Analysis and Prediction of Land Cover Changes using the Land Change Modeler (LCM): A Case Study of Candolim, Bardez-Goa, India

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Abstract
Earth is changing ever since it is born. Once entire earth was covered by molten material which later took the shape of the lithosphere. The primordial lithosphere had only land and water as land cover and later other land covers such as forests, grasslands, wetlands etc. took shape. With the humanization of the Earth, the landscape was used for development and conservation resulting in land use. Land is a fixed resource and every accessible piece of land has been utilized by man for his needs. The land use continues to change, today's built-up area may have been agricultural land a decade ago or today's plantation might have been forest. Detection of changes in the use of land will offer policymakers and planners to predict the future land cover and will help in the proper planning and management of towns and cities. Globally, the tour and travel industry has played an important role in bringing drastic changes in land use. Tourism leaves both constructive and destructive imprints on the environment. Of late, 'beach tourism' has fascinated a large number of travellers in the world.

In Goa, tourism arrived immediately after its liberation in 1961 from the oppressive rule of the Portuguese with the appearance of 'Hippies' in Calangute, Anjuna, Vagator, Baga and Candolim villages of Bardez taluka. Tourism has played a vital role in the overall economic development of these villages and has led to change in the character of these villages. Hence, this study makes an in-depth analysis of the impact of tourism on the land use land cover in Candolim village of Bardez Taluka. The spatio-temporal analysis of land cover change is undertaken using Image Processing software Idrisi Selva 17.0 and ArcGIS 10.3. Landsat multi-temporal satellite imageries of the year 2001 and 2021 and Google Earth data of the same period are used to define the current changes in the land use land cover patterns. ArcScene was used for 3D creation and modelling of Candolim village between the years 2001 and 2021. The study indicates that due to unplanned tourism growth, six land parcels such as the area under forestland, sandy beaches, barren land, agricultural land, plantations and shrub land have declined by 0.94, 2.33, 3.42, 1.52, 0.23 and 6.83 per cent respectively. Net change to Built-up land from different classes and cubic trend map of 2001 to 2021 depicts that shrub Land was more vulnerable to change into built-up land at a large scale.

Keywords: Tourism, Coastal areas, Land use, Land cover, Change, Land degradation.

Introduction

Tourism is a billion-dollar thriving industry which is working to offer the populace jobs and other opportunities across the globe. Physical and cultural landscapes along with the historical heritage of any geographical location act as vital resources for the dynamic growth and development of tourism. Tourism brings both constructive and destructive changes. The activities such as un-planned infrastructural expansion like the building of beach shacks, resorts, pubs, roads network, airfields and human interfering activities like pollution, dune mining, dune dressing and artificial beautification of beach areas with pavers, waste disposal, encroachments and beaches beyond carrying capacities have led to land degradation.

On the planet earth, coastal areas are the most breathtaking tourist destinations. Of late, 'beach tourism' has fascinated a large number of travellers in the world. As tourism aids the overall development, hence, in the coastal areas, tourism has become the spine of the economy. Land use and land cover are two distinct concepts that are frequently used interchangeably[6]. Land cover is defined as the soil and biomass layer covering the earth's surface, including natural vegetation, plants and human structures. Land use refers to the purpose of people using land cover[11].

The land is a limited resource but due to rapid urban growth, expanding populations and huge demand for other economic necessities, the land is becoming further scarce. Human history reveals that mankind always had a close relationship with land[3]. Degradation of land occurs as a result of unplanned human activities, be it in coastal areas, urban areas or rural areas. Land use and cover change assessment (LULCC) helps to identify the extent of degradation of the natural environment[5].

Mankind consistently has a cosy relationship with the coast. Land clearing is one of the most common negative effects of tourism on forests, shrub land and also on barren land[7]. Land

degradation, altered water balance, vegetation loss and biodiversity loss are all signs of changes brought on by intensive human activities[9].

One of the unique necessities to foster tourism is land. Speculation of land is fundamental for structuring tourism facilities and tourism-related activities[2]. Tourism is a resource-intensive industry that is expected to degrade its environmental base due to lack of planning and management[12].

With the Remote Sensing and Geographical Information System (GIS) procedures, land use/cover planning has given a valuable and definite approach to work on the determination of regions intended for farming, metropolitan or potentially mechanical spaces of area[10]. Various examinations have been attempted to clarify the viability of these advances for dissecting LULC changes [8]. Land change modeler (LCM) is the application that could recreate and shows empower those thoughts. This module imitates the land cover dependency on certain drivers and time series of land cover information. It consolidates a special module among GIS and particular logical programming[13].

Visualization supersedes analysis and interpretations, a layman can be exempted from the latter two stages but the more rigorous approach requires a combination of all three. Visualization is a key feature and 3D modelling of cityscape is a forthcoming tool for understanding the swath and elevation of the built-up area under consideration. A 3D city model is a representation of an urban environment with a three-dimensional geometry of common urban objects and structures with buildings as the most prominent feature[4].

In city planning management, the third dimension is becoming a necessity. Using 3D GIS modelling offers a flexible interactive system while providing one of the best visual interpretations of data that supports planning and decision processes or city planners[1].

Structure Area

Candolim which is popularly known as the "Beach Lover's Paradise" is a coastal village in Bardez taluka, located in the western Indian State of Goa. It is a piece of the Goan threesome of Baga, Calangute and Candolim shoreline. The village and entire taluka is globally known for its touristic identity. Candolim is located 7 km from Mapusa and 12.6 km from Panaji, the capital city of Goa. Candolim village is located between $15^{0}29^{'}26^{''}$ North to $15^{0}31^{'}46^{''}$ North and $73^{0}45^{'}46^{''}$ East to $73^{0}46^{'}58^{''}$ East (Figure 1).

