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ORIGINAL ARTICLE **OPEN ACCESS**

Spatio-temporal monitoring and predicting the Land Use/Land Cover Transformations using Cellular Automata (CA) – Markov Model: A case study of Urban Canacona, Goa-India

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ABSTRACT
This research paper aims to examine the Land Use/Land Cover variations in Canacona, located in the extreme southern part of Goa, India, which a well-known global tourist destination and one of the fastest-growing towns of Goa during a period from 2010-2020. It further, investigates and forecasts the future Land Use/Land Cover (LU/LC) Map for the year 2030 using the Markov Model to provide policymakers and planners with data about the present-day and past spatial variations of LU/LC change. Imageries from Resourcesat-2, LISS-III acquired on 12-11-2010 and 12-11-2020 with 23.5 meters resolution were used in the analysis of Land Use Land Cover in the area of investigation. To ascertaining future changes, application software such as IDRISI SELVA 17.0 and ERDAS 2014 are used. Two models namely MARKOV, CA MARKOV are applied to generate probability data for 2030 and the projected land cover map of 2030 respectively. Resultant maps were generated for 2010, 2020 and 2030 In light of Markov model forecasts, the built-up area is expected to upsurge from 9.89 percent in 2010 to 17.15 percent in 2030 due to the promotion of mass tourism. The world-acclaimed Palolem Beach is expected to contract by about 0.50 percent due to enormous coastal erosion and human impedance. In addition, the deforestation of Dense Mixed and Fairly Dense Mixed Jungle is expected to grow the territory under lateritic outcrop. Because of urban growth, the territory under Open Scrub is anticipated to diminish by 4%. Coastal areas are some of the highly dynamic areas on the Earth. Hence, the town and city planners must take into consideration the sustainable development of the area.
Key Words: *Land,Markov, built-up area, open scrub, prediction, change, geospatial technologies.*

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INTRODUCTION

The land as an asset is an interplay of elements like geography, environment, climate, soil, in addition, human factors like demography, technological capability, cultural and traditional activities. The land is a fixed resource and is vulnerable to deterioration due to abuse and misuse by man and his non-friendly activities be it in coastal areas or any other ecosystem. Similarly, the land is also subjected to degradation by forces of nature such as erosion, weathering, landslides etc. Hence, the utilization of land is of paramount significance.

Land use/land cover (LU/LC) are two unique words commonly used in amix. The first word indicates the actual properties of surface components and the last specifies utilization of land cover by human beings(1), (2). LU/LC signifies the outcome of man-nature interaction within a given geographical expanse (3), (4), largely determined by the dynamics such as socioeconomic factors and climate change processes (Verburg et al., 2011), (6).

Both natural and man-made factors regulate the LU/LC of any area. The anthropogenic factors include the technology, institutional and socio-economic setup. Similarly, the natural factors those influence land use are environmental conditions, rock structure, elevation, and gradient of a place(7). Scholars and scientists have contended that in the functioning of socio-economic and ecosystems, land use has a great impact with significant balances for food safety, biological diversity, sustainability, and socioeconomic susceptibility of society and ecosystems (8).

The journey of humans began from the forest. All of us depend on nature for the necessities of life such as food, clothing and shelter, apart from divine and aesthetic pleasure. In the last half a century, our demands for food and energy have increased many-fold which has resulted in ecosystem modifications.

Quite a long time ago, the whole human populace lived in the rustic regions, however today, an enormous populace in nations, like the USA, Canada, Brazil, Russia, Australia, United Kingdom, and Saudi Arabia dwells in metropolitan regions, which are most susceptible to the effects of LU/LC changes. In developing countries, cities are growing at a faster rate thereby inflicting drastic change in the urban landscape. Such unplanned growth accelerates LU/LC deviations related to the degradation of environmental services and the welfare of mankind (9). Planet Earth is experiencing rapid progress and advancement in Science and Technology, which has led to unbelievable urbanization (10).

The most noticeable changes taking place around us is the change in LU/LC (11). Identifying LULC alteration has become a major concern for geographers, earth scientists, ecologists, preservationists and land-use architects due to its impact on physical ecosystems (12). For millenniums, people have been using resources in hilly terrains; but the magnitude and endurance of such land-use changes are not understood well (13). LU/LC changes are perceived as perhaps the most pertinent drivers of biodiversity misfortune in biological systems (14).

Land use/land cover assumes a significant part in worldwide climate change and sustainability, including reaction to environmental change, impacts on environmental arrangement and operation, water, energy budget, levels of biodiversity, and agro-biological potential (15).

