RESEARCH PAPER

HUMAN-INDUCED LANDSCAPE ALTERATION IN THE COASTAL REGULATION ZONE OF GOA, INDIA, FROM 2000 TO 2017

Tanvi Deshpande[1*], Sudhakar Pardeshi[2]
[1] Assistant Professor in Geography incl. EVS, Rosary College of Commerce & Arts, Navelim, Margao, Goa, India.
[2] Professor, Department of Geography, Savitribai Phule Pune University, Pune, Maharashtra, India.
***Corresponding author:** tanvi@rosarycollege.org
Received: August 10th, 2021 / Accepted: February 15th, 2023 / Published: March 31st, 2023
https://DOI-10.24057/2071-9388-2021-093

ABSTRACT. In Goa, the tourism industry is the major cornerstone of the economy. With the increasing number of tourists along the coastal areas, more tourism-related infrastructure is emerging within the Coastal Regulation Zone. The sensitive and fragile coastal zones are being covered by concrete structures and the coastal environment becomes vulnerable to degradation. The objective of the paper was to study the changes in landuse and landcover in the Coastal Regulation Zone of Salcete taluka using remote sensing data and geospatial techniques. To fulfill the objective, both primary and secondary data were used. Primary data was based on personal observations and field visits while secondary data consisted of topographic maps, LANDSAT 7 ETM, and LANDSAT 8 satellite images, which were processed and analyzed using ArcGIS 10.3, ERDAS IMAGINE 2014, SAGA (System for Automated Geoscientific Analyses) and MS Excel. From the landuse and landcover analysis for a period of 17 years (2000-2017), it was found that the land cover within the CRZ underwent a tremendous change with the increase in tourism activity and related infrastructure. The analysis revealed that the agricultural area has decreased, whereas built-up areas, barren land, and vegetation area increased. The change detection analysis using SAGA software allowed to understand the conversion between different classes. The study revealed that the increasing number of tourists and tourism activities along the Salcete Coast is deteriorating the environmental setup and disturbing the inherent coastal landscape.

KEYWORDS: Coastal Regulation Zone (CRZ), Landuse and landcover (LULC), Salcete

CITATION: Deshpande T., Pardeshi S. (2023). Human-Induced Landscape Alteration in the Coastal Regulation Zone of Goa, India, from 2000 to 2017. Geography, Environment, Sustainability, 1(16), 36-44
https://DOI-10.24057/2071-9388-2021-093

ACKNOWLEDGEMENTS: My sincere thanks to the Department of Geography, Savitribai Phule Pune University, and to Ms. Pallavi Kulkarni, Ms. Ashwini Lanke, Mr. Vishal Doke for their support received during the completion of this work.

Conflict of interests: The authors reported no potential conflict of interest.

INTRODUCTION

A coastal zone is an area of interface between the land and the sea (Panigrahi and Mohanty 2012). Coastal zones are the most biologically productive regions and form an important component of the global biosystem (Yagouband Kolam 2006). Coastal zones have a high environmental, economic, and social value (Ramesh and Vel 2011). Moreover, the coasts have played an eminent role in economic growth over the years, but over-dependence and various human activities have led to the unsustainable management of coastal ecosystems (Chinnasamy and Parikh 2020).

In recent times, human interference in coastal areas has increased, leading to the major degradation of the fragile coastal environment. Approximately 50% of the world's population resides in coastal zones which puts them under very high stress from population growth, pollution, and over-exploitation of resources (Shi et al. 2001). Zahedi (2008) observed that with the ever-increasing pressure on the coastal belt, and as more people are moving towards the coast, the conditions of beaches are worsening. The population growth along the Indian coasts is also rapidly rising, resulting in a negative impact on land due to the spread of built-up areas, settlements, and recreational facilities (Kaliraj et al. 2017). Development along the coasts is taking place in an uncoordinated and unsustainable manner thereby degrading the coastal environment (Panigrahi and Mohanty 2012).

The Ministry of Environment and Forests (MoEF) passed legislation called the Coastal Regulation Zone (CRZ) notification issued under the Environment Protection Act of 1986. The 2011 notification defines the CRZ as the area from the high tide line (HTL) to 500 m on the landward side, and from the HTL to 100 m or width of the creek, whichever is less, on the landward side of tidally-influenced water bodies connected to the sea (Coastal Regulation Zone (CRZ) Notification, 2011). There are four categories of CRZ, namely CRZ I (Ecologically Sensitive Area), CRZ II (Built-up areas), CRZ III (Rural areas), and CRZ IV territorial waters and tidally-influenced water bodies (Chouhan et al. 2017).

The main purpose of issuing the CRZ notification was to control and minimize the increasing anthropogenic activities and protect the coastal environment from hap-hazardous development and human interference (Mascarenhas 1999).

However, Nayak (2017) stated that coastal regulation has undergone immense changes over the last 25 years, mostly due to incorrect interpretation of the High Tide Line and conflicting laws of the State and Central governments.

Goa, a small coastal State located on the western coast of India is known worldwide as a tourist destination because of its scenic nature and cultural hospitality. Tourism is the fastest-growing industry in the State and is also the backbone of the State's economy. According to the Department of Tourism, Government of Goa website (2018), in the year 1985, 775,212 tourists (682,545 domestic and 92,667 foreign) visited Goa, which increased to 7,785,693 (6,895,234 domestic and 890,459 foreign) in 2017. To provide tourists with basic recreational facilities, many coastal zones in Goa were encroached upon by unplanned built-up areas. With the rise in tourism, many eco-sensitive zones were disturbed and most of the land is under reclamation for recreational purposes.

The present study was carried out with the aim to understand the human-induced landscape alteration in the Coastal Regulation Zone of Salcete taluka. The objective of the paper was to study the changes in land use and land cover in this area using remote sensing data and geospatial techniques.