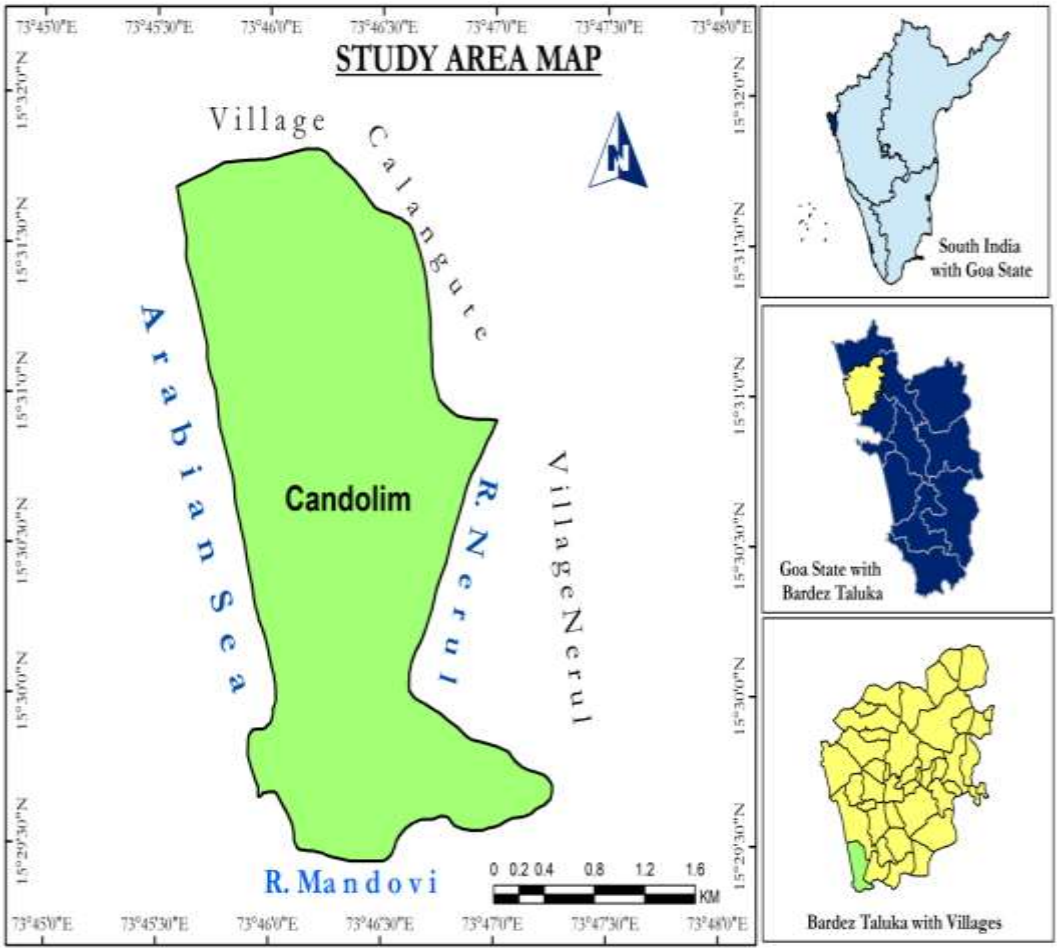

Figure 1: Location Map of the study area

For census purposes, Candolim village is declared as a census town. The population of the town as per the 2011 census is 8500; 4392 and 4108 are males and females respectively. The town has a cosmopolitan look with 48.60 per cent Hindus, 45.07 per cent Christian, 5.80 per cent Muslims, 0.05 per cent Sikh, 0.02 per cent Buddhists and 0.01 per cent Jain. The sex ratio of the town is 935 which is lower than Goa State i.e. 973. The literacy rate of Candolim is also lower than the State's 87.39 per cent (88.70 per cent).

Material and Methods

For the analysis, both primary and secondary data sources have been utilized. Primary data is acquired from field observations and ground-truthing whereas secondary geo-data is assimilated through satellite imageries. The satellite imageries used in the current study were obtained from https://glovis.usgs.gov (Table 1 and figure 2).

The radiometric and atmospheric corrections were performed. Shapefiles were obtained from DIVA-GIS. The study area was clipped from these satellite images by overlaying the shape file and the satellite images. Anderson level 1 classification was used to classify satellite images.

The clipped area was digitized and classified into 10 classes namely Forestland, Built-up Land, Sandy Beach, Rocky Areas, Barren Land, Agricultural Land, Water, Mangrove Swamps, Plantations and Shrub lands.

The data obtained from satellite images and Google Earth revealed that both positive and negative changes are occurring in the land use land cover of the study area. For the classification of LULC classes and comparative study of spatio-temporal changes of an area, ArcMap 10.7.1 version was used which is an effective Imagine Processing desktop application and another application is IDRISI SELVA 17.0 used for comparative study of different classes of LULC. For land change modeler, data was converted from ERDAS to IDRISI. With help of LCM, different maps such as gain and loss, net change to built-up areas, class conversion map between 2001 to 2021 and trend maps were generated and interpretation was carried out. The tables were generated using MS Excel (Figure 3).