Man-Nature interaction offers a diverse point of view on land-use land-cover change and social-ecological systems; nevertheless, both practices faces some difficulties (16). LU/LC change is the main worry in many corners of the world. It is perceived that the intense LU/LC change can fundamentally affect the environment of a geographical region, water budget, river sedimentation, socio-economic practices, and biological diversity (17).Land use/land cover change is the most phenomenal change that is taking place globally on spatial and temporal scales. Changes in LU/LC indicate the influence of humans on the environment (18). Alterations in landuse can be attributed to the multifaceted interlinkage among natural and social aspects conjoined with demand, technical capabilities, which has influenced carrying capacity, and environs (P.H.Verburg, 2004).

The present modifications brought by humans on the planet earth are more widespread and visible than in any other period. The consequences of these modifications have become more prominent due to the growing populace, decline in land base, and the flexibility of our environment turns which is over-burdened (19).

The changing Earth's surface can be effectively monitored using remote sensing technologies as they are equipped with spatial, spectral, and temporal resolutions. Remote sensing technologies have many advantages concerning time, cost and re-visit time. For the extraction of land use/land cover material, remote sensing has a huge data source, which at times freely available (20).

Coastal areas are some of the fastest-growing stretches in the world and they are prone to kinds of catastrophes. To minimize the devastation along the shoreline, there has to be no development until some distance from the coast. To comprehend the influences of natural tragedies and catastrophes, land cover change analysis is of paramount importance. Similarly, for future planning and mitigation, data on land use and land cover change is of critical use(21).

Remote Sensing techniques are constantly used for Environmental Management (EM) and Environmental Impact Analysis (EIA) (22).To detect and monitor temporal changes in a given area, Remote sensing procedures are extensively used (23). Policymakers and planners are intrigued to know, the changes that have transpired and the reasons for such changes and their occurrences (24). The dynamics of LULC can aid policymakers and planners in the management (25).

Remote Sensing techniques are distinctly used to identify land use/land cover transformations. Progress in the Science of Remote Sensing and human ability to ability to evaluate sequential changes in the topography put to rest on the relevance of Remote Sensing (26).

Coastal zones are the most dynamic, highly sensitive and vulnerable ecosystems of Planet Earth. As a result of unregulated development, the LULC of coastal ecosystems has undergone tremendous change. Changes in land use in the coastal areas will influence the biological diversity and the quality of habitat (27).

As a result of large scale tourism, extensive industrialization, and urbanization, the coastal areas have experienced incredible change. The major shift in the land use from nature-based activities i.e., cultivation etc. to tertiary activities such as travel and tourism as a result of a robust network of railways, roadways, airways, waterways and communication structure, tourism infrastructures like Starred Hotels, Beach Resorts, Shacks, and housing centres. With the technology change, the capabilities of man to alter the environment also changes.

This research paper examines the LULC variations in Canacona, located in the extreme southern part of Goa, India, which a well-known global tourist destination and one of the fastest-growing towns of Goa during a period from 2010-2020. The changes taking place in LULC patterns have been investigated with the help of Toposheets and geospatial tools. Similarly, the comparison has been made by obtaining data for two different periods to comprehend the degree of deviations and conclusions have been drawn. It further, investigates and forecasts the prospective LULC Map for 2030 generated with the help of the Markov Model to provide policymakers and city and town planners with data about the present-day and past spatial variations of LULC change.

Area of Investigation:

Canacona is one of the key talukas of Goa, located to the extreme South, touching Karnataka State (Karwar) in the South, Sanguem taluka in the East, Quepem taluka in the North and Arabian Sea in the West (Figure 1).

Canacona jurisdiction covers 352.02 sq. km of geographical area, of which urban area accounts for 18.64 sq. km (7.20 sq. miles). However, the urban area is minuscule; it accommodates about 27.52 per cent of the population of Canacona taluka. Canacona town (Chaudi) is located between the latitudes of is 14º59`00`` to 15º02`00`` North and 74º00`24`` to 74º03`59``.

