Transition Modelling of Land Use Land Cover Dynamics in Bardez Taluka of Goa-India (1991-2021)

Prabhu Gaonkar Venkatesh G.[1] and Nadaf F.M.[2*]
1. Department of Geoinformatics, Goa University, Parvatibai Chowgule College, Margao Goa, INDIA
2. Department of Geography, DPM's Shree Mallikarjun and Shri Chetan Manju Desai College, Canacona, Goa, INDIA
*fmnadaf@gmail.com

Abstract

In the age of global climate change, land use and land cover mapping help us to understand the vital modifications taking place in our environment. LULC mapping assumes great significance in planning, management of resources and keeping track of various programmes at different levels. The data acquired from the land use and land cover investigations are vital for policy formulation and sustainable development of our towns, cities and villages and also to track the disorganized growth of urban areas. Tourism is a tool for economic development in many developing countries of the world. The unplanned tourism growth has led to many ecological problems. This study makes an earnest effort to examine the LULC change using the transition model in the Bardez taluka, which is a well-known global tourist destination in Goa, India.

The study has been investigated by using satellite imageries and GIS technologies have been used to analyse the changes occurring in LULC patterns for the years 1991, 2001 and 2021. The result indicates that the area under the built-up class has increased substantially by 11.12 sq. km. as a result of the rise in commercialization, tourism growth and tourism-related activities. Bardez taluka is known for some of the most breath-taking beaches in the world. During 2019-20, just before Covid-19, about 25, 33,234 domestic and 2, 74,840 foreign tourists visited the enchanting beaches of Bardez taluka. Land use classes such as residential, commercial and services, industrial, transportation and utilities also witnessed the growth in their land use and land cover classes whereas classes like agricultural land, coconut plantation, cashew plantation, barren land, DM and FDM forest land, open scrub and fairly dense scrub witnessed a negative change in their class values.

Keywords: Land Use, Land Cover, Change, Tourism, Detection, Transition Matrix.

Introduction

For human subsistence and land-based ecosystem services, the land is an essential natural resource [1,2,16]. Land is a vital natural resource as it safeguards land-based habitats and guarantees human survival[18]. Earth, which is the abode of man, is undergoing tremendous alterations as a result of the increase in anthropogenic activities[33]. The variables such as physical, demographic, technological and human traditions affect a piece of land's worth[30]. Land is a fixed resource and due to the multiplications of towns and cities, the exponential growth of population, economic desires and other dynamics of the struggle for land are becoming more intense[6,15].

Though the words "land use" and "land cover" are perspicuous, they are used synonymously. Land use illustrates the characteristics of surface elements while land cover demonstrates how land cover is used by humans. In other words, it is the result of human-nature interaction within a geographic entity[9,32]. Human beings are the main agents of change as they can transform their environs at a quicker rate including land use and land cover (LULC).

According to the National Climate Assessment Report 2022, land use and land cover change and the release of GHG by humans influence climate change through land use and land cover change at local, regional and global levels. Due to changes in land use and land cover, the urban areas are comparatively warmer than rural areas since large cemented areas affect the exchange of water and energy between the lithosphere and the atmosphere. A variety of factors influence spatially and temporally and act intricately and stimulate land use land cover change. Primarily, land use change crops up at a micro-level which later results in higher spatial levels at the macro-level due to factors such as biophysical and societal subject to their origin[10].

LUCC changes bring highly significant modifications to the terrestrial ecosystems which have a great effect on the immediate surroundings and ecological processes and they are the key catalyst of the worldwide ecosystem change[9]. Ecosystem changes influence natural resources, human health and the quality of ecosystems[40]. Anthropogenic activities like industrialization, urbanization and mining may have an impact on changes in land use and land cover[8,24].

LULC changes play a crucial role in spatio-temporal ecological sustainability, owing to its connections with clean water, agriculture and food security under local, regional and global climate conditions[1,28,39].

To understand the environmental changes to safeguard sustainable development and utilization of natural resources, LULC change detection assists policymakers. Hence, the study of LULC has emerged as an important area of research and therefore, an appropriate methodology for LULC classification is needed[5,27,37].

Various methods of LULC mapping and change detections have been developed and used all around the world. Some of them include Manual Techniques, Numerical and Digital Techniques, Hybrid Techniques and other methods of classification such as Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Soil-adjusted Vegetation Index (SAVI), Normalized Difference Built Index (NDBI), Spectral Mixture Analysis and Modified Soil Adjusted Vegetation Index (MSAVI) [3, 21, 29]. Similarly, there are many models to study and identify the dynamics and drives of land use change with strengths and shortcomings based on the research objective of the study [34].

To appreciate the human-land interplay and divulge key socio-economic developmental issues and their ecological ramifications, the study of land use transition has attained a vital breakthrough point[26]. The models used for evaluating and simulating the land use land cover changes provide a tool for detecting the spatial pattern and dynamics of LULC[17,20].

Globally and in particular, in the least developed and developing world, tourism is acquiring the status of an industry and it is regarded as a tool for economic development. Apart from the religious places, historical monuments and wildlife, the coastal stretches provide a golden opportunity for the promotion of tourism. No doubt, tourism has countless advantages but it suffers from several drawbacks in the age of climate change, global warming and sea level rise. The drawbacks include environmental complications and changes in land use and land cover along the beaches. It is observed that the unplanned growth of tourism has led to the destruction of sand dunes, coastal vegetation, mangroves, illegal pumping of groundwater and landscaping of beaches leading to eutrophication in coastal waters.

To study efficiently and precisely the changes in land use and land cover caused by tourism, researchers now have an excellent resource in the form of land use and land cover data collected from satellite sensors and multi-spectral imaging[4,38]. Remote sensing and Geographic Information Systems (GIS) are acknowledged as useful technologies for the development of sustainable tourism[35,41]. By examining data from several periods, the technique of change detection can be used to spot changes in any process or resource[8,36].

This research study makes an earnest effort to examine the LULC change using the transition model in the Bardez taluka, which is a well-known global tourist destination in Goa, India. The study has been investigated by using satellite imageries and GIS technologies have been used to analyse the changes occurring in LULC patterns for the years 1991, 2001 and 2021.

