



Land use land cover change detection and monitoring of urban growth using remote sensing and GIS techniques: a micro-level study

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Accepted: 9 December 2020 / Published online: 3 January 2021
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Abstract Accurate information on the rate of land-use pattern changes and urban expansion is essential for the sustainable development and management of natural resources. The rapid urban growth is a major challenge for local government and urban planners in small cities of India due to an insufficient database and inadequate analysis of chaotic urban expansion. The present paper has evaluated the land use/land cover change (LULCC) dynamics of the Barrackpore Sub-division area, India using remote sensing data and utilized the urban growth. Multi-temporal Landsat images with the maximum likelihood classifier (MLC) method were applied to generate the land use land cover maps. The spatiotemporal changes were performed by the “from-to” change matrix identifier to study land transformation. LULCC matrix demonstrated that vegetation cover, agricultural/cropland, wetland, and water bodies have decreased area under 23%, 7%, 6%, 1.7%, while the area under built-up and fallow lands have increased by 32.2% and 6.3% during 1972–2016. The results also revealed marked variation in the growth of built-up areas. The positive correlation between population and built-up land growth indicated that the impact of population pressure has contributed to faster growth of built-up land in the study area. The study calls for policies for proper

land use management and sustainable urban development.

Keywords LULCC · Post classification matrix · Urban growth · Barrackpore Subdivision · Remote Sensing and GIS

Introduction

The land use/land cover (LULC) scenario of a region is the result of physical and natural characteristics of the earth’s surface which are utilized and altered by humans in time and space (Rawat and Kumar 2015). Land use/ land cover is essential to get the spatial information at a micro and global scale for making future land use planning (Zhao et al. 2004; Dwivedi et al. 2005; Erle and Pontius 2007; Fan et al. 2007). The spatiotemporal monitoring of land-use dynamics is also essential to observe the changing demands of an increasing population and a better understanding of the relationship between natural phenomena and human activities (Hafez 2011). Change detection is a process of manipulating, managing, and monitoring “up to date” spatial distribution of land resources (Turner and Ruscher 1988). The rapidly changing landscape is the main driver of global environmental changes and a critical issue for sustainable development globally (Kates and Torrie 1998; Hegazy and

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Kaloop 2015). Land-use changes contribute to land degradation, land fragmentation, and loss of biodiversity significantly (Maitima et al. 2009). The changes in land-use patterns have been analyzed by different scholars to identify the drivers on a wide scale. The fastest urban population growth and consequent urbanization are the drivers of fragmentation of the natural landscape over the surface (Long et al. 2007; Haregeweyn et al. 2012; Berihum et al. 2019). It is projected that around 2.5 billion people will be added to the world's urban population and of which developing countries will alone experience 90% of urban growth (United Nations 2014). According to a United Nations report, a total of 512 cities with more than 1 million population and 31 megacities were recorded in 2016 and it is projected that there will be 662 cities and 41 megacities by the year 2030 (United Nations 2016). During the last few decades, the unplanned and haphazard urban expansion has significantly increased in developing nations due to population growth and socio-economic development (Cohen 2006; Fenta et al. 2017). Urban growth in terms of 'urbanization' is a process of alteration in land dynamics from rural to urban areas due to the factors such as migration, economic development, increase in social infrastructure, increase in the number of facilities and services (Taubenbock et al. 2009; Bhagat and Mohanty 2009; Altieri et al. 2014). The urbanization led to the expansion of the city at its suburban and peripheral areas (Ewing 1997; Galster et al. 2001; Zhang 2001). Continuous expanding built-up areas have encroached on the surrounding valuable fertile land, forestland, natural vegetation, and wetlands, etc. (Pathan and Jothimani 1989; Xu et al. 2000; Kumar et al. 2007). The urban land is mostly conquered by an impervious surface which has negative impacts on the ecosystem, the hydrological processes, biodiversity, and micro-climate (Mckinney 2002; Grimm et al. 2008; Atu et al. 2013), the ecological habitat (Mosammam et al. 2017), water quality (Al-Kharabsheh and Ta'any 2003), air quality (Poyil and Misra 2015), etc.

Urban expansion and LULC changes will continue with time and space, but at the same time, it's necessary to protect the land resources by taking imperative planning models with appropriate spatial data (Sarvestani et al. 2011). The spatial data and information are required to carry out the urban growth analysis and its impacts on the landscape of the earth. Though many researchers have attempted urban expansion at a large

scale (Turner and Ruscher 1988; Zhang 2001; Herold et al. 2003), still small and medium cities in the developing countries are less documented due to the lack of site-specified data (Cohen 2006). Recent developments in geospatial technology have made it possible for quantitative and statistical analysis about the LULC changes and urban expansion patterns (Pathan et al. 1993; Epstein et al. 2002; Kumar et al. 2007). The satellite data have the flexibility to study the changes in the landscape with less time at free to lower cost (Yeh and Li 2001; Cihlar 2000). The different spatial resolution satellite imageries with advanced image processing models have helped to routinely monitor and update land-use patterns over the surface (Lo and Choi 2004; Rawat and Kumar 2015). Several methods have been applied for LULC classification and urban growth detection i.e., unsupervised classification method, supervised classification (Bhatta 2010; Sarvestani 2011; Kim 2016), normalized difference vegetation index (NDVI) (Cihlar 2000), principal component analysis (PCA) (Deng et al. 2008), hybrid method (Lo and Choi 2004; Mas et al. 2017), object-based detection (Liu et al. 2020). Several models of urban expansion and its prediction have been utilized in urban landscape studies such as the cellular automata (CA) model (Bhatta 2010; Mondal et al. 2016; Li and Gong 2016), multivariate statistical approach (Salvati 2014); markov chain model (Hegazy and Kaloop 2015; Liping et al. 2018), artificial neural network (ANN) algorithm (Pijanowski et al. 2005), support vector machine (SVM) technique (Mugiraneza et al. 2019), geographically weighted regression (Mondal et al. 2015a, b), sleuth model (Clarke 2008; Chaudhuri and Clarke 2013).

The present paper emphasizes the understanding of spatiotemporal LULC analysis in the Barrackpore Subdivisional areas. Moreover, a micro-level study of an area using geospatial techniques has the advantage to get the periodic spatial information which can be directly linked with the socio-demographic and economic parameters (Report, European Commission 2001). The micro-scale study depends on different multi-agent factors which can be performed to explicitly the land uses over the space (Verburg et al. 2004). And it can bring out the degree of the local evolutionary process and functioning of the landscape. The Barrackpore Subdivision region is an administrative unit of North 24 Parganas district, West Bengal. The study area has experienced the growth rate of the

towns by 110% and the number of villages decreased by 47.5% during the 1951–2011 census year (Census of India 1951 and 2011). The Barrackpore region is continuously facing changes in the land-use pattern by alteration of rural places to the urban territory. Industrial influences along the river pulled the population to grow denser settlements among the towns. The municipal towns of the subdivision are being compacted by built-up land due to huge population pressure which influenced adjacent village areas to convert into census towns. The Barrackpore Subdivision region is a part of the KMDA (Kolkata Metropolitan Development Authority) agglomeration. The location of the capital Kolkata influenced to build the region more urbanized over the past decades. Many scholars have carried out their works on LULCC using the geospatial techniques on the KMDA area, but no such work has been done at this regional scale. The present paper has selected this regional area to examine the detailed land-use changes and assess the urban growth which would help to reduce the urban environmental challenges. The study has taken a long period (44 years) data with six-temporal satellite imageries (1972, 1980, 1990, 2001, 2010, and 2016) at this regional level to analyze the urban growth in a justified manner that would carry a future implementation of further studies. The objectives of the study are to detect land use/land cover (LULC) scenarios from 1972 to 2016, the change matrix has been computed to access land transformation, and lastly to find out the main drivers of the transformation.

Literature review

During the last few decades, the changing pattern of the World's landscape has been drawn attention by the measure of LULC alteration and this is a subject to focus on national and international study programs (Abera 2018). Urbanization can be demonstrated as a process that is caused by rapid population growth, migration of population from rural places, and economic development (Liu Y 2007; Taubenbock et al. 2009; Thapa and Murayama 2009). Increases in demand and needs of habitat in the rural settlement have forced to transform and merged into urban areas (Balha and Singh 2018). Satellite remote sensing techniques and GIS are the popular techniques in recent decades for mapping out a city's urban scenario