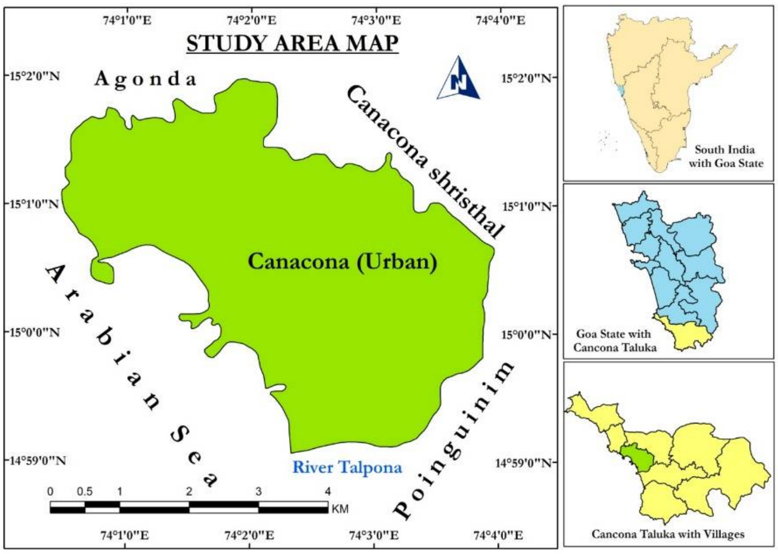


Figure 1 Location of the study area

The investigation region is blessed with vital ecosystems such as Forest, Wetlands, Mangroves, backwaters, Sand dunes, Beaches, and Estuarine Rivers. The Western Ghats, one of the biodiversity focal points of the world runs parallel to the Arabian Sea along the coast of Canacona; accordingly making it geo-ecologically a delicate zone.

The topography of Canacona in particular and Goa, in general, is composed of rocks of the Chitradurga group of Archaean to lower Proterozoic age such as greywacke-argillite and meta-basalt. Canacona is well known for one of the earliest rocks called *Trondhjemite gneiss*, which is dated back to 3.4billion years. Similarly, beach-sand and alluvial soil belong to the quaternary formations. The shoreline of Canacona is shaped and characterized by erosional and depositional processes influenced by tidal currents and long-shore drift and gusty winds originating from the Arabian Sea (28).

MATERIAL AND METHODS

For the analysis, both primary and secondary sources data has been utilized. Primary data is acquired from GPS Survey (GARMIN etrex 20) and ground-truthing and field observations whereas, secondary geo-data is assimilated through satellite imageries.

The satellite imageries used in the current study areobtained from https://bhuvan.nrsc.gov.in/ (Table 1). The Radiometric and Atmospheric correction was performed. The study area was clipped from these satellite images by overlaying the shapefile and the satellite images. Anderson Level 1 classification was used to classify satellite images. The clipped area was digitized and classified into the 12 categories namely Dense Mixed and Fairly Dense Mixed Jungle (DM & FDM Jungle), Built-up Area, Open Scrub, Farming, Plantations, Lateritic Outcrop, Wetlands, Water Bodies, Mangrove Swamps, Sand covered on Lawn, Rocky Areas, Sandy Beach. The data obtained from satellite images and Google Earth revealed the positive and the negative change occurring in the land use land cover of the study area (Figure 2).

For the classification of LULC classes and comparative study of Spatio-temporal changes of an area, ERDAS Imagine 14 versionis used, which is an effective Imagine Processing desktop application, Similarly, another application that is IDRISI SELVA 17.0 is used for predictions.

For prediction, data was converted from ERDAS to IDRISI (.img to .rst). Models were created to generate statistical probability data for 2030. Two models were used namely MARKOV, CA MARKOV. MARKOV was used to generate probability data for 2030. CA MARKOV was used to generate a projected land cover map for 2030. Resultant maps were generated for 2010, 2020 and 2030. The tables were generated using MS Excel.

