J. Asiat. Soc. Bangladesh, Sci. **49**(2): 139-148, December 2023 DOI: https://doi.org/10.3329/jasbs.v49i2.70763

ANALYZING THE LANDUSE LAND COVER CHANGE OF SONADIA ISLAND FROM 1990 TO 2020

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Abstract

Remote sensing and Geographic Information Systems (GIS) are essential tools in determining the spatiotemporal extent of Landuse, and Land Cover (LULC) changes, as well as a variety of individual concerns, such as annual and seasonal changes in LULC caused by human interferences and interactions between the physical environment, cultural context, and anthropogenic factors. This study focuses on the LULC change of Sonadia Island, and it uses multi-temporal Landsat imagery from 1990 through 2020. The output analysis revealed four sub-features: mudflats, vegetation, open space, and water bodies. Vegetation cover decreased from 1486.71 hectares in 1990 to 986.13 hectares in 2000, and in 2020, the total area covered by vegetation increased significantly, reaching 1186.47 hectares, up from 497.97 hectares in 2010. Open space increased from 317.16 hectares in 1990 to 510.75 hectares in 2000. The net area expanded to 631.98 hectares in 2010 and then lost to 421.29 hectares in 2020. There was a consistent increase in the mudflats section from 1990 to 2010, when the amounts were 491.4 and 1179 hectares, respectively. By 2020, the area extent decreased to 796.41 hectares. From 1990 to 2000, the waterbody declined from 305.46 to 262.17 hectares, then slightly increased to 291.78 hectares in 2010, and then shrank again to 196.56 hectares in 2020. Therefore, this study could help policymakers decide on future landscape planning and evaluate Sonadia Island's current condition for long-term coastal management.

Keywords: LULC change, Remote sensing, GIS, Landsat, Coastal management.

Introduction

Land use denotes any anthropogenic activities or economic purpose linked with a specific piece of land. In contrast, land cover pertains to the features on the earth's surface (Lillesand and Kiefer, 2000). Land use and land cover are the most widely used techniques in geospatial analysis. Dynamic processes, land change matrices, and facts have all been identified using this change-based research. Land cover refers to the biophysical state of the earth's surface, which comprises soil, vegetation cover, water

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bodies, and other physical features (Liping *et al*., 2018). Land use is a method by which we can get maximum advantages in multiple types of activities, such as agriculture, habitations, industries, forestation, etc., through systematic land-use planning. This process is imperative for such development works strongly associated with a particular region's socio-economical outgrowth and to protect that region from environmental and ecological degradation (Islam *et al*., 2011).

Sonadia Island at Moheshkhali of Cox's Bazar district is located in the southeastern coastal region of Bangladesh with partial regular inundations by saline water. The island includes coastal and mangrove plantations, salt production fields, shrimp culture farms, plain agriculture lands, human settlements, etc. The ecosystem of this island was affected due to the accelerating rate of anthropogenic interceptions. To protect the ecosystem of this island, it was declared an Ecologically Critical Area (ECA) in 1999 under a section of the Bangladesh Environment Conservation Act, 1995 (MoEF, 2015). ECAs are ecologically designated areas or ecosystems influenced by human activities (Arefin *et al*., 2017). Bangladesh's coastal regions are a well-known cyclonic path subjected to strong cyclonic winds, storm surges, and tidal waves for many years, originating in the Bay of Bengal. Since 1820, cyclones have killed an estimated one million people in Bangladesh (Talukder *et al*., 1992), and the after-effects of these natural hazards include loss of human life, crops, and houses, pollution of the drinking water due to the inundation of land and ponds by saline water (Islam *et al*., 2011). Sonadia Island has gone through profound changes because the Government required to make it a digital island with seventeen projects, which include three power plants, four gas pipelines, two LNG terminals, five economic zones, one regional highway, and one eco-tourism park along with IT park (Mollah *et al*., 2021). Remote sensing and GIS techniques are becoming some of the most useful and prominent analytical tools for resource planners and managers (FAO, 1988), as they interlink spatial and attribute data for outputs in the form of maps, tables, and figures (Hossain *et al*., 2007). Therefore, the study focuses on detailed land cover and land-use transformations in Sonadia Island to find information about pre-existing land-use patterns and spatio-temporal land-use changes in land use over 30 years utilizing GIS and RS techniques.

