mainly found in North-East, East Central and some patches of North-West

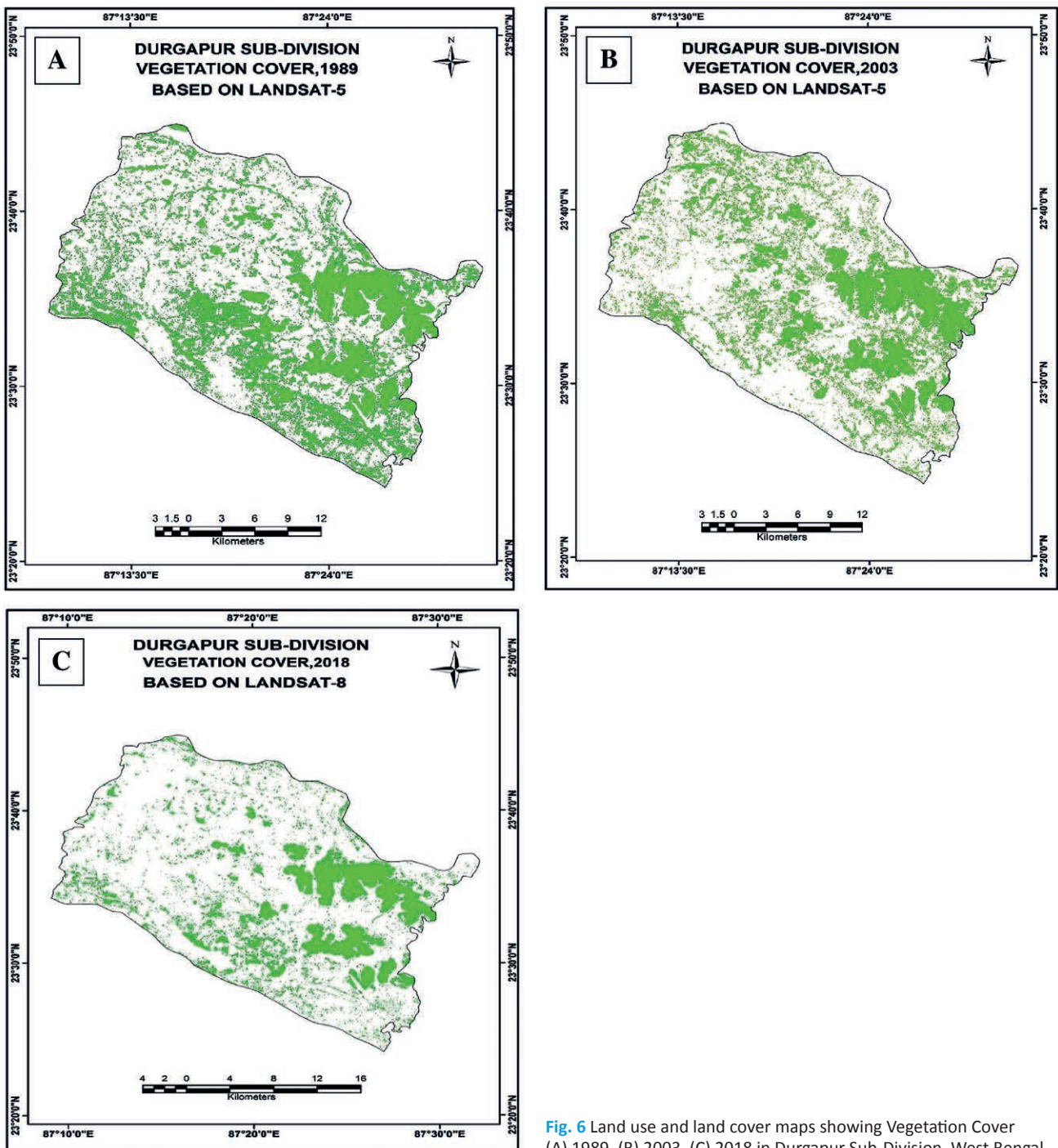


Fig. 6 Land use and land cover maps showing Vegetation Cover (A) 1989, (B) 2003, (C) 2018 in Durgapur Sub-Division, West Bengal.



and southern parts. By 2018 the vegetation cover is seen in North-East and Eastern parts of the regions where many plantation sectors coming along the river and in Durgapur Municipal Corporation. Now this covers 119.0188 km<sup>2</sup> areas which are 15% of the total geographical area (Figure 6).