Table 1
Remote Sensing data used

S.N.	Satellite	Sensor	Date of pass	Resolution	WRS Path	WRS Row	No of bands	Cloud Cover
1	LANDSAT	ETM+	03-01-2001	30 m	147	49	8	0
2	LANDSAT	OLI	18-01-2021	30 m	147	49	11	0

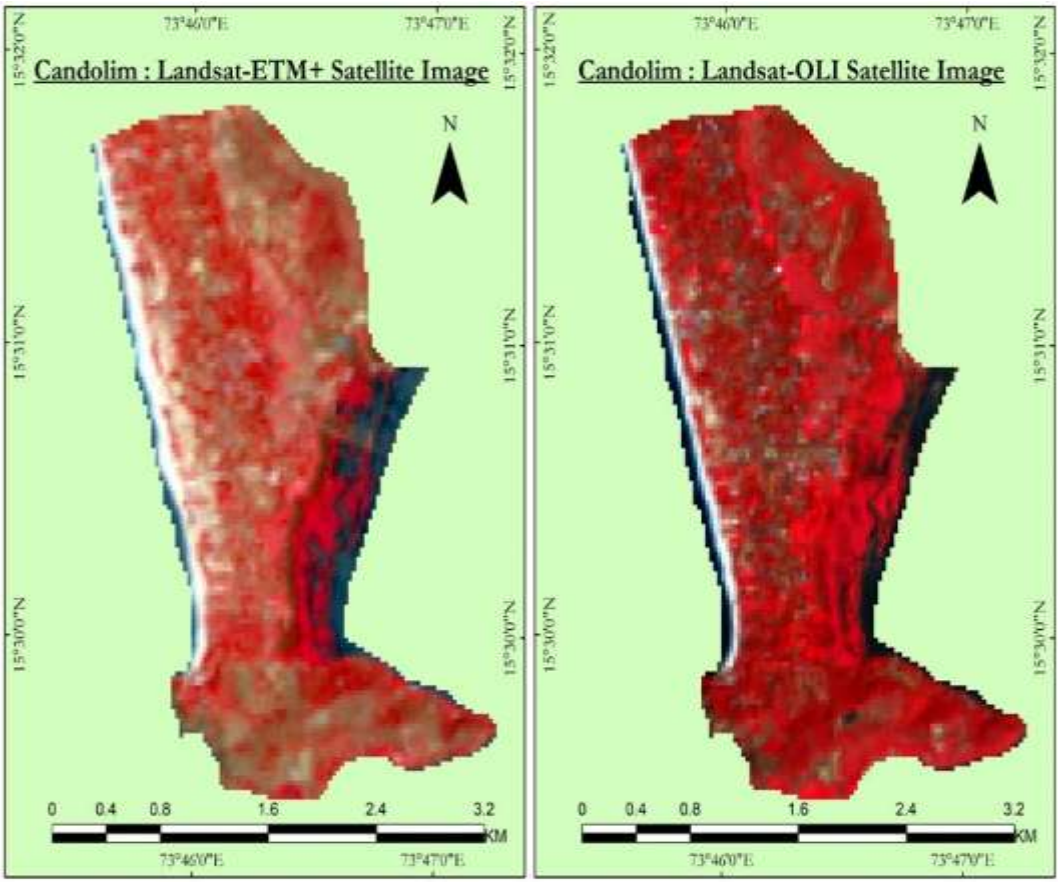

Figure 2: Landsat ETM+ and OLI Images

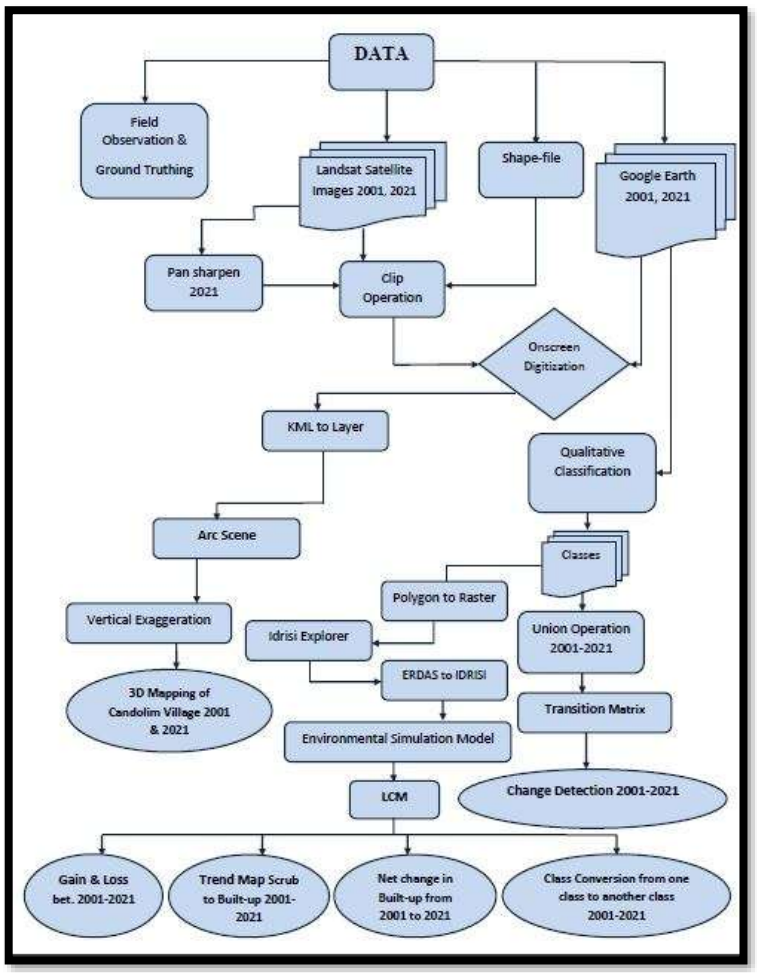

Figure 3: Methodology Chart

Table 2
Land-use Land-cover 2001

Classes	Area in Hectares	Area in %
Forest Land	104.39	14.68
Built-up Land	55.52	7.81
Sandy Beach	52.77	7.42
Rocky areas	10.16	1.43
Barren Land	143.93	20.25
Agricultural Land	82.21	11.56
Water	54.16	7.62
Mangrove Swamps	17.28	2.43
Plantations	26.31	3.70
Shrub Land	163.99	23.07
Grand Total	710.78	100.00

