The Dhaka University Journal of Earth and Environmental Sciences, Vol. 8, 2019

Md. Bodruddoza Mia[1*]
Tanzeer Hasan[1]
Syed Humayun Akhter[1]

Change Detection of Landuse-landcover in and around Cox's Bazar-Teknaf Coastal Area of Bangladesh Using Satellite Images

Manuscript Received: 20 April 2019
Accepted: 25 October 2019

[1]Department of Geology, University of Dhaka, Dhaka-1000, Bangladesh

**Corresponding author*
Email: bodruddoza@du.ac.bd

***Abstract**: The prime objective of this study is to detect changes of the biophysical resources (or landuse-landocver) of the Cox's Bazar-Teknaf area from 1999 to 2015 using Landsat TM/ETM+/OLI sensors images after applying classifications and indices approaches. The normalized differential vegetation index (NDVI) result showed that water bodies reduced by about 20% of the study area from 1999 to 2015. Bared land or beach decreased by 6% from 1999 to 2005 and then increasing trend is observed in this study from 2005 to 2015. Mixed land was more or less an increasing trend in this study area. Vegetation cover increased from 1999 to 2005 and then suddenly decreased a lot from 2009 to 2015. The declining trend of water bodies is mostly in the northern part of the study area, which is mostly shallow area where shrimp or salt farms exist. The result of normalized differential water index (NDWI) showed that the water bodies decreased from 1999 to 2015 about 10% of the study area. Land area was increased from 1999 to 2005 and then increased a little from 2005 to 2009 and afterward it decreased. The normalized differential salinity index (NDSI) result shows that the area of non-saline zone increased from 1999 to 2015. Low saline zones reduced from 1999 to 2005 but it increased after 2005 due to absence of high and medium salinity signature from NDSI value. The low saline zone is mostly in the northern side of Cox's Bazar where shrimp farms or salt bed exist. In unsupervised thematic maps, the water bodies increased in this region from 1999 to 2009 and then declined again. The declining trend of water bodies indicates the erosion activities from 1999 to 2009. The fallow lands including beach also decreased from 2005 to 2015, indicates more agricultural activities including fisheries, salt production in this study area. On the other hand, the vegetated region decreased but settlements area including vegetation increased in this area. In supervised thematic map, the result showed that the shrimp cultivation and salt bed increased in this region from 1999 to 2015 and agricultural land has decreasing trend. On the other hand, the vegetated region was ups and down trend from 1999 to 2009. The study indicates that the Landsat images are quite efficient to map biophysical resources of the study area with various techniques.*

***Keywords**: Landuse-landcover, Indices, Classification, Landsat, Cox's Bazar-Teknaf*

Introduction

Cox's Bazar-Teknaf is one of the longest sandy sea beaches in Bangladesh that has a huge amount of heavy minerals, exposed rocks, vegetation, shrimp farms and crops surrounding of this region (Figure 1). Rapid growth of this region as a tourist place threats natural habitats as well as resources such as vegetation, forest, farm areas, beach sands and agriculture (Kibria and Yousuf, 2017). Recent human induced climate change is also greatly affecting the resources of this area (Kausher et al., 1996). This region is one of the most attractive tourist places of Bangladesh. Landslides and coastal erosion is the prominent natural hazard in this area (Rahman and Khan, 1995). To understand the geo-environment, there are not sufficient research based on ground truth investigation due to inaccessibility and safely factors. Remote investigation could be the option for detail exploration and monitoring the natural ecosystem, economic minerals and environmental components for coastal dynamics.

Land Use and Land Cover (LULC) changes are one of the most important and easily detectable indicators of change in ecosystem and livelihood support systems (Giri et al., 2005). Understanding the complexity of LULC changes, its assessment and monitoring are essential for sustainable management of natural resources, environmental protection and food security (Drummond et al., 2012; Foley et al., 2005). Studies on LULC changes are also helpful to predict likely future trends, and to make decisions for natural resource management planning (Prenzel, 2004). Humans have directly or indirectly affected the earth surface through various activities. Landuse is defined by the purposes for which humans exploit the landcover and shaped by human, socio-economic and political influences (Lambin et al., 2003). Land cover refers to the biophysical earth surface (Lambin, 2003). Therefore, to understand the dynamics of LULC changes it is important to understand human dimension and its effects. Verburg et al. (2010) have stated that LULC change as a result of diverse interactions between society and the environment. Many studies have shown that the human dimensions are affected by social, ecological and economic factors, and an interdisciplinary approach is required to understand and address the relationship between environment and society (Drummond et al., 2012; Garedew et al., 2009; Lambin et al., 2003; Liu, 2001). Liu (2001) states an urgent need to integrate environment with human dimensions, including its behavior and socio-economics, in order to understand and manage ecological patterns and processes. Garedew et al. (2009) have emphasized that there is a need to conduct research beyond one disciplinary boundary and explore the methods which can integrate the LULC change studies, socio-economic data and learning of different stakeholders. Socio-economic factors may cause changes in LULC by imposing various land based practices, and through the decisions and actions of institutions managing natural resources. Likewise, the LULC change, on the other hand, may cause changes in landuse decisions (Lambin and Meyfroidt, 2011). Lambin et al. (2003) have listed various factors such as changing opportunities created by market, loss of adaptive capacity, increased vulnerability, changes in social organization, changes in attitudes, access to resources, income distribution, urban rural interaction, labor availability, infrastructure, governance are the fundamental causes of landuse change.