Landuse and landcover conversion refers to the process of transformation of land cover to land use and change in land use from one type to another due to natural or anthropogenic activities (Kaliraj et al. 2017). Butt et al. (2015) stated that it is essential to study and analyze these changes to better understand the relationship between human activities and natural phenomena. The factors influencing land use and land cover changes should be studied in order to understand and assess environmental impacts and plan for sustainable development (Waiyasusri and Chotpantarat 2022). According to Berlanga-Robles and Ruiz-Luna (2011), landuse and landcover changes are responsible for a 35-50% loss of coastal wetlands. Landuse and landcover change detection has become a necessity for developing efficient strategies for managing natural resources, monitoring environmental changes, and planning policies in various coastal areas (Muttitanon and Tripathi 2005; Kaul and Ingle 2012; Islam et al. 2016).

Remote sensing and Geographic Information Systems (GIS) provide efficient tools for ecosystem and socio-economic management (Haque and Basak 2017). Misra and Balaji (2015) stated that these tools provide a unique opportunity for building information sources and supporting decision-making activities for various coastal zone applications. Remote sensing data is a very useful source of information as it provides up-to-date and complete coverage of any area and is proven to be useful in assessing and monitoring land use and landcover changes (Muttitanon and Tripathi 2005). In order to manage and protect the coastal environment from further exploitation, landuse and landcover changes must be studied.

Study Area

This study focused on the coastal areas of Salcete taluka, which is a sub-division of the South Goa district in the Indian state of Goa. Salcete taluka is located at 15° 12' 44.82" N and 74° 4' 23.628" E, and its coastal area occupies about 27 km of straight continuous beach strip and numerous sand dunes along the Arabian Sea, with Utorda beach in the north and Betul Beach at the mouth of the Sal River in the south. The Salcete taluka consists of ten major beaches, namely Utorda, Majorda, Betalbatim, Colva, Sernabatim, Benaulim, Varca, Cavelossim, Mobor, and Betul, along with other small beaches such as Carmona and Fatrade (Fig. 1).

Compared to the coastal region of North Goa, the beaches of South Goa are less exploited. However, with the increasing tourism trend and popularity of the destination, exploitation is likely to increase at a tremendous rate in the coming years. Therefore, the coastal area of Salcete taluka was selected to understand its present coastal environmental issues.

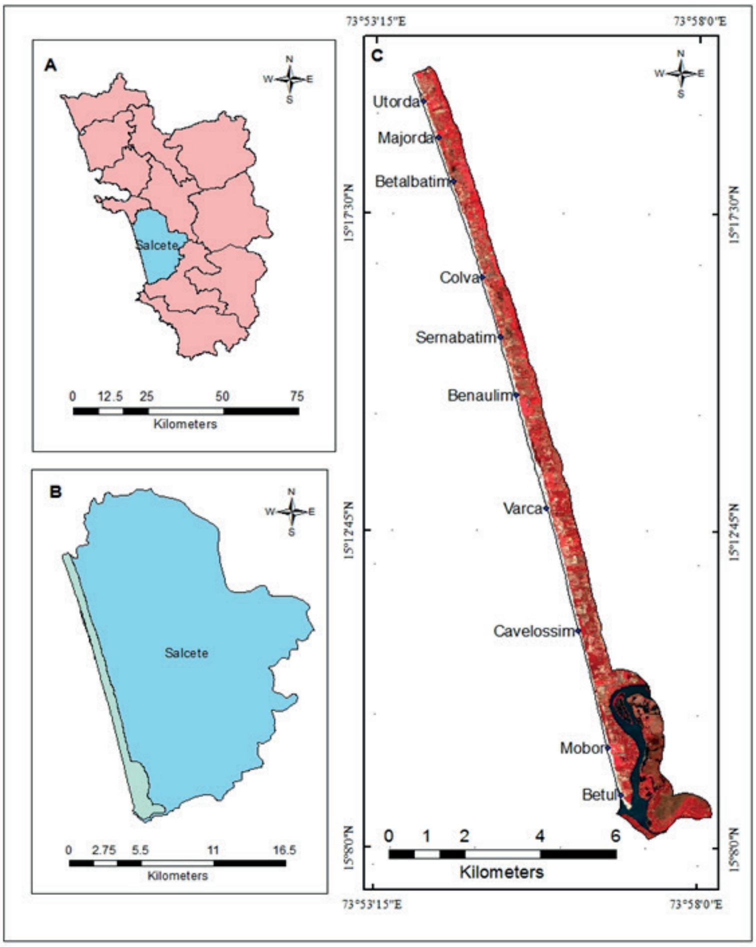

Fig. 1. Location of the study area

MATERIALS AND METHODS

The present study required digital spatial data, which was processed using ArcGIS 10.3, SAGA (System for Automated Geoscientific Analyses), and ERDAS IMAGINE 2014 software. Most of the present study was based on secondary data, particularly the satellite images of LANDSAT 7 ETM and LANDSAT 8 of the year 2000 and 2017 with a 30 m resolution, as well as Survey of India (SOI) topographic maps of 1:50,000 scale. LANDSAT satellite images were used to classify and map landcover changes using geospatial techniques. The change detection was carried out using ERDAS IMAGINE 2014 and SAGA software. Fig. 2 represents the detailed methodology chart, which was followed to carry out the study. LANDSAT images were downloaded from the United States Geological Survey (USGS) website. Table 1 displays the data derived and used for the analysis.

The toposheets were georeferenced to extract the high tide line and use it for creating a buffer of 500 m, which demarcates the extent of the Coastal Regulation Zone of Salcete taluka.

Image processing and stacking were done in ERDAS IMAGINE 2014 software. The images were classified into seven classes, namely sand, agricultural land, barren land, vegetation, water bodies, fallow land, and built-up areas. The spectral signature files were developed for each class to be later used for image classification. The analysis of landuse and landcover changes was performed using the Supervised Classification method with training samples for a more accurate result. Supervised Classification requires preceding knowledge of the study area and involves choosing representative training pixels from a pre-defined classification scheme that will be used with a decision rule (Misra et al. 2015).