Results and Discussion

Before the liberation of Goa in 1961, Candolim with a geographical expanse of 7.10 square kilometres (710.786 hectares) was an eco-friendly sleeping village with agriculture and fishing as the main occupation of the people. Immediately after the liberation, it became a bustling place with the arrival of tourists and tourism activities which resulted in the change in the character of the village. About two decades back i.e. in the year 2001, only 7.81 of the village accounted for the built-up land. 14.68 per cent of it was under green cover. Sandy beach, rocky areas, barren land, agricultural land, water, mangrove swamps, plantations and shrub land accounted for 7.42, 1.43, 20.25, 11.56, 7.62, 2.43, 3.70 and 23.07 per cent respectively (Table 2 and figure 4).

In the last two decades, there has been a tremendous spurt in tourism activity and the village has become a global tourist destination. It is evident from table 3 that the areas under forest land, sandy beaches, barren land, agricultural land,

plantations and shrub land have declined by 0.94, 2.33, 3.42, 1.52, 0.23 and 6.83 per cent respectively whereas the area under built-up land has increased from 7.81 per cent in 2001 to 21.89 in 2021 showing an increase of 14.08 per cent. The increase in the built-up area is at the cost of a decrease in area under forest, sandy beaches, barren land, agricultural land, plantations and shrub land. It is interesting to note that the area under water bodies has increased from 7.62 per cent in 2001 to 8.83 per cent in 2021 and the area under sandy beaches has declined by 2.33 per cent for the same period thereby indicating land lost by sea erosion. An increase in area under mangrove swamps is a good indication as they are vital in protecting the coast from degradation (Figure 5).

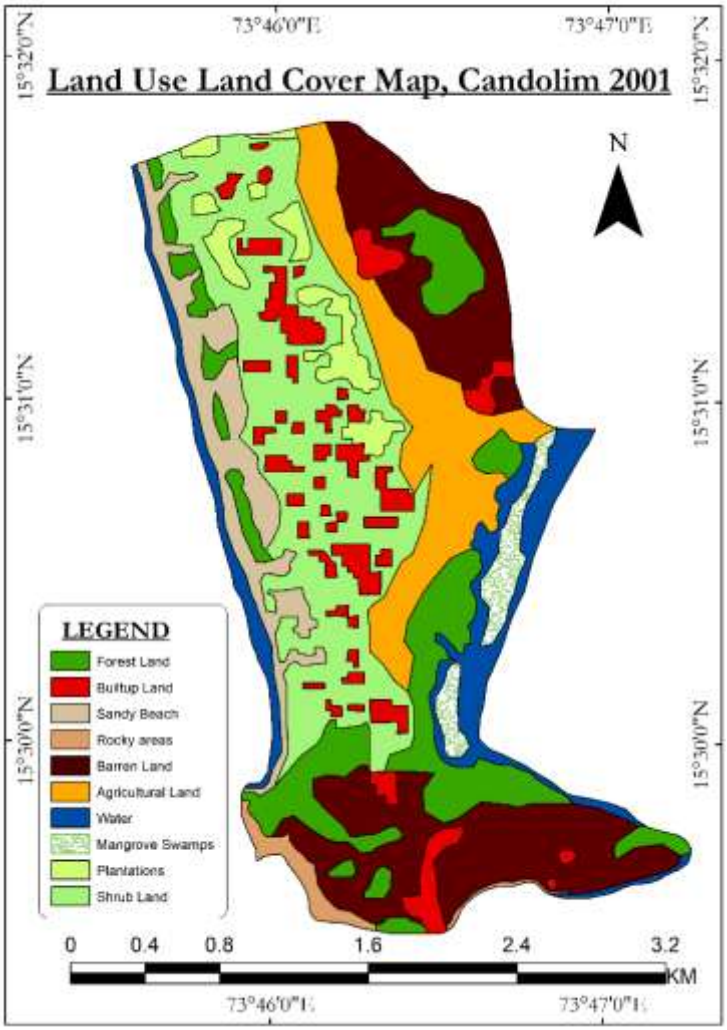

Figure 4: Land Use Land Cover Map of Candolim – 2001

Table 3
Land Use Land Cover Change 2001- 2021

Classes	Area in Hectares	Area in % 2021	Area in % 2001	Change from 2001 in %
Forest land	97.689	13.74372	14.6867	-0.94298
Built-up land	155.6118	21.8929	7.81227	+14.08063
Sandy Beach	36.1753	5.0894	7.42501	-2.33561
Rocky areas	10.19	1.4336	1.43014	-0.00346
Barren land	119.5719	16.8224	20.2506	-3.4282
Agricultural land	71.3825	10.0427	11.5672	-1.5245
Water	62.7897	8.8338	7.62103	+1.21277
Mangrove Swamps	17.29	2.4325	2.4318	+0.0007
Plantations	24.64	3.4665	3.70293	-0.23643
Shrub land	115.4464	16.24	23.0723	-6.8323
Grand Total	710.7866	100.00	100.00	