Study Area

The current study area is Bardez, a well-known taluka in North Goa as well as one of the famous tourist destinations. It is surrounded on the north by the river Chapora, on the south by the river Mandovi, on the east by the river Mapusa and on the west by the Arabian Sea. Bardez taluka is located between the latitudinal extent of 15°37'17.15"N to 15°35'23.66"N and the longitudinal extent of 73°48'0.73"E to 73°51'50.35"E (Figure 1).

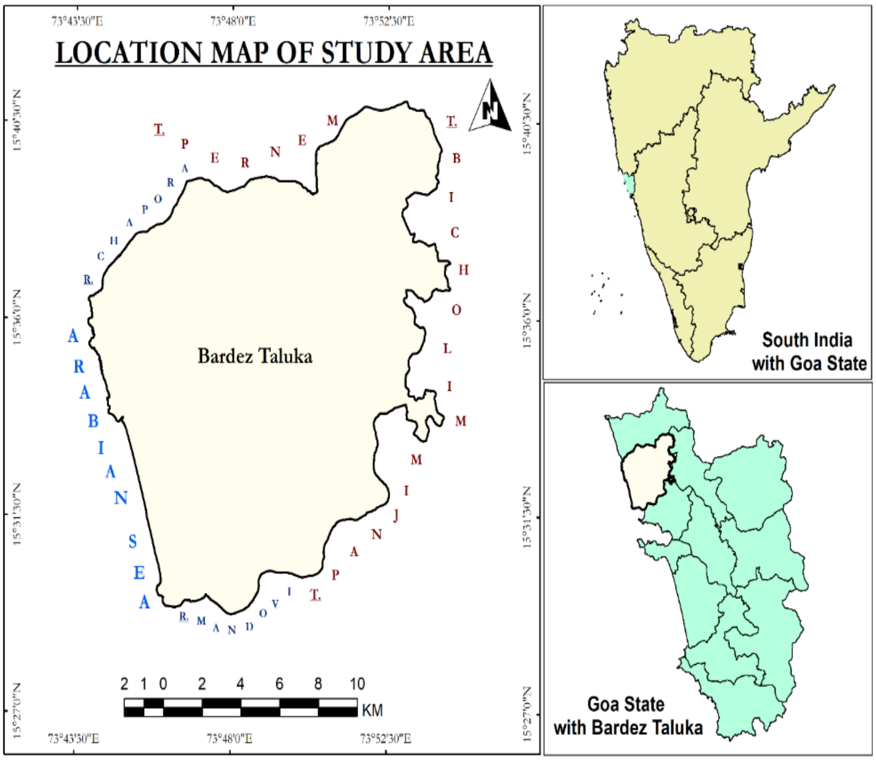

Figure 1: Study Area Map

Material and Methods

Primary and secondary data were employed for the investigation. Secondary data was primarily used for analysis. Thematic Mapper (TM) and Operational Land Imager (OLI) are some of the Landsat satellites with distinct sensors that were used for the analysis and were retrieved from the www.glovis.usgs.gov.in portal (Table 1). As a reference for classifying the land use and land cover of the study area, Google Earth 2021 and regional plan maps from the period 2001 and 2021 respectively were also used (Figure 2). By superimposing the study region shapefile that was downloaded from https://www.diva-gis.org/ data over the satellite images, clip operations were performed to extract the study area.

Image classification: According to Jensen[23], image classification is a procedure of identifying and grouping a raster image into distinct classes based on reflectance values. Similarly, ArcGIS defines image classification as the task of obtaining data of classes from a multiband raster image. Based on this, different classifications were formed using the Anderson Level 2 classification scheme. The image was classified based on local geographical knowledge of the area of investigation, visual interpretation of each LULC and other supplementary pieces of evidence. Onscreen digitization was used to digitize the clipped area and the study area was divided into 19 classes (Table 2).

Using the union method, transition matrices were developed in ArcMap 10.7.1. For the years 1991-2001 and 2001-2021, two matrices were obtained which aid in understanding changes that took place within various classes. To provide a clear image of the land use and land cover of Bardez taluka, maps of land use and land cover were generated for the years 1991, 2001 and 2021. Finally, MS Excel was used to create tables and figures. Primary data includes field observations and ground truthing.

Results and Discussion

Transition matrix 1991-2001: Matrix analysis for the decade 1991-2001 exhibited a decrement of 10 classes in the area whereas the remaining 9 classes show an increment in the area. Further, it was seen that in certain classes, the change was more noteworthy and in some it was negligible.

Table 1
Characteristics of the Landsat images used in the investigation

Satellite	Sensor	Date of Pass	Resolution	WRS Path	WRS Row	No. of bands	Cloud Cover
LANDSAT	TM	01-02-1991	30 m	147	049	07	0
LANDSAT	TM	12-02-2001	30 m	147	049	07	0
LANDSAT	OLI-TIRS	03-02-2021	30 m	147	049	11	0

Table 2
Anderson classification

Anderson Level I	Anderson Level II
1 Water bodies	1 Tidal River, 2 Freshwater Bodies, 3 Salt Pans,
2 Wetland	4 Forested Wetland, 5 Non-forested Wetland,
3 Vegetation	6 Dense mixed and Fairly Dense Mixed forest land 7 Open Scrub and Fairly Dense Scrub
4 Agriculture	8 Agricultural Land, 9 Coconut Plantation, 10 Cashew Plantation,
5 Fallow Land	11 Fallow Land
6 Barren Land,	12 Barren Land, 13 Sand Dunes and sandy area, 14 Bare exposed rocks,
7 Built-up area	15 Residential, 16 Commercial and Services, 17 Industrial, 18 Transportation and Utilities
8 Mining	19 Mining