Maximum Likelihood Classifier (MLC) algorithm was employed to identify the land cover types in ERDAS IMAGINE 2014. This technique works with the hypothesis of assigning each pixel to the class for which it has the maximum likelihood probability (Ayele et al. 2018). Accuracy assessment, or validation, now has become an integral constituent in incorporating remotely sensed data (Congalton 2001). The results of the land use and land cover change analysis, produced using the Supervised Classification method, are presented with the Overall Accuracy and Kappa coefficients. The values obtained from the accuracy assessment performed using ERDAS IMAGINE validated the output of landuse and landcover classification. For both time periods, more than 75% accuracy was achieved. The data from classified images was processed and analyzed using Microsoft Excel, which included the calculation of the area for each class and preparation of graphs for comparison and understanding of the changes.

SAGA software was used to detect the changes. SAGA offers a large number of scientific methods and tools for processing remote sensing data, including geometrical preprocessing and spectral filtering techniques, supervised and unsupervised classification algorithms, as well as methods for change detection and segmentation for object-oriented image analysis (Conrad et al. 2015). The classified images were given as input in SAGA to identify the changes. The results were mapped using GIS.

Table 1. Data sources and the derived data

Sr. no.	Data source	Data derived
1.	SOI toposheet 48 E/15 , 48 E/16 (1:50,000)	High tide line
2.	LANDSAT 8 image (March, 2017) LANDSAT 7 ETM (March, 2000)	LULC, Change detection using SAGA software

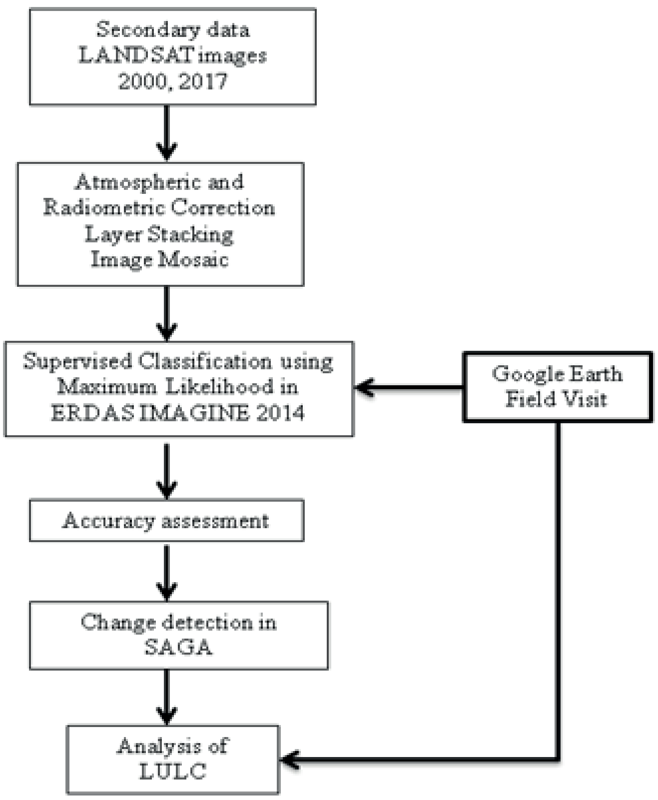

Fig. 2. Methodology Chart

RESULT AND DISCUSSION

Landuse and landcover analysis

Landuse and landcover are dynamic in nature and are affected by both natural and human factors (Dewan et al. 2010). The study of landuse and landcover allows to understand the impact of human interference in the coastal environment. With the increase in the need and greed of human beings, the rate of environmental exploitation has also increased. According to Fabbri (1998), coastal zones have been exploited by man to a greater extent for the growth of industry, resource extraction, tourism, and urbanization, which led to the flourishing of coastal economies.

The unplanned and hap-hazardous development of the tourism industry leads to negative land use and land cover transformations resulting in ecological imbalance and degradation (Saha and Paul 2020). Similar problems have been observed along the coastal region of Salcete taluka with the increase in tourism and development activities. Most of the development activities are directly related to tourism and alter the existing state of landuse and landcover in the coastal region. After all, coastal tourism is growing at a very rapid rate, and so is the hap-hazardous and unplanned development.

The land use and land cover change analysis is incomplete without the accuracy assessment of the classified image (MohanRajan et al. 2020). The result of the accuracy assessment for the classified LANDSAT images showed an overall accuracy of 95.65% and 96.67%, and an overall Kappa coefficient of 0.94 and 0.95 for the years 2000 and 2017, respectively. Remote sensing has given the opportunity to study the dynamics of long-term change in landuse and land cover (Rahman et al. 2017). The long-term change assessment of the coastal regulation zone of Salcete taluka was performed using LANDSAT images for a period of 17 years, from 2000 to 2017. Fig. 3 represents the land use and land cover maps based on supervised classification for these years, while the area distribution for each class is presented in Table 2.