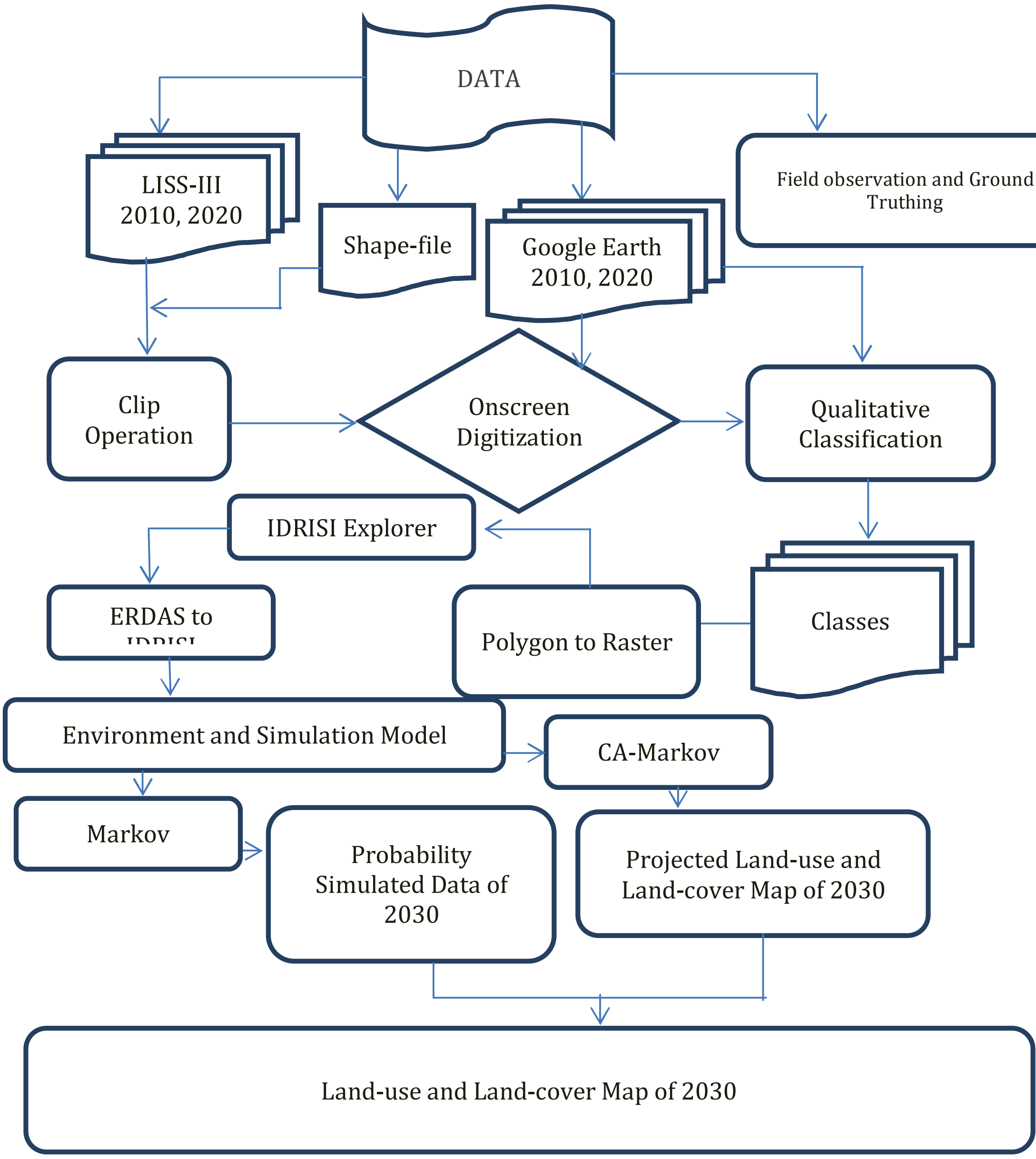


Figure 2 Methodology Chart

Table 1 Remote Sensing data sets used

Sr. No	Satellite	Sensor	Date of pass	Resolution	Path	Row	No of bands	Cloud Cover
1	Resourcesat-2	LISS-III	12-11-2010	23.5 m	096	062	4	0
2	Resourcesat-2	LISS-III	12-11-2020	23.5 m	096	062	4	0

Markov Chain Model:

The Markov is a model established on the arrangement of Markov random framework system for the forecast and ideal control theory method. The Markov model is commonly used for LULC modelling; this model takes an account of conversion state as well as conversion rate. Information obtained is about spatial as well as temporal changes.

Markov Model is known for estimating modification in the landuse from a specified period to a predicted period. The model demonstrates a fairly consistent probabilistic outcome.

The following equation explains how predictions of land-use changes can be calculated.

$$S(t, t+1) = P_{ij} \times S(t)$$

And,

$$||P_{ij}|| = \left\| \begin{matrix} P_{1,1}P_{1,2} \ldots .P_{1,N} \\ P_{2,1}P_{2,2} \ldots .P_{2,N} \\ \ldots \ldots \ldots \ldots \ldots \ldots \ldots \\ P_{N,1}P_{N,2} \ldots .P_{N,N} \end{matrix} \right\|$$

Understanding terms involved in the equation:
$S(t)$: State of the system at time t
$S(t, t+1)$: State of the system at time t+1 i.e. the consecutive state after $S(t)$.
P_{ij}: This is a transition probability matrix.
Here P is the transition probability and the subscripts i, j gives the states. iBeing the current state and j being the later state.
Numerical value of P_{ij} can vary between 0 and 1 ($0 \leq P_{ij} \leq 1$)
If the transition of given LULC in given time is low then transition probability will be near 0 and high transition have probabilities near 1.

CA-Markov Model:

In Geospatial Sciences, a blend of Cellular Automata and Markov Chain Model is well known as CA-Markov, which is used to predict the LU/LC trends and the Spatio-temporal patterns. CA-Markov Model takes an account of land-use variations and their effects over natural, social and economic factors.
Cellular Automata was originally developed to study and examine the logical framework of underpinnings of life. Purely mathematical formulations were devised to reproduce biological automata. This concept was then carried forward to model the land-use changes. Different approaches have been used to modify the original cellular automata model so that it would be useful in the study of LULC. The CA Markov Model computes the transition probabilities of different classes of landuse on the basis of land suitability and it further calculates transition probability from one category to another category of land.
GIS and cellular automata model can be utilized for plant growth, forest cover, watershed management, forest fire, andurban sprawl. It is a prerequisite for us to study the current and future scenario of LU/LC so that a symbiotic relationship can be established between humans and the environment.