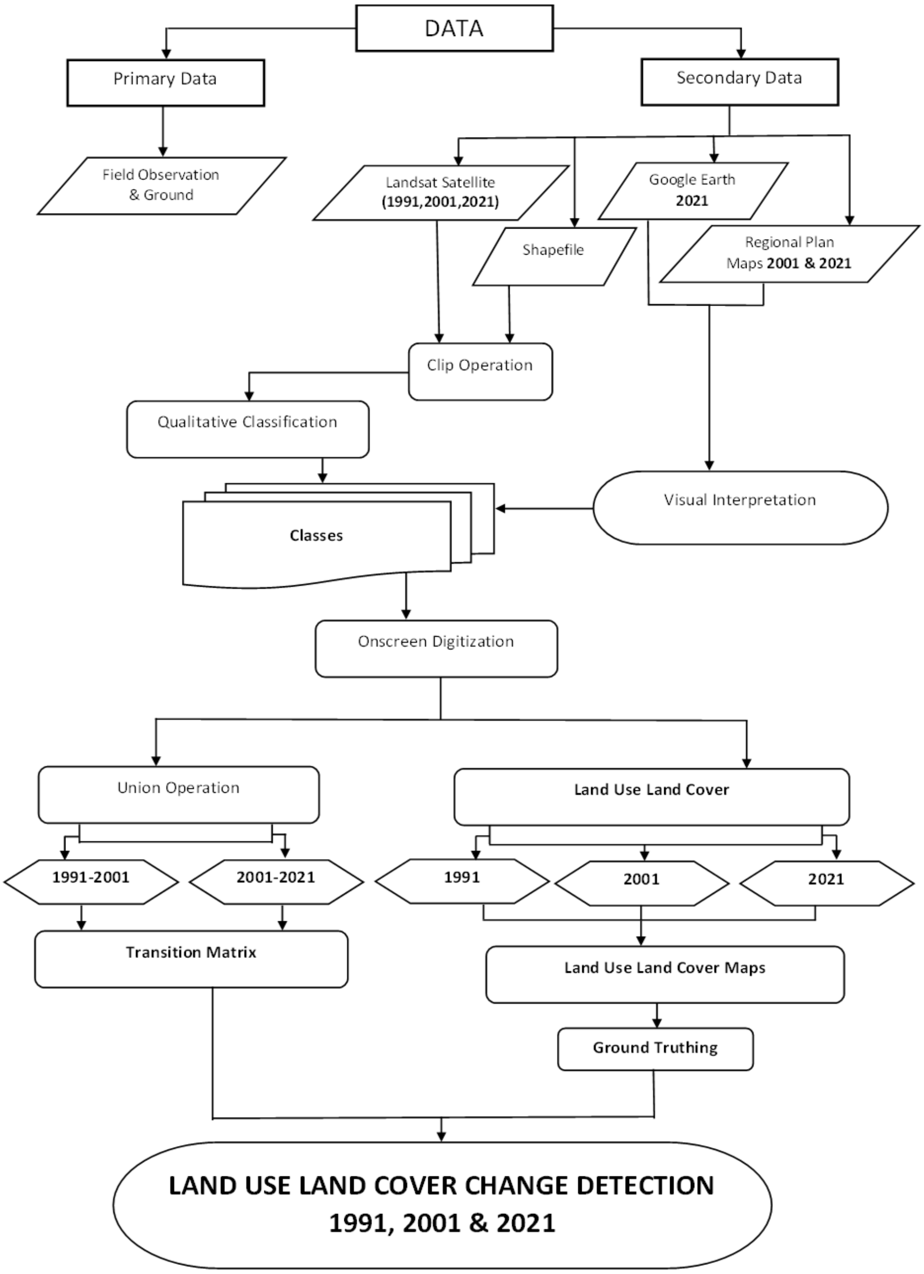

Figure 2: Methodology chart

Figures 4 and figure 6 demonstrate the land use land cover map for the years 1991 and 2001 respectively whereas figure 7 portrays the transition matrix which reflects positive, negative and stable changes or the area conversion from 1991-2001.

The tidal river has seen a negative change during 1991-2001. In 1991, total area of the tidal river declined from 16.65 sq. km to 16.43 sq. km in the year 2001. During 1991-2001, about 16.05 sq. km. of the area has remained unchanged. The decrement area of the tidal river has amalgamated into four classes namely forested wetland, non-forested wetland, agricultural land and transportation and utilities i.e. 0.34, 0.22,0.02 and 0.02 sq. km. respectively. On the contrary, forested wetland and non-forested wetland from dunes and sandy areas got transformed into tidal river to make the total area of class to 16.43 sq. km in the year 2001.

The area under freshwater bodies remained unaffected and did not change into any other class but areas from agricultural land, cashew plantation and barren land got renewed into the freshwater bodies, making an area accounting for 0.14 sq. km. in the year 1991 to 0.97 sq. km. in 2001. This transformation was predominantly owing to the building of canals for irrigation in the study area. Likewise, about 0.5 sq. km. area of agricultural land was transmuted into saltpans which showed an increase in area 0.11 in 1991 to 0.17 in 2001.

It is evident from figure 7 that the increase in the forested wetland was a result of the growth of mangrove forests in the region. In the year 1991, the forested wetland was marked at 5.16 sq. km. and the area from this class conceded into three classes namely tidal river 0.08 sq. km., non-forested wetland 0.16 sq. km. and transportation and utilities 0.02 sq. km.

which was negligible in the count. From 1991 to 2001, it can be noted that area from tidal river 0.34 sq. km., forested wetland 0.42 sq. km. and agricultural land 0.12 sq. km. altered into a forested wetland which increased from 5.24 sq. km. to 5.84 sq. km.

