17 Assessment of Land Use and Land Cover Change in the Purulia District, India Using LANDSAT Data

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Abstract

The analysis of land use and land cover change has become necessary and urgent in the field of man–environment relation or resultant global environmental change. The present study analysed temporal and spatial changes of land use and land cover (LULC) in Purulia district covering an area of 6300 km^2 by comparing classified LANDSAT satellite images of 1990 and 2020 coupled by land use transition matrix and Markov Chain model to derive functional information of the spatio-temporal change of the LULC classes. The same analysis was performed at the watershed level. The results show that all selected LULC classes have changed from 1990 to 2020. About 113 km^2 of dense forest (i.e. 21% of the total forest area) has been lost whereas, 452 km^2 of fallow (i.e. 35% of the total fallow land) has been lost because of afforestation and expansion of agriculture. The conversion of dense forest to fallow with vegetation and fallow to fallow with vegetation were the major processes of deforestation and afforestation respectively. The loss of dense forest and gain of fallow with vegetation were lumped with several govt. plantation programmes in the last few years. The transition from fallow to agriculture and from dense forest to fallow with vegetation were the dominant LULC transition processes. The probability of built-up area (98%), fallow with vegetation (96%), and waterbodies (95%) to remain in the same LULC was high. Fallow was noticed as the most disturbed land cover followed by dense forest and agriculture. Future efforts should be made to manage the forest health in this naturally disturbed area where land is sloppy, the soil is infertile, and water is limited. For the proper formulation and implementation of sustainable forest management practices or policies, these findings can be used as primary references.

Keywords

Land use land cover · Transition matrices · Markov chain · Purulia · Watershed

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17.1 Introduction

Land cover (LC) and land use (LU) are two major indicators describing the natural and man-made environment concerning both environmental or natural processes, and anthropogenic activities like human settlement and economy. Land covers refer to objects which are mainly naturally originated and subject to change by anthropogenic intervenes like deforestation, cultivation, construction etc. In contrast, land use is a man-made result and refers to the outcome of developmental activities, which means a higher degree of development is coincide with more diversified and complex land uses.

The study of LULC change is one of the main parameters to recognise the environmental modification (Xiao et al. 2006; Basommi et al. 2016) and level of economic development (Currit and Easterling 2009; Najmuddin et al. 2017) at different spatio-temporal scale, such as continent like Africa (Brink and Eva 2009); country like Slovakia (Pazúr and Bolliger 2017) and Mexico (Mas et al. 2004); watershed (Gautam et al. 2003; Allende et al. 2009; Mendoza et al. 2011; Najmuddin et al. 2017); regional (Lambin 1997; Gomez-Mendoza et al. 2006; Wang et al. 2008) or local scale (Lopez et al. 2001; Bayarsaikhan et al. 2009). LULC change is a dynamic process and directly associated with biodiversity loss (Jansen and Gregorio 2002), water and soil quality, runoff and soil erosion rates (Dunjó et al. 2003), local or global food security and poverty (Lambin et al. 2001; Geist and Lambin 2002; Shriar 2002; Carr 2004; Carr et al. 2005; Ewers 2006), human health (Shi et al. 2018), inter and intra-migration (Lopez et al. 2006), environmental hazards (Liu and Shi 2017), etc.

The balance between these could resolve the future biodiversity conservation on every parcel of land over this planet. Similarly, a perfect balance could act as an important active booster not only enhance the economic prosperity of a region, but also resolve the conflicts that arise through man's practices over the environment. Therefore, it is significant to identify the area and quantify the degree of land diversion from land covers to land uses (Lee et al. 1995; Verburg et al. 2009). In recent time tendency to recover, regenerate of land covers such as forest or water bodies through LULC transition have demonstrated. In India, numerous efforts have been given by the Central and State Governments in land conversion procedure and MGNEREGA is the world's largest programme in this circumstance where maximum attentions have been paid in excavation and renovation of water bodies, creation of vegetal cover, and conversion of land for cultivation. Therefore, researchers and policymakers need to realise the interconnections amongst the processes that result in the two-way transition (Mendoza et al. 2011). Such processes and interconnections are so much complex in India that land conflict and man–environment conflict concerning land is an everyday event and often regarded as the main hindrance for any land-related project, makes it time-consuming. India has attracted worldwide attention as the country holds the second populous position of the world, her very fast emerging economy, and increasing share in global trade.

Amongst the land conversions or transitions, deforestation is the most important process of LU change (Lambin 2001), as it is positively related to the other processes of the environment. Many studies have successfully established the close relationship between deforestation and climate change (Malhi et al. 2008; Bonan 2008), loss of biodiversity, increasing CO content and other greenhouse elements (Chakravarty et al. 2012; Barlow et al. 2016), soil erosion and degradation (Lal 1996), flooding (Gentry and Lopez-Parodi1980), and also the human livelihood (Soltani et al. 2014). For proper policy intervention, it is necessary to understand the deforestation processes and related sub-processes both quantitatively and qualitatively. Deforestation is the conversion of forest land to other land use types (e.g. forest to agricultural land, grassland, built-up area or any other land use types). Thus, in the present study deforestation is defined as dense forest being transformed to other land use types, whilst afforestation is the reverse process. The regulatory factors of deforestation are varied regionally; the most common factors of deforestation are logging for timber, generation of agricultural field, mining and urbanisation, industrialisation, and grazing in developing countries of Asia (Hosonuma et al. 2012). In India, uncontrolled population growth leads to a dramatic increase in food and allied products is considered the main driver of deforestation (Nagdeve 2007; Basnayat 2009). According to the 2019 summary of the Forest Survey of India (FSI), a positive change in forest cover is noticed in India, as it was 21.67% of the total geographical area as of 2019 whereas it was only 19.39% in 1999. But the statistics are not so satisfactory if we considered the states or districts as the study unit. It varies from 3.59% for Haryana, 3.65% for Punjab in 2017 to 86.27% in Mizoram, 79.96% in Arunachal Pradesh. As of 2017, the recorded forest area in West Bengal was 18.68% of the state's geographical area, which was 18.98% in 2015. Types of forest cover are also an important factor to recognise as the mixed and open forest is increasing in the area whereas the decreasing trend is noticed in the case of dense forest.

Current interests of the researchers have been paid for real-time mapping and monitoring the LULC changes at different spatial scales using satellite imageries, conventional aerial photo, digital photograph, topographical sheet, or Google Earth (Shultz et al. 2010; Hegazy and Kaloop 2015; Kibret et al. 2016; Pazúr and Bolliger 2017). Such data or techniques are facing lots of limitations associated with measurement of landscape change during different periods, data quality, data processing techniques etc. (Fuller et al. 2003). The use of satellite imageries improves the quality of LULC assessment since there is a lack of study at different spatial scale. Therefore, multi-temporal analyses of LULC changes should fill the gap to understand the processes and patterns during the historical periods (Mendoza et al. 2011). For the researchers, it is important to realise how these changes over time and what are the factors or driving forces that oversee the rates of LULC change over a particular region and also how these factors vary from region to region. Such understanding would allow us to identify the relationship between LULC processes and socioeconomic variables like population growth (Ningal et al. 2008), migration (Lopez et al. 2006), industrialisation (Currit and Easterling 2009), urbanisation (Lopez et al. 2001).

The watershed is considered as an ideal spatial unit to understand the LULC processes over time as the hydrological processes are easy to identify within this particular spatial unit and other environmental or socioeconomic factors are directly related to these processes. There is no universal or single method for achieving effective watershed management (Naiman et al. 1997; Bhatta et al. 1999; Gautam et al. 2003). Therefore, it could be valuable for watershed management to incorporate explicit watershed information with LULC changes and makes an integrated approach (Mendoza et al. 2011). For that, a watershed can be divided into microscale or sub-watersheds. In the present study, our study area Purulia district of West Bengal is subdivided into five watersheds amongst them Damodar, Silabati, Dwarakeswar, and Kangshabati are belong to Damodar River Basin (DRB) and Subarnarekha belongs to Subarnarekha River Basin (SRB).

This paper analyses the LULC change process over 30 years from 1990 to 2020 in the Purulia district of West Bengal, India as a whole and also at the watershed level. Specifically, the objectives of this paper are:

- To identify the LULC at the 30-year period between 1990 and 2020 using Landsat imageries at district and watershed level.
- To quantify the LULC change through Transition Matrices.
- To predict the future trend of LULC change using Markov Chain at the watershed level.