RESULT AND DISCUSSION:

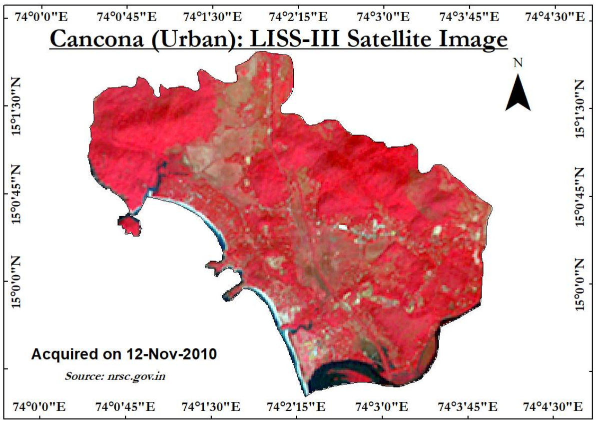
LISS-III Image interpretation (2010)

To comprehend the changes taking place in LULC from 2010 to 2020, the tabulated data, maps, figures, and tables are generated for further analysis and investigation. Based on the processed data, the study area is alienated into 12 lasses namely, Dense Mixed and Fairly Dense Mixed Jungle (DMand FDMJ), Built-up Area, Open Scrub, Farming, Plantations, Lateritic Outcrop, Wetlands, Water Bodies, Mangrove Swamps, Sand covered on Lawn, Rocky areas, and Sandy Beach (Table 2).

Table 2: Land Use Land Cover-2010

Land Use Land Cover Classes	Area in Hectares	Area in %
DMand FDMJ	653.4546	35.0513
Built-up Area	184.3855	9.8904
Open Scrub	323.1434	17.3333
Farming	183.8446	9.8614
Plantations	155.9671	8.3661
Lateritic Outcrop	61.4946	3.2986
Wetlands	119.9247	6.4328
Water Bodies	61.8543	3.3179
Mangrove Swamps	44.9769	2.4126
Sand covered on Lawn	33.9944	1.8235
Rocky areas	16.6927	0.8954
Sandy Beach	24.5464	1.3167
Total	**1864.2792**	**100.0000**

It is apparent from table 2, figure 2, and 3 that the Dense Mixed and Fairly Dense Mixed Jungle portray about 35.05 percent of the absolute geographical space of Urban Canacona. The built-up area accounts for about 9.89 percent of the total region. Open Scrub records for 17.33 percent of the entire area. Even though Canacona is an urban area, about 9.86 percent of the space is used for farming and allied activities. Apart from, DM and FDMJ, 8.36 of the space is under Plantation, which is largely Coconut Plantation.



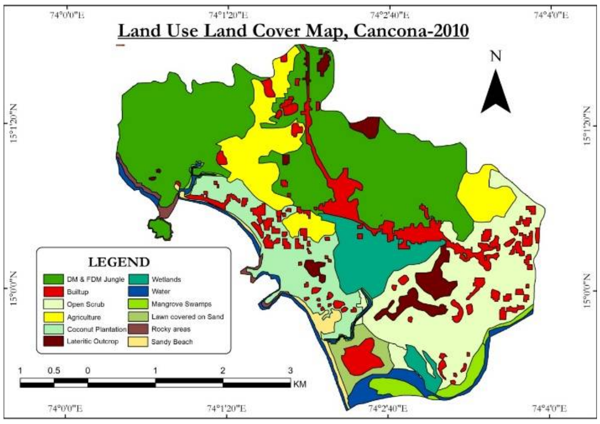


Figure 3: Satellite Image of 2010 **Figure 4 Land use Land Cover Map of 2010**

A huge piece of Canacona territory is geologically made of Lateritic landscape, because of which, 3.3 percent of the whole region in Urban Canacona represents Lateritic Outcrop. Wetlands and Mangrove Swamps are probably the most useful environments on the Earth; the investigation region has a sizeable area under Wetlands and Mangrove Swamps adding up to 6.43 and 2.41 percent of the total geographical area respectively. The travel industry is the quickest developing industry in this part of the world because of the presence of world-renowned spectacular golden sandy beaches such as Palolem, Patnem, Colamb and Rajbag. The area under sandy beaches has a sizeable area i.e., 1.32 per cent of the whole geographic expanse. Starred Hotels dot the study area; hence, sand-covered by lawn is another class of land use that accounts for 1.82 per cent of the total physical area.