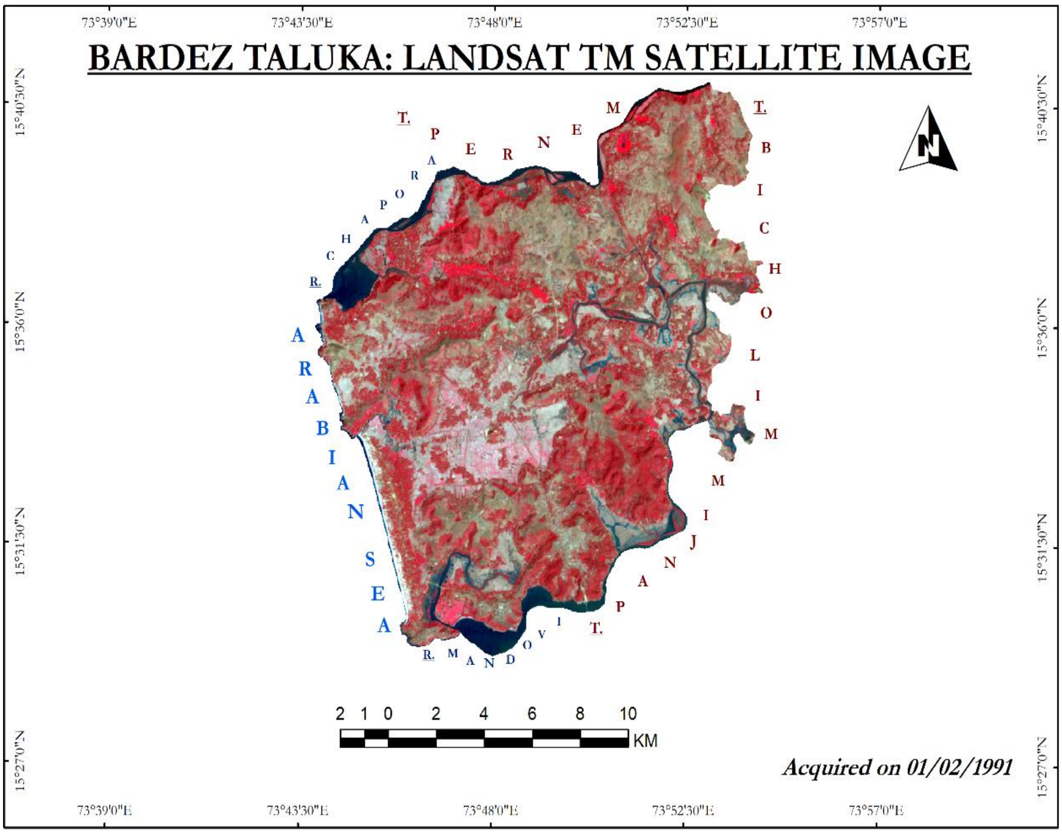

Figure 3: LANDSAT (TM) Image of 1991

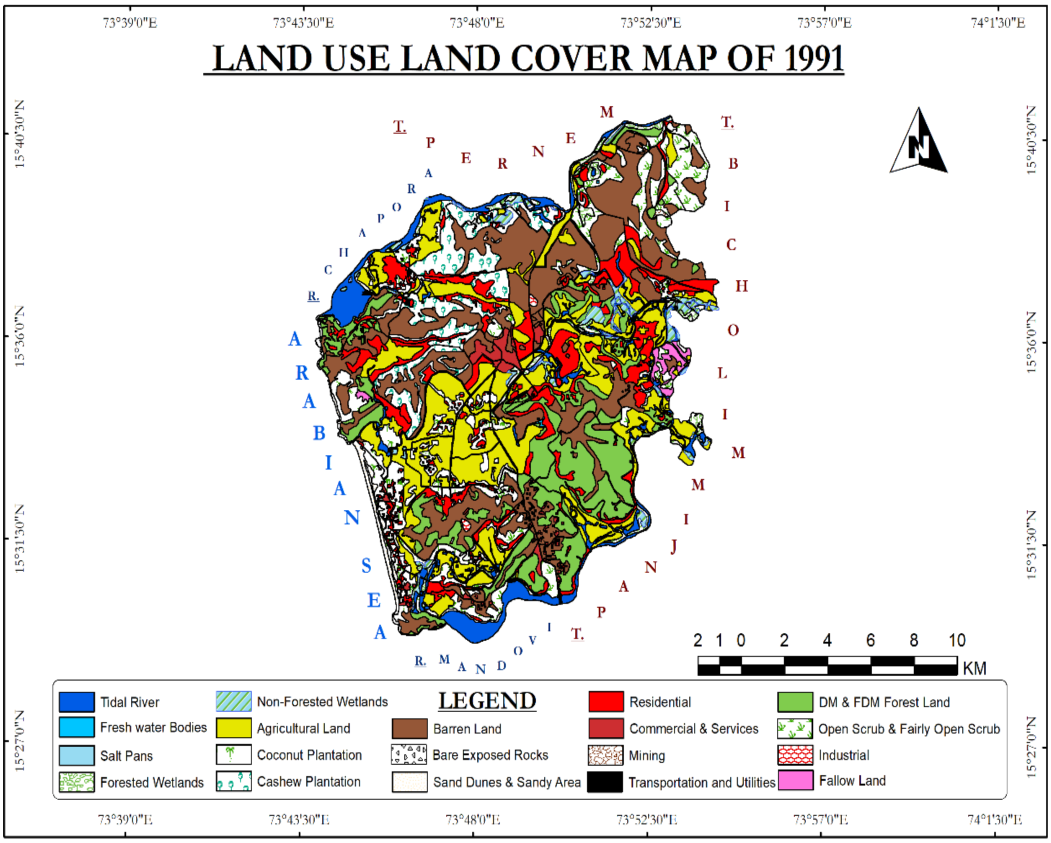

Figure 4: LULC Map of 1991

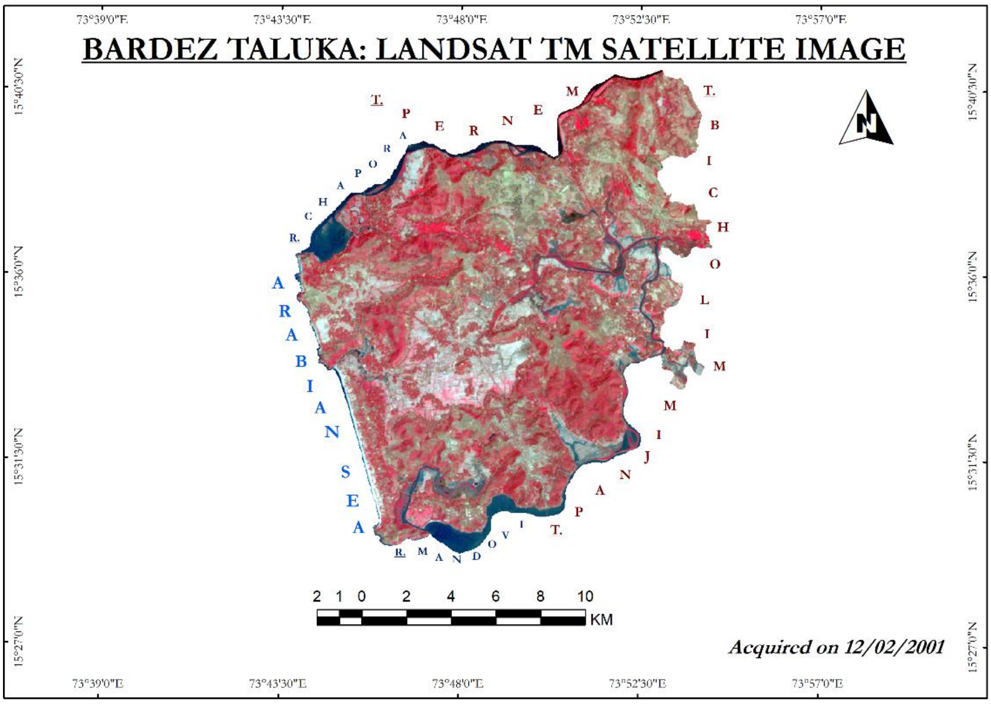

Figure 5: LANDSAT (TM) Image of 2001

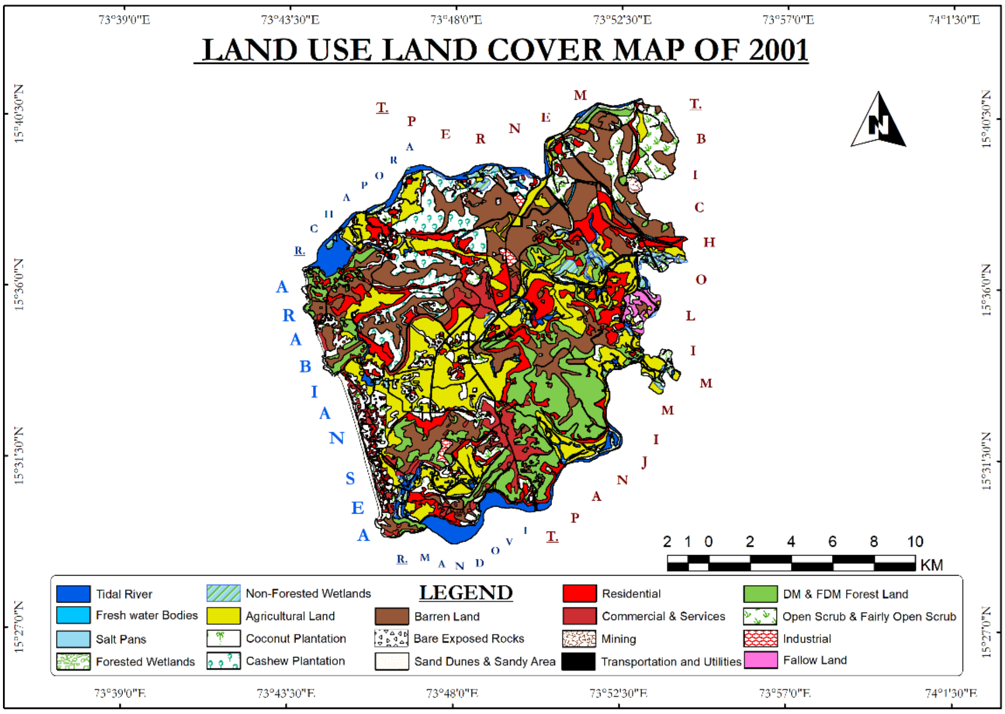

Figure 6: LULC Map of 2001

The non-forested wetland showed a diminution in the area by 0.32 sq. km. in the year 2001. The reason behind this decline was the transference of area to forested wetland, tidal river and agricultural land to about 0.71 sq. km. Agricultural land is the second-largest land use class in terms of area. The land under agriculture has peripherally declined from 47.81 sq. km. in 1991 to 47.16 sq. km in 2001 and about 46.85 sq. km. of land under agriculture remained unaffected during the decade 1991-2001. The decline in agricultural land transformed into the forested wetland, residential and commercial and services freshwater bodies, salt pans, non-forested wetlands, coconut plantations and transportation and utilities. The values specified in figure 7 state that the major conversion of agricultural land was witnessed in man-made classes such as residential, commercial and services and in transportation and utilities which accounts to about 0.74 sq. km.

Figure 7 elucidates the shrinkage of 1.09 sq. km. of the area in coconut plantations during 1991-2001. Similarly, it is evident from figure 7 that about 11.98 sq. km. of land remained unchanged during 1991-2001.

1991

2001

Classes	Tidal River	Fresh water bodies	Salt Pans	Forested Wetland	Non-forested wetland	Agricultural Land	Coconut Plantation	Cashew Plantation	Fallow Land	Barren Land	Bare Exposed Rocks	Sand dunes & Sandy Area	Residential	Commercial & Services	Industrial	Transportation & Utilities	DM & FDM Forest Land	Open scrub & Fairly Dense scrub	Mining	Total