(v) **Barren Land.** It is found in the Central and the North-Western parts of the region. Some patches are seen in the North-East portion of the study area. The area included in this category was reported about 61.3674 km<sup>2</sup> which accounted for 8% of the total area of the region in 1989. In the year 2003, the Barren

Land covered 27.9828 km<sup>2</sup> of the region which is half of that found in 1989. 2018, this land-use covers 4% of the total geographical area and largely found in the Central parts and rest is fragmented all over the region (Figure 7).

(vi) **Water Bodies-**In the study area water bodies mainly consists of rivers, canals, reservoirs, ponds, tanks, etc. Two major rivers flow in the region: one is on the northern side the Ajoy and the other is the Damodar towards the southern boundary. A canal is seen in the southeastern region. Many tanks and ponds are also found in the region (Figure 8). In 1989, the

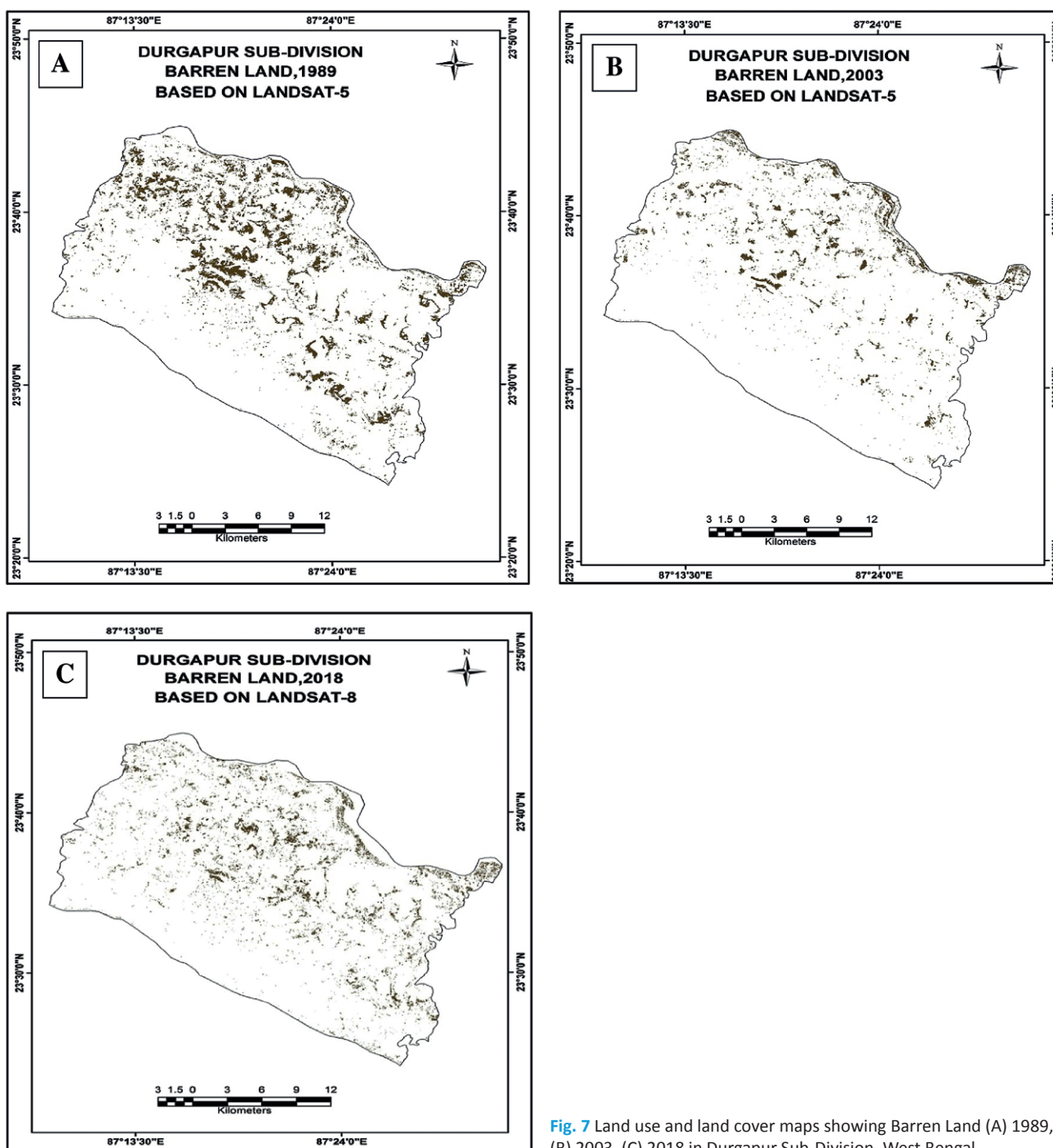


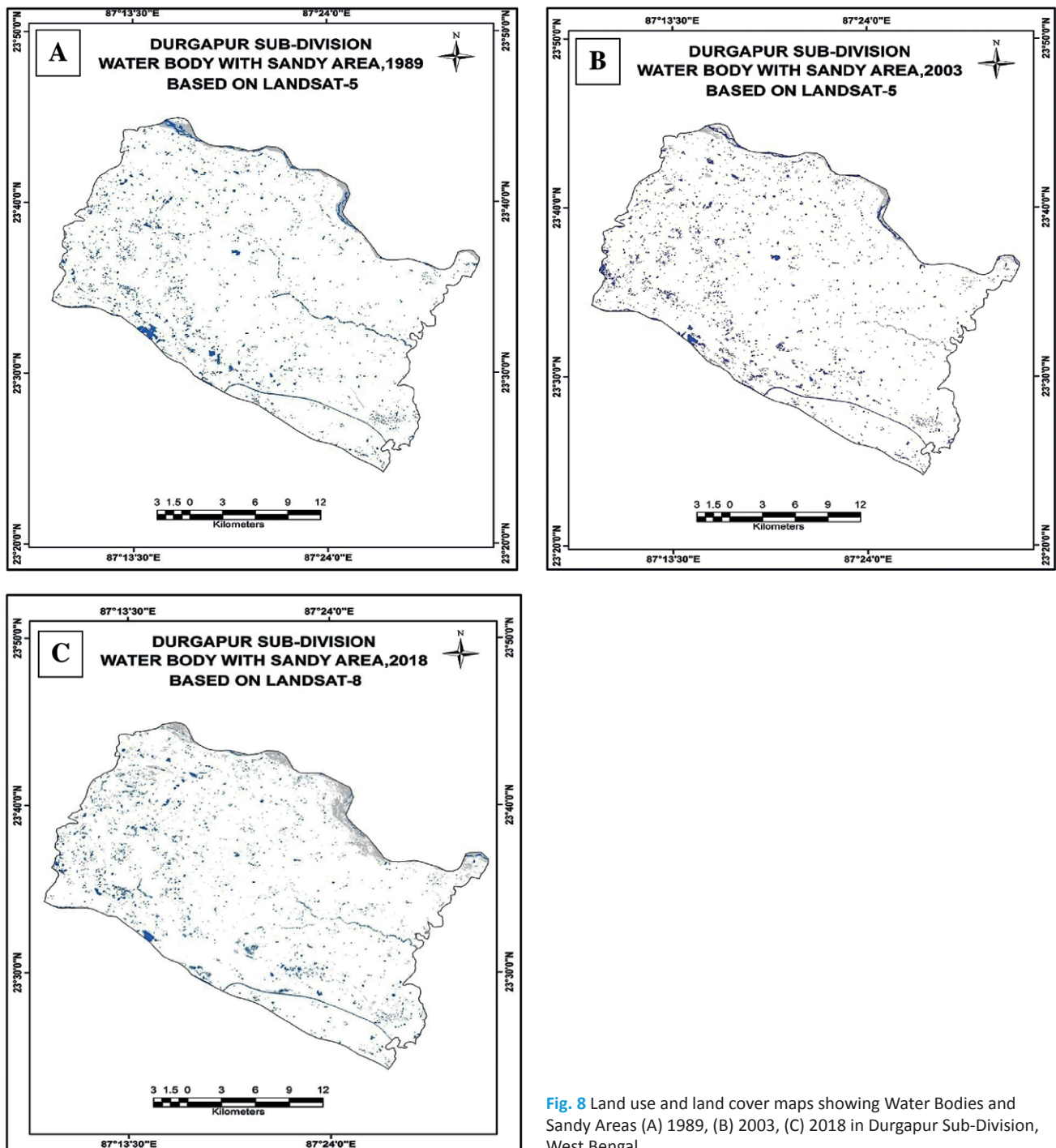
Fig. 7 Land use and land cover maps showing Barren Land (A) 1989, (B) 2003, (C) 2018 in Durgapur Sub-Division, West Bengal.