LISS-III image interpretation (2020)

The urban area of Canacona which is inhabited by 12,434 people is known for its excellent tourism resources. The tourism sector was opened for the overall growth of Canacona in 1995 with Palolem as the only tourist attraction. After 2000, many other beaches were kept open for tourists for pleasure and leisure. Following table 3depicts the arrival of tourists in Canacona sine 2011-12.

Table 3: Tourists Arrivals 2011-2019

Year	No of Domestic Tourists	No of Foreign Tourists	Total Tourists	Growth Rate
2011-12	18399	10730	29129	-
2012-13	20091	11413	31504	08.15
2013-14	22502	13214	35716	13.36
2014-15	28999	14531	43530	21.87
2015-16	32859	18754	51613	18.50
2016-17	38284	22949	61233	18.63
2017-18	47344	29697	77041	25.81
2018-19	47482	28451	75933	-01.43

Source: Directorate of Planning, Statistics and Evaluation, Goa

The pressure of tourism is very high on urban Canacona because about 18.67 sq. km of the area caters to the needs of more than 75000 tourists which is more than 6 times higher than the local population (12,434 people). After healthy growth till 2018, it has seen a decline due to the impact of Covid-19.

As a result of the rapidly growing travel industry and overall economic development, the area under Dense Mixed and Fairly Dense Mixed Jungle, Open Scrub, Plantations, Wetlands, Water Bodies, Mangrove Swamps, and Sandy Beach has declined by 0.63, 2.12, 0.64, 1.23, 0.37, 0.08 and 0.39 per cent respectively. The area under 4 classes namely Built-up Area, Lateritic Outcrop, Sand covered by Lawn and Roky area has indicated positive change by 3.90, 1.64, 0.077 and 0.39 per cent respectively (Table 4, Figure 5, 6).

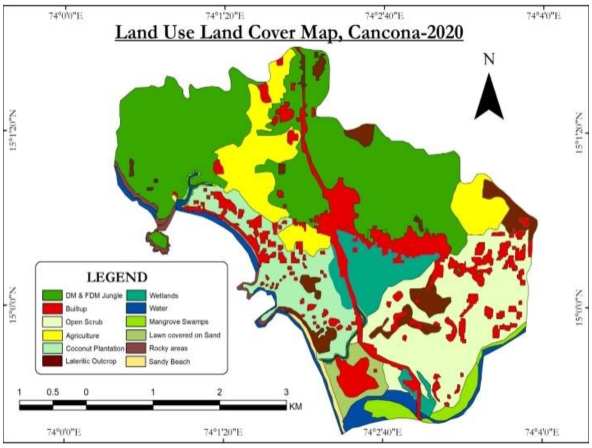


Figure 5: Satellite Image of 2020

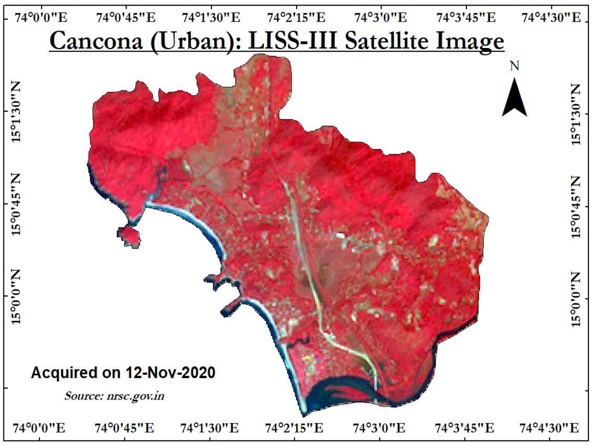


Figure 6Land use Land Cover Map of 2020

Table 4: Land Use Land Cover based o ETM image, 2020

Land Use Classes	Land Use in 2020 (ha)	Land Use 2020 in %	Change with reference to 2010
DMand FDMJ	638.0993	34.4171	-0.6342
Built-up Area	256.1878	13.7932	3.9028
Open Scrub	283.6727	15.2054	-2.1279
Farming	183.8206	9.8604	-0.001
Plantations	143.9752	7.7228	-0.6433
Lateritic Outcrop	88.4008	4.9408	1.6422
Wetlands	96.5922	5.2013	-1.2315
Water Bodies	68.8075	3.6905	-0.3726
Mangrove Swamps	43.6577	2.3318	-0.0808
Sand covered by Lawn	31.7084	1.9008	0.0773
Rocky areas	17.7767	0.9359	0.0405
Sandy Beach	11.5803	0.9212	-0.3955
Total	**1864.2792**	**100.0000**	

Table 5 illustrates the projection of land use for the year 2030. From the resultant data, it can be inferred that the area under DMand FDMJ is expected to decrease by 1.42 per cent, built-up is projected to increase by 7.26 per cent. The area under Open Scrub, Plantations, Wetlands, Mangrove Swamps, Sand covered by Lawn and Sandy Beaches is predicted to fall by 3.92, 1.20, 2.26, 0.06, 0.26, and 0.98 per cent respectively during 2030. Apart from built-up area, Farming, Lateritic Outcrop, Water Bodies, and Rocky areas are likely to increase.