Tidal River	16.05			0.08	0.21							0.09								16.43
Fresh water bodies		0.14				0.01		0.05		0.71								0.05		0.97
Salt Pans			0.11			0.05														0.17
Forested Wetland	0.34			4.90	0.42	0.12											0.06			5.82
Non-forested wetland	0.22			0.16	3.87	0.01														4.26
Agricultural Land	0.02				0.05	46.85			0.24											47.16
Coconut Plantation						0.02	11.98					0.09								12.08
Cashew Plantation								15.27												15.27
Fallow Land									1.49											1.49
Barren Land										51.11							0.02		0.03	51.15
Bare Exposed Rocks							0.02			0.03	0.53						0.06	0.03		0.66
Sand dunes and Sandy Area												1.89								1.89
Residential						0.08	0.52	0.05		0.20		0.01	27.32				0.95	0.73		29.85
Commercial and Services						0.65	1.33	0.05		3.95		0.22	0.26	3.69			0.64	0.61		11.20
Industrial										0.87					0.31					1.18
Transportation and Utilities	0.02			0.02	0.03	0.02	0.03	0.05		0.17						4.08		0.07		4.55
DM & FDM Forest Land										0.54							30.40			31.13
Open scrub & Fairly Dense scrub										0.59								16.12		16.72
Mining										0.17								0.32	0.18	0.67
Total	**16.65**	**0.14**	**0.11**	**5.16**	**4.58**	**47.81**	**13.89**	**15.47**	**1.73**	**58.35**	**0.53**	**2.30**	**27.59**	**3.69**	**0.31**	**4.08**	**32.13**	**17.93**	**0.21**	**252.67**

Stable area | Negative Change | Positive Change

Figure 7: Transition Probability Matrix (1991-2001)

(Note: Transition Matrix depicts land use land cover data for two time period. Data shown in the columns indicate data of preceding years and data displayed in rows specify data from subsequent years. Values presented diagonally illustrate stable data. The area is shown in square kilometres) (Figures shown elsewhere in brackets indicate square kilometres of area).