Remote sensing data and geo-spatial tools provide information and opportunities to understand and quantify the rate of changes occurring on the earth's surface over time (Guerschman et al., 2003; Huang and Asner, 2009). Selection of appropriate satellite images and methods pose key challenges for monitoring LULC changes. Many researchers have applied Landsat images to monitor LULC changes, in spite of being medium resolution data (Drummond et al., 2012; Jansen, 2007). It is being popular because of its free availability and for having the longest record of global-scale data for earth observation (Giri et al., 2005). Hansen and Loveland (2012) have reviewed a large area monitoring of land cover change using Landsat data. Spectral imaging for remote sensing of terrestrial features and objects arose as an alternative to high-spatial resolution, large-aperture satellite imaging systems. Early applications of spectral imaging were oriented toward ground-cover classification, mineral exploration, and agricultural assessment, employing a small number of carefully chosen spectral bands spread across the visible and infrared regions of the electromagnetic spectrum. Improved versions of these early multispectral imaging sensors continue in use today. A new class of sensor, the hyperspectral imager, has also emerged, employing hundreds of contiguous bands to detect and identify a variety of natural and man-made materials. The prime goal of this proposed research is to detect and monitor changes of the various biophysical resources or landuse-landcover (LULC) of the study area from 1999 to 2015 using four sets of Landsat TM/ETM+/OLI sensors imageries. The result would be used to assess aerial coverage of natural resources along the coastal area as well as used to infer the growth of vegetation and crops with the dynamics of coastal region. The outcomes could be used in other parts of Bangladesh to quantify the biophysical resources.

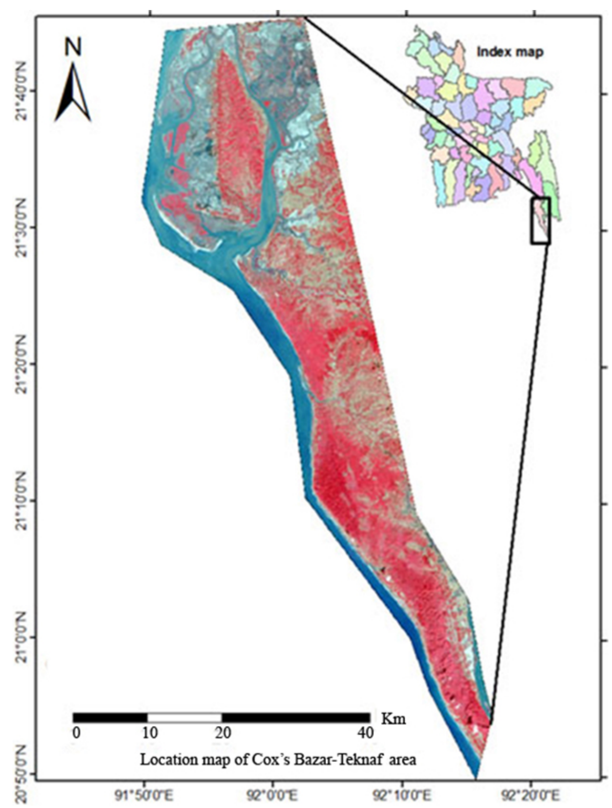

Figure 1: Location Map of the Study Area

Study Area

The total study area of Cox's Bazar-Teknaf is 1580 Km^2 (158,000 ha) (Figure 1). The longitude of the study area is 91°47'00"E to 92°20'00"E and the latitude of the study area is 20°50'00"N to 21°45'00"N. It is bounded by Chattogram district on the north, Bay of Bengal on the south, Bandarban district, Arakan (Myanmar) and the Naf River on the east, the Bay of Bengal on the west (Figure 1). The longest sea beach of the world belongs to Cox's Bazar. The climate of Bangladesh is mostly determined by its location in the tropical monsoon region: high temperature, heavy rainfall, generally excessive humidity, and distinct seasonal variations. The climate of Cox's Bazar is mostly similar to the rest of the country. It is further characterized by the location in the coastal area. The annual average temperature in Cox's Bazar remains at about a maximum of 34.8 °C and a minimum of 16.1 °C. The average amount of rainfall remains at 4,285 mm.