Table 5: projection of land use for the year 2030 with change detection from 2010

Land Use Classes	Projected Land Use in 2030 in (ha)	Projected Land Use in 2030 in %	Land Use 2010 in %	Change
DMand FDMJ	626.9736	33.6308	35.0513	-1.4205
Built-up Area	319.6976	17.1501	9.8904	7.2597
Open Scrub	249.9396	13.4067	17.3333	-3.9266
Farming	184.4544	9.8941	9.8614	0.0327
Plantations	133.4584	7.1582	8.3661	-1.2079
Lateritic Outcrop	103.7796	5.5667	3.2986	2.2681
Wetlands	77.6336	4.1642	6.4328	-2.2686
Water Bodies	71.2964	3.8243	3.3179	0.5064
Mangrove Swamps	43.7546	2.3469	2.4126	-0.0657
Sand covered by Lawn	29.0894	1.5603	1.8235	-0.2632
Rocky areas	18.0048	0.9657	0.8954	0.0703
Sandy Beach	6.1972	0.3320	1.3167	-0.9847
Total	**1864.2792**	**100**	**100.0000**	

Probability Matrix

Markov chain is used for the prediction of future class which is summarized in the above land-use change transition probabilities in Markov analysis, which creates the probability of making a change or transformation from one class of land use to another class of land use.

The Transitional Probability matrix plays a vital role in recording the probability that one parcel of land use will change to another parcel of land use. Matrix is formed by multiplication of each column in Transitional Probability matrix.

The below table depicts 12 by 12 matrix, according to which C1- Farming, C2-Mangrove Swamps, C3-Water Bodies, C4-Rocky Areas, C5 Built-up Area, C6- Lateritic Outcrop, C7-Wetlands, C8-DM & FDM Jungle, C9-Sandy Beach, C10-Sand covered on Lawn, C11- Plantations, and C-12 Open Scrub. In the Transitional Probability Matrix, values in the column indicate LULC for 2010, while values in rows demonstrate LULC of 2020.

According to the Transitional Probability Matrix during 2030, Agriculture will remain unchanged. Mangrove Swamps are expected to remain unaffected at 99.24 per cent and about 0.76 per cent of the area under Mangrove Swamps will be converted into built-up. The area under water bodies is likely to remain unchanged by 97.57 per cent, whereas 2.28 per cent will merge into the built-up area. According to the matrix, both rocky areas and built-up areas will remain 100 per cent unchanged. It is expected that the area under Lateritic Outcrop is projected to change by 85.52 per cent which will result in a built-up area of 14.48 per cent. Wetlands are very important ecosystems in coastal areas. In the study area, wetlands are expected to shrink by 16.66 per cent, which will be converted into a built-up area. Mixed Dense and Fairly Dense Mixed Jungle is estimated to decline by about 2.35 per cent. Of the 2.35 per cent, 1.86 per cent will result in the built-up area.0.19 and 0.31 per cent of the Mixed Dense and Fairly mixed jungle will get converted in lateritic outcrop and rocky areas. This indicates that Mixed Dense and Fairly mixed jungle is subjected to deforestation (Figure 7).

Figure 7: Probability Matrix 2030

Classes	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
C1	100	0	0	0	0	0	0	0	0	0	0	0
C2	0	99.24	0	0	0.76	0	0	0	0	0	0	0
C3	0	0	97.57	0	2.28	0	0	0	0	0	0	0
C4	0	0	0	100	0	0	0	0	0	0	0	0
C5	0	0	0	0	100	0	0	0	0	0	0	0
C6	0	0	0	0	14.48	85.52	0	0	0	0	0	0
C7	0	0	0	0	16.66	0	80.44	0	0	0	2.9	0
C8	0	0	0	0.31	1.86	0.19	0	97.65	0	0	0	0
C9	0	0	17.28	0	39.39	0	0	0	43.62	0	0	0
C10	0	0	0	0	7	0	0	0	0	93	0	0
C11	0	0	0.62	0	6.66	1.67	0	0	0.8	0	90.25	0
C12	0	0	0	0	5.86	6.78	0	0	0	0	0	87.36