in a digital format (Lillesand et al. 2004; Chen et al. 2006; Hassan M. M. 2017; Fenta et al. 2017). The earth observing data, such as Landsat imagery (MSS, TM, and ETM+ and Landsat 8 OLI) being cost-effective has been widely used for urban land use observation (Zhu 2017; Zhu et al. 2019). The urban expansion provides a scenario of natural landscape fragmentation and the transition of land transformation (Ramachandra et al. 2014a, b; Shukla and Jain 2019). Various negative impacts of city expansion over the world are well documented with the help of remote sensing and the GIS method (Xu et al. 2000; Mallick et al. 2008; Pal and Ziaul 2017; Niyogi et al. 2018). Continue increasing population puts adverse effects of escalating the heat capacity in impervious surfaces (Karl et al. 1988; Grimmond 2007). Several scholars have focused on to find out the causes and consequences of LULC change scenarios and urban landscape as a part of their study in different aspects, and concluded with proper planning recommendations in a sustainable manner. Belal and Moghanm (2011) studied the urban growth and its consequence of productive agricultural land loss in Al Charbiya governorate areas in Egypt during 1972–2005. Hafez (2011) revealed land-use change patterns from 1990–2000 due to urban expansion and vegetation are increases in the Burg El-Arab area. Hassan et al. (2016) worked on land use/land cover changes due to socio-economic development, population growth, and climate changes. The study finds out that urbanization could change the natural forest land in Islamabad city, Pakistan. Kim (2016) has focused on the LULC changes to identify the percentage of deforestation or forest degradation in Lombok Island, Indonesia. Subasinghe et al. (2016) have worked on the spatio-temporal land use classification to examine the land-use changes and predicted the future of the cities based on drivers in the Colombo Metropolitan Area, Sri Lanka. Hassan MM (2017) has quantified and characterized the Landscape pattern and urban expansion of five selected cities in Bangladesh. Fenta et al. (2017) have used three decades of data (1984–2014) to study the urban expansion of Mekelle City in northern Ethiopia. Tong et al. (2018) have monitored land use/land cover change's effects on the main grassland degradation in Inner Mongolia. Nath et al. (2018) studied the land-use changes in earthquake-prone areas using multi-criteria techniques of the Dujianyan City, China and recommended suitable planning for

the sustainable landscape to build habitation. Jenberu and Admasu (2019) have discussed the driving forces behind the urbanization process in Arba Minch town, Ethiopia. Liu et al. (2020) have explained the factors of urban population growth. The study identified population growth, transportation development, industrial, and real estate values as factors for Islamabad city urban expansion.

The cities of India are expanding very rapidly. At present, the urban population is 377.1 million, and nearly 9.1 crore urban population added during the last 10 years in India (Census of India 2011). It was the first time where the absolute number of urban populations has increased than the rural population. The population distributions in rural and urban areas were 68.84% and 31.16%. The level of urbanism has also been increased by 31.16% in 2011. The growth of the urban population has led to the growth of urban land due to mainly migration (Ramachandra and Uttman 2008). In India, several cities have experienced the rapid growth of urban expansion from CBD (Central Business District) to the outer peripheral regions in the form of the outskirts. Several studies have also used remote sensing techniques for land use/ land cover classification and urban growth in different cities. Mallupattu et al. (2013) have analysed the land-use changes and built-up expansion in Tirupati areas. Rawat and Kumar (2015) have also studied land use/ land cover changes in Uttarakhand using the supervised classification method of the maximum likelihood classifier technique. Mondal et al. (2015a, b) have used satellite imageries to understand the total change of land uses during study periods and quantified changes through the gain, loss, persistence, and net change. Bhat et al. (2017) evaluated urban growth and its impacts on LULC changes over Dehradun City, India. Shukla and Jain (2019) have discussed the urban expansion through modelling of rural-urban transformation in Lucknow city. It was a micro-level study that quantified the pixel-based information about urban growth in different classes. Ganaie et al. (2020) have quantified the population growth and changes land use changing scenario at the Wular catchment of Kashmir Valley. Mishra et al. (2019) have used supervised classification techniques to detect land use/ land cover in the Sikkim Himalaya regions. Many studies have been done on the Kolkata city like urban expansion, city growth, and land use land cover changes using the help of different geospatial models. Bhatta (2010) has

examined urban growth using by application of the CA prediction model and forecasting urban expansion up to the year 2040 in Kolkata city. Ramachandra et al. (2014a, b) have explained the land fragmentation and expansion of urban through modelling of landscape metrics patterns in Kolkata city. Mondal et al. (2015a, b) evaluated urban factors through modelling of geographically weighted regression in the Kolkata city. Mondal et al. (2016) have studied the urban expansion in Kolkata agglomeration areas using CA (cellular automata) method to examine the uncontrolled fragmentation of urban landscape and land-use changes in consideration of selected driving forces. Mithun et al. (2016) have used the landscape metrics in an urban and rural zone of the Kolkata metropolitan region and analysed the urban dynamics. Sahana et al. (2018) have quantified land use land cover change matrix to analyse built-up land expanded during 1990–2015 over the Kolkata metropolitan areas and also found that a large share of urban land has transformed from agricultural land and the authors have used an integrated approach of geospatial techniques to analyse urban expansion and planning management.

Methods and materials

Study area

“Barrackpore Subdivision” is one of the administrative parts among five administrations such as Bangaon, Barasat, Basirhat, and Bidhan Nagar of the North 24 Parganas district and occupied by a very dense settlement. The presence of small and medium industries promoted the area as colonized in the earlier periods. The area is situated over the southern part of the Bengal basin; therefore, the average elevation is only 25 m above mean sea level with a plain slope structure. Hooghly River flows on the western side of the area. Soil structure is mostly medium pouring with loamy, clayey, and silt in nature (<http://wbwridd.gov.in/>). The study area has been recognized as tropical monsoon types and received rainfalls by the South-West monsoon in the monsoon period and by North-East Monsoon in winter. Four climatic seasons such as summer, autumn, spring, and winter have been observed here. In the summer season, the temperature range reaches up to 40°C, while it reaches below 10°C

in the winter season. The present administration setup is divided into a rural boundary (Panchayat) and urban boundary (municipality) based on their population criteria (Census of India 2011). Urban areas hold 16 municipalities or ULBs (Urban Local Bodies) such as Kanchrapara, Haliashahar, Naihati, Bhatpara, Garulia, North Barrackpore, Barrackpore, Titagarh, Khardah, Panihati, Kamarhati, Baranagar, South Dumdum, Dumdum, North Dumdum, and New Barrackpore, 24 census towns (Census of India 2011). The rural areas hold 14 Gram panchayat and 53 villages (Fig. 1).

Database preparation

Satellite imageries (Landsat collection level -1) from the USGS website (United States Geological Survey, <https://earthexplorer.usgs.gov>) and population data from the district Census handbook (<https://>

censusindia.gov.in) have been used to execute the whole research work. The topographical-sheet maps of scale 1:50,000 (F45K5 and F45K6) provided by the Survey of India (SOI) were used to delineate the area boundary. These sheets were scanned and geo-referenced by the given coordinate system using the tool in ArcGIS software and assigned the projection of Universal Transverse Mercator Projection (UTM) and ellipsoid WGS 84 (45N zone). MSS (Multispectral scanner) satellite images of 1972 and 1980; TM (Thematic Mapper) images of 1990, 2001, and 2010; ETM+ (Enhanced Thematic Mapper) image of 2016 was used to mapping out of land use/ land cover characterization of the 44 years within the study area (Table 1).

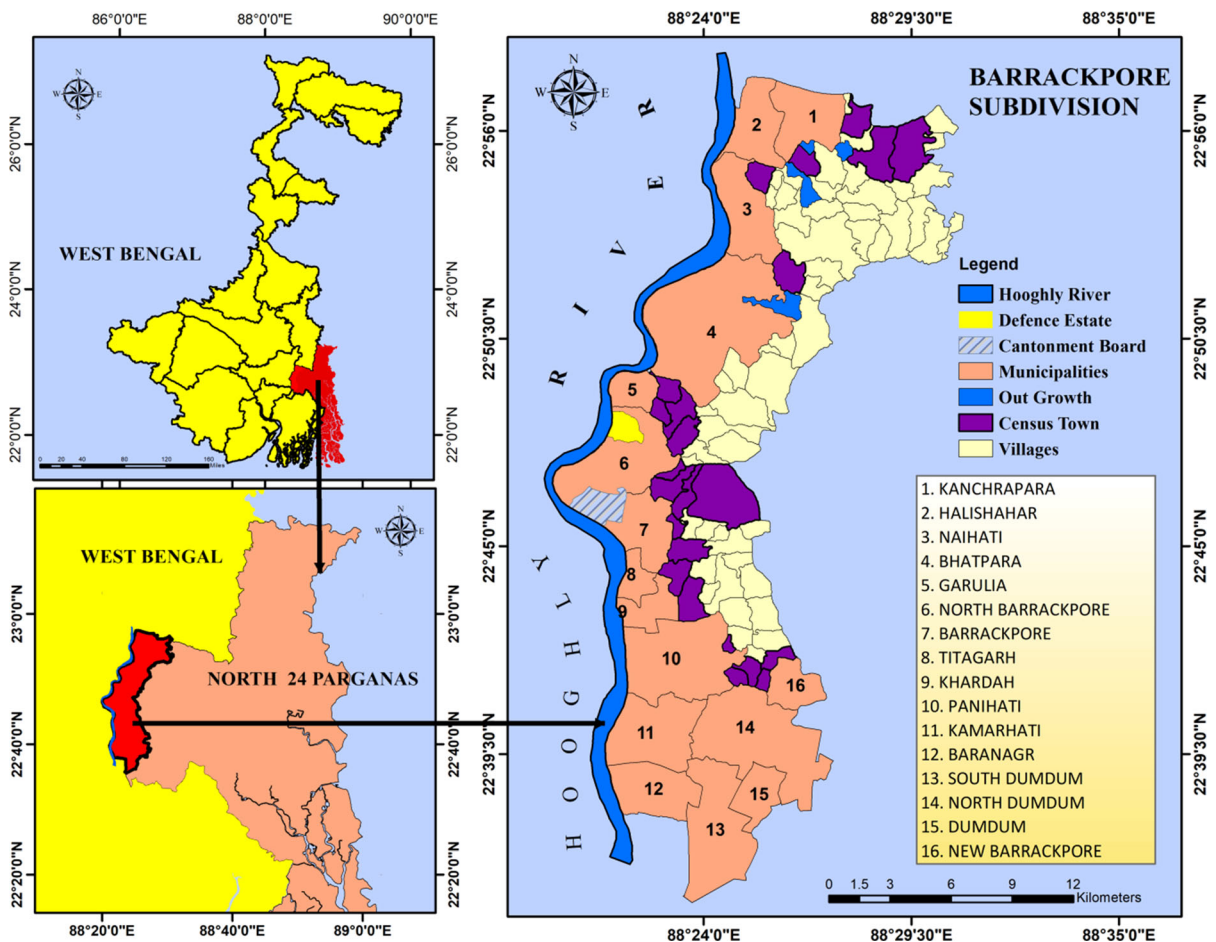


Fig. 1 The study area

Table 1 SourceDetails of multi-temporal data set : USGS earth explorer, <https://earthexplorer.usgs.gov/>, Glovis, <https://glovis.usgs.gov/>