area included in this category was 16.8129 km<sup>2</sup> which accounts for 2% of the total area and 15.6402 km<sup>2</sup>, in 2003 and 13.8159 km<sup>2</sup> in 2018.

(vii) **Sandy Area.** Sandy area is mostly found in the northern side in the Ajoy river flood plain. Some patches are found in southern parts of the Damodar river basin. In 1989 sandy area consisted of 9.7254 km<sup>2</sup> area which was 1% of the total area. In 2003, the water bodies covered about 15.6402 km<sup>2</sup> area accounting for 2% of the total geographical area and sandy area 5.3001 km<sup>2</sup> which is 1% of the total geographical area. In 2018, the water bodies covered 13.8159 km<sup>2</sup> of the area of the region accounting for

2% and the sandy area was 18.3150 km<sup>2</sup> with 2% of the total geographical area of the Durgapur Sub-Division region (Table 6). By 2018 the sandy area is mostly seen in the northern region along the bank of the Ajay River. Few dense patches are also seen in the Southern region along the bank of the Damodar River (Figure 8).

Pearson's Product Moment Correlation coefficient ( $r$ ) technique is applied here to exhibit the association among the Land use/Land cover classes. The value of  $r$  lies between  $\pm 1$ . A value of  $r = +1.0$  indicates a perfectly direct or perfectly positive correlation, and a value of  $r = -1.0$  indicates a perfectly inverse



**Fig. 8** Land use and land cover maps showing Water Bodies and Sandy Areas (A) 1989, (B) 2003, (C) 2018 in Durgapur Sub-Division, West Bengal.

**Tab. 7** Showing correlation coefficient (r) among the classified land use and land cover types of the Durgapur Sub-Division.

Pearson Product Moment Correlation Coefficient								
Land use/Land cover classes		Built-up Land	Crop Land	Fallow Land	Vegetation	Barren Land	Water Bodies	Sandy Area
Built-up Land	Pearson Correlation	1.000	.657	-.703	-.986	-.925	-.956	.509
	Sig. (2-tailed)		.543	.504	.105	.248	.189	.660
Crop Land	Pearson Correlation	.657	1.000	-.998*	-.772	-.322	-.849	.983
	Sig. (2-tailed)	.543		.039	.438	.792	.354	.117
Fallow Land	Pearson Correlation	-.703	-.998*	1.000	.810	.379	.880	-.970
	Sig. (2-tailed)	.504	.039		.399	.752	.315	.156
Vegetation	Pearson Correlation	-.986	-.772	.810	1.000	.850	.991	-.644
	Sig. (2-tailed)	.105	.438	.399		.354	.084	.555
Barren Land	Pearson Correlation	-.925	-.322	.379	.850	1.000	.773	-.143
	Sig. (2-tailed)	.248	.792	.752	.354		.437	.908
Water Bodies	Pearson Correlation	-.956	-.849	.880	.991	.773	1.000	-.739
	Sig. (2-tailed)	.189	.354	.315	.084	.437		.471
Sandy Area	Pearson Correlation	.509	.983	-.970	-.644	-.143	-.739	1.000
	Sig. (2-tailed)	.660	.117	.156	.555	.908	.471	