Sonadia Island is located at 21°N and 91°E in Bangladesh's far southeastern edge, a few kilometers north of Teknaf Peninsula, north-west of Cox's Bazar town, and is delimited on the west and east by the Bay of Bengal (Fig. 1) (Arefin *et al*., 2017). The Moheshkhali Channel separates Sonadia Island from the mainland, while the Bara Channel separates it from Moheshkhali Island. The soil in this area is made up of various proportions of sand and clay. The soil in the north is clayey, and it is flooded by the sea. The land in the southern half of the island is almost entirely sandy (DoE, 1999). The island as a whole has a mild climate with significant humidity. Summer starts in March and lasts until the beginning of June. Sonadia Island is a low-lying barrier island with a gently sloping altitude range of 0-4 meters (DoE, 1999).

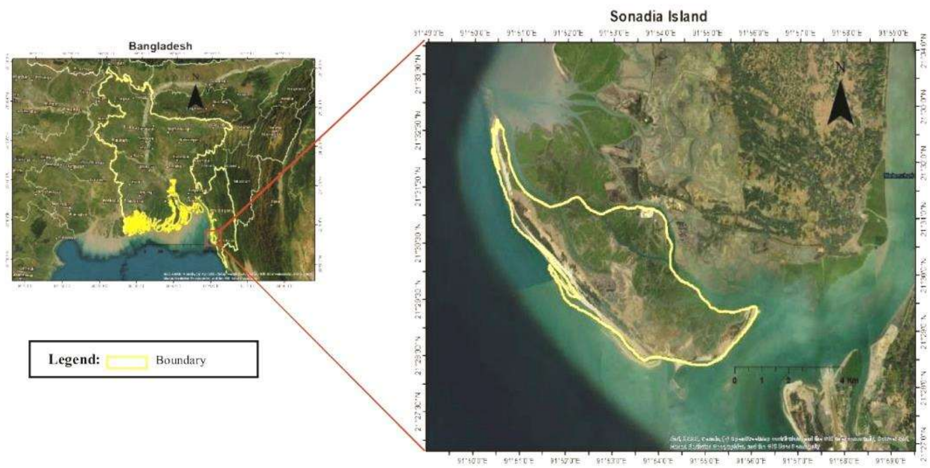

Fig. 1. Sonadia Island in Moheshkhali upazila of Cox's Bazar district, Bangladesh.

Materials and Methods

Data Acquisition and Image Processing: Table 1 shows the type of data collected from which sources and the key information needed to understand the data acquisition clearly. After data collection, the images were processed in ArcMap 10.8, which included layer stacking and research area clipping through the shape file.

*Development of Classification Scheme (Supervised Classification)***:** The maximum likelihood classification mechanism was implemented for image interpretation. In supervised classification, sample pixels from images that are characteristics of specific classes are picked. Then, image processing software (ArcMap 10.8) is used to classify all other pixels in the image using these training sites as references.

Production of Initial Land Cover Map (Post-processing): After completing all the required steps, the acquired maps have been produced by ArcMap 10.8. The statistical analysis and graphs of different land classes of the images have been prepared with the help of Microsoft Excel.

Table 1. Landsat data acquisition details were used in the study.

Satellite ID	Path/Row	Acquisition date	Spatial resolution
Landsat 5	136/45	16-1-1990	30 m
Landsat 5	136/45	28-1-2000	30 m
Landsat 5	136/45	23-1-2010	30 m
Landsat 8	136/45	19-1-2020	30 m

Source: (earthexplorer.usgs.gov)

Accuracy Assessment: For image accuracy, the Kappa coefficient and overall accuracy, including individual user and producer accuracy of each class, have been assessed (Table 2 and Table 3).

Table 2. Image accuracy assessment.