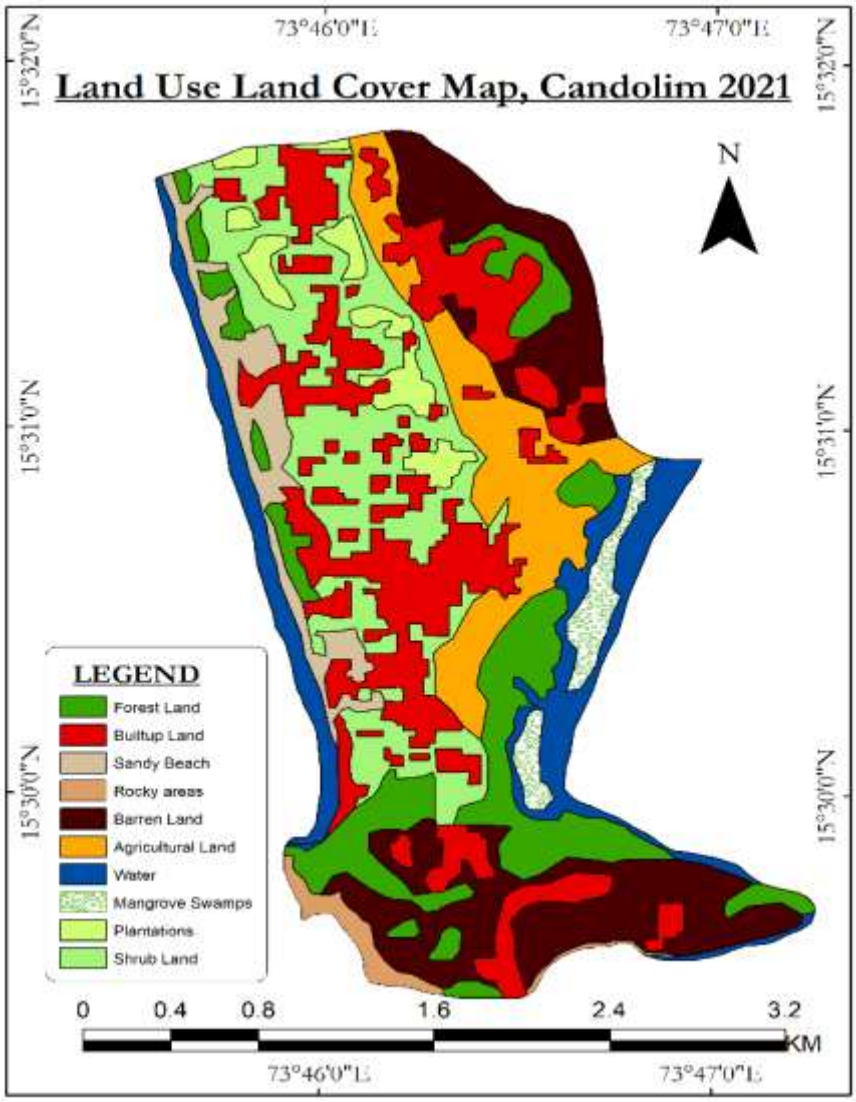

Figure 5: Land Use Land Cover Map of Candolim 2021

Transition Matrix: The transition matrix is used to understand class conversion. Negative change is highlighted in the colour red, positive change is shown in green colour and area which is in stable form is shown diagonally and highlighted in yellow colour.

It is apparent from table 4 that during 2001-2021, 91.88 per cent of the forest land has remained unaffected whereas 6.94 and 1.18 per cent of the area covered by forest transformed into built-up land and sandy beaches respectively. As per the matrix, 66.19 per cent of the area under sandy beaches has continued to remain constant and of the remaining 3.37 per cent has altered into the forest and 14.09 per cent into the built-up area. It is striking to note that 16.34 per cent of the sandy area has been replaced with water bodies, thereby indicating a rise in sea level and erosion of beaches due to both natural and human factors. Of the total barren land, 16.93 per cent has transformed into built-up area. Similarly, 13.17 per cent of the agricultural land is transposed into built-up areas. A big chunk of land belonging to shrub land i.e. 29.60 per cent is replaced by built-up land. During the period from 2001-2021, the built-up land, rocky areas, water bodies and mangrove swamps have not changed into any other class. Built-up land is one major class category that has benefitted from other classes such as forest land, sandy beaches, barren land, agricultural land, plantations and shrub land by an overall 87.05 per cent.

Land Change Modeler: The land change modeler (LCM) is a tool to forecast land transformation for land use planning. LCM utilizes recorded land cover modifications to experimentally show the connection between land cover changes and illustrative aspects to plot forthcoming situations of transformation. Like transition matrix**,** the LCM (Figure 5, 6 and 7) also clearly indicate that forest land, barren land and shrub land would be used for built-up. The gain and loss model indicates that loss of natural environment is gain for built-up.

The LCM is created to compare 2001 and 2021 data which indicates that shrub land has changed to the built-up. Sandy beaches are also used widely for built-up which is observed all along the coastal area. Other classes show a negligible change.