17.2 The Study Area

Purulia, a district of West Bengal in India is situated in the western side of the state (22°60′N–23°50′N latitudes and 85°75′E–86°65′E longitudes). It belongs to a sub-tropical climate and is characterised by a high rate of evaporation where monsoon is prevalent. The district receives 1100–1500 mm of rainfall annually, with monsoon rains accounting for about 75–80% of the total rainfall. The annual temperature range is high as the average temperature is 2.8 °C in winter to 52 °C in summer approximately. The district is represented by pediplain with some residual hills of the Archean Era that belongs to the peninsular shield of India with an altitude of 150–300 m and covered by the Chhotonagpur Gneissic complex. Based on the difference in physiographic features, the district is sub-divided into three broad micro-physiographic regions namely (a) Damodar–Darkeshwar Upland, (b) Upper Kasai Basin, and (c) Bagmundi–Bundwan Upland. The geology of Purulia mainly composed of granitic terrain consisting of a crystalline basement covered by a very thin layer of soil of haplustalfs subgroup of alfisol group which is mainly rock fragments and weathered materials. This kind of soil is generally infertile. Groundwater potentiality of the district is poor (< 40MCM) to moderate (40–90 MCM), but it is fairly good (> 90 MCM) in the North-Eastern (Raghunathpur-1, 2 and Santuri) and Western (Jhalda-1, 2) parts only. Kangshabati, Kumari, Damodar, Subarnarekha, Dwarakeswar, Silabati are the main rivers of Purulia district. Damodar flows along the northern boundary, Subarnarekha along the southern portion, Kangshabati and Kumari along the middle of the district. Silabati and Dwarakeswar originate along the north-eastern part of the district. Silabati, Dwarakeswar, Kangshabati, Damodar are the sub-watershed of Damodar River Basin (DRB), which is the lifeline of the entire South Bengal including the Purulia district. About 84% of the district's total geographical area covers under the DRB and Kangshabati alone covers 48% of the total geographical area. Subarnarekha belongs to Subarnarekha River Basin (SRB) and serves the southern parts of the district. There are also several small to large dams like Murguma, Pardi, Boronti, Burda, Gopalpur, Saheb Bandh, Moutore, upper and lower dam in Ayodha, Panchet etc., which are mainly used for electricity generation, flood protection, and irrigation. Due to sloppy and undulated topography, a significant amount of water passes as runoff. Instead of sufficient rainfall, Purulia is famous for water scarcity, dryness, and frequent drought events. According to an estimation of the Indian Meteorological Department (IMD), one out of five years is a drought year and all blocks (20) of Purulia are listed under Drought Prone Areas Programme (DPAP) by the Department of Land Reforms, Ministry of Rural Development (GoI). The district lies under the Northern Tropical Dry Deciduous forest (5B/C 1c). Dense forests are found in the hilly parts of Northern and southern (Jhalda1, Jhalda II and Baghmundi, Bandwan, Arsha, and Neturia) blocks whereas, Sal forests mixed with other species like Palash, Kusum, Mahua, Kend, and Neem are very common and extensively distributed throughout the district.

Presently the district of Purulia has four subdivisions, three municipalities namely Purulia, Raghunathpur and Jhalda amongst them Purulia is the oldest, established in 1876. It is also the district headquarter situated in the Kangshabati watershed mainly. Purulia is the 5th district of West Bengal in terms of area, and 16th in terms of population. According to the 2011 census, the district is the homeland of more than 3 million residents and the number should be 4.7 million after 2051. The percentage share of the population to the total population is highest in the Kangshabati watershed (52.24% in 1951, 51.56% in 2011). But a good increase in this share is observed in the Damodar watershed (23.92% in1951; 25.55% in 2011) where industrialisation is progressing gradually. The principal economic activity undertaken in the study area is agriculture and allied activities and on average 90% of the economically active populations worked on primary sectors (Fig. 17.1).

17.3 Materials and Methods

17.3.1 Materials

LULC was mapped at two different years (1990 and 2020), based on widely and easily available

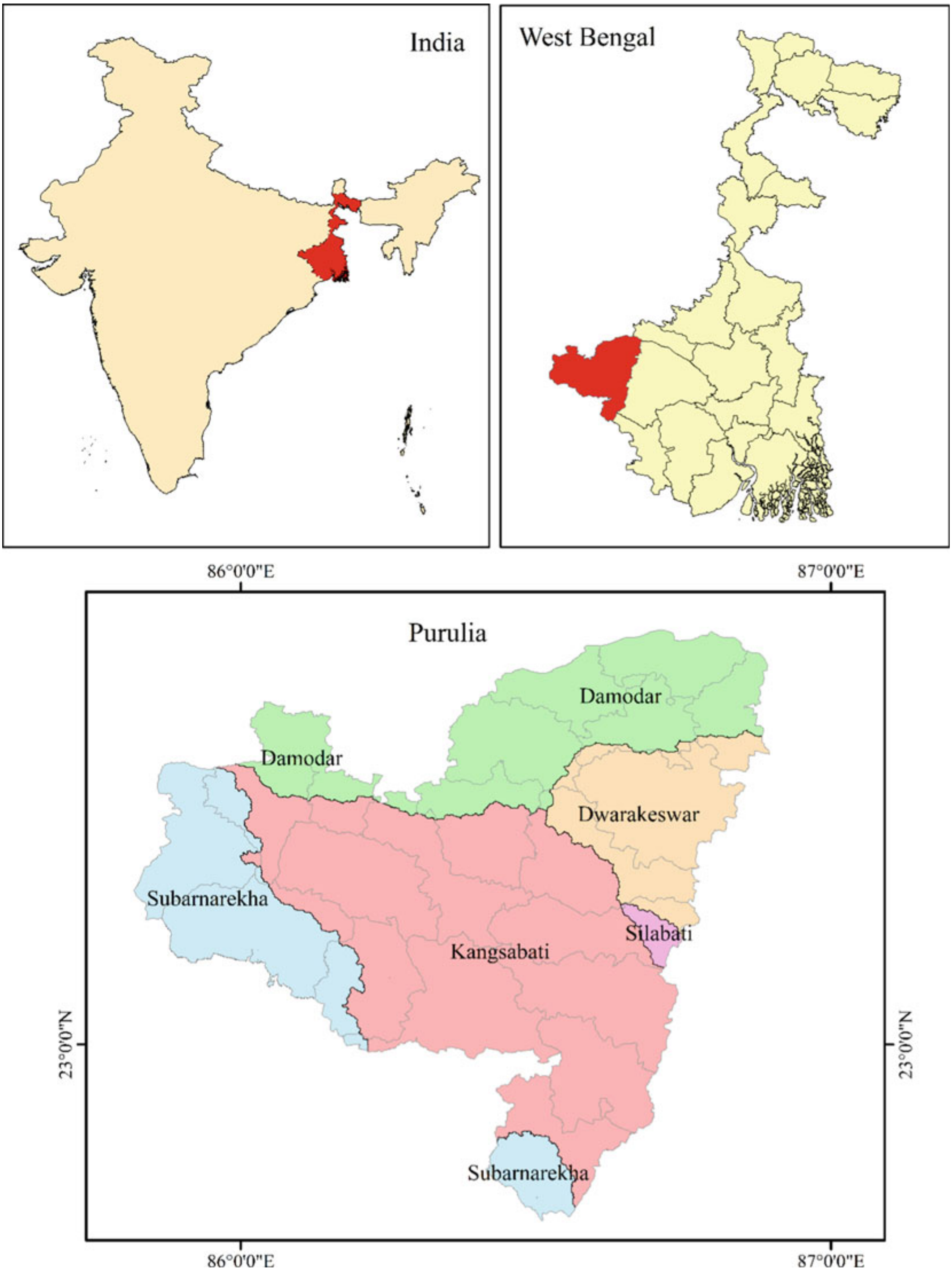

Fig. 17.1 Location of the Purulia district and areal coverage of five watersheds

LANDSAT imageries from USGS (Table 17.1), and the prepared LULC maps were validated by using the references from Topographical maps, and Google Earth, as well as our field observations, interviews, and group discussions, were included as the primary data. The required satellite imageries for the present study are downloaded from the USGS Earth Explores. We used LANDSAT MSS image (30 m × 30 m) for 1990 and LANDSAT OLI (30 m × 30 m) for 2020. For both years two adjacent images were combined to cover the whole study area. These data have different spectral but same spatial characteristics; hence a uniform legend and scale were set before the analysis. To render all images comparable, all images were transformed to Universal Transverse Mercator (UTM) projection. Image processing and image interpretation for the development of LCLU maps were done by using the algorithm of Supervised Maximum Likelihood Classification in ERDAS Imagine 2014 software.

17.3.2 Methods

17.3.2.1 Digital Image Processing (DIP)

To enhance the image quality, DIP was manipulated by using ERDAS Imagine 2014 software. The images were geometrically corrected, calibrated, and finally subsetted. Image enhancement techniques, like histogram equalisation, were also performed on each image for improving the radiometric quality of the images.

17.3.2.2 Image Classification

The Supervised Classification was done on the pre-processed images for LULC mapping. In this classification technique, the Maximum Likelihood Algorithm will organise the pixels to a particular class based on covariance information provided by the user based on his or her knowledge of field experience and is expected a superior performance than the other classification methods (Richards 1994). The inputs were given by the user to guide the software concerning the pixels to be selected for the certain LULC types. In this study, six major LULC classes namely Waterbodies (WB), Dense forest (DF), Fallow with vegetation (FV), Fallow land (F), Settlement and built-up area (S), and Agricultural land (A) were identified (Table 17.2).