Category	Formula
Overall Accuracy	(Total number of correctly classified pixels/ Total Number of reference pixels) *100%
User Accuracy	{Number of correctly classified pixels in each category/ Total Number of reference pixels in that category (The Row Total)} * 100%
Producer Accuracy	{Number of correctly classified pixels in each category/ Total Number of reference pixels in that category (The Column Total)} * 100%
Kappa Coefficient (T)	{(TS *TCS) −Σ (Column Total * Row Total)} / {TS^2- Σ (Column Total * Row Total)} *100%

Table 3. Image accuracy assessment results for LULC classification of the Sonadia Island.

Feature classes	User (%)				Producer (%)				Overall accuracy (%)	Kappa coefficient (T) (%)
	1990	2000	2010	2020	1990	2000	2010	2020		
Mixed vegetation	80	100	87.5	100	80	85.7	100	100	92	89.2
Open space	100	87.5	100	100	83.3	100	100	100	92.3	89.7
Water body	100	100	100	100	100	100	87.5	91.8	96.2	98.3
Mudflats	88.8	83.3	88.8	88.8	100	83.3	100	100	96.9	95.8

Area Calculation and Spatio-Temporal Change Detection: Following the creation of the initial land cover map, the area was measured using ArcMap10.8 to detect spatio-temporal changes.

Results and Discussion

The land use land cover distribution maps, acquired from the Landsat images analysis, are described below. Four different land classes have been identified from the images, and each color symbolizes the distribution of the area of each classified LULC, which is for four distinct periods (1990, 2000, 2010, 2020) outlined in the subsequent segment in a regulated way.

Landuse/ Land cover classification

Land class (1): Mixed vegetation: Sonadia Island is mostly covered with mangroves and coastal forest, which contains diverse vegetation, Jhau trees, and hilly forests. Sonadia Island's natural safeguard against cyclonic wind and storm surges is the mangrove forest, which is largely found in the southwestern half of the island. This class is critical for the coastal ecology and, more importantly, for protecting people and property in the area from cyclones and tidal surges. Again, the hilly forest, Jhau trees, and mixed vegetation are essential for the local communities, as they protect the topsoil from the impact of raindrops and add organic matter to the soil. Besides, they rely on the forest for many of their daily needs, e.g., fuel, wood, fodder, etc.

Land class (2): Open space: The sections of vacant segments not used for any purpose are called open spaces, including sand beaches, dunes, and salt fields.

Land class (3): Mudflats: Mud flats constitute the upper zone of tidal flats, depositional processes being dominated by the fallout of suspended sediment comprising sortable silts, flocs, and aggregates (Chang *et al.,* 2007; Flemming, 2012). Mudflats, or tidal flats, are coastal wetlands formed on sheltered shores where the rivers or tides can deposit greater sediments (silt, clay, and detritus). These form in areas where tides or rivers have deposited sediments. As rivers and numerous streams are present in Sonadia and bounded by the Bay of Bengal in the west, east, and south, this island has its fair share of mudflats.

Land Class (4): Water Body: Small wetlands, ponds, and lagoons are examples of intertidal zones delineated by water bodies. This stretch's northwestern and northeastern parts, which are mostly exposed to storm surges, include intertidal flat deposits.

Fig. 2 depicts the distribution of land cover for the study area in 1990. The map clearly shows that there was a significant amount of vegetation present throughout the area. The most prevalent land cover types then were vegetation cover and mudflats. The distribution of the study area's land cover in 2000 is shown in Fig. 3. The map showed that the area's substantial amount of vegetation, which was present throughout 1990, had decreased, and the number of mudflats emerged in the vicinity with the decline of vegetation cover. Mudflats and open spaces were the two predominant land cover types at the time. Figure 4 illustrates how the study area's land cover was distributed in 2010. The map reflects that between 1990 and 2000, the area's substantial extent of vegetation cover had declined. Around that area where the vegetation decreased, the number of mudflats also expanded. The two most prominent land cover types at that time were mudflats and open spaces. The distribution of land cover for the study area in 2020 is represented in Fig. 5.