Materials and Methods

Satellite Remote Sensing (RS) technology provided an excellent alternative over conventional mapping techniques with a view to monitoring and mapping of surface waterlogged areas. Biophysical parameters or landuse-landcovers of the study area were evaluating and monitor using Landsat satellite images from 1999 to 2015. We have acquired four sets of Landsat images of TM, ETM+ and OLI sensors in this study (Table 1). A number of approaches were used in this study according to the flow chart (Figure 2).

Table 1: Satellite Images with Acquisition Dates and Spatial Resolution of Used Bands

Sensor Platform	Acquisition Date	Used Bands Spatial Resolution
Landsat 7 ETM+	December 19,1999	30 m
Landsat 5 TM	November 25, 2005	30 m
Landsat 5 TM	December 12, 2009	30 m
Landsat 8 OLI	December 23, 2015	30 m

Indices Approaches for Landuse-landcover Mapping

Normalized Differential Vegetation Index (NDVI)

NDVI is an index of vegetation abundance, also used as an indication factor of vegetation health, which is related to biomass, chlorophyll content and water stress. Generally, vegetated areas have high reflectance in the near infrared and low reflectance in the red visible region. NDVI is defined as: NDVI= $(\rho_2-\rho_1)/(\rho_2+\rho_1)$, where ρ_2 represents the reflectance measured in the near infrared, and ρ_1 represents the reflectance in the red wavebands (Rouse et al., 1974). The NDVI value ranges from -1 to +1. In this index, green vegetation has high values, water has negative values and bare soil has a value around 0. As a normalized index, NDVI is compensated for any changes in illumination conditions, surface and aspect (Lillesand et al., 2004).

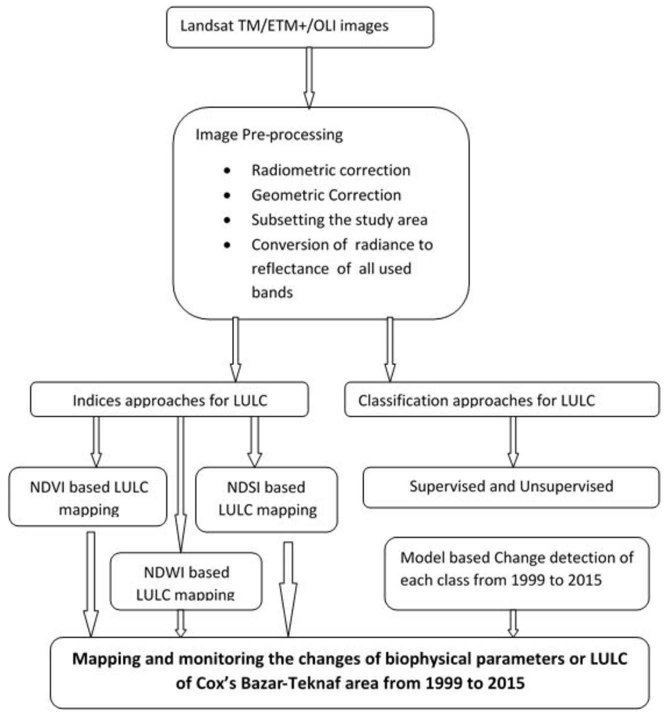

Figure 2: Satellite Image Processing Flow Chart of the Study

Normalized Differential Water Index (NDWI)

NDWI was designed to maximum the high reflectance of water by using green wavelengths and minimize the low reflectance by NIR bands. In addition, it also uses the advantages of high reflectance of NIR by vegetation and soil features. As a result, water features have positive values and thus are enhanced, while vegetation and soil usually have zero and negative values and therefore are suppressed (Mcfeeters, 1996). However, the extracted water information was often mixed with built-up land noise. This is because that the reflectance pattern of built-up land in the green band and NIR band is similar with that of water, and built-up land features also have positive values in the NDWI image. But the reflectance of MIR (mid-infrared) band is much greater than the green bands. Therefore, the NDWI is modified by substituting the MIR band for the NIR band (Gao, 1996).

$$\text{NDWI}=\frac{\text{Green}-\text{Nir}}{\text{Green}+\text{Nir}} \qquad (1)$$

Where, Green and NIR is the reflectance value of these bands respectively.