\* Correlation is significant at the 0.05 level (2-tailed). Source: Calculated by the authors.

or perfectly negative correlation (Sarkar 2015). The Table 7 indicates the positive and negative relationship among the LU/LC classes of the study period. It reveals that Built-up Land positively associated with the Crop Land and Sandy Area. The calculated value of these two classes is 0.657 and 0.509 respectively, on the other hand, a strong negative relationship with the vegetation and Barren land. The calculated value of these two classes is -0.986 and -0.925 respectively (Table 7)

### 5.1 Surface Change Detection

Change detection techniques for various studies have been reviewed by many researchers. Remote Sensing and Geographical Information System (GIS) based change detection (by using digital satellite imageries) is the process that helps in determining the change associated with land use and land cover properties with reference to geo-referenced multi-temporal data (Jensen 1996). From a policy and planning perspective, change detection in such cases helps in enhancing the capacity of local governments to implement sound environmental management practices (Prenzel and Treitz 2004).

Multiple linear regression (MLR), also known simply as multiple regression, is a statistical technique that uses several explanatory variables to predict the outcome of a response variable. The goal of multiple linear regressions (Table 8) is to model the linear

relationship between the explanatory (independent) variables and response (dependent) variable (Kenton 2019). Table 8 shows the linear relationship among the land use and land cover classes of the study region.

#### (i) Land use and land cover change: 1989 and 2003

Table 9 shows the land use and land cover change during 1989 and 2003 under different classes. The composite land use and land cover of Durgapur Sub-Division are shown in Figure 9. The imagery which was taken from the Landsat-5 on Dec 17, 1989 (USGS), showed that the built-up land was 87.2302 km<sup>2</sup> accounting for 11% of the total geographical area. But the imagery captured on Nov 15, 2003 (USGS) showed the built-up area increased to 174.5542 km<sup>2</sup>. This constitutes 23% of the total geographical area. The total change between the two time periods is 87.3240 km<sup>2</sup> and the percentage increase is 12%. This considerable change happened due to an increase in the mining area at Andal and Pandabeswar Block.

Above Maps depict spatial change with respect to different classes' categories of land use and land cover during 1989–2003. Higher change is witnessed under the built-up area which has registered a 12% increase in the discussed period. This may be associated with a decrease in cropland (-3%), vegetation (-6%) and barren land (-4%) in Table 9. Classified imagery showed that it is clear that there is growing more in urban and followed by rural settlements in the region. The new settlement is set up

Tab. 8 Multiple linear regression model.

Multiple linear regression model	R2	Adjusted R square	Standard error of estimate	F	Standardized Coefficients (Beta)	t-value	sig (p-value)
<b>Built-up Land (x1)</b>							
x2	0.432	-0.135	72.57956	0.76100	0.657	0.873	0.543
x3	0.494	-0.13	68.54350	0.97500	-0.703	-0.987	0.504
x4	0.973	0.946	15.84690	35.94800	-0.986	-5.996	0.105
x5	0.855	0.711	36.62812	5.91600	-0.925	-2.432	0.248
x6	0.914	0.829	28.20084	10.66700	-0.956	-3.266	0.189
x7	0.259	-0.482	82.91339	0.35000	0.509	0.591	0.660
<b>Crop Land (x2)</b>							
x3	0.996	0.992	3.93607	262.90600	-0.998	-16.214	0.039
x4	0.597	0.193	40.60682	1.48000	-0.772	-1.216	0.438
x5	0.103	-0.793	60.54609	0.11500	-0.322	-0.340	0.792
x6	0.721	0.442	33.76055	2.58700	-0.849	-1.608	0.354
x7	0.967	0.993	11.66295	29.05800	0.983	5.391	0.117
<b>Fallow Land (x3)</b>							
x4	0.656	0.313	45.70929	1.90900	0.810	1.382	0.399
x5	0.144	-0.721	72.13830	0.16800	0.379	0.410	0.752
x6	0.775	0.549	37.60922	3.43800	0.880	1.854	0.315
x7	0.941	0.882	18.91180	15.99400	-0.970	-3.999	0.156
<b>Vegetation (x4)</b>							
x5	0.722	0.440	32.94319	2.59700	0.850	1.612	0.540
x6	0.983	0.965	8.21481	56.85400	0.991	7.540	0.084
x7	0.414	-0.171	47.81855	47.81855	-0.644	-0.841	0.555
<b>Barren Land (x5)</b>							
x6	0.598	0.195	16.92628	1.48500	0.773	1.219	0.437
x7	0.210	-0.956	26.40610	0.02100	-0.143	-0.145	0.908
<b>Water Bodies (x6)</b>							
x7	0.546	0.091	1.43962	1.20100	-0.739	-1.096	0.471