17.3.2.3 Land Use and Land Cover

The land is one of the most valuable natural resources gifted by our mother earth and never be increased its physical limit in general. The entire

Table 17.1 Data used in the study and the data details

Image (sensor)	Band	Spectral resolution	Spatial resolution (m)	Raw	Path	Date of capture
Landsat 5 (TM)	Band 1	0.45–0.52	30	139	040	11/04/1990
	Band 2	0.52–0.6	30	140	040	18/08/1990
	Band 3	0.63–0.69	30			
	Band 4	0.77–0.9	30			
	Band 5	1.55–1.75	30			
Landsat 8 (OLI)	Band 2	0.45–0.51	30	139	040	28/03/2020
	Band 3	0.53–0.59	30	140	040	25/02/2020
	Band 4	0.64–0.67	30			
	Band 5 (NIR)	0.85–0.88	30			
	Band 6 (SWIR 1)	1.57–1.65	30			
	Band 7 (SWIR 2)	2.11–2.29	30			

Table 17.2 Major Land Use Land Cover (LULC) features from visual interpretation of images

Major LULC features	Description (LULC types included in the category)
Water bodies (WB)	Rivers, lakes, reservoirs, swamp, and ponds
Dense forest (DF)	Natural forest, dense canopy contents
Fallow with vegetation (FV)	Scrubs, bushes, grassland, natural vegetation with sparse density, plantations etc
Fallow land (F)	Area without woody vegetation throughout the year, but temporarily grass in some cases, stony, rocky bare land, dry river bed etc
Settlement and built-up area (S)	Rural and urban settlements, roads, railways, industries, power stations etc
Agricultural land (A)	Dominant agriculture with patches of grass and bare land includes irrigated and unirrigated land

living world on this planet is directly or indirectly depends on land for food, energy and other needs of livelihood. Human activities have intensely changed the land cover and create imbalances between land cover and land use from the very beginning of modern civilisation. Now it is very crucial to watch the Earth from above to understand the influence of human activities on these natural resources over time. In most of the developing countries where such change is rapid and often undocumented and unrecorded, observations of the Earth through satellites provide objective information regarding land use change. At the same time, satellite images provide valuable information of the past, which were not recorded through other mediums. For the present study, LULC mapping was executed in two ways:

(a) District level LULC mapping as a whole, carried out on the LANDSAT imageries of 1990 and 2020.
(b) Watershed or basin wise LULC mapping by using the same LANDSAT imageries of 1990 and 2020.

17.3.2.4 Accuracy Assessment

The validation of the 1990 LULC image was done by using the Topographical maps and direct interviews conducted during several field visits in 2017, 2018, 2019, and 2020. The 2020 LULC results were validated by using primary data from field visits, interviewed and from Google Earth. An accuracy table (Table 17.3) was created using the observed and the classified land use data through the randomly select Ground Control Points (GCPs), and validated these points with

Table 17.3 Accuracy assessment for the LULC classes of the different periods (1990, 2020) at the watershed level

Land cover type	Kappa of each LULC class per period									
	Damodar		Dwarakeswar		Kangshabati		Silabati		Subarnarekha	
	1990	2020	1990	2020	1990	2020	1990	2020	1990	2020
WB	0.87	0.86	0.87	0.89	0.83	0.90	0.93	0.91	0.83	0.85
DF	0.91	0.90	–	–	0.81	0.83	–	–	0.87	0.90
FV	0.90	0.91	0.80	0.87	0.86	0.89	0.90	0.92	0.82	0.86
F	0.85	0.86	0.81	0.88	0.76	0.79	0.87	0.90	0.80	0.81
S	0.82	0.84	0.83	0.84	0.79	0.82	0.92	0.94	0.79	0.82
A	0.86	0.88	0.81	0.82	0.82	0.86	0.89	0.88	0.82	0.86
Kappa (overall)	0.84	0.84	0.79	0.85	0.80	0.88	0.90	0.90	0.83	0.85
Observed GCP	500	500	500	500	500	500	200	200	500	500
Correct GCP	440	435	420	435	410	440	180	180	410	430
% observed correct	88	87	84	87	82	88	90	90	82	86

the above said sources. Furthermore, both overall Kappa (accompanied by its variance) and class estimated Kappa values were calculated using the function of Accuracy Assessment in ERDAS Imagine 2014.

In the present study, 500 GCPs were randomly selected for Damodar, Dwarakeswar, Kangshabati, Subarnarekha river basin and 200 GCPs for Silabati river basin as the geographical area of this basin is only 56 km^2 (covering only 0.91% of the district's total geographical area). The accuracy assessment of the different watershed's and period's LULC maps show that land cover mapping applied in this study achieved 82–90% overall accuracy and 0.79–0.90 overall Kappa (Table 17.3). Kappa values for individual LULC classes range from 0.76 to 0.93 and these values were varying over time.

17.3.2.5 LULC Change Detection

Several techniques are applied to detect the conversion of landform one use to another, such as Dynamic of Land System (DLS) (Najmuddin et al. 2017), Simpsons-dominance index and location index (Liu and Shi 2017), Supervised Classification (Kibret et al. 2016; Hegazy and Kaloop 2015). In the present study, to make a detail discussion of the dynamics of LULC change, Transition Matrices were created both at the district and watershed level. The transition matrix is a table of symmetric rows and columns, consists of LULC classes from the initial year (period 1) on the vertical axis and the same LULC classes from the end year (period 2) on the horizontal axis. The diagonal cell of the matrix contains the surface area (in km^2) of each class of LULC that remains unaltered during the analysed period, whilst the main remaining cells contain the estimated surface area of a particular LULC class that transformed to a different class during the same period (Luenberger 1979) or transition from one class to another. Such a transition is also representing the dynamics of LULC change at different spatial scale. In this matrix, the conditional probability of LULC changes at any given time mostly depends on the present LULC, and there is no such role of previous changes (Bell and Hinojosa 1977). The model describes the result of LULC changes in aggregated ways, which are not truly spatial, but can still provide valuable information for the decision-makers (Lambin 1997). In the present study, the entire calculations of transition matrices were carried out using Land Change Modeler (LCM) which is an integrated model available in TerrSet 2020 software (v.19.0.2), developed by Clark Labs at Clark University. The LCM is a set of tools for LULC change analysis, helps users to map the changes, identify the transition between different LULC classes, model and predict the future tendency as specified by the users.

Finally, the study adopted a Markovian model to predict the future patterns of LULC change. Markov process is a random shifting from one state to another at each time step. A first-order Markov is a system in which probability distribution over the next step is assumed to only depend on the current state (Fischer and Sun 2001; Veldkamp and Lambin 2001; Pijanowski et al. 2002). These probability values calculated from the proportional area of each LULC in relation to total area (Horn 1975; Balzter 2000; Logofet and Lesnaya 2000; Lopez-Granados et al. 2001). The estimation rates of LULC change between start and end dates predict changes in type for a third date, assuming that the rate of changes is constant, and this is the main drawback of this model. The Markov model is also included in the LCM tool and makes the tool more acceptable and comprehensive to the researchers.

Rates of LULC changes were calculated by using the approach proposed by FAO (1995) described in Eq. 17.1.

$$q = \left((A2/A1)^{-1/(t2-t1)} - 1 \times 100 \right) \quad (17.1)$$

where $A1$ is the surface area of the LCLU category for period 1, $A2$ is the LCLU category for period 2, $t1$ is the initial year (time 1), and $t2$ is the final year (time 2).

17.4 Results

17.4.1 Land Cover Changes at the District Level

Over the whole study period in the Purulia district, agriculture occupied the largest surface area, although this LU shows an increasing trend from 44.58 to 46.3% during the study period of 30 years (1990–2020) with an annual increase rate of 0.13%. Agricultural land (A) is distributed throughout the district, from river plains to undulating hilly sides. Most of the agricultural land is under single cropped and crops are grown mainly in the rainy season (July–October). Fallow with vegetation (FV) has consistently been the second more extensive LC in the district, with a tendency to increase its coverage from 20.69 to 23.35% with an annual rate of 0.4%. Fallow (F) is the third more extensive LC in the study area, exhibiting a remarkable decreasing trend in surface area from 20.77% in 1990 to 13.55% in 2020, with a highest annual decreasing rate of 1.41%. Similarly, dense forest (DF) is also decreasing remarkably at an annual rate of 0.79% and covers 6.82% of surface area after 2020 which was 8.64% in 1990. The most significant increase is noticed for settlement and built up (S) area with an annual rate of 2.83% and covers 7.57% after 2020, which was only 3.28% in 1990. An increase in waterbodies (W) is mainly due to non-biased erroneous image classification. In the 2020 image, a vast area of waterbodies (mainly behind the dams) is covered by water hyacinth and excluded from waterbodies after supervised classification as the spectral range is coincide with agricultural land and fallow with vegetation. A detail of gains and losses amongst the major LULC classes over the study period is included in Table 17.4.