SL No.	Date of images	Sensor	Sensors	Resolution	Bands	Band name	Bandwidth
1	11-12-1972	LANDSAT-1	MSS	60	4	Band 1—Green	0.5–0.6
						Band 2— Red	0.6–0.7
2	21-02-1980	LANDSAT-3				Band 3—NIR	0.7–0.8
						Band 4—NIR	0.8–1.1
3	20-04-1990	LANDSAT-5	TM	30	7	Band 1—Blue	0.45–0.52
						Band 2—Green	0.52–0.60
4	26-04-2001					Band 3—Red	0.63–0.69
						Band 4—NIR	0.77–0.90
						Band 5—SWIR 1	1.55–1.75
5	11-04-2010					Band 7—SWIR 2	2.09–2.35
						Band 6—TIR	10.40–12.50
6	19-04-2016	LANDSAT-7	ETM+	30	8	Band 1— Blue	0.45–0.52
						Band 2—Green	0.52–0.60
						Band 3—Red	0.63–0.69
						Band 4—NIR	0.77–0.90
						Band 5—SWIR 1	1.55–1.75
						Band 7—SWIR 2	2.09–2.35
						Band 8—Panchromatic	0.52–0.9
						Band 6—TIR	10.40–12.50

Pre-processing and land use/ cover classification

Image processing involves layer staking of Landsat spectral bands (optical wavelength) to obtain the FCC (False colour Composite) image and these multispectral images clipped by the area of interest (area boundary) to minimize the computation time. Then, the six satellite images were geometrically and radiometrically corrected to reduce distortions. Accurate information on land-use changes from satellite images is important to monitor urban growth and land resource management (Jensen 2007). Obtaining accurate information from satellite images is a quite difficult and challenging task because the heterogeneous land uses may occur mixed pixel problems especially in urban land (Lu and Weng 2005; Hassan MM 2017). The study has used the rule-based supervised classification- maximum likelihood classifier (MLC) algorithm for LULC classification for acquired images of 1972, 1980, 1990, 2001, 2010, and 2016. The supervised classification was performed by taking training samples with known class types in the ground truth and compared with the spectral

signatures of the pixels in the image with decision rules (Lillesand et al. 2004). This MLC is a probability-based technique (Rawat and Kumar 2015) and more reliable for multi-temporal classification (Strahler 1980; Shukla and Jain 2019). MLC algorithm assembles the spectral signature of the pixel in a specific class was considered as adequate to minimize the complexity of the land uses (Li et al. 2014). MLC method has been applied for this study because the objective is to observe the landscape pattern changes and spatial extension of built-up on a regional scale (Das and Angadi 2020). This method has been adopted by different scholars to carry out the land use classification over the different cities (Sudhira et al. 2003; Rawat and Kumar 2015; Mithun et al. 2016). Based on the ground truth knowledge, the signature training set has been assigned for the respective land-use class in the image. The spectral signature of each class was computed based on the reflectance of the pixel value (Strahler 1980). Land-use categories have been adopted the classification system given by Anderson et al. in 1976 as per the study needs. During the classification process, the mixed pixel problem in

the medium resolution satellite images was solved out by visual interpretation knowledge taken from ground GPS (Global Positioning System) survey and Google earth engine with the 1-meter spatial resolution to get an accuracy of the classification. This study area has classified the landscape into six classes (i) Vegetation (mixed and urban vegetation), (ii) Agricultural land/ Cropland (cultivable land, temporal and seasonal cropland) (iii) Built-up land (residential, industrial zone, commercial areas, and all impervious land), (iv) Fallow land/ open field (Agricultural fallow field, grassland, open spaces, and scrubland), (v) Water bodies and (vi) Wetland.

Many change detection methods can be used for the extraction of land cover change from satellite image classification (Hussain et al. 2013). Digital change detection provides the LULC changes between the two dates to identify the variations (Belal and Moghanm 2011). The direct comparison change detection methods have involved image difference by the rationing of a particular spectral channel. This method is helpful for operational simplification, but it's difficult to get "from-to" change information. Examples of direct comparison methods are band rationing, vegetation indices, principal component analysis, etc (Liu et al. 2020) where the post-classification method is carried out by overlay technique on the classified images of two dates. Accuracy of classification always defines the increases in the post-classification result (Burrough and McDonnell 1998). The post-classification method provides comparisons and quantifies the different changes in the same place of interest. The method was applied in the present study to carry out the "from-to" land use transformation by overlaying the operation of a pixel to pixel on classified data of different periods.

The function of this study is to mapping out the built-up growth for each period. After post-classification, each classified image was again reclassified into binary images (0, 1 format) representing 'Non-built-up' and 'built-up' land using ArcGIS software. The binary images were converted into vector format to observing the urban footprint for each period (Mithun et al. 2016).

Accuracy assessment

An accuracy assessment of classified images has been measured by confusion error matrix tabulation

(Congalton R 1991). The actual and prediction result of the classification is justified by the confusion matrix. The matrix confirmed that the pixel has correctly classified as a particular feature type compared to the same site in the field. The accurate result of classified images provides by the calculation of overall accuracy, user's accuracy (UA), producer's accuracy (PA), and Kappa coefficient. A total of 600 sample points (reference data) have been selected randomly from the different sites of the study by ground verification of GPS survey and Google Earth engine for accurate calculation. The overall accuracy equals the total number of corrected samples are divided by the total number of samples and converted into a percentage. Overall accuracy was calculated in the same way for each year of classification. The producer's accuracy measures the "error of omission" where the user's accuracy measures the "error of commission" (Story and Congalton 1986; Congalton and Green 1999). These two approaches have been calculated for each land-use class. Kappa coefficient (K) was also used in this study for the assessment (Foody 2002) because it is a sophisticated measurement that gives better interclass discriminating than overall accuracy assessment (Foody 2004).

Result and discussion

Population growth and dynamics

The study area is known as the industrial zone of the district. The industries were established along the river for the accessibility of water and transportation could influence to pull migrants from different places. Several industries in the earlier period, such as jute mills, petrochemicals, factories, cotton mills could make this zone an economic zone since independence (Das and Angadi 2020). The total population has increased from 2 lakhs to 41 lakhs during 100 years of time interval (1901–2011) (Fig. 2a). The shares of the rural-urban population were 5% and 95% over the study area (Census of India 2011). The higher population growth rate was recorded during 1951–1961 (after independence) by 46%, and the lowest growth rate was recorded during 2001–2011 (Census of India 2011) (Fig. 2b). Infrastructural development in municipal towns was the reason to pull populations of adjacent villages to get better facilities and services for