x1 = Built-Up Land, x2 = Crop Land, x3 = Fallow Land, x4 = Vegetation, x5= Barren Land, x6 = Water Bodies, x7= Sandy Area

Source: Calculated by the authors.

in the Durgapur Municipal limits and beyond and around the Andal town area that is identified from the classified imagery. In 2003, the built-up area is also seen as have increased in the South-East region (Figure 9).

#### (ii) Land use and land cover change: 2003 and 2018

The imagery is taken from the Landsat-5 on Nov 15, 2003 (USGS) noted Built-upland 174.5547 km<sup>2</sup> or 23% but imagery taken on Nov 18, 2018 (USGS) the Built-up land reported about 221.4387 km<sup>2</sup> which is 29% of the total geographical area. The rapid growth up to 2018 has taken place due to the establishment of a new industrial parks and sectors along the NH2 in Andal to Panagarh (Figure 10). This also with a rapid increase of the population in the municipal area of the Durgapur (about 566,937 in 2011 census), Andal town (186,915), Pandabeswar (161,891). Under

built-up category, the mining area also increased in 2018 compared to 2003 at Andal and Pandabeswar block. A newly setup Airport is seen near Andal (War-ia) in 2018. An increase in cropland i.e. 12% took place simultaneously when there is a further decrease in fallow land (-13%) and vegetation (-6%) (Table 10). Anyhow, barren land, water bodies, and sandy areas remain intact. The fact is that there is an expansion of industrial activities in the virgin areas and follow up is the rise of urban areas and the growth of rural settlements as well. There are also linkages that with increase in population in the areas located in the region, there has been consistent pressure on land since the agriculture area has to be increased. This is resulting in a decrease in fallow land and vegetation cover in the Durgapur Sub-Division. Thus, the landscape of the region is changing by these activities that accelerated over the last few years.