C1: Farming C2: Mangrove Swamps, C3: Water Bodies, C4: Rocky areas, C5: Builtup Area, C6: Lateritic Outcrop, C7: Wetlands, C8:Densed Mixed & Fairly Densed Mixed Jungle, C9: Sandy Beach, C10: Sand Covered on Lawn , C11: Plantations, C12: Open Scrub

Sandy areas in the form of dunes and beaches are vital for coastal ecosystems. The projected figures for 2030 indicate that the study area is expected to lose a major chunk of the area falling under sandy beaches. Only 43.62 per cent of the sandy beaches class of land use is likely to remain stable but 56.38 per cent of the area is estimated to change into built-up area and water bodies by 39.39 and 17.28 per cent respectively. 17.28 per cent change in the water bodies indicate that the study area is losing valuable beaches due to erosion. 93 per cent of the area under Sand covered by lawn is expected to remain static and only 7 per cent will add up to the built-up area. The study area is known to have coconut plantations which are expected to remain unchanged at 90.25 per cent and 9.75 would change into C-3, C-5 and C-6. Open Scrub is a type of natural vegetation that is essentially composed of dry deciduous trees. Under this class of land use, the area is likely to remain stable at 87.36 per cent and 12.64 per cent will change into C-5 and C-6.Built-up area is the only class of land use that is expected to acquire land from 11 classes of land use except farming (Figure 8).

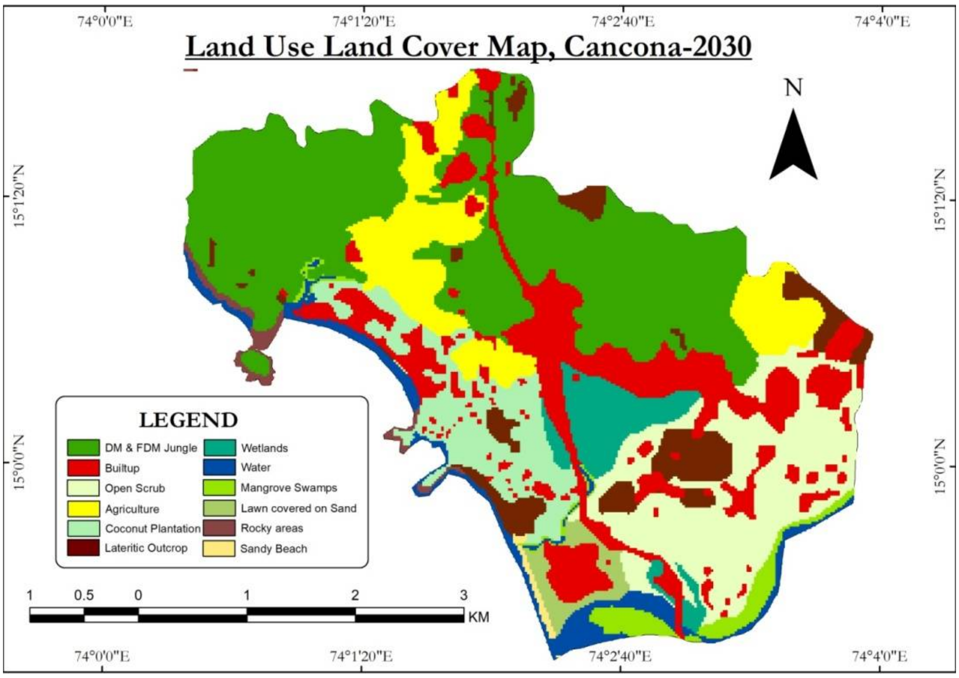


Figure 8: Projected Land use Land Cover Map of 2030

CONCLUSION

Urban Canacona is geo-ecologically highly diversified. It is blessed with the sea, beaches, thick forest, hills, ghats, wetlands, mangroves, and other productive ecosystems. Canacona town is one of the fastest-growing towns of Goa largely due to tourism activities. Since the town is sandwiched between the blues waters Arabian Sea in the West and the green cover of the Western Ghats in the East, the land available for development is limited.

The coastal town of Canacona is subjected to erosion due to storm surges and other coastal forces. The average annual rainfall of this place is more than 3500 mm, hence, it is prone to floodings in low lying areas and landslides in hilly tracks. The result obtained through this study indicates that the land-use pattern of Urban Canacona is drastically changing. The most disturbing trend is the loss of sandy/beach area due to erosion, which is a warning signal in itself. In the age of Climate Change, Global Warming, and Sea Level Rise, sustainable development is the only mantra for the future. The projected LULC map which is resulted from this study will enable the town and city planners, governmental authorities and other stakeholders to establish land-use planning of Urban Canacona in particular and taluka and district, in general, to prevent losses from natural hazards.

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