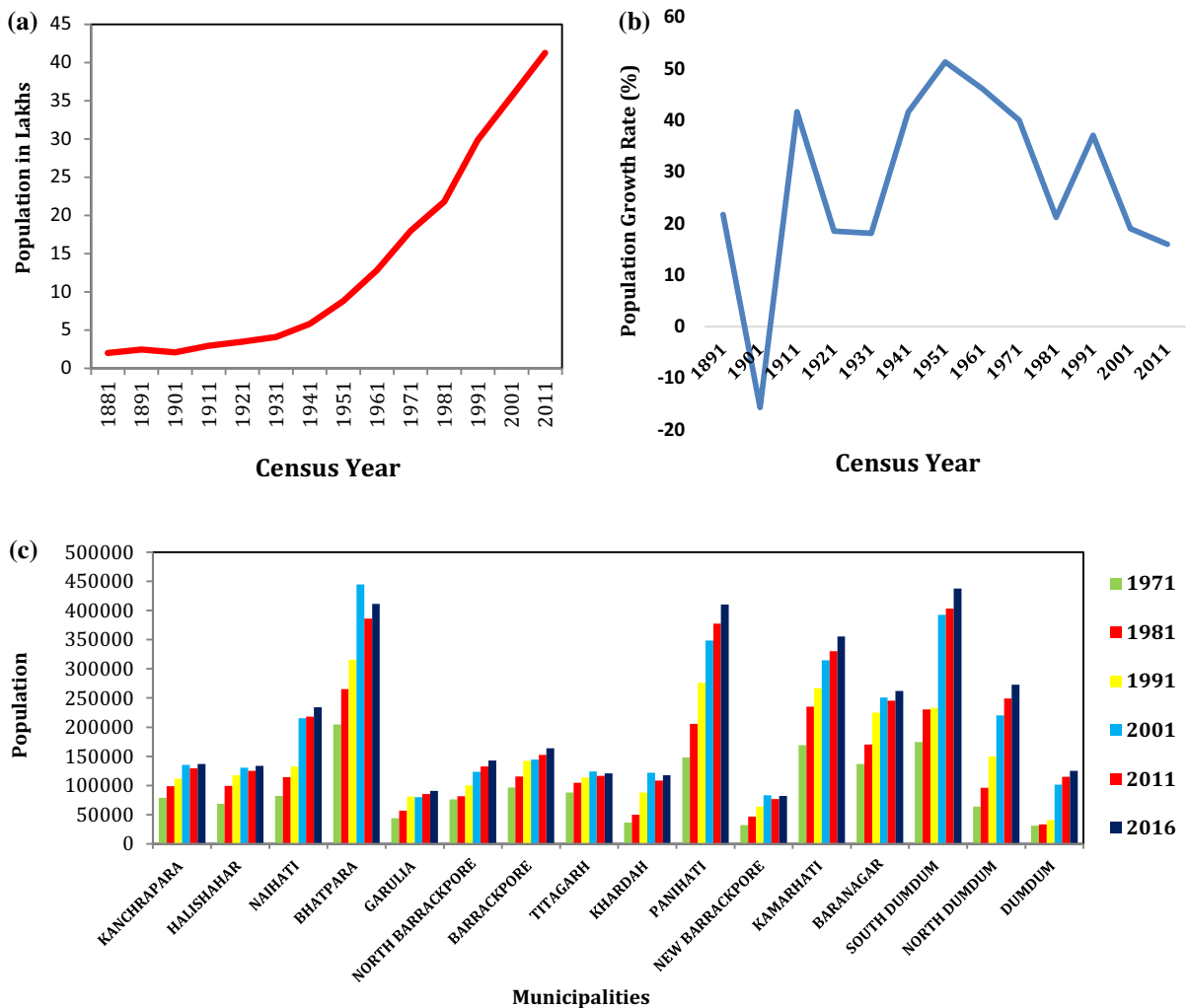


Fig. 2 a Population growth, b Population growth rate, c Population in ULBs

their daily livelihood. The number of villages was 101 in 1951 and now its decrease to 53 in 2011, where the number of towns has increased from 17 to 42 (includes census town) during 1951–2011. Population growth scenarios in the ULBs are plotted in Fig. 2c. In 1971, Bhatpara Municipality was the most populated area (12% of the urban population) of the subdivision, because of the concentration of jute mills. Similarly, the South Dumdum and Kamarhati municipality had contributed more than 10 % of the urban population (Census of India 1971). South Dumdum, North Dumdum, Baranagar, Dumdum, Kamarhati municipalities were faced with more population pressure and maximum growth rate over time (Fig. 2). A total of 33 lakhs (82%) people are live in these municipalities at

present. As per the census report 2011, South Dumdum shares 10% of the urban population which is followed by Bhatpara (9.8%), Panihati (9.6%), Kamarhati (8.42%), and North Dumdum (6.35%), but some of the towns have experienced the negative growth of population such as Kanchrapara, Halishahar, Titagarh, Khardah, Baranagar, and North Barrackpore from 2001 to 2011. The actual population growth happened in all municipalities during the 1971–2011 census years (Census of India 1971 and 2011). The maximum growth rate was observed in municipalities of Naihati (165%), New Barrackpore (136%), South Dumdum (131%), North Dumdum (290.06%), and Dumdum (265%).

Land use/cover status

The quantitative results from the digital LULC classification of six respective years of 1972, 1980, 1990, 2001, 2010, and 2016 are shown in Table 2. The total area of the Barrackpore Subdivision is 30156.5 hectares (ha). Each classified map contains six LULC classes and illustrated the magnitude of changes in the land use categories (Fig. 3). Spatial distribution patterns of land use for 1972 shows that the maximum area was covered by vegetation of 45%, and followed by agricultural land of 28.73%. Fallow field and built-up areas were less in area coverage (Fig. 3a). In 1980, vegetated land was reduced to 44.72% and transformed into built-up land. Agricultural land was also slightly reduced to 28.35%. The surface water areas (wetland and water bodies) were decreased during the period (Fig. 3b). The classified image of 1990 showed that 40% and 27.94% of the area was covered by vegetation, agricultural land. Wetland and water bodies were occupied only 5.73% and 6.62% area, where built-up land was only 15.51% (Fig. 3c). The land-use scenario in 2001 reveals that the amount of area under vegetation, agriculture land, and built-up land was 33.51%, 25.46%, 23.65% (Fig. 3d), where the area under vegetation and agricultural land was 32.62% and 23.01% in 2010 (Fig. 3e). The area of built-up land and the fallow field was increased by 40.71% and 7.91% in 2016 (Fig. 3f).

Accuracy measurement of classification

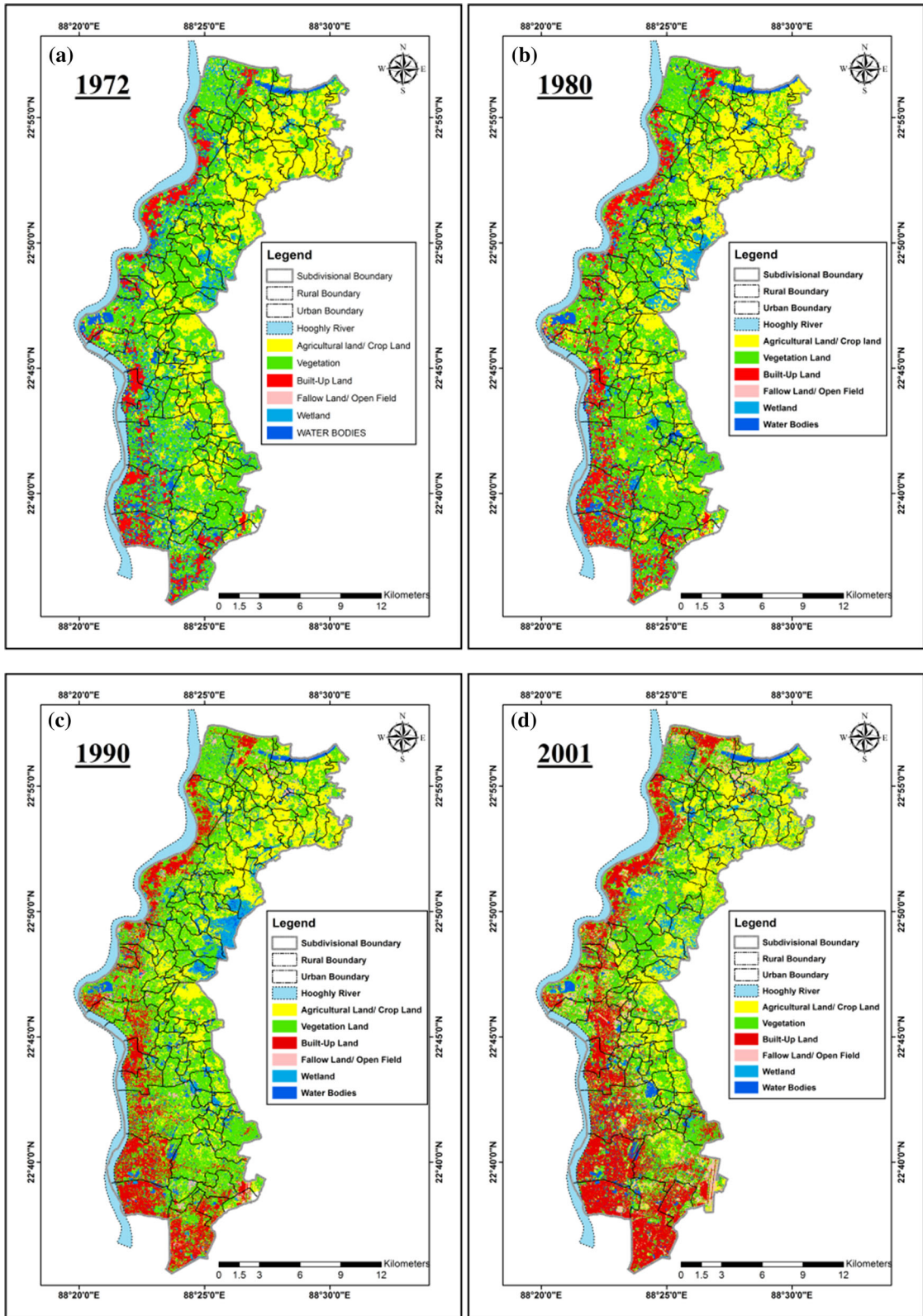
The produced LULC maps from different Landsat imageries were validated by confusing error matrices. The overall accuracy, producer's accuracy, and user's accuracy were computed individually. The summarized results of the assessment were plotted in Table 3. The overall accuracy values of 88.33%, 90.5%, 92.16%, 93.33%, 95%, and 95.16% were achieved from classified images of 1972, 1980, 1990, 2001, 2010, 2016. The classified images consists the kappa coefficient values of 0.86, 0.88, 0.90, 0.92, 0.94, and 0.94 each. The percentage of producer's accuracy and user's accuracy was more than 80% in every land-use class excluding vegetation in 1972. The result of accuracy signifies the agreement between digital classification and ground truths (reference points) have a strong relationship (Congalton R 1991). This was sensibly good overall accuracy as well as accepted to meet the requirement of change detection analysis (Anderson et al. 1976; Lea and Curtis 2010).