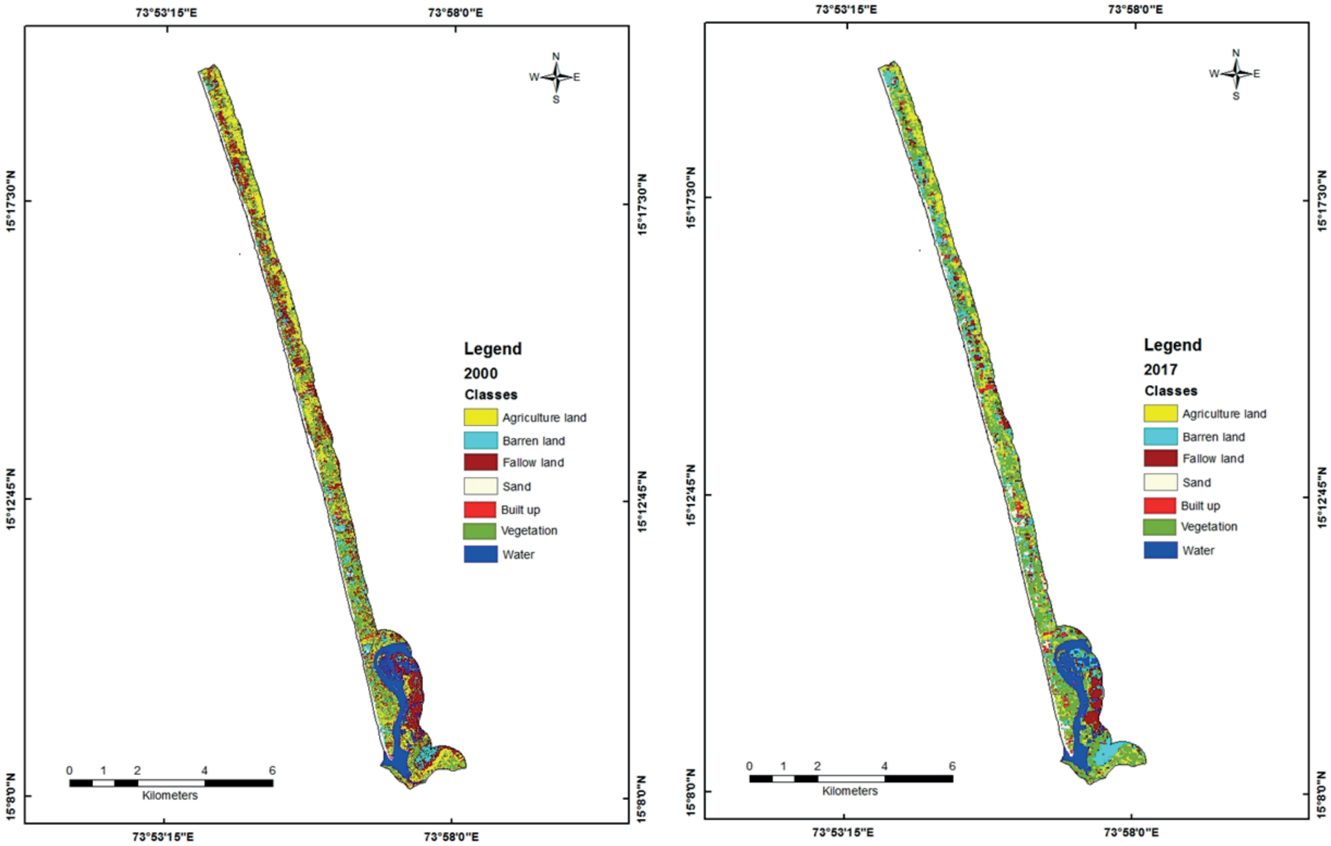

Fig. 3. Land use and land cover maps of 2000 and 2017

Table 2. Land use and land cover data for the years 2000 and 2017

Classes	2000 Area (km^2)	2000 Area%	2017 Area (km^2)	2017 Area%	Change difference (%)
Agricultural land	2.99	17.18	1.73	9.94	-7.24
Barren land	3.21	18.45	3.35	19.25	0.8
Fallow land	1.49	8.56	1.72	9.89	1.33
Sand	1.26	7.24	1.29	7.41	0.17
Built-up area	0.39	2.24	0.59	3.39	1.15
Vegetation	6.29	36.15	6.99	40.17	4.02
Water	1.77	10.17	1.73	9.94	-0.23
Total	17.40	100	17.40	100	-

From the analysis of supervised classification data, it was found that land features underwent tremendous changes under the impact of both natural and anthropogenic factors. The comparative analysis of the years 2000 and 2017 presented in Fig. 4 shows that there was a decrease in agricultural land (from 17.18% in 2000 to 9.94% in 2017) and consequently an increase in fallow land from 8.56% in 2000 to 9.89% in 2017. The drastic change in the area of agricultural land can be highly associated with the changes in the occupational patterns amongst the locals as many of them gave their lands for the development of tourist infrastructure and got involved in tourism activities themselves.

Infrastructure development is the base of the tourism industry. It usually gets boosted to attract more tourists, and when a place gets popularized, to accommodate more tourists, even more large-scale infrastructure development takes place. A similar development pattern is observed in the coastal region of Salcete taluka, with Colva, Benaulim, Majorda, and Cavelosim being the most crowded beaches, receiving a large number of visitors every year. With the increasing tourism activity, built-up areas in the forms of resorts, beach shacks, restaurants, recreational parks, parking spaces, etc. increased from 2.24% in 2000 to 3.39 % in 2017. Various permanent and temporary structures were established on the sand dunes, such as roads, resorts, hotels, parks, etc.

There was also an increase in the area of barren land. In the year 2000, barren land covered 18.45% of the area, which increased up to 19.25% by 2017. However, there has been a small amount of change for sand (7.24% in 2000 and 7.41% in 2017) and water (10.17 % in 2000 to 9.94 % in 2017). On the contrary, the area of vegetation has increased from 6.29 km^2 to 6.99 km^2. The increase in vegetation can be attributed to the growth of mangroves in the inter-tidal zone of the Sal River. Small-scale sand bars have formed at the mouth of the Sal River, which is dominated by mangrove vegetation. An increase in the area under vegetation can also be associated with the development of a commercial coconut plantation. Also, vegetation is grown for recreational purposes along the 5-star properties situated in the beach area. According to our personal perception and the perception of locals, land utilization pattern has changed over the years towards recreational purpose.

Field observation also helped in studying and interpreting the changes along the coast of Salcete taluka. From field observation, it was noticed that coastal sand dunes were removed or flattened for the construction of beach shacks/restaurants. These structures became a source of litter, as can be seen on the beaches of Colva, Benaulim, etc. The beaches are losing their intrinsic value. Mass tourism and the development of tourist infrastructure are the major contributors towards increasing coastal degradation in Salcete taluka.

Change detection using SAGA software

Balasaraswathi and Srinivasalu (2016) stated that studying changes in the coastal environment is necessary for coastal planners to provide efficient management and planning of the region. SAGA GIS is open-source and easy-to-use software (Gašparović et al. 2019). SAGA software was used to detect the changes in the CRZ of Salcete taluka from 2000 to 2017. Supervised classification of images from the years 2000 and 2017 was given as input for class-wise change detection. Change detection using SAGA facilitated the study of changes in landuse and landcover classes. The land use and land cover change is shown in Table 3, while Fig. 5 provides a graphical representation of the changes that occurred over a period of 17 years.