Normalized Differential Salinity Index (NDSI)

Modeling soil salinity in a salt-affected ecosystem is a difficult task when using remote sensing data because of the complicated soil context (vegetation cover, moisture, surface roughness, and organic matter) and the weak spectral features of salinized soil. The use of vegetation reflectance as an indirect indicator can avoid limitations associated with the direct use of soil reflectance. As a remotely sensed indicator, the type and growing conditions of vegetation can provide a spatial overview of salinity distribution. Soil salinity could be estimated in numerous studies by using vegetation reflectance, and many of these studies preferred the use of vegetation indices, especially the normalized difference vegetation index (NDVI) (Tilley et al., 2007). Normalized salinity index (NDSI) have been found to be useful for predicting salinity (Aldakheel et al., 2005). These will be respectively derived using the equations:

$$\text{NDSI}=\frac{\text{Red}-\text{Nir}}{\text{Red}+\text{Nir}} \qquad (2)$$

Where, Red and NIR is the reflectance value of these bands respectively.

Landuse-landcover Mapping

Both supervised and unsupervised classification approaches were applied in this study. In case of unsupervised classification, pixels are grouped based on the reflectance properties of pixels. These groupings are called “clusters”**.** We have to identify the number of clusters to generate and which bands to use. With this information, the image classification software generates clusters. There are different image clustering algorithms such as K-means and ISODATA. The user manually identifies each cluster with landcover classes. It is often the case that multiple clusters represent a single landcover class. The user merges clusters into a landcover type. The unsupervised classification image classification technique is commonly used when no sample sites exist. The collected images of the year of 1999, 2005, 2009, and 2015 have been used for landuse-landcover (LULC) mapping of the study area. The purpose of identifying the changes has significant advantage to detect the changes of biophysical parameters over those years. To find out the landuse-landcover (LULC) changes, unsupervised classification method using ERDAS IMAGINE 9.1 software has been employed. The Iterative Self Organizing Data Analysis Technique or ISODATA method has been followed for this classification. Using such unsupervised classification approach, 30 classes were created at first and after merging them one another by “Recoding”, 6 identifiable spectral classes have been identified for information extraction. Supervised classification approach was applied for this study to map gross biophysical parameters such as vegetation, water bodies, agricultural lands, settlements, shrimps/salt farm and bare land / sea beach of Cox’s Bazar-Teknaf area in Southeast part in Bangladesh using four sets of satellite images from 1999 to 2015. We have collected the signature sets of these land covers during the field investigation in this area for the supervised classification.

Results and Discussion

Landuse in Bangladesh is generally determined by physiography, climate and land levels (Brammer, 2002). However, lands in coastal areas in Bangladesh is used for agriculture, shrimp cultivation and fish farming, forestry, salt production, ship-breaking yards, ports, industries, human settlements and wetlands. As a result, landuse in the coastal areas is diverse, competitive and often conflicting. The application of remote sensing and geographical information system concerning mapping land cover and landcover change detection has considerably evolved. Supervised and unsupervised techniques are normally adopted for landcover mapping. Though, landcover change analysis methods are many and some are highly applied than others depending on professional’s choice. Traditionally in remote sensing, landcover change detection has been performed applying the vegetation indices that are mathematical transformations designed to evaluate the spectral contribution of vegetation. The normalized difference vegetation index is derived by dividing the difference between infrared and red reflectance measurements by their sum which provides the effective measure of photosynthetic active biomass.

LULC Mapping Based on NDVI

NDVI used to analysis the health of vegetation of any area. Higher the NDVI value is the healthier vegetation and lower value shows no vegetation or less i.e., bare land or water or sparse vegetation. Another important factor is the resolution of the image used in this study i.e., coarser resolution shows less information about the ground and fine resolution shows the detail of ground. NDVI value ranges from -1 to +1. We have classified the LULC of the study area into four classes using the NDVI value such as water body (NDVI<0), bare land/beach (NDVI=0-0.2), mixed land (NDVI=0.2-0.5) and vegetated land (NDVI>0.5) (Figure 3). Total study area is about 158,000 hectares in this study. The result shows that water bodies decreased about 19% of the study area from 1999 to 2015 (Figure 3; Figure 4). Bared land or beach decreased about 6% from 1999 to 2005 and then increasing trend is observed in this study from 2005 to 2015. Mixed land was more or less an increasing trend in this study area. Vegetation increased from 1999 to 2005 and then suddenly decreased a lot from 2009 to 2015 that might be due to satellite sensor variations as well as 2015 image (Landsat 8 OLI sensor is still in experiment stage) (Figure 4). The declining trend of water bodies is mostly in the northern part of the study area which is mostly shallow area where shrimp or salt farms exist (Figure 3).