Land use/cover changes

The land-use change has shown that the remarkable loss of the water surface was 900 ha during 1972–1980. The huge amount of 'refugee' migration population from Bangladesh had come and settled down in the different parts of the district, meanwhile, the built-up growth rate was 40.55%. During 1980–1990, vegetated land (around 940 ha) has converted rapidly by built-up land. In the next decade

Table 2 Area under Various classes of Land use/land cover

LULC Class	1972		1980		1990		2001		2010		2016	
	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)
Vegetation	13658.03	45.30	13481.76	44.72	12541.58	41.59	10106.10	33.51	9836.88	32.62	6512.04	21.59
Agricultural Land/Crop Land	8662.35	28.73	8578.35	28.46	8426.15	27.94	7676.72	25.46	6938.34	23.01	6510.52	21.59
Wetland	2547.86	8.44	1839.11	6.10	1728.10	5.73	1522.63	5.05	987.40	3.27	714.20	2.37
Built-up Land	2537.46	8.42	3566.44	11.83	4677.76	15.51	7131.68	23.65	8617.38	28.58	12276.04	40.71
Fallow Land/Open Field	472.28	1.57	607.61	2.02	785.07	2.60	1780.64	5.91	1997.84	6.62	2384.00	7.91
Water Bodies	2278.52	7.56	2072.57	6.88	1995.61	6.62	1936.33	6.42	1778.68	5.90	1759.71	5.84



◀ **Fig. 3** Land use/Land Cover Map: **a** 1972 **b** 1980 **c** 1990 **d** 2001 **e** 2010 **f** 2016

of 1990–2001 has shown the proportion of vegetation lost by more than 2435 ha simultaneously (Fig. 4). Degradation of the vegetated land leads to loss of

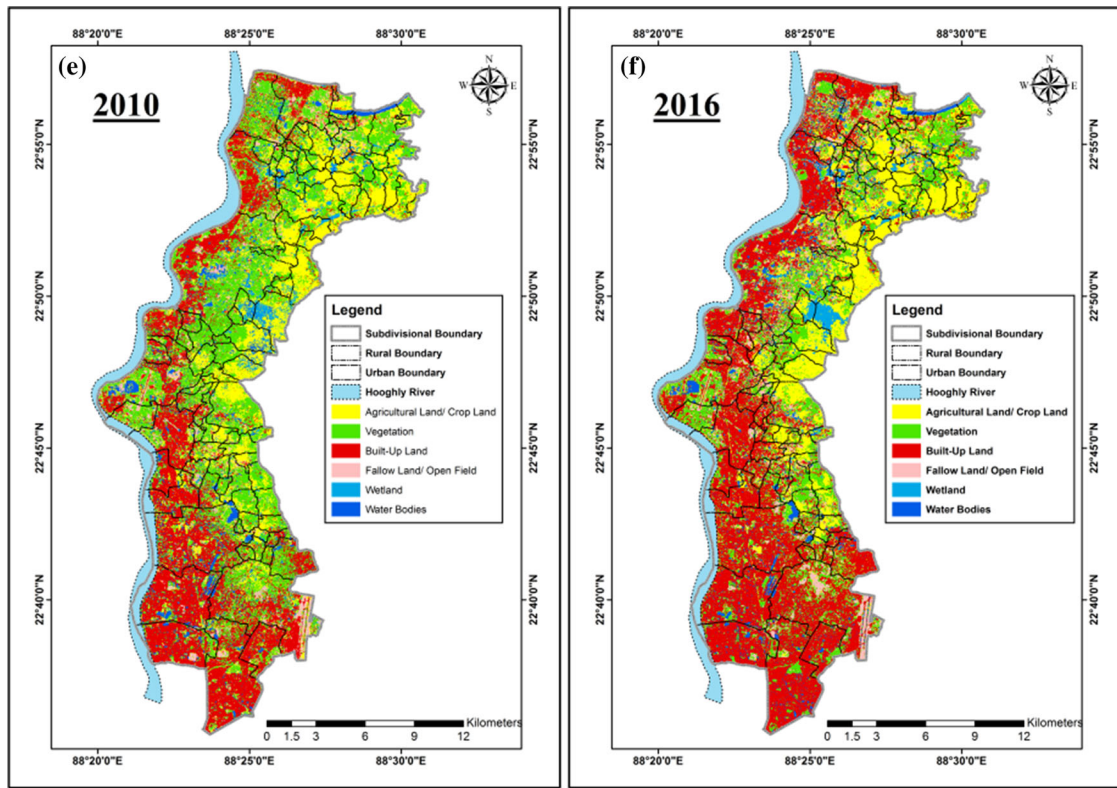


Fig. 3 continued

Table 3 Accuracy of Land use/land cover classification

Land use classes	1972		1980		1990		2001		2010		2016	
	PA (%)	UA (%)	PA (%)	UA (%)	PA (%)	UA (%)	PA (%)	UA (%)	PA (%)	UA (%)	PA (%)	UA (%)
Agricultural land/ Crop land	90.82	89.00	88.07	96.00	89.58	86.00	88.78	87.00	91.09	92.00	94.06	95.00
Vegetation	75.40	95.00	81.51	97.00	88.46	92.00	90.29	93.00	96.04	97.00	94.90	93.00
Built-up land	87.74	93.00	85.58	89.00	93.00	93.00	94.95	94.00	90.74	98.00	94.06	95.00
Fallow land/ Open field	95.45	84.00	98.82	84.00	85.58	89.00	90.74	98.00	95.05	96.00	95.96	95.00
Wetland	95.74	90.00	98.89	89.00	98.95	94.00	98.92	92.00	98.04	100.00	100.00	100.00
Water bodies	89.77	79.00	94.62	88.00	98.02	99.00	96.97	96.00	100.00	87.00	95.88	93.00
Overall accuracy	88.33%		90.5%		92.16%		93.33%		95%		95.16%	
Kappa coefficient	0.86		0.88		0.90		0.92		0.94		0.942	

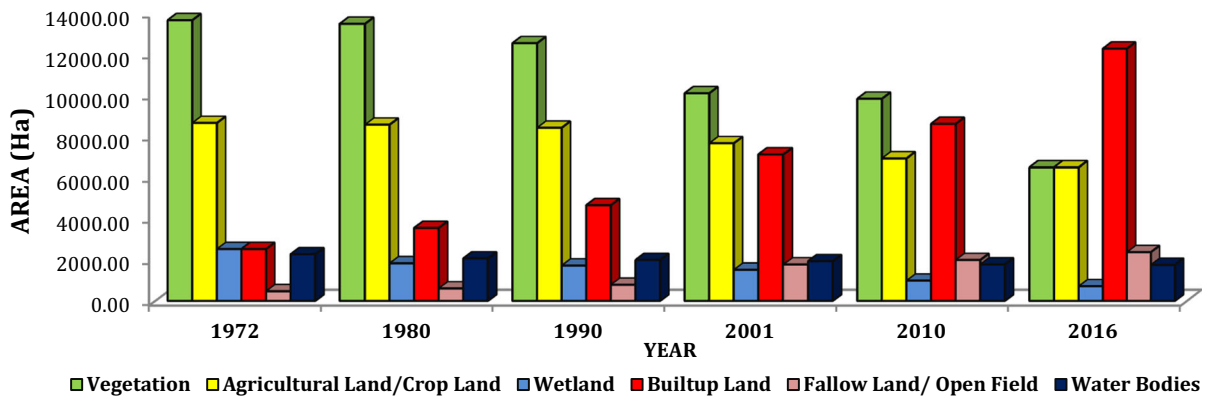


Fig. 4 Land use/cover change during 1972–2016

habitat would impact on micro-climate of the city (Pal and Ziaul 2017). In the study area, vegetation is reducing sharply due to the build of urban inhabitation in municipalities and hinterland areas. It's noticeable that the agricultural land is transforming into fallow land or open grassland at the edges of the urban-rural boundary zone. These zones are facing the slow conversion of agricultural land into built-up land by the development of scattering urban settlements. The most dominating changes were found in built-up land which gained 1485.70 ha during 2001–2010. Most of the wetland areas were filled by a build of residencies in municipal areas. The study has found that the urban settlement is expanding on a rapid scale due to the effects of emerging private business sectors, IT companies in the southern part near to the Kolkata city during 2010–2016 (Fig. 4; Table 4). There are 24 census towns increased in the study area during the 44 years, which evidenced the urban development impacts on rural transformation. As a result of urban sprawl, the villages close to the municipal border were merged and converted into census towns i.e., Balibhara, Chakla, Jayanpur, Jetia, Nagdaha, Nanna, Palashi, Palladah, Shotribati in Bijnur police station; Kaugachchi, Paltapara in Jagaddal police station, Dogachhia in Naihati police station; Babanpur, ChakKathalia, Jafarpur, Mohanpur, Telinipara in Titagarh police station; and Bandipur, Chandpur, Muragachha, Patulia, Ruiya, Telinipara in Khardah police station.