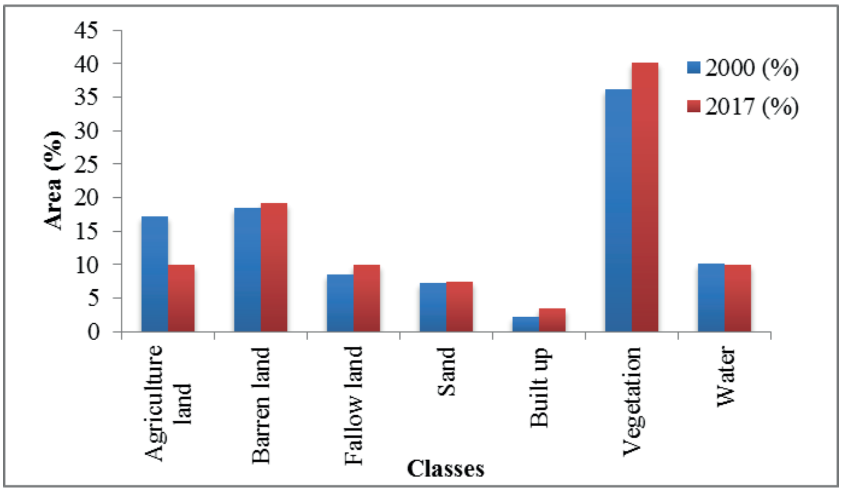

Fig. 4. Change in the area (in %) of different classes from the year 2000 to 2017

Table 3. LULC Change Detection Matrix for 2000-2017 (Area in km^2)

LULC Classes	Agricultural land	Barren land	Built-up area	Fallow land	Sand	Vegetation	Water
Agricultural land	0.28	0.03	0.03	0.05	0	0.2	0
Barren land	0.18	0.51	0.47	0.26	0.02	0.42	0.1
Built-up area	0	0	1.2	0	0	0	0
Fallow land	0.13	0.11	0.48	0.68	0.2	0.32	0.4
Sand	0.15	0.58	0.43	0.08	1.69	0.43	0.35
Vegetation	0.82	0.41	0.44	0.29	0.31	3.42	0.39
Water	0	0	0	0	0.42	0.31	0.81

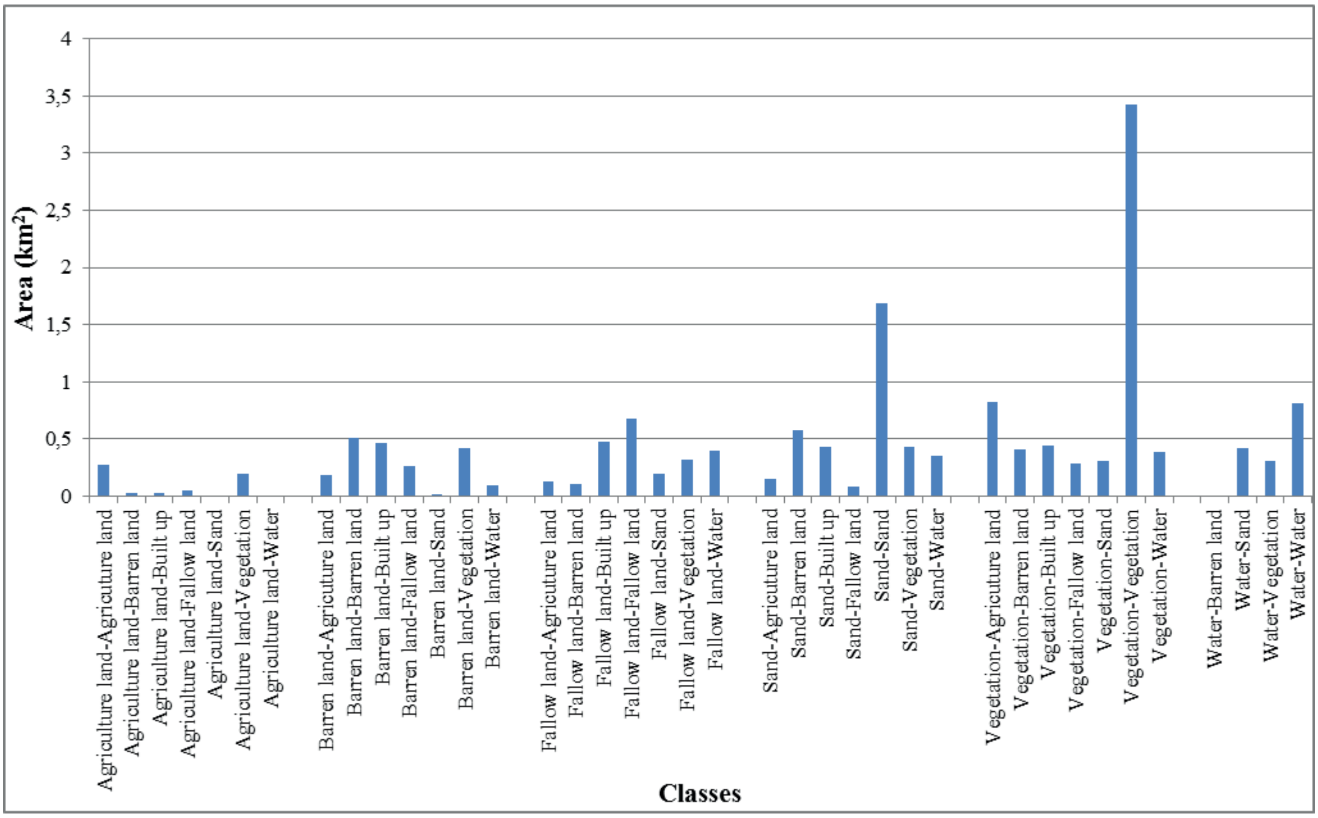

Fig. 5. Representation of LULC changes from 2000 to 2017

Fig.6 represents the change map of the Salcete Taluka CRZ region over a period of 17 years. The area under agricultural land underwent minor changes. First of all, agricultural land became less present in the coastal region due to the shift in the economic and occupational patterns (agrarian to tourism) amongst the local people. People living in coastal regions are mostly dependent upon the tourism industry and the majority of people work in other countries. Hence, agricultural activity is limited. However, 0.2 km^2 of the agricultural land was converted into other classes, primarily vegetation. The conversion of agricultural land into fallow land, sand, water, barren land, and built-up area was negligible.