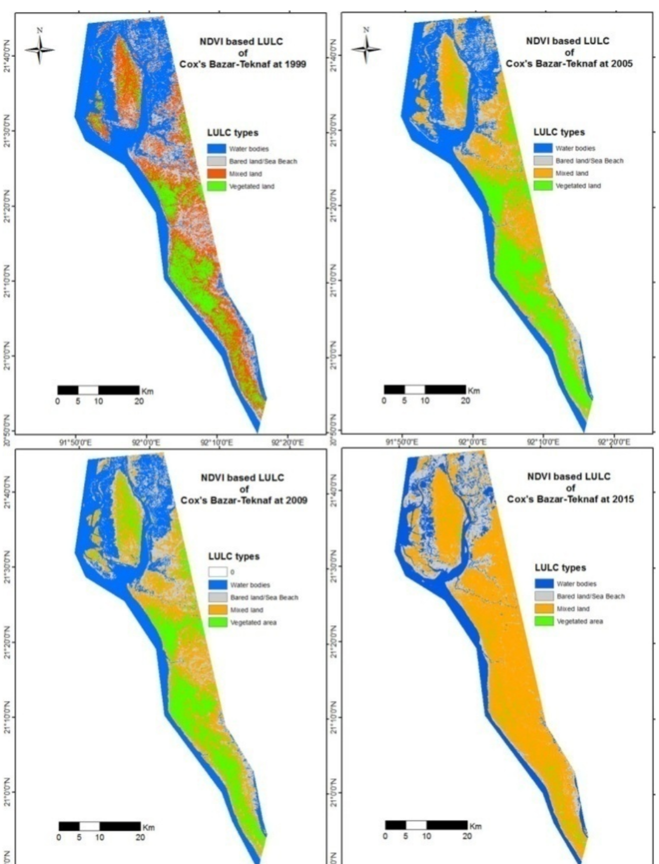

Figure 3: LULC of Cox's Bazar-Teknaf Area Based on NDVI in 1999, 2005, 2009 and 2015

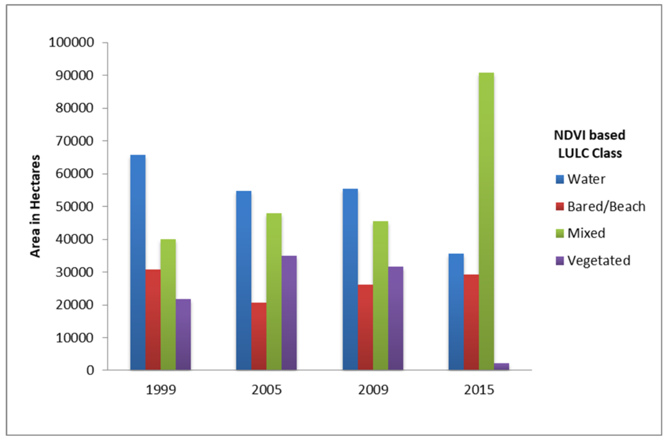

Figure 4: Comparison of NDVI Based LULC Classes of the Study Area from 1999 to 2015

LULC Mapping Based on NDWI

NDWI indices used to delineate the surface water bodies as a whole in this study. Water body means the NDWI value above zero and land is below zero of NDWI. The result of this study shows that the water bodies decreased from 1999 to 2015 about 10% of the study area (Figure 5; Figure 6). Land area increased from 1999 to 2005 and then increased a little from 2005 to 2009 and afterward it decreased (Figure 6).