Land use/cover transformation (1972–2016)

A change detection comparison map was produced after the post-classification of imageries (1972–2016) to comprehend the spatial changes over the study area among years by overlay techniques in GIS (Fig. 5). The number of net changes in each LULC category was summarized after minimizing the total gross losses from the total amount of gross gains. The transformation from one category to another type of land category is quite significant; therefore, the post classified matrix table from 1972 to 2016 indicated the transformation of six land-use classes. The row total designated the quantity of LULC in 1972 and the proportion of land use classes in 2016 was summarized by the column total at the bottom (Table 5). The off-diagonal values represent landscape transitions from one to another land use category, while matrix diagonal values indicate the existence of each landscape category.

Urbanization and its development activities have been the main reasons for the transformation of land use over the last 44 years in the Barrackpore region. Most of the non-urban areas were changed into built-up land at the cost of vegetation cover and wetland. About 20% (6030.52 ha) of the area under vegetation was transformed into urban land during the 1972–2016 (Fig. 5). Population growth, demand for urban life activities, increasing urban households, and colonies are enhanced to remove trees around the environment. The other important change was observed in agricultural land. Nearly 1804.35 ha (6%) of land was transformed into urban land. The water surfaces, fallow land, and other land uses were also transformed

Table 4 Changes in an area under various classes of LULC (1972–2016)

LULC class	1972–1980		1980–1990		1990–2001		2001–2010		2010–2016	
	Area (ha)	Change (%)	Area (ha)	Change (%)	Area (ha)	Change (%)	Area (ha)	Change (%)	Area (ha)	Change (%)
Vegetation	- 176.27	- 1.29	- 940.18	- 6.97	- 2435.48	- 24.10	- 269.22	- 2.66	- 3324.84	- 33.80
Agricultural land/Crop land	- 84.00	- 0.97	- 152.20	- 2	- 749	- 10	- 738.39	- 10	- 427.81	- 6.17
Wetland	- 699.13	- 27.54	- 111.01	- 6.04	- 205.47	- 13.49	- 535.23	- 35.15	- 273.20	- 27.67
Built-up land	+1028.97	+40.55	+1111.33	+31.16	+2453.91	+34.41	+1485.71	+20.83	+3658.66	+42.46
Fallow land/ Open field	+135.33	+28.65	+177.46	+29.21	+995.57	+55.91	+217.20	+12.20	+386.17	+19.33
Water bodies	- 205.95	- 9.04	- 76.96	- 3.71	- 59.28	- 3.06	- 157.65	- 8.14	- 18.98	- 1.07

into impervious areas. Vegetation is considered a natural resource in ecology. The total loss of vegetation was 10031.2 ha (33.2%). The alteration from vegetation to agricultural land was 1867.62 ha (6%). Increasing in population among the villages can emphasize cutting out vegetation and convert it into an agricultural field. Agricultural land (4848.2 ha) was lost due to changes in land uses (Table 5). Total conversion from agriculture to other land was 16% during 1972–2016. Vegetation cover, agricultural land, and surface water bodies have been converted into fallow lands by 2.6%, 3.76%, and 1.2%. With high demands for household settlement and the extreme residential threshold limits in municipal areas are forced to expanding urban land towards periphery and fringe areas along with transportation nodes (Balha and Singh 2018; Shukla and Jain 2019). Water bodies and wetland areas have been encroached by human activities. Nearly 9994.38 ha (33.5%) land out of the total area has remained as no changing area. On the other hand, 20162.12 ha (66.5%) has changed in the different landforms to another landform (Fig. 5).

Post- classification changes in built-up land

The impact of human actions has intensely changed the land use pattern of the study area (Ramachandra et al. 2014a, b). Post-classification images revealed that the non-built-up land intruded by rapid population growth. Gains and losses of urban land have been illustrated in Fig. 6. The conversion of urban land during 1972 -1980 indicated that the net urban built-up land was transformed from agricultural land, fallow land or open field, vegetation, water bodies, and wetland by the area of 0.93 ha, 37.24 ha, 609.88 ha, 239.6 ha, 141.28 ha. The persistence urban area was 1619.91 ha (5.3%). Total gains and losses of urban land were 6.4 % and 3% out of the total study area (Fig. 6a). In the next decade (1980–1990), persistent urban land was 2171.5ha. Net Changes in built-up land was increased at 1111.33 ha. The conversion from other land uses such as vegetation, agricultural land, wetland, water bodies, and open land into built-up land was 655.03 ha, 36.98 ha, 187.78 ha, 175.54 ha, and 56.06 ha (Fig. 6b). During 1990–2001, the gain percentage of the total built-up land has increased than before decades. The steady urban land was 3625.80 ha. Total 11.64 % built-up area was gained by converting non-built-up land (Fig. 6c). Urban growth

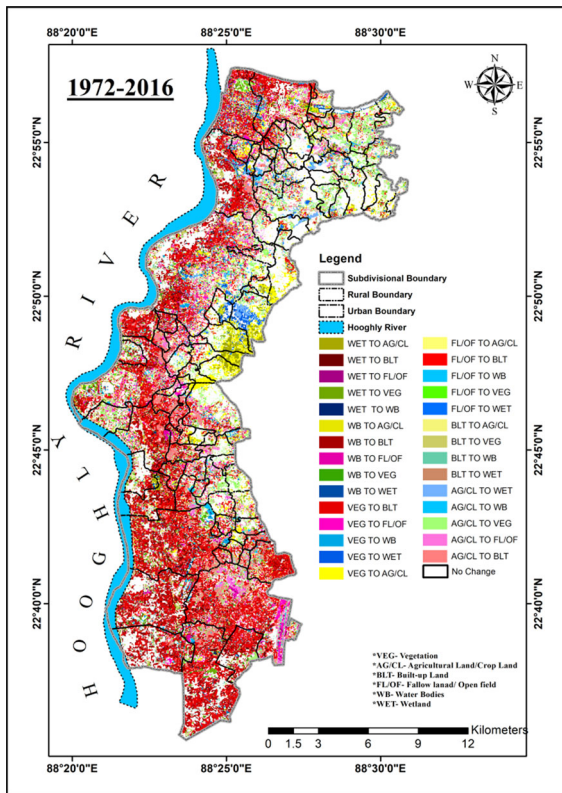


Fig. 5 Change Detection Map (1972–2016)

during 2001–2010 illustrated that built-up land was gained by 11% from transforming of the other land such as vegetation (687.98 ha), agricultural land (453.78 ha), fallow land (242.37 ha), water bodies (70.93 ha), and wetland (30.53) (Fig. 6d). The maximum transformation in urban land-use (3658.66

Fig. 6 Built-up growth: **a** 1972–1980, **b** 1980–1990, **c** 1990–2001, **d** 2001–2010, **e** 2010–2016

ha) happened by converting vegetation land during 2010–2016 (Fig. 6e).