As shown by the transition matrices (Tables 17.5 and 17.6), during the study period of 30 years, the probability of settlement remaining in the same LU is high (above 98%). The lowest probabilities of performance (i.e. higher transition probability) in the same period correspond to the fallow and dense forest respectively. Considering the transition fact, agriculture is on the top of the gainer list and received almost 409 km^2 of land from other LULC categories. This increase has taken place at the expense of fallow land, fallow with vegetation and dense forest, which have diminished respectively by 352 (27% of total fallow land), 32, and 21 km^2. And this is caused due to the increasing population, improving irrigation facilities, land conversion under MGNREGA schemes etc. Fallow with vegetation remains in the second rank and receives 398 km^2 of land and maximum from fallow land (155 km^2) and dense forest (149 km^2). Fallow is converted to fallow with vegetation due to plantation mainly (Table 17.6). The dense forest becomes fallow with vegetation due to deforestation mainly. Only 76% of dense forest having

Table 17.4 Distribution of LULC and their changes during 1990–2020

	Area (km^2)		Share in %		Net change	Change in %	Annual change (FAO)
LULC	1990	2020	1990	2020	(km^2)	during 30 years	
F	1300.14	848.06	20.77	13.55	− 452.08	− 34.77	− 1.41%
S	205.31	473.75	3.28	7.57	268.44	130.75	2.83%
FV	1294.71	1461.4	20.69	23.35	166.69	12.87	0.40%
A	2789.69	2897.41	44.58	46.3	107.72	3.86	0.13%
DF	540.59	426.96	8.64	6.82	− 113.63	− 21.02	− 0.79%
W	127.79	150.66	2.04	2.41	22.86	17.89	0.55%

Table 17.5 Transition matrices of change for different LULC classes during the period of 1990–2020

Transition (km^2)						
Cover/km^2	2020					
1990	F	S	FV	A	D	W
F	687.56 (52.85)	96.14 (7.39)	154.63 (11.89)	352.58 (27.1)	6.52 (0.51)	3.44 (0.26)
S	0 (0)	201.98 (98.38)	0 (0)	2.44 (1.19)	0 (0)	0.89 (0.43)
FV	0.98 (0.07)	8 (0.62)	1243.85 (96.07)	32.58 (2.52)	0 (0)	9.3 (0.72)
A	0 (0)	131.88 (4.74)	148.63 (5.35)	2492.48 (89.36)	0 (0)	12.92 (0.46)
D	3.57 (0.66)	5.13 (0.95)	95 (17.57)	21.33 (3.95)	412.52 (76.31)	3.04 (0.56)
W	4.77 (3.73)	1.25 (0.98)	0 (0)	0 (0)	0.14 (0.11)	121.63 (95.18)

Table 17.6 Plantation programmes and their areal coverage in Purulia district from 2009 to 2018

	Plantation type (in km^2)						
Year	QGS	Namami Ganga	CAMPA	JICA (A3)	Sal	Others	Grand total
2018	0.3	1.3365	0.2597	2.24	0.20		4.34
2017	1.2	0.14		1.80	0.30		3.44
2016	2.65				0.20	Bamboo-0.40	3.25
2015	3.25					Bamboo-0.60	3.85
2014	2.7				0.25	Bambo-0.20, Fodder-0.60	3.75
2013	2.45				0.30		2.75
2012	3.2				0.30		3.50
2011	3.7		0.0648		0.40	Swing and planting-0.80, FDA-2.00	7.00
2010	5.6				0.40	Kangshabati Socoing and planting-0.80	6.80
2009	2.5				0.40	MGNREGA-0.50, RIDF-1.50	4.90

Source Divisional Forest Office, Purulia Division, Department of Forest, Govt. of West Bengal
QGS Quick generated species; *CAMPA* Compensatory Afforestation Fund Management and Planning Authority; *JICA* Japan International Cooperation Agency; *FDA* Forest Development Authority; *MGNREGA* Mahatma Gandhi National Rural Employment Guaranty Act; *RIDF* Rural Infrastructure Development Fund

the probability to stay at their same position means 24% of the dense forest has already lost or degraded. The settlement is the next important LU, receiving 242 km^2 of land and maximum from agricultural land (131 km^2) and fallow land (96 km^2) respectively (Fig. 17.2).

17.4.2 Watershed Scale Land Cover Changes

17.4.2.1 Subarnarekha Watershed

The Subarnarekha watershed is the third largest watershed of Purulia district, situated mostly

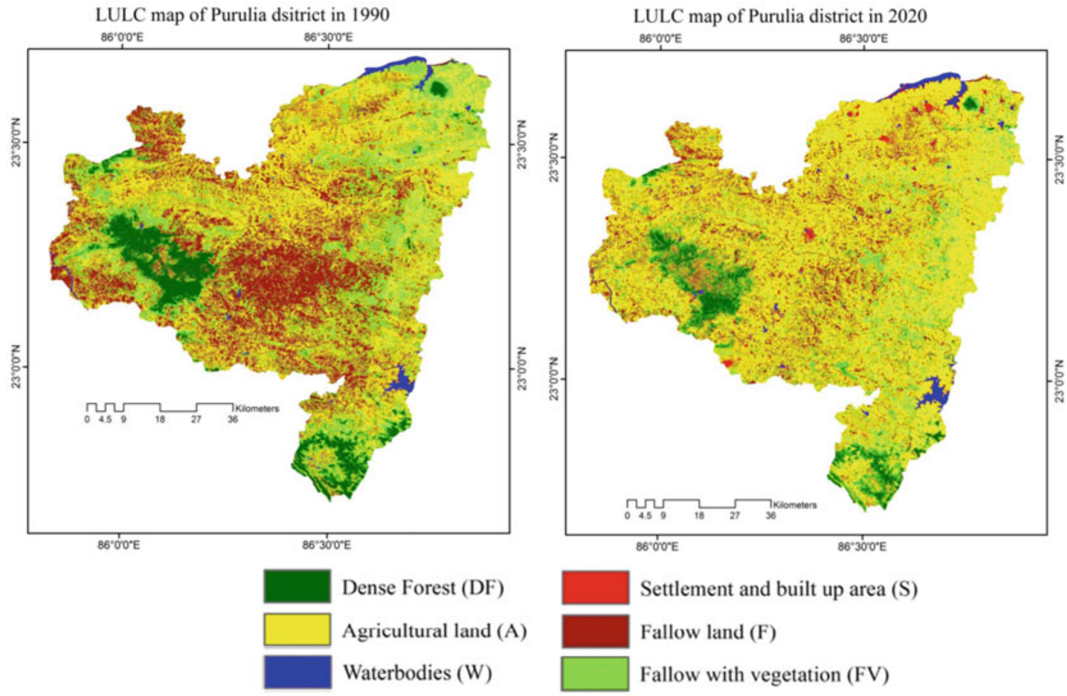

Fig. 17.2 LULC map of Purulia district for years 1990 and 2020

along the rocky and hilly tract of the southern portion of the district. The LULC analysis of the year 1990 of Subarnarekha watershed points out that agricultural land had the highest share (36.73%), followed by dense forest (31.59%), fallow land with vegetation (18.19%), barren fallow land (9.79%), settlement and built-up area (2.69%), and water bodies (1.01%) (Table 17.7). This result as usual is different in the analysis of LULC in the year 2020. Now, the order of percentage share by different landforms is similar to the result of 1990. But the amount varies. In 2020, agriculture occupies 41.40% of the land of the Subarnarekha watershed indicating an increase of about 0.4% per Annum. But the dense forest is decreasing at a rate of 1.07% per year. So the percentage share of the amount of land to total land by dense forest is 22.85% in 2020. Fallow land with vegetation (21.63%), settlement and built up area (2.86%), and water bodies (2.06%) show an increasing trend with an annual rate of 0.58%, 0.21%, and 2.38%

Table 17.7 Distribution of LULC in Subarnarekha watershed and their changes during 1990–2020

LULC classes	Area in km^2		Share in %		Net change	Annual change in %
	1990	2020	1990	2020		
Waterbodies (WB)	10.48	21.23	1.01	2.06	10.75	3.42
Dense forest (DF)	326.22	236.04	31.59	22.85	− 90.19	− 0.92
Fallow with vegetation (FV)	187.89	223.42	18.19	21.63	35.53	0.63
Fallow land (F)	101.09	95.02	9.79	9.20	− 6.07	− 0.20
Settlement and built up area (S)	27.76	29.53	2.69	2.86	1.78	0.21
Agricultural land (A)	379.41	427.60	36.73	41.40	48.19	0.42

Table 17.8 Transition matrices (km^2 per cent) of change for different LULC classes during the period of 1990–2020 in the Subarnarekha watershed

	WB	DF	FV	F	S	A
WB	**(99.24)**	2.9 (0)	2.33 (0)	1.07 (0)	− 0.08 (0.76)	4.53 (0)
DF	− 2.9 (0.89)	**(72.35)**	− 62.11 (19.04)	− 3.57 (1.09)	− 1.75 (0.54)	− 19.87 (6.09)
FV	− 2.33 (1.24)	62.11 (0)	**(83.67)**	4.12 (0)	− 0.46 (0.24)	− 27.9 (14.85)
F	− 1.07 (1.06)	3.57 (0)	− 4.17 (4.13)	**(90.42)**	− 1.67 (1.65)	− 2.77 (2.74)
S	0.08 (0)	1.75 (0)	0.46 (0)	1.67 (0)	**(92.15)**	− 2.18 (7.85)
A	− 4.53 (1.19)	19.87 (0)	27.9 (0)	2.77 (0)	2.18 (0)	**(98.91)**

respectively. Barren fallow land (9.20%) is also squeezing.

The transition matrices (Table 17.8) show that the probability of agricultural land to remain in the same is 98.91% whilst to alter into water bodies is 1.18%. The probability of water bodies to remain in the same LC is maximum (99.24%) whilst it is minimum in the case of dense forest (72.35%) during the study period of 30 years (1990–2020). Most of the dense forest is located along the hilly tract of the Subarnarekha watershed. Most of the dense forest is altered into fallow with vegetation (19.04%) and agricultural land (6.09%) which implies a sharp deforestation process during these 30 years. Agricultural land gained most of the land from fallow land with vegetation (14.85%). The probability of barren fallow land to remain in the same is 90.42% whilst the alteration probability of this LC into fallow land with vegetation is 4.13% indicating towards some afforestation programme during 1990–2020. So the highest probability of transformation of dense forest is very common in the Subarnarekha watershed. The low lying areas of these hilly tracts are occupied by agricultural land where water is available.