The transformed land use from plantation was distributed into bare exposed rocks, residential, commercial and services and transportation and utilities whereas about 0.09 sq. km of sandy area merged into coconut plantation during the same time period. The main reason for coconut plantations turning into residential and commercial areas was the growth of tourism and tourism-related activities and the commercialization of the area.

During the decade 1991-2001, about 0.20 sq. km. area declined in cashew plantations which transformed into freshwater bodies, residential, commercial services and transportation and utilities. Fallow land also indicated a minor decline in its total area from 1.73 sq. km in 1991 to 1.49 sq. km in the year 2001 resulting in the conversion of about 0.24 sq. km. of the area into agricultural land.

Barren land accounted for the extreme decline in its area. It covered 58.35 sq. km and 51.15 sq km in 1991 and 2001 respectively indicating a total decrement of 7.2 sq. km. Of the total area under barren land, about 51.11sq. km. area was unaffected by any other class during the same time period. The decline in area under barren land resulted in the enlargement of land use classes such as freshwater bodies (0.71 sq. km), residential (0.20 sq. km), commercial and services (3.95 sq. km), industrial (0.87 sq. km), transportation and utilities (0.17 sq. km), DM and FDM forest land (0.54 sq. km), open scrub and fairly dense scrub (0.59 sq. km) and mining (0.17 sq. km). The maximum conversion from barren land was into the area under commercial and services.

A declination of 0.41 sq. km. of the area in dunes and the sandy area was noticed. The area from dunes and the sandy area converted mainly into four classes namely tidal river and coconut plantation to 0.09 sq. km., each residential 0.01 sq. km. and commercial and services to 0.22 sq. km. Variation in this class was mainly seen near to coastal belt of the study area due to spurt in tourism and its related activities.

An increase in residential areas depicts man-made activities such as the construction of private dwellings, rooming houses, apartments, satellite towns etc. In the year 1991, the area under residential use was 27.58 sq. km. which augmented to 29.85 sq. km in 2001, out of which 27.32 sq. km. of the area remained unchanged. It is remarkable to note that the area of the residential area expanded at the cost of coconut plantation 0.52 sq. km., DM and FDM jungle 0.95 sq. km. and open scrub and fairly dense scrub 0.73 sq. km. agricultural land 0.08 sq. km., cashew plantation 0.05 sq. km., barren land 0.19 sq. km. and dune and sandy area 0.01 sq. km.

The area under commercial and services increased three-fold during 1991-2001 where the area increased from 3.50 sq. km. in 1991 to 11.20sq. km. in 2001. The area under commercial and services expanded at the expense of barren land 3.95 sq. km, coconut plantation 1.33 sq. km, agriculture land 0.65 sq. km, DM and FDM forest land 0.64 sq. km, open scrub and fairly dense scrub 0.61 sq. km and others.

The area under transportation and utilities showed an increment from 4.08 sq. km in 1991 to 4.55 sq. km in 2001 of which 4.08 sq. km. area remained unchanged during 1991-2001. Forested wetland, non-forested wetland, agricultural land, coconut plantation, cashew plantation, barren land, open scrub and fairly dense scrub transformed into transportation and utilities during the same time period.

A total area of DM and FDM forest land was 32.13 sq. km. in 1991 which declined to 31.13 sq. km in 2001, out of which 30.40 sq. km. of land remained stable. The loss of DM and FDM forest was again for barren land 0.54 sq. km bare exposed rocks 0.06 sq. km, residential 0.95 sq. km and commercial and services class 0.64 sq. km.

In the open scrub and fairly dense scrub area, about 16.12 sq. km. of land remained unchanged out of 17.93 sq. km. in the year 1991. The mining area increased from 0.21 sq. km to 0.67 sq. km during 1991-2001. Similarly, the area under bare exposed rocks also increased from 0.53 sq. km to 0.66 sq. km during 1991-2001. The area under industrial use accounted for a negligible area i.e. 0.31 sq.km in 1991 which swelled to 1.18 sq. km in 2001. The increase in area was primarily from the sandy areas and barren land.

Transition Probability Matrix (2001-2021): It is apparent from figure 10 and table 3 that during 2001-2021, the tidal river, agricultural land, coconut plantation, cashew plantation, barren land, dunes and sandy area, DM and FDM forest land, open scrub and fairly dense scrub and mining have shown a negative change. Whereas, freshwater bodies, forested wetlands, non-forested wetlands, residential, commercial and services, industrial, transportation and utilities have indicated a positive change. Areas under salt pans, fallow land and bare exposed rocks have remained stable over the period of time (Table 3).

Table 3
Comparative Transition Matrix 1991-2021

Classes	1991	2001	2021	1991 % to the total	2001 % to the total	2021 % to the total
Tidal River	16.65	16.43	15.88	6.59	6.50	6.28
Freshwater bodies	0.14	0.97	1.02	0.06	0.39	0.40
Salt Pans	0.11	0.17	0.17	0.04	0.07	0.07
Forested Wetland	5.16	5.84	6.09	2.04	2.31	2.41
Non-forested wetland	4.58	4.26	4.44	1.81	1.69	1.76
Agricultural Land	47.81	47.16	45.60	18.92	18.67	18.05
Coconut Plantation	13.89	12.09	6.96	5.50	4.78	2.76
Cashew Plantation	15.47	15.27	13.70	6.12	6.05	5.42
Fallow Land	1.73	1.49	1.49	0.68	0.59	0.59
Barren Land	58.35	51.13	43.07	23.09	20.24	17.04
Bare Exposed Rocks	0.53	0.66	0.66	0.21	0.26	0.26
Sand dunes and Sandy Area	2.3	1.89	1.60	0.91	0.75	0.64
Residential	27.59	29.85	37.78	10.92	11.82	14.95
Commercial and Services	3.69	11.21	24.30	1.46	4.44	9.62
Industrial	0.31	1.18	2.20	0.12	0.47	0.87
Transportation and Utilities	4.08	4.55	4.89	1.61	1.80	1.93
DM & FDM Forest Land	32.13	31.11	27.04	12.73	12.31	10.70
Open Scrub & Fairly Dense Scrub	17.93	16.71	15.43	7.10	6.61	6.11
Mining	0.21	0.67	0.34	0.09	0.27	0.13
Total	**252.66**	**252.66**	**252.66**	**100.00**	**100.00**	**100.00**