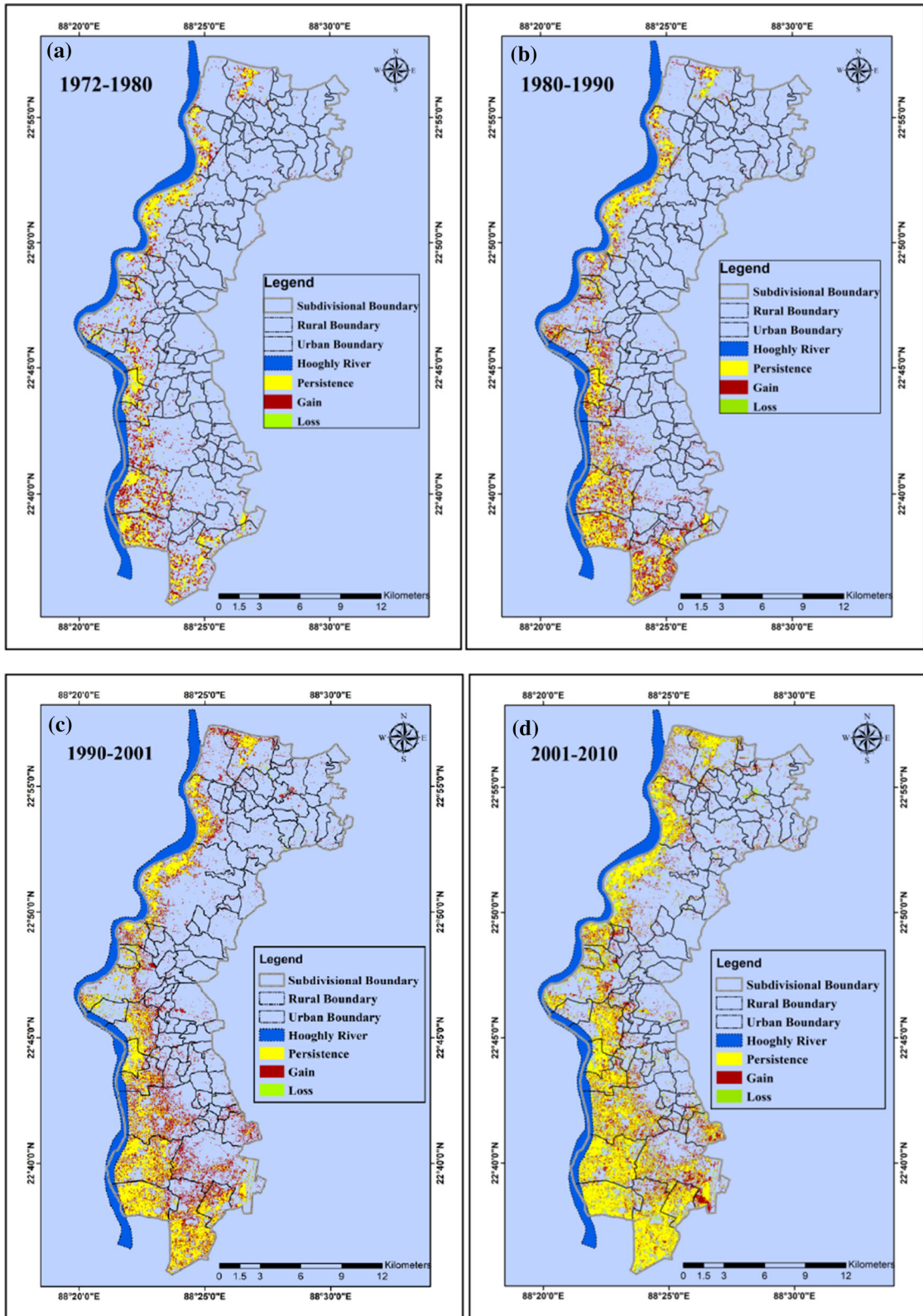
Figure 7 depicts the spatial distribution pattern of the urban sprawl of the Barrackpore Subdivision from 1972 to 2016. Urban footprint indicated the percentage share of the built-up extent was 8.41 % and increased to 11.83 % during eight years (1972–1980). The built-up land was 15.51% and 23.65 % in 1990 and 2001. The urban scenario was 28.58% in 2010, and the fastest growth has been noticed in 2016 (Table 2). Here, the overall growth rate was 384% over the study period (1972–2016). Especially, the eastern side is protected by the Hooghly River; therefore, the concentration of urban sprawl is occurring toward the western part.

Driving forces to build impervious land in urban centers

Urban growth in the municipal towns of Barrackpore sub-division has been described in this section. Higher built-up land concentration was found in the industry-oriented municipalities in 1972. Bhatpara, Naihati, Titagarh, Kamarhati, Baranagar, and South Dumdum towns had the higher built-up land of 393.34 ha, 205.45 ha, 143.25 ha, 304.24 ha, 309.0 ha, and 288.19 ha, where the North Barrackpore, Barrackpore, Panihati, Khardah, and Garulia towns had steady

Table 5 Land use/cover Change matrix from 1972 to 2016 (area in Ha)

1972	2016						
LULC Categories	Agricultural Land/ Crop Land	Built-up Land	Fallow Land/ Open Field	Vegetation	Water Bodies	Wetland	Grand Total
Agricultural Land/ Crop Land	3814.14	1804.35	795.23	1742.24	250.13	256.27	8662.35
Built-up Land	81.50	2040	76.15	202.13	132.29	5.39	2537.46
Fallow Land/ Open Field	67.17	207.79	57.5	112.73	21.07	6.02	472.28
Vegetation	1867.62	6030.52	1133.92	3626.83	751.77	247.37	13658.03
Water Bodies	242.24	1043.60	149.88	334.06	437.75	70.99	2278.52
Wetland	437.87	1149.78	171.32	494.05	166.70	128.16	2547.86
Grand Total	6510.52	12276.04	2384	6512.04	1759.71	714.2	30156.5



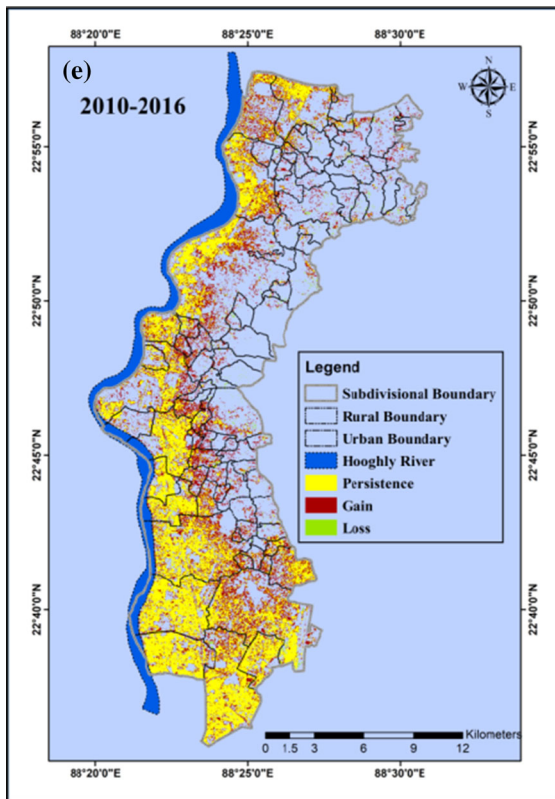


Fig. 6 continued

impervious land of 105.38 ha, 108.57, 105.87 ha, 75.39 ha, and 66.48 ha in 1972. The locational influences of the Ishapur Rifle factories, Barrackpore cantonment board, sub-divisional headquarters at Barrackpore, and Khardah Panihati industrial belt could help to build residential growth in the central part of the study area. The railway workshop commercial farm influenced the growth of the city Kanchrapara and Halishahar. In the Southern part of the study area, Dumdum, and North Dumdum municipal town had faced more urban residencies due to the presence of the Kolkata district (Fig. 8). New Barrackpore and Halishahar municipality have gained more than 300 ha built-up land-use due to the extreme compactness of urban land in neighbouring municipalities during 1972–2016. The rapid increase in built-up land at South Dumdum, North Dumdum, Dumdum, Kamarhati cities could promote to develop of the New Barrackpore town, where the Kanchrapara town influenced to grow the adjacent Halishahar town.

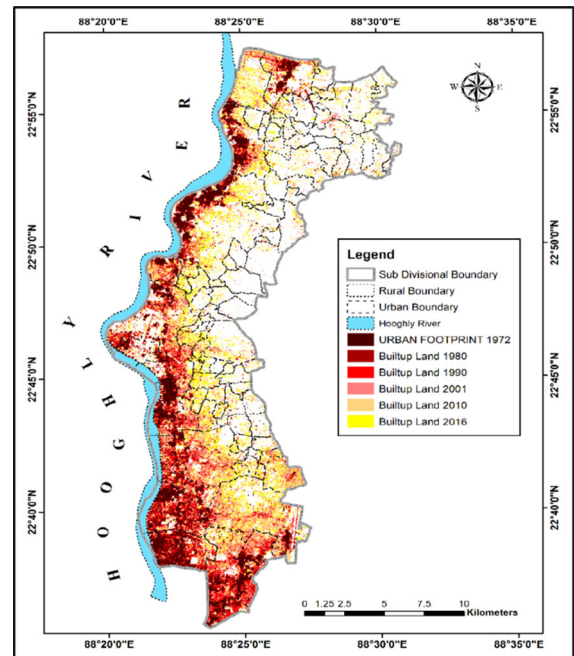


Fig. 7 Urban Footprint map (1972–2016)

The urban growth rate of different municipalities is varying due to the diverse roles of development and socio-economic status over the decades. The highest growth rate was found in Panihati, Kamarhati, Baranagar, South Dumdum municipality during 1972–1980. In the interval between 1980–1990, the huge built-up growth has found in South Dumdum (added 228 ha), Kamarhati (added 127 ha), Baranagar (added 130ha) urban centres, and low concentration built-up land found in Halishahar, New Barrackpore, and North Dumdum areas. Naihati, Bhatpara, and Barrackpore town were faced with rapid built-up growth in 1991. Maximum built-up land has been added to the Panihati municipality by 327.37 ha. The decade of 1990–2001 was the rapid urban growth period among the municipalities, while the decade of 2001–2010 was the steady growth period. With the growing periods, it is noticeable that most of the towns are becoming compact by built-up land, especially in the Titagarh, Baranagar, Kamarhati, Dumdum, Garulia town. Bhatpara, North Dumdum, and Panihati are facing continued urbanization with time in the study area (Fig. 8).

In 2016, the built-up scenario was full at every corner of each ULB. The result displayed that Kanchrapara, Halishahar, Naihati, Bhatpara have

increased in urban built-up land by 365 ha, 343.69 ha, 615 ha, 1146.82 ha out of their total municipal area. Municipal authorities such as Garulia, North Barrackpore, Barrackpore, and Titagarh holds 257.31 ha; 575.33 ha; 515.60 ha, and 201.65 ha built-up land. Khardah, Panihati, Kamarhati, and Baranagar ULBs have increased by more than 60 % of urban land. North Dumdum, South Dumdum, Dumdum, and New Barrackpore towns are having more than 70 % of built-up land at present days (Fig. 8). Industries, factories, and commercial companies as major drivers provided an ideal development environment to upsurge the basic amenities such as hospitals, transportation networks, higher education facilities, shops, and recreational activities, small and medium industries for daily employment. Almost many old productive industries like Jute mills were closed at present in the ULBs but development factors and effects of capitalism could support the persistent growth of built-up areas. Urban development of a city has both positive and negative impacts on the environment. The positive sides of urbanism are economic development, social infrastructure improvement, and capitalism, but negative impacts lead to an increase in the slum environment because the piece of land is very crucial to settle in a compact urban extent. Air pollution, water pollution, reduced hydrological balance; loss of vegetation and emission of CO₂ are promoted due to urban growth.