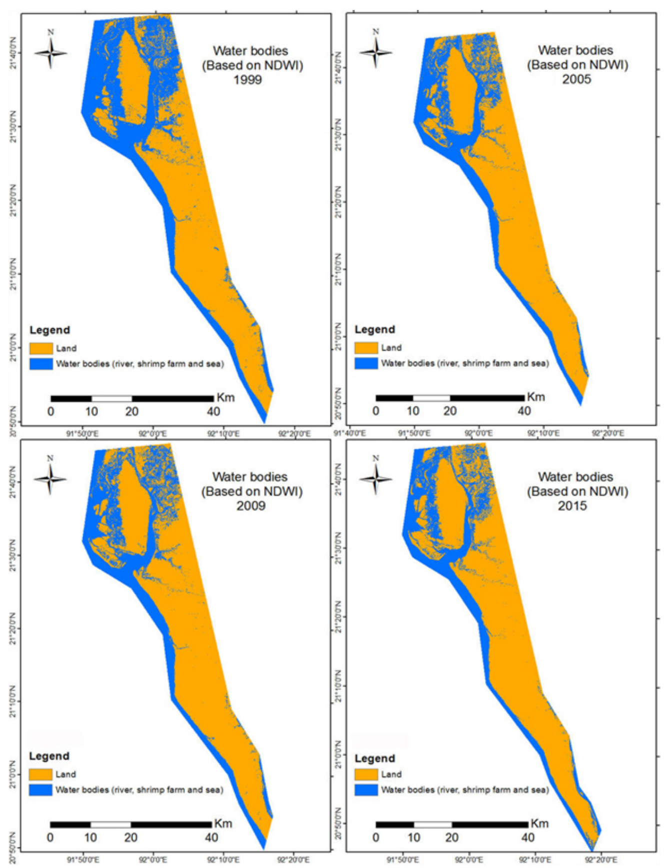

Figure 5: LULC Map of Cox's Bazar-Teknaf Area Based on NDWI in 1999, 2005, 2009 and 2015

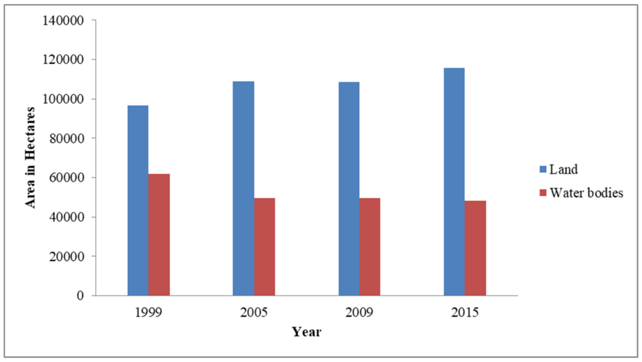

Figure 6: Comparison of NDWI Based LULC Classes of the Study Area from 1999 to 2015

LULC Mapping Based on NDSI

The derived value of NDSI of the study area was divided into four ranges of salinity such as non-saline zone (NDSI<0), low saline zone (NDSI= 0-0.2), moderate saline zone (NDSI= 0.2-0.4) and high saline zone (NDSI>0.4) (Figure 7). The result shows that the area of non-saline zone is increasing from 1999 to 2015. Low saline zones reduced from 1999 to 2005 but it increased after 2005 due to absence of high and medium salinity signature from NDSI value (Figure 8). The low saline zone is mostly in the northern side of Cox's Bazar where shrimp farms or salt bed exist. The shallow rivers also contain the signature of low salinity in this study (Figure 8).

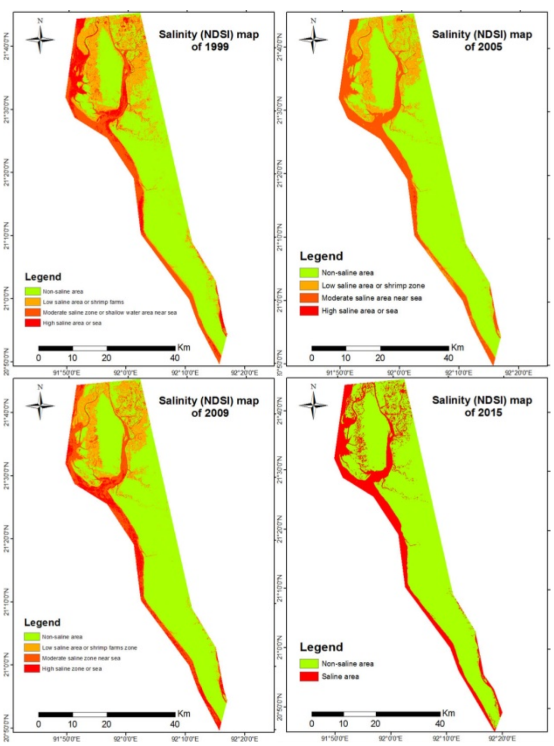

Figure 7: NDSI Based Spatial Distribution of Salinity within the Cox's Bazar-Teknaf Area