17.4.2.2 Damodar Watershed

Damodar watershed is the second-largest watershed of Purulia district, situated along the northern part of the district. By analysing the supervised classification of the LANDSAT image of 1990 of this watershed, it is clear that likewise other watersheds of Purulia here also agricultural land predominates (Table 17.9). Around 50% of the land of this watershed is under agricultural activities. The percentage share of dense forest to total areal extension of this watershed is minimum (1.72% i.e. 23.94 km^2 out of total 1388 km^2). About 40% of the land is fallow land either barren or covered by vegetation. Settlement and built-up area and water bodies share 4.87% and 3.73% of land respectively. In 2020, the percentage of agricultural land increases to55% at a rate of 0.35% per year; settlement and built-up area increases by up to 7.67% at a rate of 1.52% per year. But the percentage of all other LULC decreases.

Table 17.9 Distribution of LULC in Damodar watershed and their changes during 1990–2020

LULC classes	Area km^2		Share in %		Net change	Annual change in %
	1990	2020	1990	2020		
Waterbodies (WB)	51.84	61.44	3.73	4.43	9.60	0.617361
Dense forest (DF)	23.94	15.36	1.72	1.11	− 8.58	− 1.19433
Fallow with vegetation (FV)	349.93	259.24	25.21	18.67	− 90.69	− 0.86392
Fallow land (F)	198.08	172.96	14.27	12.46	− 25.12	− 0.42276
Settlement and built up area (S)	67.68	106.49	4.87	7.67	38.82	1.911778
Agricultural land (A)	696.86	772.83	50.19	55.67	75.98	0.363419

Table 17.10 Transition matrices (km^2 per cent) of change for different LULC classes during the period of 1990–2020 in the Damodar watershed

	WB	DF	FV	F	S	A
WB	**(100)**	0.14 (0)	6 (0)	2.29 (0)	0.64 (0)	0.54 (0)
DF	− 0.14 (0.6)	**(60.82)**	− 7.28 (30.41)	0.81 (0)	− 0.5 (2.08)	− 1.46 (6.09)
FV	− 6 (1.71)	7.28 (0)	**(97.03)**	28.65 (0)	− 4.41 (1.26)	35.63 (0)
F	− 2.29 (1.16)	− 0.81 (0.41)	− 28.65 (14.46)	**(10.66)**	− 16.31 (8.23)	− 128.91 (65.08)
S	− 0.64 (0.95)	0.5 (0)	4.4 (0)	16.31 (0)	**(99.05)**	18.23 (0)
A	− 0.54 (0.08)	1.46 (0)	− 35.63 (5.11)	128.91 (0)	− 18.23 (2.61)	**(92.19)**

The probability of remaining in the same LULC category is highest of water bodies (100%) followed by settlement and built-up area (99.05), fallow land with vegetation (97.03%), agricultural land (92.19%) as analysed by transition matrices (Table 17.10). But dense forest (60.82%) and barren fallow land (10.66%) show minimum probability to remain in the same category. Maximum alteration of barren fallow land into agricultural land occurred during these 30 years with a probability of 65.08% which is highest amongst all other watersheds as a result of increasing population density in this area (population data) and availability of water. As shown by the transition matrices another important deviation during this period is an alteration of dense forest to fallow land with vegetation with a probability of about 30%. The probability of extension of settlement and built-up area from other LULC is also noticeable (2.08% from dense forest, 2.61% from agricultural land, 1.26% from fallow land with vegetation, 8.23% from barren fallow land). These statistics indicate an increase in population density and establishment of new industries in this area which may result in a deforestation process and a higher probability of alteration of fallow land into agricultural land.

17.4.2.3 Kangshabati Watershed

The rivers Kangshabati and Kumari jointly drain the largest area in the middle of the Purulia district. Two amongst the three municipal towns (Jhalda & Purulia) and the maximum portion of the largest town and headquarter of the district (Purulia) and fall in this watershed. The data derived from the analysis of the supervised classification of the LANDSAT 5 image of this watershed of 1990 reveal that 42.94% of the land was under agricultural practices, 27.62% under barren fallow land, 18.10% under fallow land with vegetation, 6.33% under dense forest which is situated along the hilly tract of Ajodhya Hills, 3.26% under the settlement and built-up area, and 1.75% underwater bodies. The 2020 image shows that agricultural land is squeezing at a rate of 0.11% per year leads to a decline in percentage share to total land area (41.61%). Barren fallow land (15.76%), dense forest (5.83%), and water bodies (1.74%) are also declining. Only settlement and built-up area (10.23%) and fallow land with vegetation (24.83%) are increasing. Settlement and built-up area are expanding at a high rate of 3.9% per year (Table 17.11).

The result of transition matrices shows that Settlement and built-up area and fallow land with vegetation has a high probability to sustain in their status whilst fallow land has the lowest. Here is a probability of alteration of Barren fallow land, dense forest, agricultural land, and water bodies into Settlement and the built-up area which implies a rapid urban sprawl and establishment of new industries. Here, another important alteration faced by water bodies to fallow land (7.67%). Due to the unavailability of water, the probability of transformation of agricultural land to Barren fallow land is 7.63%, whereas an increase of population leads to alteration of later to former is 21.25% (Table 17.12). A high probability of alteration of dense forest to fallow land with vegetation (13.45%) apprises towards deforestation process near the low lying areas of Ajodhya Hills.

Table 17.11 Distribution of LULC in Kangshabati watershed and their changes during 1990–2020

LULC classes	Area (km^2)		Share in %		Net change	Annual change in %
	1990	2020	1990	2020		
Waterbodies (WB)	52.58	52.30	1.75	1.74	− 0.28	− 0.02
Dense forest (DF)	190.43	175.56	6.33	5.83	− 14.87	− 0.26
Fallow with vegetation (FV)	545.02	747.69	18.10	24.83	202.67	1.24
Fallow land (F)	831.69	474.56	27.62	15.76	− 357.13	− 1.43
Settlement and built up area (S)	98.08	307.84	3.26	10.23	209.76	7.13
Agricultural land (A)	1292.85	1252.69	42.94	41.61	− 40.15	− 0.10

Table 17.12 Transition matrices (km^2 per cent) of change for different LULC classes during the period of 1990–2020 in the Kangshabati watershed

	WB	DF	FV	F	S	A
WB	**(89.83)**	− 0.14 (0.27)	0.47 (0)	− 4.04 (7.67)	− 1.17 (2.23)	5.15 (0)
DF	0.14 (0)	**(85.04)**	− 25.61 (13.45)	5.71 (0)	− 2.88 (1.51)	7.78 (0)
FV	− 0.47 (0.09)	25.61 (0)	**(99.91)**	107.83 (0)	28.82 (0)	98.51 (0)
F	4.04 (0)	− 5.71 (0.69)	− 107.83 (13)	**(56.56)**	− 70.68 (8.5)	− 176.95 (21.25)
S	1.72 (0)	2.88 (0)	28.82 (0)	70.68 (0)	**(100)**	105.67 (0)
A	− 5.15 (0.38)	− 7.78 (0.6)	− 98.51 (7.63)	176.95 (0)	− 105.67 (8.17)	**(83.22)**

17.4.2.4 Dwarakeswar Watershed

The watershed of the Dwarakeswar River occupies a much smaller area than the watershed of river Kangshabati, Damodar, and Subarnarekha. It is situated in the easternmost part of the district. During 1990 agricultural land (51.12%), fallow land with vegetation (25.55%), barren fallow land (20.56%), water bodies (1.53), settlement and built-up area (1.24%) were the main LULC of this watershed (Table 17.13). There was no dense forest area. 2020 image shows an increase in agricultural land (53.41%) and settlement and built-up area (3.57%). Fallow land with vegetation also expanded (28.80%). In this case also barren fallow land is decreasing (12.36%).

The transition matrices show that, except barren fallow land, all other LULC has above 90% probability to lie in their categories.

Table 17.13 Distribution of LULC in Dwarakeswar watershed and their changes during 1990–2020

LULC classes	Area (km^2)		Share in %		Net change	Annual change in %
	1990	2020	1990	2020		
Waterbodies (WB)	11.80	14.28	1.53	1.85	2.48	0.70
Fallow with vegetation (FV)	196.66	221.69	25.55	28.80	25.03	0.42
Fallow land (F)	158.96	95.12	20.56	12.36	− 63.84	− 1.34
Settlement and built up area (S)	9.54	27.49	1.24	3.57	17.95	6.27
Agricultural land (A)	393.45	411.11	51.12	53.41	17.66	0.15

Table 17.14 Transition matrices (km^2 per cent) of change for different LULC classes during the period of 1990–2020 in the Dwarakeswar watershed

	WB	FV	F	S	A
WB	**(93.81)**	0.48 (0)	− 0.73 (6.19)	0.25 (0)	2.48 (0)
FV	− 0.48 (0.24)	**(98.25)**	13.98 (0)	− 2.96 (1.51)	14.49 (0)
F	0.73 (0)	− 13.98 (8.79)	**(59.84)**	− 7.25 (4.57)	− 42.61 (26.8)
S	− 0.25 (2.62)	2.96 (0)	7.25 (0)	**97.38**	7.98 (0)
A	− 2.48 (0.63)	− 14.49 (3.68)	42.61 (0)	− 7.98 (2.03)	**(93.66)**

A major portion of barren fallow land may have been transformed into agricultural land (26.8%). But agricultural land was also converted into fallow land with vegetation (3.68%) which was expanded during these 30 years. Settlement and the built-up area gained land from agricultural land (2.03%), fallow land with vegetation (1.51%), barren fallow land (4.57%) and enlarged its area at a rate of 3.59% per year which is the maximum rate of areal expansion within this watershed of Purulia (Table 17.14).