It was also found that a major part of the barren land was converted into built-up areas (0.47 km^2), which can be attributed to the development of infrastructure to support tourism activities. 0.42 km^2 of land was converted to vegetation, as in some regions barren land became utilized for coconut farms or recreation. Meanwhile, the changes from barren land to other classes, such as agricultural land, fallow land, water, and sand, are much lower. The conversion of fallow land into water (0.4 km^2) can be associated with aquaculture activity. In many areas, especially near Betul, there is an increase in aquaculture activities due to the increasing demand for fish in the resorts and other restaurants situated in the coastal region. The conversion of fallow land into built-up areas (0.48 km^2) might be attributed to the increase in the number of houses and tourist-related infrastructure. This indicates the shifting of occupation from agriculture to the tourism industry as many local people are involved in it directly or indirectly.

Large areas of sand were converted into barren land (0.58 km^2) and vegetation (0.43 km^2). The conversion of the land under sand into vegetation can be associated with the growth of mangroves at the mouth of the Sal River. Furthermore, lawns were developed by hotels and resorts located along the coastal area for recreational purposes. In addition, sand dunes present in the coastal area were covered by different types of coastal vegetation, such as Casurina, Spinifex and *Ipomea*. 0.35 km^2 of the area under sand was converted into water which can be attributed to the increase in aquaculture activities in the coastal villages of Betul, Cavelossim, Assolna, etc. The increase in built-up area (0.43 km^2) was due to the growth in tourist infrastructure on the beach.

Vegetation cover was also converted to agricultural land (0.82 km^2), particularly in the most northern part of the study area, in the village of Utorda. It is a very common scenario in coastal areas, where people sell or give away agricultural land for development purposes and convert the land under natural vegetation for agricultural use. The area under vegetation was also converted into built-up land (0.44 km^2) for the development of tourism-related infrastructure. 0.41 km^2, 0.29 km^2, and 0.31 km^2 of land were converted into barren land, fallow land, and sand. 0.39 km^2 of vegetation area was converted into water, which can be associated with aquaculture activities. 0.42 km^2 of water were converted into sand, which is partially represented by a sand bar formed at the mouth of the River Sal. There was also an increase in riverine vegetation such as mangroves, which relates to the conversion of water to vegetation (0.31 km^2).

Limitations and Suggestions

There are a few limitations associated with the present work. First of all, there are no proper records of the infrastructure development taking place in the coastal zone as some of the constructions are illegal. 30 meters spatial resolution of LANDSAT images is also a drawback as land use cannot be identified in detail. Also, there is a lack of data regarding the number of tourists visiting a beach per day in order to study the human pressure on the ecosystem. However, there are also a few suggestions for solving the existing problems related to human interference. Firstly, there is a need for adequate monitoring of hap-hazardous activities and strict implementation of the CRZ rules and regulations to encounter rising environmental