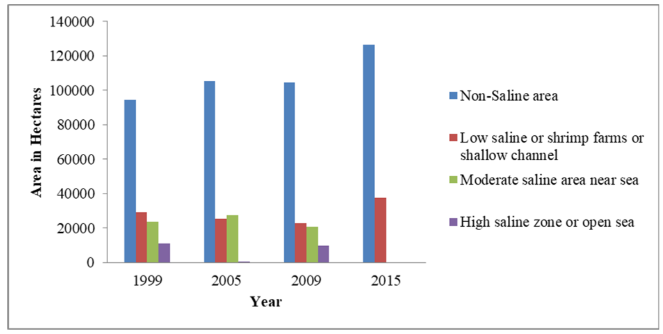

Figure 8: Comparison of NDSI Based LULC Classes of the Study Area from 1999 to 2015

Classification Based Biophysical Resources Mapping

There are two classification approaches for biophysical parameters i.e., landuse-landcover of the study area such as unsupervised and supervised classification.

Unsupervised Classification

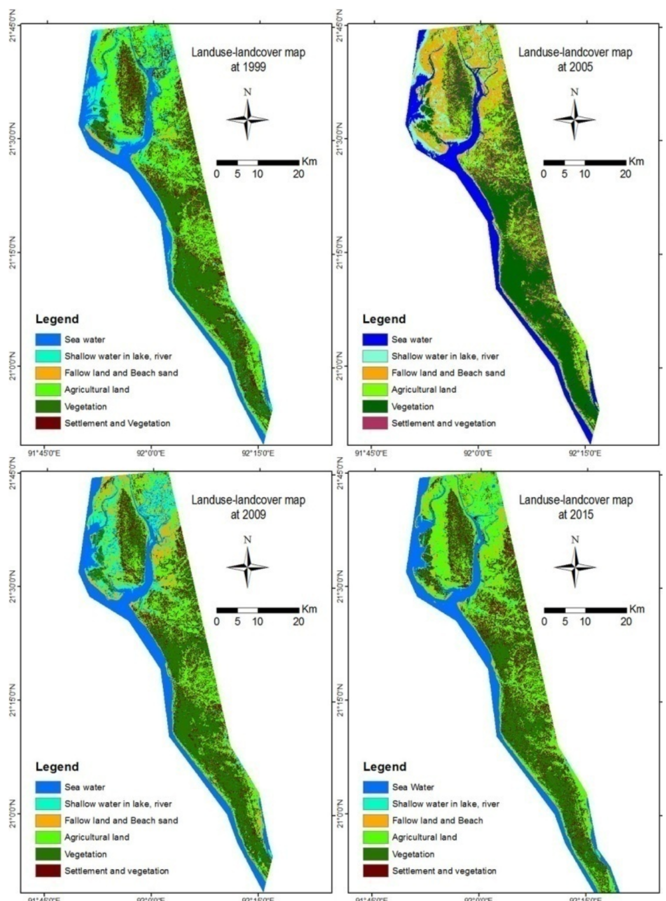

Figure 9: Biophysical Resource Distribution (LULC types) of the Study Area Based on Unsupervised Classification from 1999 to 2015

Four classified LULC thematic maps were prepared from the Landsat images of 1999, 2005, 2009 and 2015 of Cox'sbazar-Teknaf area (Figure 9). The LULC classes were broadly identified based on statistical approach of ISODATA algorithm. The identified landcover types are sea water, shallow water (lake, ponds and river), fallow land and beach sand, agricultural area, vegetation and settlements with vegetation region of this study area. Although there is clear trend of any land cover types in this study but the result showed that the water bodies increased in this region from 1999 to 2009 and then declined again (Figure 10). The declining trend of water bodes indicates the erosion activities from 1999 to 2009. The fallow lands including beach also decreases from 2005 to 2015, indicates more agricultural activities including fisheries, salt production in this study area. On the other hand, the vegetated region decreased but settlements area including vegetation increased in this area (Figure 10).

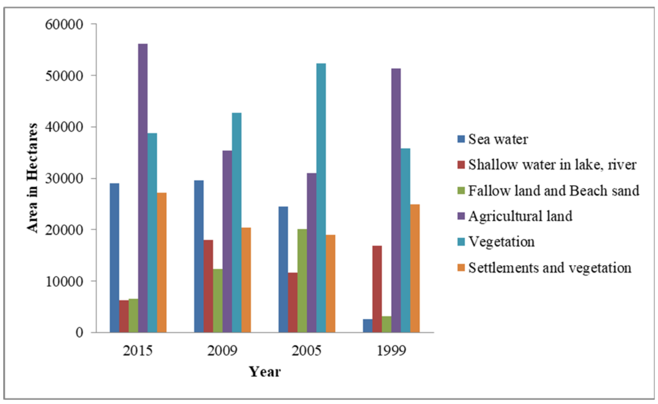

Figure 10: Comparison of Biophysical Resources Based of Unsupervised Classification of the Study Area