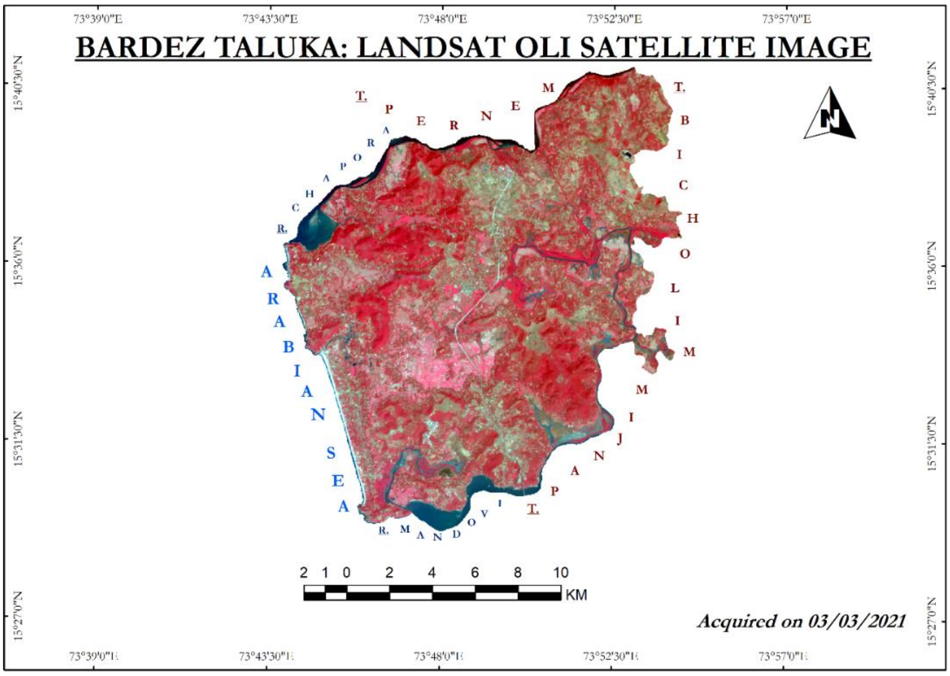

Figure 8: LANDSAT (OLI) Image of 2021

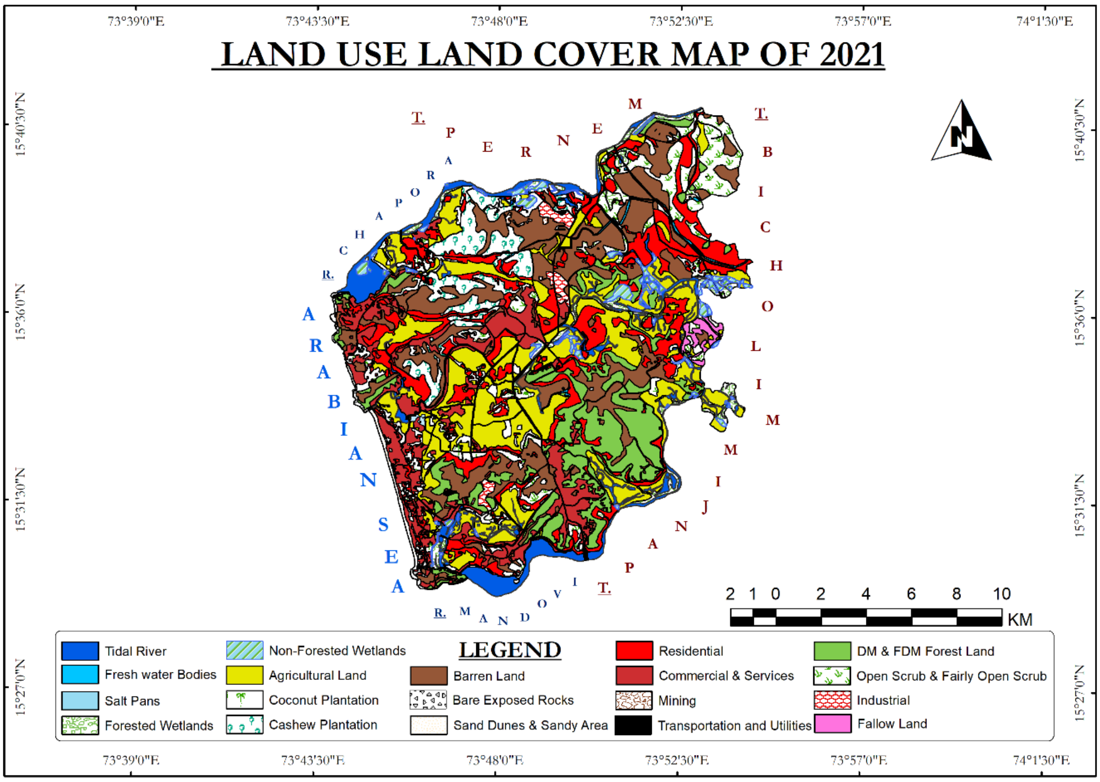

Figure 9: LULC Map of 2021

2001

2021

Classes	Tidal River	Fresh water bodies	Salt Pans	Forested Wetland	Non-forested wetland	Agricultural Land	Coconut Plantation	Cashew Plantation	Fallow Land	Barren Land	Bare Exposed Rocks	Sand dunes & Sandy Area	Residential	Commercial & Services	Industrial	Transportation & Utilities	DM & FDM Forest Land	Open scrub & Fairly Dense scrub	Mining	Total
Tidal River	15.86			0.02																15.88
Fresh water bodies		0.97																	0.05	1.02
Salt Pans			0.17																	0.17
Forested Wetland	0.19			5.80	0.10															6.09
Non-forested wetland	0.27			0.01	4.16															4.44
Agricultural Land						45.60														45.60
Coconut Plantation							6.93					0.03								6.96
Cashew Plantation								13.70												13.70
Fallow Land									1.49											1.49
Barren Land										41.59							0.02	0.35		41.94
Bare Exposed Rocks											0.66									0.66
Sand dunes and Sandy Area	0.09											1.51								1.60
Residential						0.52	1.08	0.78		4.86			29.55				0.71	0.29		37.78
Commercial and Services						0.87	4.06	0.80		3.57		0.35	0.30	11.20			3.34	0.94		25.41
Industrial										1.00					1.18		0.02			2.20
Transportation and Utilities	0.02					0.17	0.02			0.10						4.55	0.01			4.89
DM & FDM Forest Land										0.02							27.03			27.06
Open scrub & Fairly Dense scrub																		15.14	0.29	15.43
Mining																			0.34	0.34
Total	**16.43**	**0.97**	**0.17**	**5.82**	**4.26**	**47.16**	**12.08**	**15.27**	**1.49**	**51.15**	**0.66**	**1.89**	**29.85**	**11.20**	**1.18**	**4.55**	**31.13**	**16.72**	**0.67**	**252.65**

Stable area | Negative Change | Positive Change

Figure 10: Transition Probability Matrix (2001-2021)

It is inferred from figure 10 that of the of total area of the tidal river i.e. 15.88 sq. km., about 0.57 sq. km of the area was replaced by forested wetlands (0.91), non-forested wetlands (0.27), dunes and sandy areas (0.09), transportation and utilities (0.02). On the other hand, 0.02 sq. km of the total area of the tidal river merged into forested wetlands. Another land use class i.e. freshwater bodies merged into mining (0.05) and it did not convert into any other land use class.

Forested wetlands class of land use changed into the tidal river (0.02) and non-forested wetlands (0.01). Likewise, about 0.19 sq. km and 0.10 sq. km of the area of forested wetlands merged into the tidal river and non-forested wetland respectively. Nonetheless, from non-forested wetlands, about 0.28 sq. km of area merged into the tidal river (0.27) and forested wetland (0.01). From agricultural land, a total of about 1.56 sq. km of the area was transformed into different land use classes such as residential (0.52), commercial and services (0.87) and transportation and utilities (0.17). Nothing merged from this class.

A large chunk of coconut plantation (5.16) was renewed into residential (1.08), commercial and services (4.06), transportation and utilities (0.02) whereas 0.03 of the area was amalgamated into dunes and sandy areas. 1.58 sq. km. of cashew plantation area transformed into residential (0.78) and commercial and services (0.80). Nothing merged from this class of land use.

A maximum alteration in land use was detected in the barren land. About 9.55 sq. km of barren land was converted into residential (4.86), commercial and services (3.57), industrial (1.00), transportation and utilities (0.10) and DM and FDM forested land (0.20). Similarly, 0.37 sq. km of area under barren land merged into DM and FDM forested land (0.02) and open scrub and fairly dense scrub (0.35). Another important land use class is dunes and sandy areas, out of which 0.38 sq. km transmuted into coconut plantation (0.03) and commercial and services (0.35) whereas 0.09 merged into the tidal river.