Table 4
Transition Matrix

2001

2021 Classes in Hectars	Forest Land	Built-up Land	Sandy Beach	Rocky areas	Barren Land	Agricultural Land	Water	Mangrove swamps	Plantations	Shrub Land	Grand Total
Forest Land	95.92	0	1.77	0	0	0	0	0	0	0	97.69
Built-up Land	7.25	55.53	7.43	0	24.36	10.83	0	0	1.66	48.54	155.61
Sandy Beach	1.23	0	34.93	0	0	0	0	0	0	0	36.18
Rocky areas	0	0	0	10.19	0	0	0	0	0	0	10.19
Barren Land	0	0	0	0	119.57	0	0	0	0	0	119.57
Agricultural Land	0	0	0	0	0	71.38	0	0	0	0	71.38
Water	0	0	8.62	0	0	0	54.17	0	0	0	62.79
Mangrove Swamps	0	0	0	0	0	0	0	17.29	0	0	17.29
Plantations	0	0	0	0	0	0	0	0	24.66	0	24.64
Shrub Land	0	0	0	0	0	0	0	0	0	115.44	115.45
Grand Total	**104.39**	**55.53**	**52.78**	**10.17**	**143.94**	**82.22**	**54.17**	**17.28**	**26.32**	**164.00**	**710.79**

2001

2021 Classes inPercent	Forest Land	Built-up Land	Sandy Beach	Rocky areas	Barren Land	Agricultural Land	Water	Mangrove swamps	Plantations	Shrub Land
Forest Land	91.88	0	3.37	0	0	0	0	0	0	0
Built-up Land	6.94	100.00	14.09	0	16.93	13.17	0	0	6.32	29.60
Sandy Beach	1.18	0	66.19	0	0	0	0	0	0	0
Rocky areas	0	0	0	100.00	0	0	0	0	0	0
Barren Land	0	0	0	0	83.07	0	0	0	0	0
Agricultural Land	0	0	0	0	0	86.83	0	0	0	0
Water	0	0	16.34	0	0	0	100.00	0	0	0
Mangrove Swamps	0	0	0	0	0	0	0	100.00	0	0
Plantations	0	0	0	0	0	0	0	0	93.68	0
Shrub Land	0	0	0	0	0	0	0	0	0	70.40