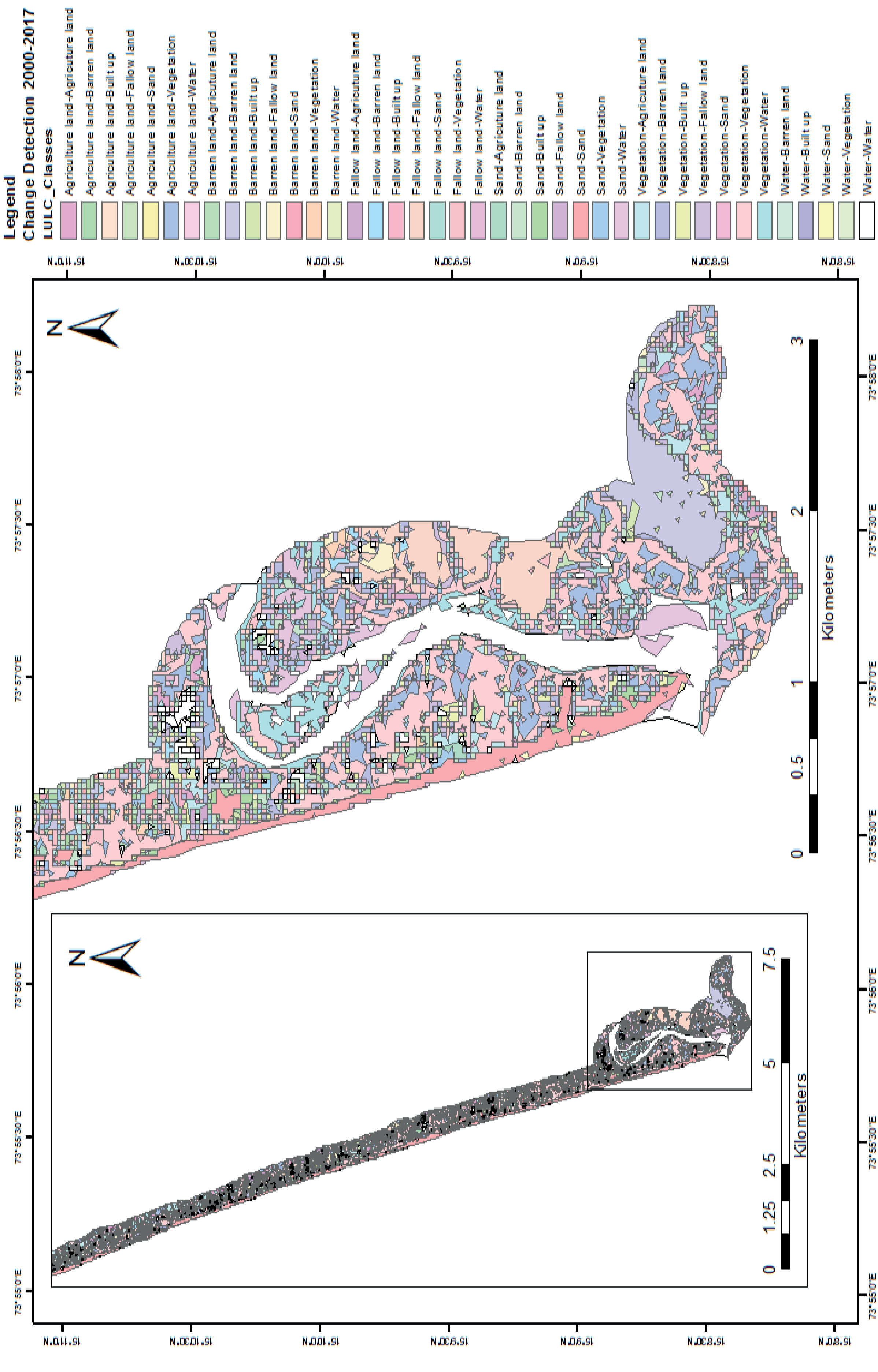

Fig. 6. Change detection map for a period of 17 years

problems. Secondly, looking at the mass tourism taking place along the coastal regions and violations of the CRZ, the government can come up with alternative tourism plans such as eco-tourism, wildlife tourism, rural tourism, agro-tourism, etc. to divert tourist flow to the interior regions of Goa which will boost the local economy and reduce pressure on the coastal environment. Thirdly, the development of sustainable and eco-friendly structures can be promoted in the coastal zones.

CONCLUSION

From the analysis, it was found that the area divided into different classes underwent tremendous change under the impact of both natural and anthropogenic factors. An extensive transformation within the CRZ of Salcete taluka took place over a period of 17 years. The results of the accuracy assessment of the classified LANDSAT images for the years 2000 and 2017 showed an overall accuracy of 95.65% and 96.67%, respectively. From the results of supervised classification for long-term changes, it was found that the area of agricultural land has decreased much higher compared to other classes, which might be attributed to the change in the perspective of locals due to the expansion of tourism.

On the other hand, vegetation, barren land, fallow land, and built-up land showed an increase in the area, while sand and water area remained the same. The agricultural land decreased by 7.24%, whereas barren land, fallow land, sand, built-up area, and vegetation increased by 0.8%, 1.33%, 0.17%, 1.15%, and 4.02%, respectively. From the change detection in the Salcete taluka coastal area, it was found that the area of agricultural land has decreased, whileother land classes showed an increasing pattern. The change detection analysis using SAGA software allowed to understand conversion between different classes. However, the limitations of the study included the spatial resolution of LANDSAT images (30 meters), which does not allow for detailed mapping of land use, while insufficient records of development activities and tourists visiting the beach on a daily/monthly/yearly basis limit the study of human interference.

Looking at the increasing mass tourism along the coast of Goa and increasing human interference in the fragile coastal ecosystem, this study can be useful for reducing further damage and raising awareness. Moreover, it showed that the authorities should constantly monitor any forms of illegal activity taking place in coastal zones. Strict rules and regulations need to be developed to protect coastal zones from further human interference. Awareness needs to be created amongst the locals and tourists for protecting the coastal environment. Sustainable development and sustainable tourism need to be promoted and practiced to avoid any further damage. The government can come up with alternative tourism plans such as eco-tourism, wildlife tourism, rural tourism, agro-tourism, etc. to divert tourist flow to the interior regions of Goa which will boost the local economy and reduce pressure on the coastal environment.

REFERENCES

Ayele G. Tebeje A. Demissie S. Belete M. Jemberrie M. Teshome W. Mengistu D.and Teshale E. (2018). Time Series Land Cover Mapping and Change Detection Analysis Using Geographic Information System andRemote Sensing, Northern Ethiopia. Air, Soil and Water Research,11, 1–18, https://doi.org/10.1177/1178622117751603.

Balasaraswathi P. and Srinivasalu S. (2016).Change detection analysis of coastal zone features in Cuddalore District, Tamil Nadu using Remote Sensing and GIS techniques. Journal of Applied Geology and Geophysics, 4 (5), 01-08, DOI: 10.9790/0990-0405020108.

Berlanga-Robles C. and Ruiz-Luna A. (2011). Integrating Remote Sensing Techniques, Geographical Information Systems (GIS), and Stochastic Models for Monitoring Land Use and Land Cover (LULC) Changes in the Northern Coastal Region of Nayarit, Mexico. GIScience& Remote Sensing, 48 (2), 245–263, DOI: 10.2747/1548-1603.48.2.245.

Butt A. Shabbir R. Ahmad S. and Aziz N. (2015) Land use change mapping and analysis usingRemote Sensing and GIS: A case study of Simly watershed, Islamabad, Pakistan. The Egyptian Journal of Remote Sensing and Space Sciences, 18, 251-259.

Chinnasamy P. and Parikh A. (2020).Remote sensing- based assessment of Coastal Regulation Zones in India: a case study of Mumbai, India. Environment, Development and Sustainability, 23(11), 1-20, DOI:10.1007/s10668-020-00955-z.

Chouhan H. Parthasarathy D. and Pattanaik S. (2017). Urban development, environmental vulnerability and CRZ violations in India: impacts on fishing communities and sustainability implications in Mumbai coast. Environment, Development and Sustainability, 19(3), 971–985, DOI:10.1007/s10668-016-9779-6.

Congalton R. (2001). Accuracy assessment and validation of remotely sensed and other spatial information. International Journal of Wildland Fire, 10, 321-328, DOI:10.1071/WF01031.