17.4.2.5 Silabati Watershed

Silabati watershed is the smallest basin, located on the eastern side of the Purulia district. The LULC analysis shows that here also agricultural land (63.68% in 1990 and 70.84% in 2020) occupies the maximum share of land use followed by fallow and built-up area (Table 17.15). Again fallow land and fallow with vegetation are the most distressed LC and prone to convert to other mainly to agricultural land (Table 17.16).

17.4.3 Markov Chain Analysis

The Markov chain was used to calculate the transition probability based on the period 1990–2020 for the prediction of LULC for 2050 (Table 17.17). The transition probability matrix is the cross-tabulation of two images and

Table 17.15 Distribution of LULC in Silabati watershed and their changes during 1990–2020

	Area (km^2)		Share in %		Net change	Annual change in %
LULC classes	1990	2020	1990	2020		
Waterbodies (WB)	1.09	1.41	2.56	3.31	0.32	0.97
Fallow with vegetation (FV)	1.09	1.41	2.56	3.31	0.32	0.97
Fallow land (F)	11.04	7.21	25.92	16.93	− 3.86	− 0.13
Settlement and built up area (S)	2.25	2.39	5.28	5.61	0.33	0.21
Agricultural land (A)	27.12	30.17	63.68	70.84	3.05	0.74

Table 17.16 Transition matrices (km^2 per cent) of change for different LULC classes during the period of 1990–2020 in the Silabati watershed

	WB	FV	F	S	A
WB	**(100)**	0.02 (0)	0.08 (0)	0 (0)	0.22 (0)
FV	− 0.02 (0.13)	**(61.54)**	− 0.98 (6.44)	− 0.17 (1.12)	− 4.68 (30.77)
F	− 0.08 (0.72)	0.98 (0)	**(85.14)**	− 0.23 (2.08)	− 1.33 (12.06)
S	0 (0)	0.17 (0)	0.23 (0)	**(88.44)**	− 0.26 (11.56)
A	− 0.22 (0.8)	4.68 (0)	1.33 (0)	0.26 (0)	**(99.20)**

Table 17.17 Markov transition probability matrix of LULC changes in 2050

Subarnarekha watershed						
	WB	DF	FV	F	S	A
WB	0.6794	0.0186	0.0378	0.0786	0.0462	0.1394
DF	0.0095	0.6043	0.249	0.0353	0.0107	0.0912
FV	0.0145	0.1018	0.3251	0.1089	0.041	0.4087
F	0.0187	0.0787	0.2432	0.2062	0.0416	0.4116
S	0.0145	0.0625	0.2609	0.0911	0.4975	0.0735
A	0.0158	0.026	0.1288	0.1024	0.0306	0.6964
Dwarakeswar watershed						
	WB	DF	FV	F	S	A
WB	0.4156		0.0873	0.2727	0.0053	0.2191
DF						
FV	0.0077		0.4296	0.1179	0.0332	0.4117
F	0.0157		0.2349	0.2466	0.0551	0.4477
S	0.0324		0.3741	0.154	0.3476	0.0919
A	0.0129		0.2426	0.0717	0.0287	0.6441
Kangshabati watershed						
	WB	DF	FV	F	S	A
WB	0.6032	0.0046	0.0235	0.1589	0.1239	0.0859
DF	0.0005	0.5743	0.2966	0.0548	0.0234	0.0505
FV	0.0031	0.0566	0.342	0.1454	0.0888	0.3641
F	0.0052	0.0194	0.2249	0.29	0.1036	0.3569
S	0.0488	0.016	0.1995	0.1575	0.4112	0.167
A	0.0075	0.0134	0.2297	0.0927	0.1129	0.5437
Damodar watershed						
	WB	DF	FV	F	S	A
WB	0.803	0.0004	0.0287	0.0256	0.0618	0.0806
DF	0.0065	0.3997	0.4381	0.0113	0.0344	0.1101
FV	0.0378	0.0162	0.3535	0.0741	0.0942	0.4243
F	0.2721	0.0103	0.1238	0.0031	0.0647	0.5259
S	0.0568	0.0047	0.2105	0.0936	0.4984	0.136
A	0.0068	0.0017	0.1717	0.0791	0.0746	0.6662
Silabati watershed						
	WB	DF	FV	F	S	A
WB	0.5557		0.0875	0.0826	0.0273	0.2469
DF						
FV	0.0076		0.1901	0.1858	0.035	0.5815
F	0.0152		0.167	0.2329	0.0541	0.5308
S	0.0116		0.1624	0.164	0.5456	0.1164
A	0.0181		0.1536	0.1672	0.0357	0.6254

Table 17.18 Basin wise estimation of surface and groundwater yield in million cubic meters (MCM)

River	1990			2020		
	Surface water yield (SWY)	Groundwater yield (GWY)	Total water yield (TWY)	Surface water yield (SWY)	Groundwater yield (GWY)	Total water yield (TWY)
Damodar	670.3	619.7	1290	684.4	475.6	1160
Dwarakeswar	459.2	391.7	850.9	451.57	327	778.57
Kangshabati	2101.3	1719.1	3820.4	2040.1	1360.16	3400.26
Silabati	39.3	31.2	70.5	40.92	27.28	68.2
Subarnarekha	580.84	536.16	1117	590.53	410.37	1000.9
Total	3850.94	3297.86	7148.8	3807.52	2600.41	6407.93

N.B. Estimation of surface and groundwater yield was done by using the SWAT model in the ArcGIS domain

contains the probable amount of change of any LULC class into other classes within the desired period. It is a very useful tool to monitor the rhythm, behaviour, and magnitude of LULC changes in an area.

The Markov Chain result shows that the probability of change to agricultural land (A) from any other LULC classes is remarkable in near future and the picture is more or less the same throughout the district and throughout the basins. And this will happen at the expense of transition from fallow land (F) and fallow with vegetation (FV). For example, in Damodar, 52% of fallow and 42% of fallow with vegetation will convert to agricultural land after 2050 (Table 17.16). Another disturbed LC is dense forest (DF). In the Damodar watershed, the dense forest will squeeze up to 20% after 2050 (61% in 2011 and 40% in 2050), 12% in Subarnarekha (72% in 2020 and 60% in 2050), and 28% in the Kangshabati watershed (85% in 2020 to 57% in 2050).

17.4.4 Impacts on the Basin Hydrology

Different hydrological parameters such as Evapotranspiration, surface water yield, groundwater yield etc. are the interactive outcomes of LULC, precipitation amount, slope, soil characters etc. Change in LULC is the main driving force to modify the hydrological outputs as LULC is changing at every moment. We considered surface water yield (SWY) and groundwater yield (GWY) as the measuring parameter to identify and quantify the impacts of changing LULC on basin hydrology. Soil and Water Assessment Tool (SWAT) was used in the ArcGIS domain to estimate these parameters by inputting the LULC maps of 1990 and 2020.

The SWAT output shows a decreasing trend in both SWY and GWY. TWY was decreased up to 10.4% (Table 17.18). In the case of SWY, the decreasing amount was 1.2%, whereas, it was 21% for GWY. The decreasing tendency of groundwater reveals the fact that due to deforestation the process of groundwater recharge is hampering. AS per Minor Irrigation Census (Ministry of Jal Shakti, Dept. of Water Resources, RD & GR, Government of India), the number of shallow, medium and deep tube wells, as well as the utilisation of irrigation potential, are also increasing. As per our study, settlement and built-up area are expanding due to the increase in population (Table 17.19). The whole effect of these is a declining groundwater level (Fig. 17.3).