Negative change | Positive change | Stable Area

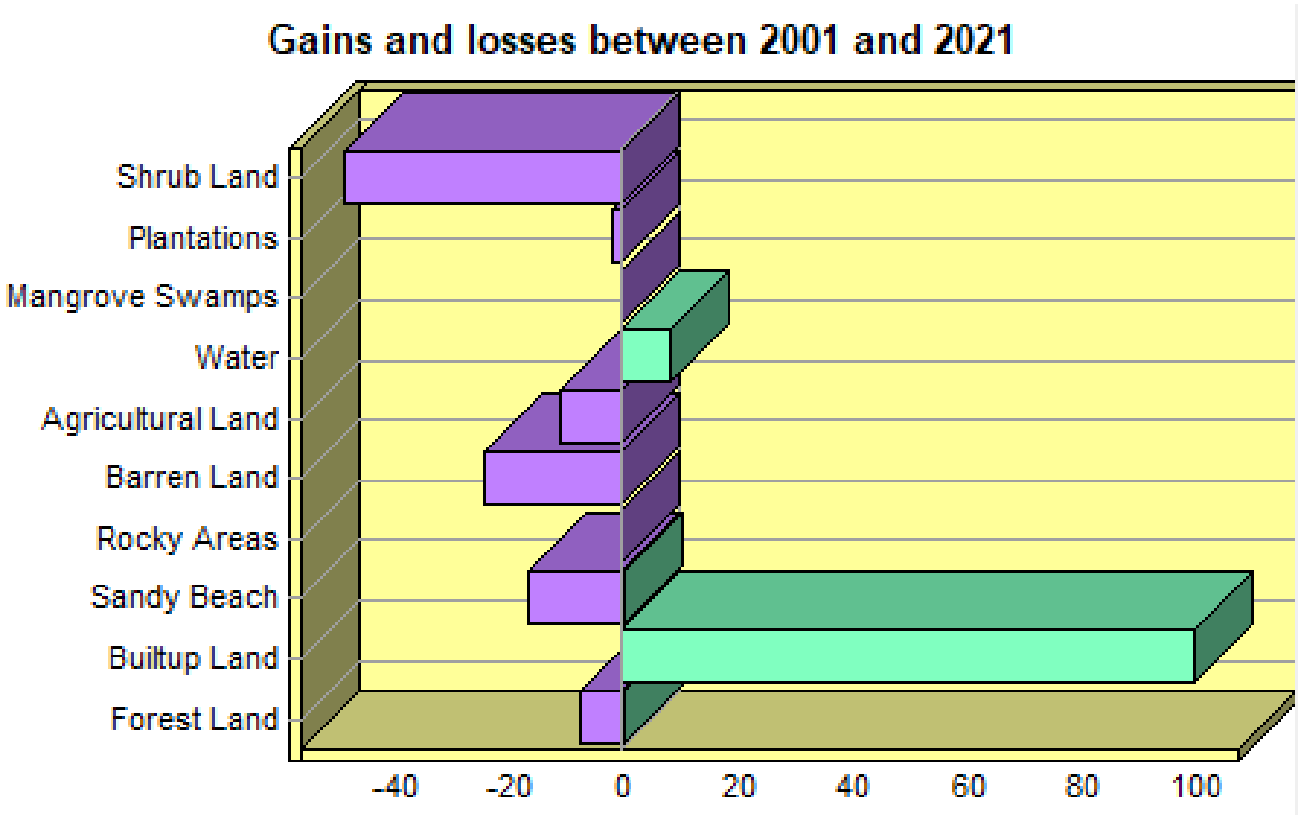

Figure 5: Gain and Loss

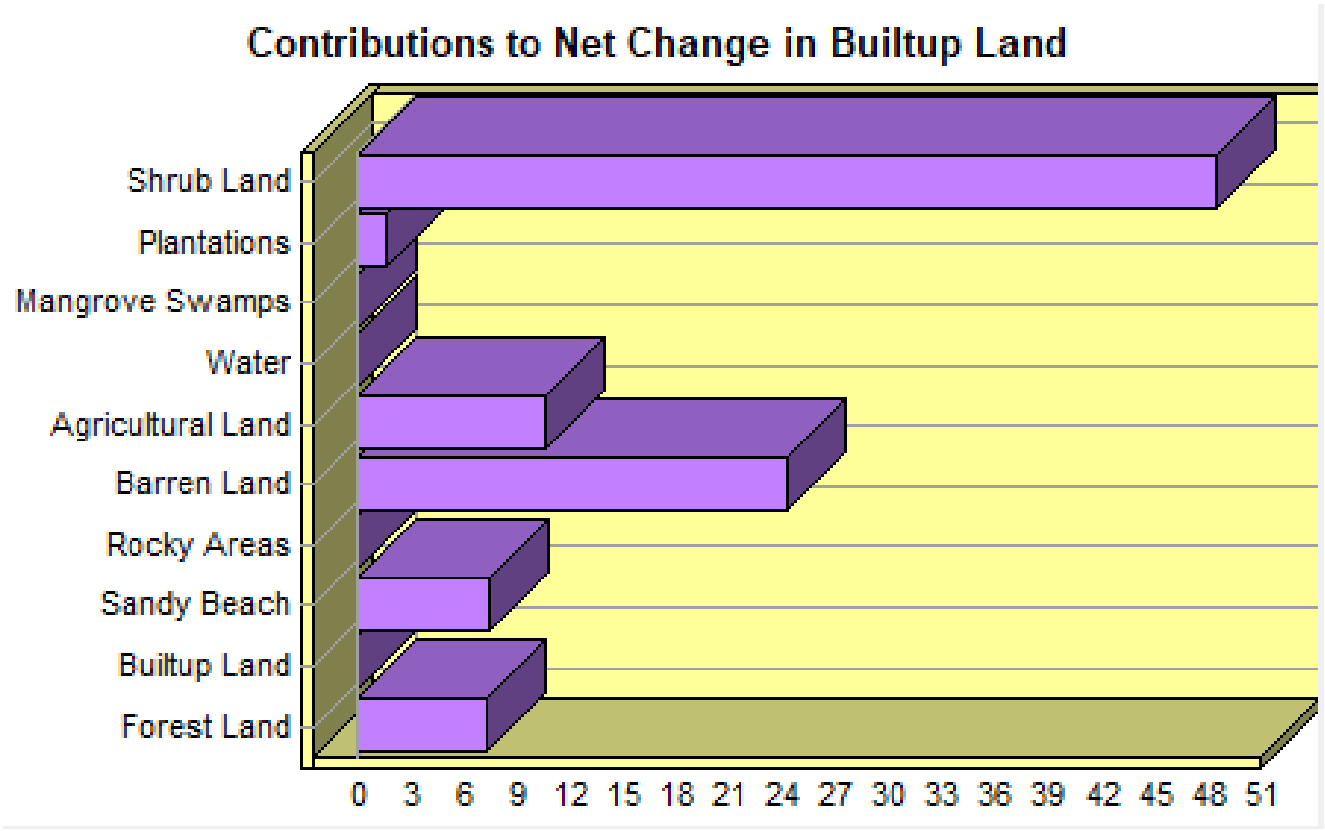

Figure 6: Net Change

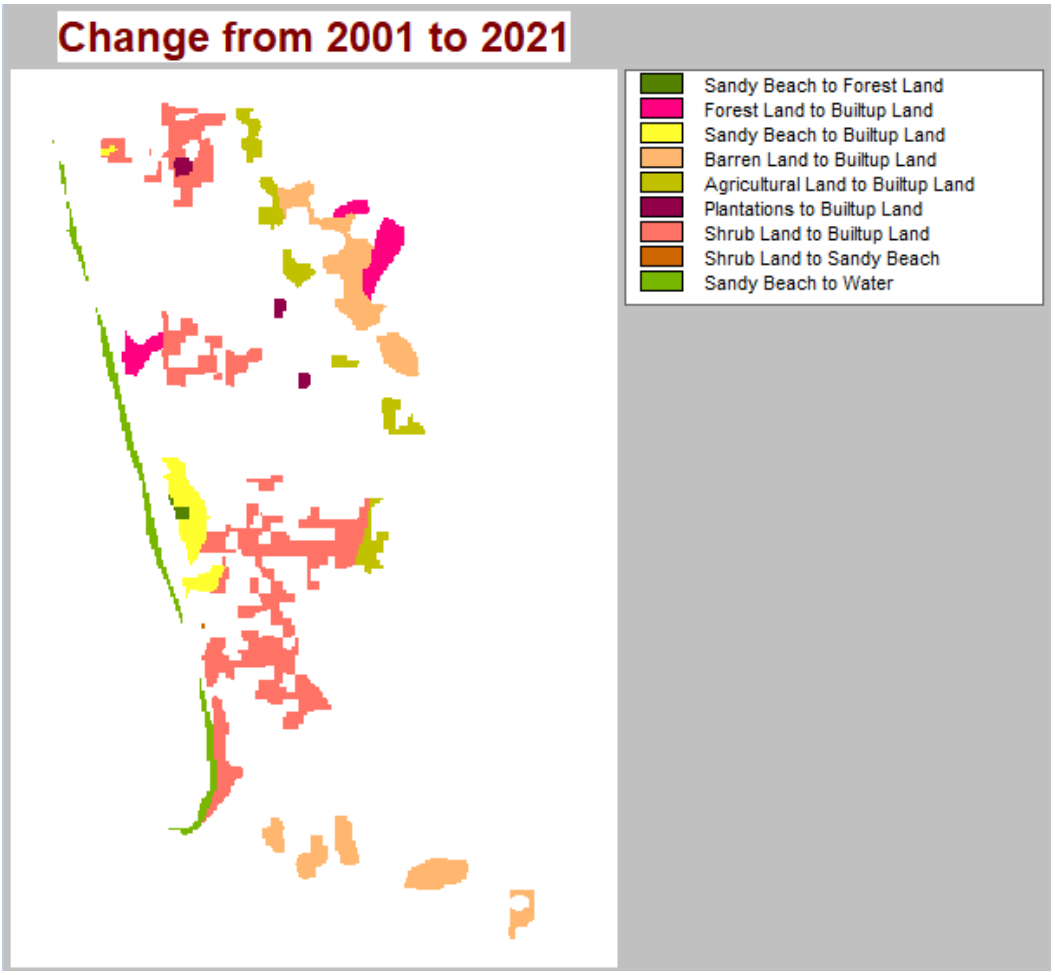

Figure 7: Class Conversion

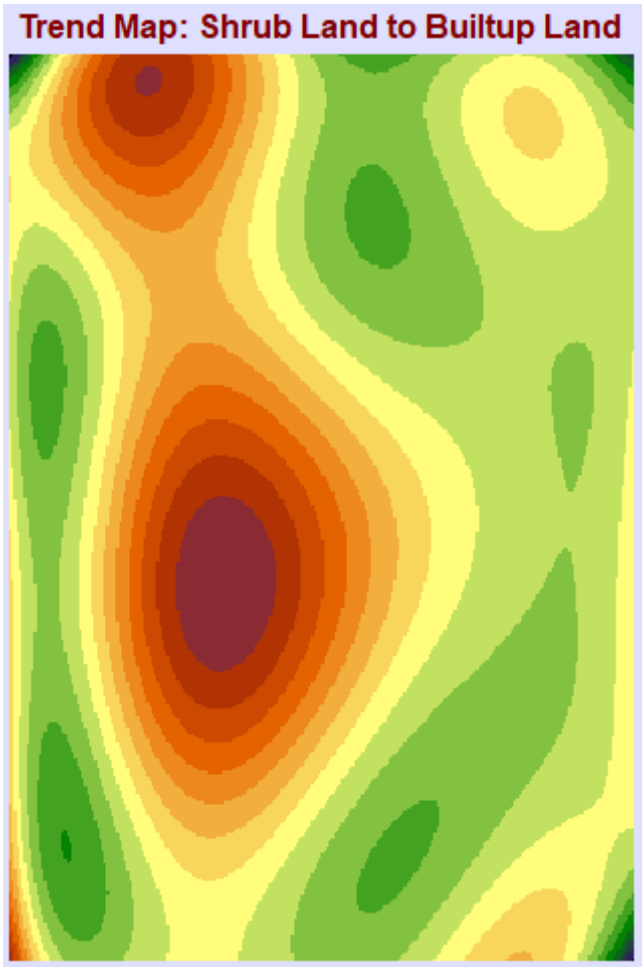

Figure 8: Trend Map

Figure 9: Built-up area 2001-2021 using Blender tool

The cubic trend map of 2001-2021 depicts that shrub land is more vulnerable to change into built-up land at a massive scale. The lowermost region depicting the darkest colour shows the lower part of the Candolim area having a higher built-up density as compared to the upper region. With the advent of tourism in Candolim, the Hippie markets became popular along the coast of Candolim coast and later the development of the village revolved around the Hippie markets which is evident from the cubic trend map of 2001-2021.

The above 3D maps are prepared using the ArcScene (Figure 9). The built-up area in 2001 showed scattered residential buildings with stand alone type commercial complexes. While in 2021, the built-up has spread across the entire village with commercial and residential areas as

indistinguishable. Built-up has increased along the beach. The temporary structures especially beach shacks mushroom during tourist season (October-June) and they are dismantled during monsoon season as per law of the land. Permanent settlements are represented in relatively higher cubes than temporary structures. Visually it is evident that the density of built-up has increased in the study area.

Conclusion

In this study, land use land cover detection of Candolim town over the last two decades has been investigated. The outcome of the study exhibits that a significant change detection had been noticed during the period of study. The areas under forest land, sandy beaches, barren land, agricultural land, plantations and shrub land have declined and the area under built-up land has increased two-fold. The increase in the built-up area is at the cost of a decrease in area under forest, sandy beaches, barren land, agricultural land, plantations and shrub land. Similarly, the area under water bodies has increased and the area under sandy beaches has declined thereby indicating land lost by sea erosion.

An increase in area under mangrove swamps is a good indication as they are vital in protecting the coast from degradation. The Candolim is on the verge of becoming a concrete jungle and overcrowded place. As a result of which tourists are moving to isolated beaches like Palolem, Agonda, Patnem in the south. The Candolim beach is subjected to erosion in many places. The changes in land use land cover may have negative implications on the sustainable tourism of Candolim town.

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