A Scatter plot displayed a strong positive correlation between population and built-up area (Fig. 9). The correlation coefficient value (R²) is 0.741 in 1972 indicates that the Bhatpara municipality was the

highest position in population size as well as a built-up area, followed by South Dumdum, Kamarhati, Baranagar; where New Barrackpore, Khardah, Halishahar, Garulia had both variables low (Fig. 9a). In 1980, the highest populated areas had more built-up land excluding Dumdum and Halishahar municipalities. The R² value (0.80) is representing a good positive relationship between the two variables (Fig. 9b). During 1990, the population growth rate exceeds built-up growth; hence, the number of the population was more than the built-up area in ULBs (Fig. 9c). The relationship displayed the same positive relationship character among all ULBs in 2001 (Fig. 9d). The constantly increasing population in urban municipal towns could support to become compacted by residential growth in 2010 and 2016. The overall scenarios in municipalities displayed that South Dumdum, Kamarhati, Baranagar, Bhatpara towns have experienced rapid growth of population and built-up land as well (Fig. 9e) and (Fig. 9f).

Conclusion

The spatiotemporal changes of land cover in the rapid urban environment of the Barrackpore Subdivision, West Bengal were explored during 1972–2016 using remote sensing data. Nearly 30% of the area under various land use/ land cover has transformed into the built-up area during the last decade. The built-up area has experienced a 384% growth during the study period. Built-up area has recorded a growth of 6.4% (1972–1980), 8.2% (1980–1990), 11.6% (1990–2001),

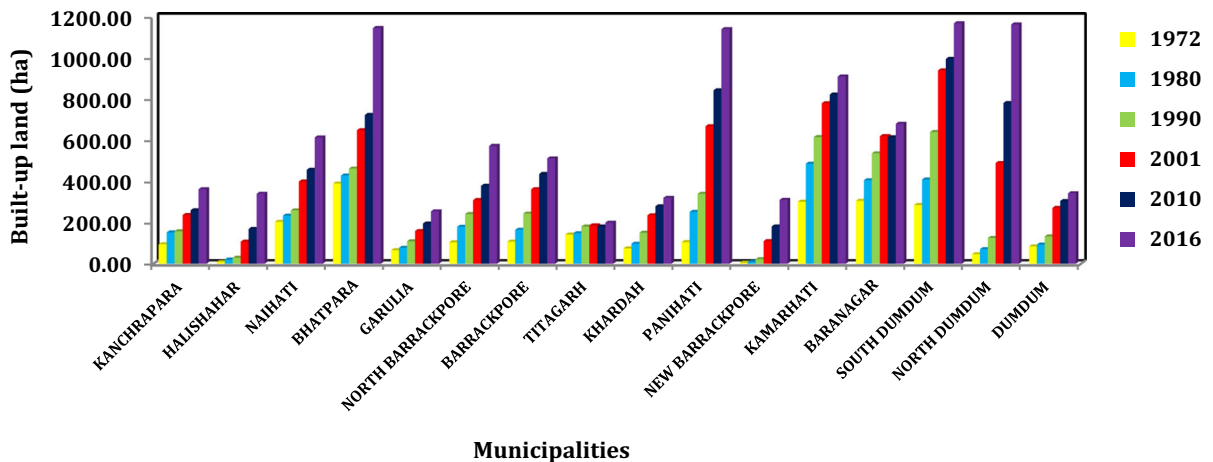


Fig. 8 Built-up land growths in Urban Local bodies

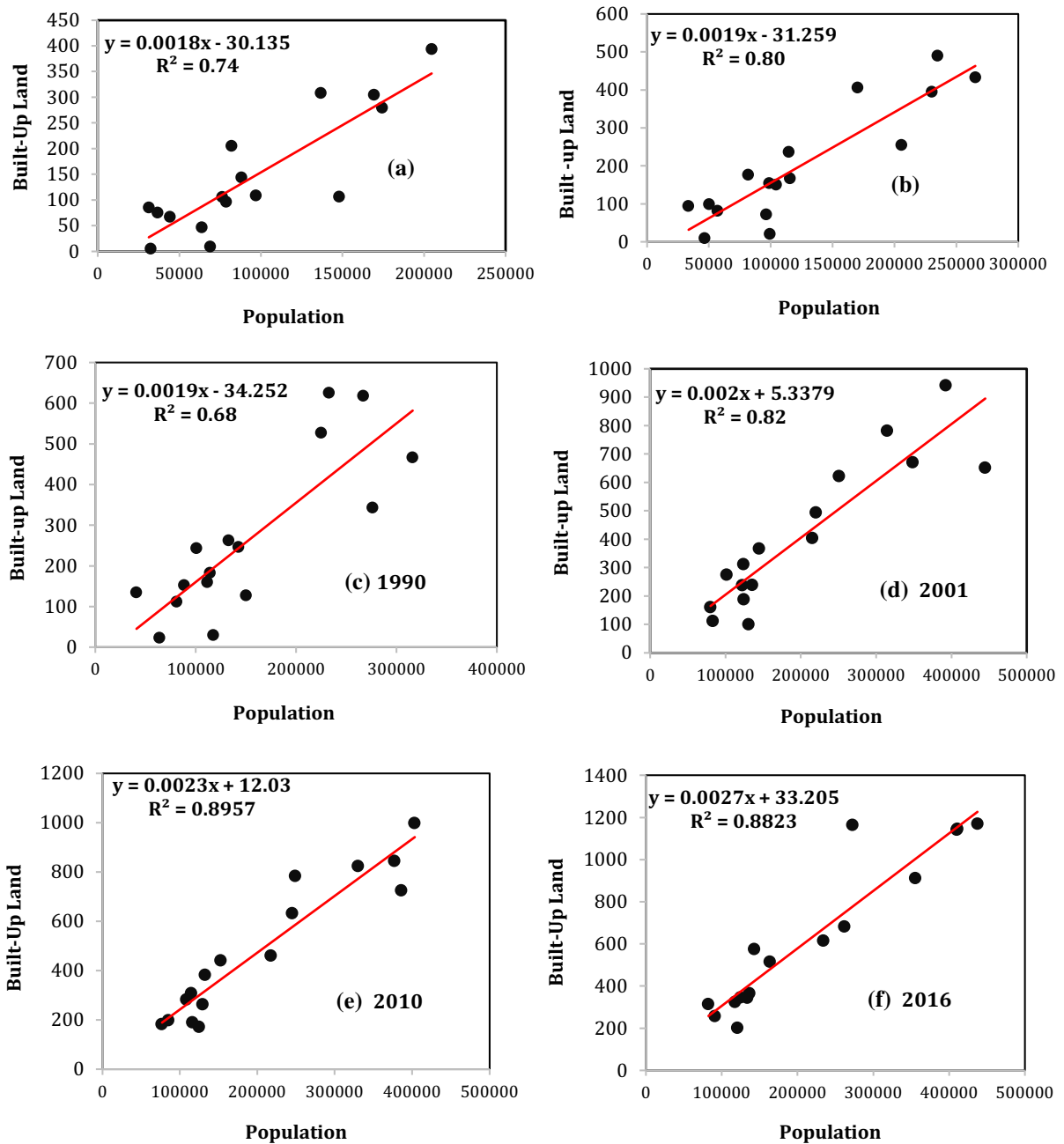


Fig. 9 Relationship between population growth and Urban Expansion: **a** 1972 **b** 1980 **c** 1990 **d** 2001 **e** 2010 **f** 2016

10.6% (2001–2010) and 16.2 % (2010–2016). The development of infrastructure for the rising population has accelerated the transformation of land and degradation of the environment. The expansion of urban land has an impact on the natural environment in terms of microclimate variability, landscape ecology fragmentation, and ecosystem degradation. It has

indicated that the area experienced horizontal urban growth at the expense of natural vegetation. Therefore, it would be important for the decision-makers and planners to consider the vertical urban growth for the optimization of land uses. The aims of land policies should be taken to make towns sustainable. The results of the study hold a direction towards understanding the

current urban expansion dynamics status and LULC pattern to take comprehensive policies for urban sustainable growth in the coming future.

Acknowledgement The first and second authors are sincerely thankful to UGC (University Grants Commission), New Delhi for financial support and incredibility grateful to the anonymous reviewers for their constructive comments and suggestions which helped to improve the overall quality of the present work. We would also thankful to the US Geological Survey for provides Landsat satellite imageries for the land use analysis free of cost.

Funding Funding is received from the University Grants Commission, National Eligibility Test (UGC-NET) Junior Research Fellowship for conducting the present research.

Compliance with ethical standard

Conflict of interest It is a declaration that there are no conflicts of interest concerning the research, authorship, and /or publication of this article.

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