17.5 Discussion

In this discussion, we integrated standard techniques and procedures for understanding LULC dynamics at the district and watershed level with detailed information. This integration is

Table 17.19 Decadal change of population since 1951 and projected population up to 2051

Watershed	Official census data[a]								Projected census[b]
	Area (km^2)	1951	1961	1971	1981	1991	2001	2011	2051
Subarnarekha	1032.84	136,044	160,439	191,655	231,493	255,756	295,057	352,031	562,320
Damodar	1388.32	288,794	347,473	424,456	517,428	594,238	681,406	777,147	1,197,635
Kangshabati	3010.65	630,706	726,706	857,660	1,053,600	1,178,973	1,344,093	1,568,208	2,452,972
Dwarakeswar	770.41	141,292	164,768	195,546	230,314	264,957	295,482	321,865	456,439
Silabati	56.72	10,390	12,063	14,024	15,733	16,720	19,291	22,171	32,495
Total	6258.95	1,207,226	1,411,449	1,683,341	2,048,568	2,310,644	2,635,329	3,041,422	4,701,861

Source[a] District Census Handbook, Purulia (1951, 1961, 1971, 1981, 1991, 2001, 2011), Registrar General and Census Commissioner, India, Ministry of Home Affairs, GoI. Mouza wise population was summed up according to watershed level
[b] Incremental Increase Method (IIM) was applied to calculate the projected census of 2051

important for the accurate identification of driving forces of LULC dynamics, and thus provides valuable inputs to the management of the watershed. LULC dynamics are considered as the key environmental indicators to change the man–environmental set-up, but their proper evaluation has not been integrated with decision-making processes in most of the countries. The basic assumptions made in this study are that the rates of LULC change are differing with time and the final period of study can only convey information concerning the recent environmental processes that affect the study area. As a consequence, decision-making processes at a watershed level should give importance to each period, so that the drivers of change during each period should identify and integrate them with land use planning. For the present study, only two satellite images (1990, 2020) were used to cover the study period of 30 years. The assumption is here that the study area is economically and socially so backward (according to the last report of Planning Commission, Govt. of India (2010) rank one in the rural poverty rate, comes the last rank in rural monthly per capita consumption, rank 15 in per capita income amongst the 17th districts of West Bengal) that the drivers of LULC change like urbanisation, industrialisation or infrastructural developments are less active or intense in this district. The rate of LULC change is very slow and difficult to estimate from satellite images through Supervised Classification.

One of the main features of this research is to study the presence of anthropogenic impact on the natural world. For example, dense forest is shrinking remarkably (Table Five) due to deforestation and is turning into fallow with vegetation which is sparse, is indicating the overall degradation of forest health. At the same time, fallow is turning into agricultural land to support the growing needs of food, fodder etc. and into fallow with vegetation through afforestation programmes (Appendix 2). Thus, population expansion is one of the major impacts on the natural assets of the region. Another important social feature of the region is the expansion of the built-up area in terms of urbanisation, settlement, and industrialisation. Extension of

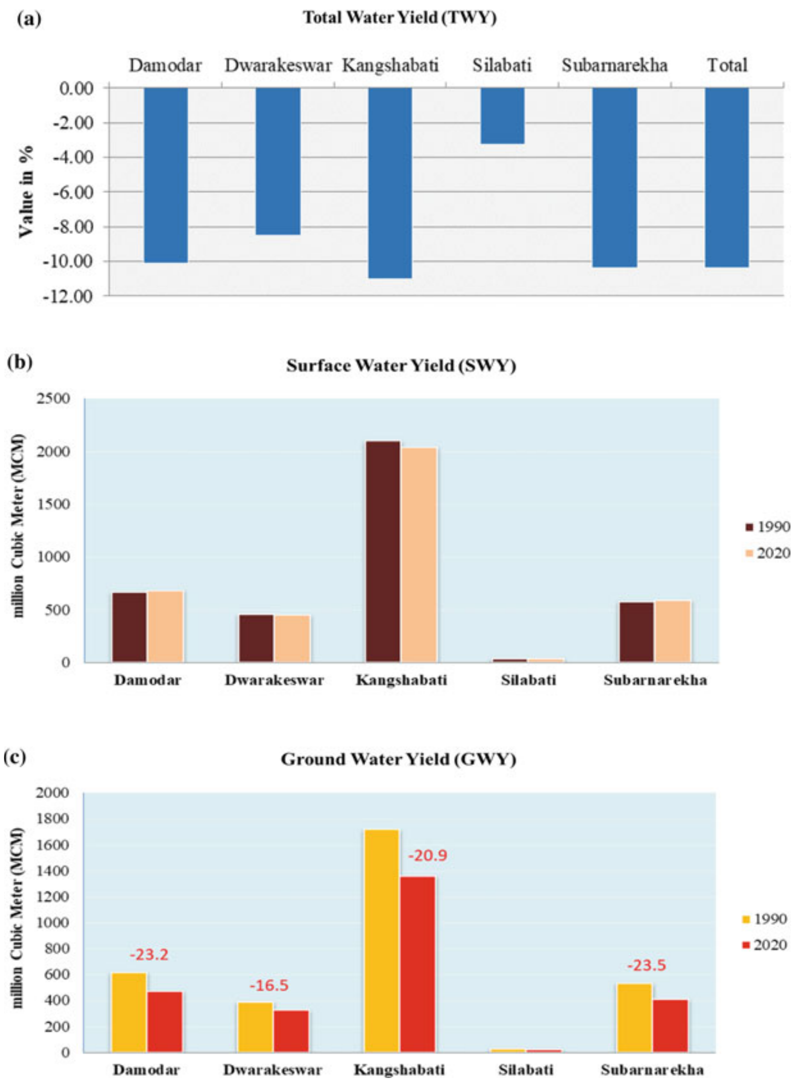

Fig. 17.3 Change in basin hydrology because of LULC change **a** TWY **b** SWY **c** GWY

settlement area is maximum in Kangshabati watershed which is the location of Purulia town, the district headquarter and the home of 121,067 population in 2011 (92,386 in 1991), whereas, rate of industrialisation is high in Damodar watershed and maximum industries were established after 2010.

17.6 Conclusions

LULC change is a dynamic and continuous process as it ensues in any region with economic development especially in developing countries where the economic structure is shifting from primary to tertiary level. Rapid urbanisation and industrialisation are the two major pillars of altering land cover into land use and lead to overall environmental degradation.

This study relates changing LULC, detected by using Remote Sensing and GIS techniques in Purulia district during the last three decades (1990–2020), to a very interesting shifting economic settings as India is entering into the new age of liberation during this period. The use of multi-temporal satellite images combined with supervised classification and validation with real data led to improved accuracy than any conventional methods. The LULC database of two periods (1990, 2020) showed that the study area has undergone enough land cover change driven by agricultural expansion and increasing built-up area. Spatial patterns of LULC change can be linked to demographic factors, availability of fertile land, increasing irrigation facilities, distance from urban centres, improving transport facilities etc.

Appendix 1

Decadal change of population since 1951 and projected population up to 2051

Watershed	Official census data[a]								Projected census[b]
	Area (km^2)	1951	1961	1971	1981	1991	2001	2011	2051
Subarnarekha	1032.84	136,044	160,439	191,655	231,493	255,756	295,057	352,031	562,320
Damodar	1388.32	288,794	347,473	424,456	517,428	594,238	681,406	777,147	1,197,635
Kangshabati	3010.65	630,706	726,706	857,660	1,053,600	1,178,973	1,344,093	1,568,208	2,452,972
Dwarakeswar	770.41	141,292	164,768	195,546	230,314	264,957	295,482	321,865	456,439
Silabati	56.72	10,390	12,063	14,024	15,733	16,720	19,291	22,171	32,495
Total	6258.95	1,207,226	1,411,449	1,683,341	2,048,568	2,310,644	2,635,329	3,041,422	4,701,861

Source[a] District Census Handbook, Purulia (1951, 1961, 1971, 1981, 1991, 2001, 2011), Registrar General and Census Commissioner, India, Ministry of Home Affairs, GoI. Mouza wise population was summed up according to watershed level
[b] Incremental Increase Method (IIM) was applied to calculate the projected census of 2051

Appendix 2

Irrigation schemes	Number of schemes implemented				Irrigation potential utilised (in Ha.)				Share in total irrigation
	2nd MI (1993–94)	3rd MI (2000–01)	4th MI (2006–07)	5th MI (2013–14)	2nd MI (1993–94)	3rd MI (2000–01)	4th MI (2006–07)	5th MI (2013–14)	
Surface flow scheme	19,448	21,283	13,732	12,758	65,403	59,429	63,554	42,984.01	62.4
Dugwells	17,133	13,322	3611	3048	5302	4026	2083	4362.5	6.2
Deep tube wells	NIL	NIL	NIL	275	NIL	NIL	NIL	14,838.12	21.49
Medium tube well	NIL	NIL	NIL	14	NIL	NIL	NIL	9.91	0.01
Shallow tube wells	11	2	15	28	12	3	10	26.22	0.4
Surface lift schemes	440	313	539	2016	2676	3444	8180	6517.01	9.5

Source Minor Irrigation Census (MIC) of 1993–94, 2000–01, 2006–07 and 2013–14. Ministry of Jal Shakti, Dept. of Water Resources, RD & GR, Government of India

References

Allende TC, Mendoza, ME, Granados, EML, Manilla, LMM (2009) Hydrogeographical regionalisation: an approach for evaluating the effects of land cover change in watersheds. A case study in the Cuitzeo Lake Watershed, Central Mexico. Water Resour Manag 23(12):2587–2603

Balzter H (2000) Markov chain models for vegetation dynamics. Ecol Model 126(2–3):139–154

Barlow J, Lennox GD, Ferreira J, Berenguer E, Lees AC, Mac Nally R, Thomson JR, de Barros Ferraz SF, Louzada J, Oliveira VHF, Parry L (2016) Anthropogenic disturbance in tropical forests can double biodiversity loss from deforestation. Nature 535 (7610):144–147

Basnyat B (2009) Impacts of demographic changes on forests and forestry in Asia and the Pacific. Bangkok, FAO of the United Nations Regional Office for Asia and the Pacific