8.24 sq. km of the area of residential land use class merged into agricultural land (0.52), coconut plantation (1.08), cashew plantation (0.78), barren land (4.86), DM and FDM forested land (0.71) and open scrub and fairly dense scrub. Only 0.30 sq. km of the residential area changed into commercial services.

9.95 commercial and services merged into agricultural land (0.87), coconut plantation (4.06), cashew plantation (0.80), barren land (3.57), dunes and sandy areas (0.35) and residential (0.30). Nothing converted from this class of land use to another class of land use. Likewise, 1.02 industrial areas merged into barren land (1.00) and DM and FDM forested land (0.02).

0.11 sq. km. from transportation and utilities merged into barren land (0.10) and DM and FDM forested land (0.01). Similarly, 4.1 sq. km of DM and FDM forested land was converted into barren land (0.02), residential (0.71) commercial and services (3.34), industrial (0.02) and transportation and utilities (0.01). A negligible area of commercial and services merged into barren land (0.02).

1.58 sq. km of the area of open scrub and fairly dense scrub transformed into barren land (0.35), residential (0.29), commercial and services (0.94). Only about 0.29 sq. km. merged into mining. The land use classes such as salt pans, fallow land and bare exposed rocks remained stable without getting merged or converted.

Conclusion

Thus, it is concluded that the area under the built-up class has increased by taking values from all other classes. The total area of built-up classes has increased from 35.66 sq. km. to 46.78 sq. km., showing an increase in the total of 11.12 sq. km. Such an intensification in the built-up classes was due to the rise in commercialization and growth in tourism and tourism-related activities. Bardez taluka is known for some of the most breath-taking beaches in the world. During 2019-20, that is just before Covid-19, about 25, 33,234 domestic and 2, 74,840 foreign tourists visited the enchanting beaches of Bardez taluka.

Similarly, land classes such as residential, commercial and services, industrial, transportation and utility witnessed the growth in their land use and land cover classes whereas classes like agricultural land, coconut plantation, cashew plantation, barren land, DM and FDM forest land, open scrub and fairly dense scrub witnessed a negative change in their class values. The change occurred due to the infrastructural development, growth in the public sector, tourism and tourism-related activities. Thus, the land use land cover saw a drastic variation between 2001 to 2021.

Bardez taluka, which is the area of investigation, geographically covers an area of 252.66 sq. km. It is observed that during the decade 1991-2001, the total area of Bardez taluka 16.28 sq. km. of area merged from one class of land use to many other classes of land use. While, during 2001-2021, the area merged increased to about 20.76 sq. km. Likewise, during 1991-2001, about 16.33 sq. km. of the area was converted from one class of land use to many land use classes of land use whereas from 2001-2021, the total converted area stood about 25.10 sq. km. The stable area for 1991-2001 and 2002-2021 was 236.29 and 236.74 sq. km respectively.

Transition modelling is an important tool in predicting distribution and project land-use change patterns with insignificant deviations and negligible errors. Change in land use and land cover is primarily due to various positive and adverse factors. Large-scale changes in land use land cover over a long period of time may prove to be ecologically destructive.

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