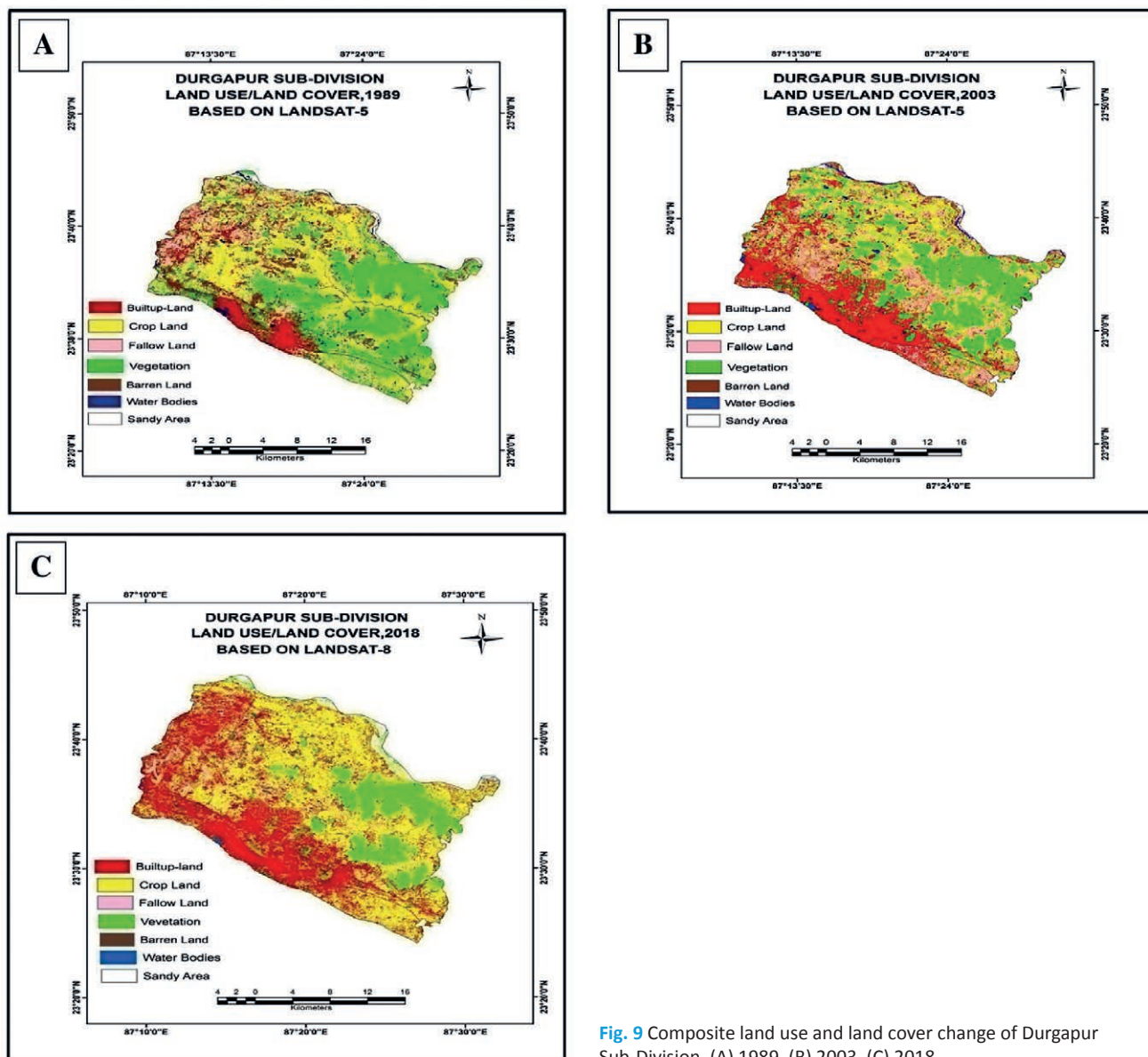


Fig. 9 Composite land use and land cover change of Durgapur Sub-Division, (A) 1989, (B) 2003, (C) 2018.

During 2003-2018, this scenario is out passed by tremendous increase in crop land. The fact is that with the implementation of Damodar Valley Project, mono-cropped areas of the Paschim Barddhaman district have been converted into multi-cropped lands. The industrial complex of Durgapur was established

at the expense of forest in the mid-fifties and it has been growing further since then. Durgapur Sub-Division has experienced a drastic change in the landscape with expansion of urban, industrial, and mining activities at the cost of forest, pasture, and cultivated lands. According to District Census Handbook of

Tab. 9 Land use and land cover change in Durgapur Sub-Division, 1989 and 2003.

Land use / Land cover classes	1989		2003		Change	
	Area (km <sup>2</sup> )	%	Area (km <sup>2</sup> )	%	Area (km <sup>2</sup> )	%
Builtup-Land	87.2302	11	174.5547	23	87.3245	12
Crop Land	203.3870	27	189.2033	24	-14.1837	-3
Fallow Land	185.3955	24	195.9534	25	10.5579	1
Vegetation	207.3816	27	162.6660	21	-44.7156	-6
Barren Land	61.3674	8	27.9828	4	-33.3846	-4
Water Bodies	16.8129	2	15.6402	2	-1.1727	0
Sandy Area	9.7254	1	5.3001	1	-4.4253	0

Source: Calculated by the authors based on satellite imageries 1989 and 2003.