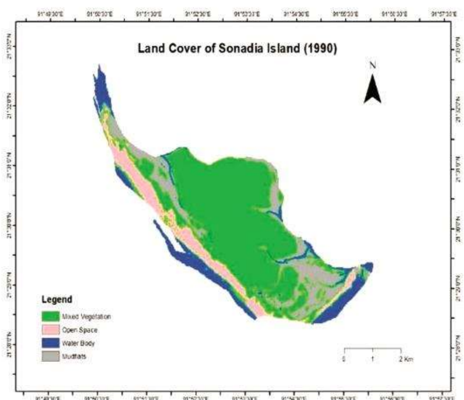

Fig. 2. Land Cover Map of Sonadia Island, 1990.

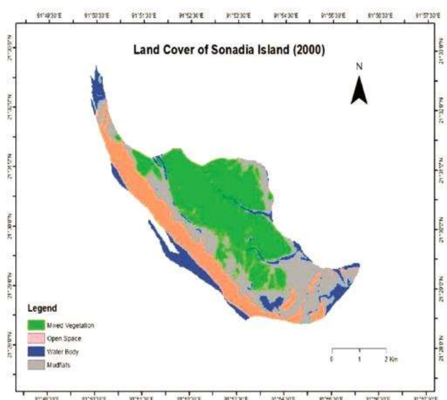

Fig. 3. Land Cover Map of Sonadia Island, 2000.

The map made it apparent that the significant decrease in vegetation cover that had been observed in previous years had dramatically reversed. Along with increased vegetation volume, there was obvious evidence of a decline in mudflats and water bodies. At that time, vegetation and mudflats were the most prevalent land cover types.

Changes in areal extent of LULC: The distribution of LULC extent of Sonadia Island from 1990 to 2020 is represented as a data table in acres so that we can study the pattern of changes in the LULC over time (Table 4). According to the analysis, the total quantity of land on Sonadia Island was estimated to be above 6000 acres.

The total area covered by vegetation decreased from 1486.71 hectares in 1990 to 986.13 hectares in 2000. Compared to 2020, the entire area covered by vegetation increased significantly, reaching 1186.47 hectares, from 2010, when it was substantially reduced to 497.97 hectares. 2000, there were 510.75 hectares of open space, up from 317.16 hectares in 1990. The size increased to 631.98 hectares in 2010 and then declined to 421.29 hectares in 2020. In the mudflats section, there was a consistent increase from 1990 to 2000 and 2010, when the extents were 491.4, 841.68, and 1179 hectares, respectively; by 2020, the extent reduced to 796.41 hectares. From 1990 to 2000, the waterbody declined again, from 305.46 to 262.17 hectares, then somewhat increased to 291.78 hectares, and then again reduced to 196.56 hectares.

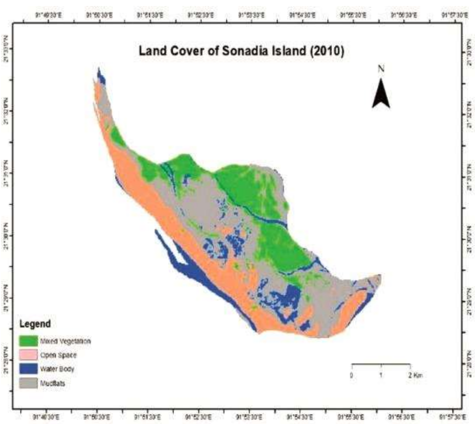

Fig 4. Land Cover Map of Sonadia Island, 2010.

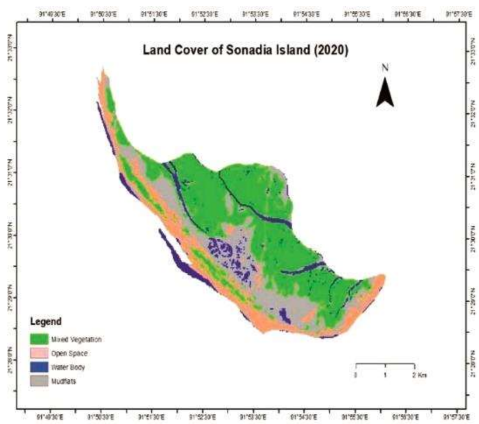

Fig 5. Land Cover Map of Sonadia Island, 2020.

Table 4. Spatio-temporal variations in areal extent of LULC Change of Sonadia Island between 1990 and 2020.