Basommi LP, Guan QF, Cheng DD, Singh SK (2016) Dynamics of land use change in a mining area: a case study of Nadowli District, Ghana. J Mt Sci 13(4):633–642

Bayarsaikhan U, Boldgiv B, Kim KR, Park KA, Lee D (2009) Change detection and classification of land cover at Hustai National Park in Mongolia. Int J Appl Earth Obs Geoinf 11(4):273–280

Bhatta BR, Chalise SR, Myint AK (1999) Recent concepts, knowledge, practices, and new skills in participatory integrated watershed management: trainers' resource book

Bonan GB (2008) Forests and climate change: forcings, feedbacks, and the climate benefits of forests. Science 320(5882):1444–1449

Brink AB, Eva HD (2009) Monitoring 25 years of land cover change dynamics in Africa: a sample based remote sensing approach. Appl Geogr 29(4):501–512

Buys P (2007) At loggerheads? agricultural expansion, poverty reduction, and environment in the tropical forests. World Bank Publications

Carr DL (2004) Proximate population factors and deforestation in tropical agricultural frontiers. Popul Environ 25(6):585–612

Carr DL, Suter L, Barbieri A (2005) Population dynamics and tropical deforestation: state of the debate and conceptual challenges. Popul Environ 27(1):89–113

Chakravarty S, Ghosh SK, Suresh CP, Dey AN, Shukla G (2012) Deforestation: causes, effects and control strategies. In: Global perspectives on sustainable forest management. IntechOpen

Currit N, Easterling WE (2009) Globalization and population drivers of rural-urban land-use change in Chihuahua, Mexico. Land Use Policy 26(3):535–544

Dunjó G, Pardini G, Gispert M (2003) Land use change effects on abandoned terraced soils in a Mediterranean catchment, NE Spain. CATENA 52(1):23–37

Ewers RM (2006) Interaction effects between economic development and forest cover determine deforestation rates. Glob Environ Chang 16(2):161–169

Fischer G, Sun L (2001) Model based analysis of future land-use development in China. Agr Ecosyst Environ 85(1–3):163–176

Fuller RM, Smith GM, Devereux BJ (2003) The characterisation and measurement of land cover change through remote sensing: problems in operational applications? Int J Appl Earth Obs Geoinf 4(3):243–253

Gautam AP, Webb EL, Shivakoti GP, Zoebisch MA (2003) Land use dynamics and landscape change pattern in a mountain watershed in Nepal. Agr Ecosyst Environ 99(1–3):83–96

Geist HJ, Lambin EF (2002) Proximate causes and underlying driving forces of tropical deforestation. Bioscience 52(2):143–150

Gentry AH, Lopez-Parodi J (1980) Deforestation and increased flooding of the upper Amazon. Science 210 (4476):1354–1356

Gomez-Mendoza L, Vega-Pena E, Ramírez MI, Palacio-Prieto JL, Galicia L (2006) Projecting land-use change processes in the Sierra Norte of Oaxaca, Mexico. Appl Geogr 26(3–4):276–290

Hannah L, Carr JL, Lankerani A (1995) Human disturbance and natural habitat: a biome level analysis of a global data set. Biodivers Conserv 4(2):128–155

Hegazy IR, Kaloop MR (2015) Monitoring urban growth and land use change detection with GIS and remote sensing techniques in Daqahlia governorate Egypt. Int J Sustain Built Environ 4(1):117–124

Horn HS (1975) Markovian properties of forest succession. Ecol Evol Communities 196–211

Hosonuma N, Herold M, De Sy V, De Fries RS, Brockhaus M, Verchot L, Angelsen A, Romijn E (2012) An assessment of deforestation and forest degradation drivers in developing countries. Environ Res Lett 7(4):044009

Jansen LJ, Di Gregorio A (2002) Parametric land cover and land-use classifications as tools for environmental change detection. Agr Ecosyst Environ 91(1–3):89–100

Kibret KS, Marohn C, Cadisch G (2016) Assessment of land use and land cover change in South Central Ethiopia during four decades based on integrated analysis of multi-temporal images and geospatial vector data. Remote Sens Appl Soc Environ 3:1–19

Lal R (1996) Deforestation and land-use effects on soil degradation and rehabilitation in western Nigeria. I. Soil physical and hydrological properties. Land Degrad Dev 7(1):19–45

Lambin EF (1997) Modelling and monitoring land-cover change processes in tropical regions. Prog Phys Geogr 21(3):375–393

Lambin EF, Turner BL, Geist HJ, Agbola SB, Angelsen A, Bruce JW, Coomes OT, Dirzo R, Fischer G. Folke C, George P (2001) The causes of land-use and land-cover change: moving beyond the myths. Glob Environ Change 11(4):261–269

Liu J, Shi ZW (2017) Quantifying land-use change impacts on the dynamic evolution of flood vulnerability. Land Use Policy 65:198–210

Logofet DO, Lesnaya EV (2000) The mathematics of Markov models: what Markov chains can really predict in forest successions. Ecol Model 126(2–3):285–298

López Granados EM, Bocco G, Mendoza Cantú ME (2001) Predicción del cambio de cobertura y uso del suelo: el caso de la ciudad de Morelia. Investigaciones Geográficas 45:39–55

López E, Bocco G, Mendoza M, Duhau E (2001) Predicting land-cover and land-use change in the urban fringe: a case in Morelia city, Mexico. Landscape Urban Plann 55(4):271–285

Lopez E, Bocco G, Mendoza M, Velázquez A, Aguirre-Rivera JR (2006) Peasant emigration and land-use change at the watershed level: A GIS-based approach in Central Mexico. Agric Syst 90(1–3):62–78

Luenberger DG (1979) Introduction to dynamic systems; theory, models, and applications (No. 04; QA402, L8)

Malhi Y, Roberts JT, Betts RA, Killeen TJ, Li W, Nobre CA (2008) Climate change, deforestation, and the fate of the Amazon. Science 319(5860):169–172

Mas JF, Velázquez A, Díaz-Gallegos JR, Mayorga-Saucedo R, Alcántara C, Bocco G, Castro R, Fernández T, Pérez-Vega A (2004) Assessing land use/cover changes: a nationwide multidate spatial database for Mexico. Int J Appl Earth Obs Geoinf 5(4):249–261

Mendoza ME, Granados EL, Geneletti D, Pérez-Salicrup DR, Salinas V (2011) Analysing land cover and land use change processes at watershed level: a multitemporal study in the Lake Cuitzeo Watershed, Mexico (1975–2003). Appl Geogr 31(1):237–250

Milesi C, Hashimoto H, Running SW, Nemani RR (2005) Climate variability, vegetation productivity and people at risk. Glob Planet Change 47(2–4):221–231

Nagdeve DA (2007) Population growth and environmental degradation in India. International Institute for Population Sciences. http://paa2007.princeton.edu/papers/7192. Department of fertility studies, Govandi station road, Deonar, Mumbai 400:088

Naiman RJ, Bisson PA, Turner MG (1997) Approaches to management at the watershed scale. In: Kohm K, Franklin JF (eds) Creating a forestry for the 21st century: the science of ecosystem management. Island Press

Najmuddin O, Deng X, Siqi J (2017) Scenario analysis of land use change in Kabul River Basin–a river basin with rapid socio-economic changes in Afghanistan. Phys Chem Earth, Parts a/b/c 101:121–136

Ningal T, Hartemink AE, Bregt AK (2008) Land use change and population growth in the Morobe Province of Papua New Guinea between 1975 and 2000. J Environ Manage 87(1):117–124

Pazúr R, Bolliger J (2017) Land changes in Slovakia: past processes and future directions. Appl Geogr 85:163–175

Pijanowski BC, Brown DG, Shellito BA, Manik GA (2002) Using neural networks and GIS to forecast land use changes: a land transformation model. Comput Environ Urban Syst 26(6):553–575

Richards JA (1994) Remote sensing digital image analysis: an introduction. Second, revised and enlarged edition. Springer-Verlag, Berlin, Heidelberg, Germany

Schulz JJ, Cayuela L, Echeverria C, Salas J, Benayas JMR (2010) Monitoring land cover change of the dryland forest landscape of Central Chile (1975–2008). Appl Geogr 30(3):436–447

Shi G, Jiang N, Yao L (2018) Land use and cover change during the rapid economic growth period from 1990 to 2010: a case study of shanghai. Sustainability 10(2):426

Shriar AJ (2002) Food security and land use deforestation in northern Guatemala. Food Policy 27(4):395–414

Soltani A, Angelsen A, Eid T (2014) Poverty, forest dependence and forest degradation links: evidence from Zagros, Iran. Environ Dev Econ 19(5):607–630

Veldkamp A, Lambin EF (2001) Predicting land-use change. Ar Ecosyst Environ 85(1–3):1–6

Verburg PH, Van De Steeg J, Veldkamp A, Willemen L (2009) From land cover change to land function dynamics: a major challenge to improve land characterization. J Environ Manage 90(3):1327–1335

Wang X, Zheng D, Shen Y (2008) Land use change and its driving forces on the Tibetan Plateau during 1990–2000. CATENA 72(1):56–66

Xiao J, Shen Y, Ge J, Tateishi R, Tang C, Liang Y, Huang Z (2006) Evaluating urban expansion and land use change in Shijiazhuang, China, by using GIS and remote sensing. Landsc Urban Plan 75(1–2):69–80