**Tab. 10** Land use and land cover change in Durgapur Sub-Division, 2003 and 2018.

Land use / Land cover classes	1989		2003		Change	
	Area (km <sup>2</sup> )	%	Area (km <sup>2</sup> )	%	Area (km <sup>2</sup> )	%
Builtup-Land	174.5547	23	221.4387	29	46.8840	6
Crop Land	189.2033	24	273.6386	36	84.4353	12
Fallow Land	195.9534	25	95.6295	12	-100.3239	-13
Vegetation	162.6660	21	119.0188	15	-43.6472	-6
Barren Land	27.9828	4	29.4435	4	1.4607	0
Water Bodies	15.6402	2	13.8159	2	-1.8243	0
Sandy Area	5.3001	1	18.3150	2	13.0149	1

Source: Calculated by the authors based on satellite imageries 2003 and 2018.

Barddhaman, the percentage of urban share of population of the district has expanded from 36% in 2001 to 39.9% in 2011 of the total population (Census 2011). The Durgapur Sub-Division is second highest, after Asansol, urbanized division of the Paschim Barddhaman district. This region has huge potential in the economic and industrial development and advancement of the district. Rapid increase in population and expansion of infrastructure and built environment are evidences of how landscape is changing. The major loss has been of fallow land in the study area as shown in the Figure 10.

## 6. Conclusion

The present study focused to analyze the landscape dynamics of Durgapur Sub-division during a long period covering years 1989, 2003 and 2018. Emphasis has been on the way spatial change occurring in the region with respect to bio-physical and socio-economic processes and associated factors. The major findings of the study are as follows:

- The dominant spatial change in the region is associated with the rapid increase in the built-up area in central and west, southwest parts and a similar rise in the cropland in central and northern, south-east parts since they are subject to human-induced intervention processes. The built-up land increased

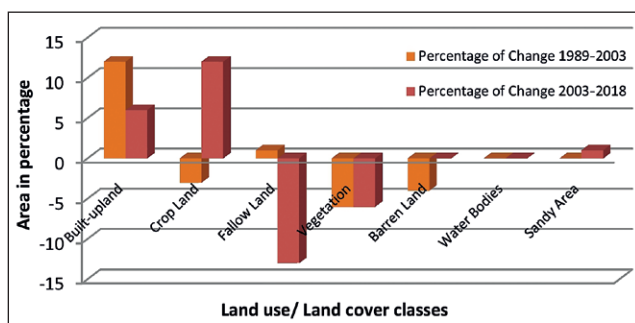
from 87.2302 km<sup>2</sup> (1989) to 174.5547 km<sup>2</sup> (2003) and further to 221.4387 km<sup>2</sup> (2018).

- The increase in industrial activities and mining i.e. western part of the region, expansion of urbanization, and growing human demands for agricultural products all have played a vital role in the landscape transformation.
- The share of biophysical elements including fallow land, natural vegetation, and barren land has been under pressure and consistently declining as is evidenced during the study period. The fallow land area increased from 185.3955 km<sup>2</sup> (1989) to 195.9534 km<sup>2</sup> (2003) but it decreased to 95.6295 km<sup>2</sup> (2018).
- Over the study found that the cropland area increased due to decrease of fallow land because of the rapid increase of population growth changes in the land use pattern from 1989, onwards till now.
- Water bodies are lost over the study period due to increase in built-up land, cropland, and sandy area. Here there is found a negative relationship among the water bodies and built-up land, cropland and sandy area.
- Most of these changes in land use or functional change are naturally unsustainable and may affect the environmental setting of the region.

It is pertinent to mention that changes in land use and land cover, the timely remedial measures are important for optimum and sustainable utilization of land resources and prevention thereof from further undesirable deterioration. There is further scope for research in this arena to look into agricultural changes, cropping pattern, productivity and fertility of the region. This may be further studied in relation to overall biophysical and human-induced changes in the region.

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**Fig. 10** Land use and land cover change between 1989 and 2003 and between 2003 and 2018.

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