Year	Mixed vegetation (ha)	Open space (ha)	Mudflats (ha)	Water body (ha)	Grand total (ha)
1990	1486.71	317.16	491.4	305.46	2600.73
2000	986.13	510.75	841.68	262.17	2600.73
2010	497.97	631.98	1179	291.78	2600.73
2020	1186.47	421.29	796.41	196.56	2600.73

The hypothesis of the analyzed LULC change of Sonadia island: Driving forces influencing the changes

Vegetation Vs. Mudflats: It can be seen from the trend analysis graph of vegetation and mudflats that there is an inverse relationship between mudflats and vegetation coverage of Sonadia Island from 1990 to 2020 (Table 4). There was a significant increase in mudflat coverage from 1990 to 2010 but a significant decrease in mixed vegetation coverage from 1999 to 2010.

The island area has lost its natural complexity due to human intervention, such as extensive and illegal deforestation and slope modification, unplanned settlement development, and crop cultivation on adjacent lands (Islam *et al.,* 2011). On the other hand, Sonadia Island's mangrove forest has been infringed upon, primarily for shrimp aquaculture. Mangroves, which generally inhabit mudflats during their early stages of formation, live in the emerging tidal mudflats. It can be hypothesized from the analysis that, even though locals have come to rely on the forest for many household necessities like firewood, housing materials, and boat-building materials, as well as herbal plants for traditional remedies and other minor items, mixed vegetation coverage has decreased between 2000 and 2010. The extent of vegetation in 2010 was at its lowest level, as shown in the trend analysis graph. Extremely Severe Cyclonic Storm Sidr, struck Sonadia Island in 2007, causing damage to the island's infrastructure. From 1990 to 2010, the expansion of mudflats may be due to increased local economic activities like shrimp cultivation, salt farming, and watermelon farming. The overall percentage of mangroves in the Sonadia Island region has been rising recently as a result of newly developed mangrove forests along the eastern and western coasts, as well as the plantation of mangrove trees by the Forest Department and locals as they become aware of the significance of protecting their property (Hossain *et al.,* 2023). The expansion of vegetation cover in certain areas is a time-consuming process. After 2010, the Forest Department and the Ministry of Environment and Forest (MoEF) launched an afforestation program, resulting in a substantial increase in vegetation coverage in 2020, and at the same time, mudflat coverage dropped substantially. As a result, the vegetation and the mudflats have an asymmetric connection. Mudflat coverage expanded significantly as vegetation coverage fell. Again, mixed vegetation coverage rose disproportionately as mudflats coverage decreased. Thus, it is apparent from the trend analysis of the hypothesis mentioned above that changes in open space and an increase in mudflats resulted from a drastic decline in vegetation and water bodies.

Open Space: The open space segment consistently increased from 1990 to 2010, with 317.16, 570.15, and 631.98 hectares, respectively. Then it reduced to 421.29 hectares in 2020. However, effective coastal afforestation initiatives, particularly from 2000 to 2017 (Abdullah *et al.,* 2019), led to a gradual increase in vegetation, impacting the extent of the island's open spaces in 2020. The significant change in the open space segment (Table 4) is attributable to Sonadia Island's limited land use diversity. The soil texture in this area contains a sizable amount of sand (DoE, 1999). Since there is a lot of saltwater intrusion, this land is unsuitable for farming.

Water Body: This section of the trend analysis graph (Table 4) depicts that water body coverage continues to shrink. Due to anthropogenic activity and excessive use of freshwater body features such as small wetlands, ponds, and lagoons, the volume of water bodies has reduced. Anthropogenic interferences also contribute to the pollution of certain freshwater bodies.

Conclusions

The current study uses remote sensing and GIS methods to depict spatio-temporal changes in land use and land cover over a thirty-year period. Four sub-features, including vegetation, open spaces, mudflats, and water bodies, were identified on Sonadia Island. The key land classes that have significantly altered during the last thirty years include vegetation, open space, mudflats, and water bodies. Knowing the island's various land cover classes is necessary to assess and carry out effective land-use planning for any development or improvement project on Sonadia Island.

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