Conrad O. Bechtel B. Bock M. Dietrich H. Fischer E. Gerlitz L. Wehberg J. Wichmann V. and Böhner J. (2015).System for Automated Geoscientific Analyses (SAGA) v. 2.1.4. Geoscientific Model Development, 8, 1991-2007, DOI:10.5194/gmd-8-1991-2015.

Coastal Regulation Zone (CRZ) Notification 2011, (2011). Coastal Regulation Zone Notification Ministry of Environment and Forests (Department of Environment, Forests and Wildlife). Available at: http://www.indiaenvironmentportal.org.in/content/321917/coastal-regulation-zone-crz-notification-2011/ [Accessed 20 Dec. 2017].

Department of Tourism, Government of Goa, (2018). Department of Tourism, Government of Goa, India - Tourist Arrivals. Available at: https://www.goatourism.gov.in/tourist-arrival-statistics/[Accessed 02 Jan. 2018].

Dewan A. Yamaguchi Y. and Rahman M. (2010). Dynamics of land use/cover changes and the analysis of landscape fragmentation in Dhaka Metropolitan, Bangladesh. Geo Journal, 77, 315–330, DOI:10.1007/s10708-010-9399-x .

Fabbri K. (1998).A methodology for supporting decision making in integrated coastal zone management. Ocean & Coastal Management, 39, 51-62.

Gašparović M. Zrinjski M. andGudelj M. (2019). Automatic cost-effective method for land cover classification (ALCC). Computers, Environment and Urban Systems, 76, 1–10, https://doi.org/10.1016/j.compenvurbsys.2019.03.001.

Haque I. andBasak R. (2017). Land cover change detection using GIS and remote sensing techniques: A spatio-temporal study on Tanguar Haor, Sunamganj, Bangladesh. The Egyptian Journal of Remote Sensing and Space Sciences, 20(2), 251–263, DOI: 10.1016/j.ejrs.2016.12.003.

Islam R. Miah G. and Inoue Y. (2016). Analysis of land use and land cover changes in the coastal area of Bangladesh using LANDSAT imagery. Land Degradation & Development, 27(4), 899–909, DOI: 10.1002/ldr.2339.

Kaliraj S. Chandrasekar N. Ramachandran K. Srinivas Y. and Saravanan S. (2017). Coastal land use and land cover change and transformations of Kanyakumari coast, India using remote sensing and GIS. The Egyptian Journal of Remote Sensing and Space Sciences, 20 (2), 169-185, DOI:10.1016/j.ejrs.2017.04.003.

Kaul H. and Ingle S. (2012). Land use land cover classification and change detection using high resolution temporal satellite data. Journal of Environment, 1(4), 146-152.

Mascarenhas A. (1999). The Coastal Regulation Zone of Goa: Oceanographic, environmental and societal perspectives. Current Science, 77(12), 1598-1605.

Misra A. and Balaji R. (2015).A study on the shoreline changes and Land-use/ land-cover along the South Gujarat coastline. Procedia Engineering, 116, 381-389, DOI:10.1016/j.proeng.2015.08.311.

Misra A. ManiMurali R. and Vethamony P. (2015).Assessment of the Land-Use/Land-Cover (LULC) and Mangrove changes along the Mandovi- Zuari Estuarine complex of Goa, India. Arab Journal of Geosciences. 8, 267-279.

MohanRajan S. Loganathan A. and Manoharan P. (2020). Survey on Land Use/Land Cover (LU/LC) change analysis in remote sensing and GIS environment: Techniques and Challenges. Environmental Science and Pollution Research, 27, 29900–29926, https://doi.org/10.1007/s11356-020-09091-7.

Muttitanon W. and Tripathi N. (2005). Land use/land cover changes in the coastal zone of Ban Don Bay, Thailand using LANDSAT 5 TM data. International Journal of Remote Sensing, 26(11),2311–2323, https://doi.org/10.1080/0143116051233132666.

Nayak S. (2017). Coastal zone management in India – present status and future needs. Geo-spatial Information Science, 20 (2), 174-183, DOI: 10.1080/10095020.2017.1333715.

Panigrahi J. and Mohanty P. (2012). Effectiveness of the Indian coastal regulation zones provisions for coastal zone management and its evaluation using SWOT analysis. Ocean & Coastal Management, 65, 34-50, DOI:10.1016/j.ocecoaman.2012.04.023.

Rahman M. Tabassum F. Rasheduzzaman M. Saba H. Sarkar L. Ferdous J. Uddin Z. and Islam Z. (2017). Temporal dynamics of land use/land cover change and its prediction using CA-ANN model for southwestern coastal Bangladesh. Environmental Monitoring and Assessment, 189, 565, DOI: 10.1007/s10661-017-6272-0.

Ramesh D. and Vel A. (2011).Methodology of Integrated Coastal Zone Management Plan Preparation-Case Study of Andaman Islands, India. Journal of Environmental Protection, 2(6), 750-760, DOI: 10.4236/jep.2011.26087.

Saha J. and Paul S. (2020). An insight on land use and land cover change due to tourism growth in coastal area and its environmental consequences from West Bengal, India. Spatial Information Research, DOI:10.1007/s41324-020-00368-0.

Shi C. Hutchinson S. Yu L. and Xu S. (2001). Towards a sustainable coast: an integrated coastal zone management framework for Shanghai, People's Republic of China. Ocean & Coastal Management, 44(5-6), 411-427.

Waiyasusri, K. and Chotpantarat, S. (2022). Spatial Evolution of Coastal Tourist City Using the Dyna-CLUE Model in Koh Chang of Thailand during 1990–2050. ISPRS International Journal of Geo-Information 11, 49. https://doi.org/10.3390/ijgi11010049

Yagoub M. and Kolam G. (2006). Monitoring Coastal Zone Land Use and Land Cover Changes of Abu Dhabi Using Remote Sensing. Journal of the Indian Society of Remote Sensing, 34 (1), 57-68.

Zahedi S. (2008). Tourism impact on coastal environment. Environmental Problems in CoastalRegions, VII 99, 45-57, DOI:10.2495/CENV080051.