Supervised Classification

Four classified LCLU thematic maps prepared from the Landsat images of 1999, 2005, 2009 and 2015 of Cox's bazar-Teknaf area using supervised classification (Figure 11). The landcover classes were broadly identified based on field observations. The identified landcover types are water, vegetation, shrimp cultivation and salt bed, Mangrove, Beach area and bare land and agricultural land of the study area. Although there is clear trend of any landcover types in this study but the result showed that the shrimp cultivation and salt bed increased in this region from 1999 to 2015 and agricultural land has decreasing trend (Figure 12). The declining trend of beach area indicates may be the erosion activities from 1999 to 2009. On the other hand, the vegetated region was ups and down trend from 1999 to 2009 (Figure 12). This vegetation includes vegetation around settlements and vegetation on hills both natural and planted. Mangrove forest seems to be constant. The analysis shows periodic ups and downs in the total area. This could be due to firewood collection or human intervention. Mangrove is a type of forest growing along tidal mudflats and along shallow water coastal area extending inland along rivers, streams and their tributaries where the water is generally brackish. Clearance of mangrove in this area causes loss of coastal habitat and aquatic resources increase erosion and vulnerability to natural disaster.

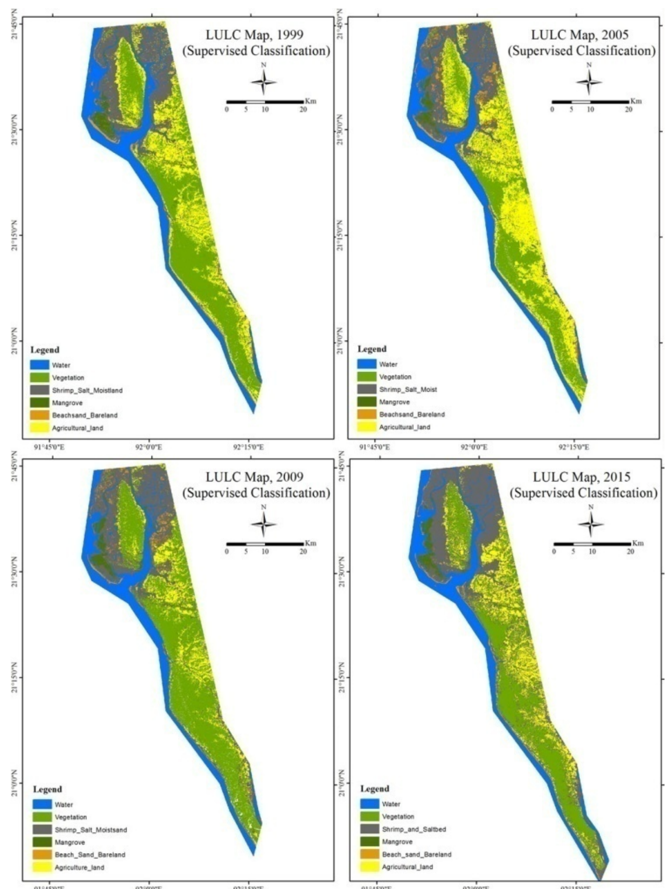

Figure 11: Biophysical Resource Distribution (LULC types) of the Study Area Based on Supervised Classification from 1999 to 2015

In discussion, NDVI based LULC of the study area determines that water bodies reduced about 19% of the study area from 1999 to 2015. Bared land or beach area declined about 6% from 1999 to 2005 and then increased from 2005 to 2015 in this study. Mixed land was more or less an increasing trend in this study area. Vegetation increased from 1999 to 2005 and then suddenly decreased a lot from 2009 to 2015. The declining trend of water bodies is mostly in the northern part of the study area which is mostly shallow area where shrimp or salt farms exist. NDWI result of this study discloses that the water bodies decreased from 1999 to 2015 about 10% of the study area. Land area was increased from 1999 to 2005 and then increased a little from 2005 to 2009 and afterward it decreased. NDSI result shows that the area of non-saline zone is increasing from 1999 to 2015. Low saline zones were reduced from 1999 to 2005 but it was increased after 2005 due to absence of high and medium salinity signature from NDSI value. The low saline zone is mostly in the northern side of Cox's Bazar where shrimp farms or salt bed exist. The shallow rivers also contain the signature of low salinity in this study.

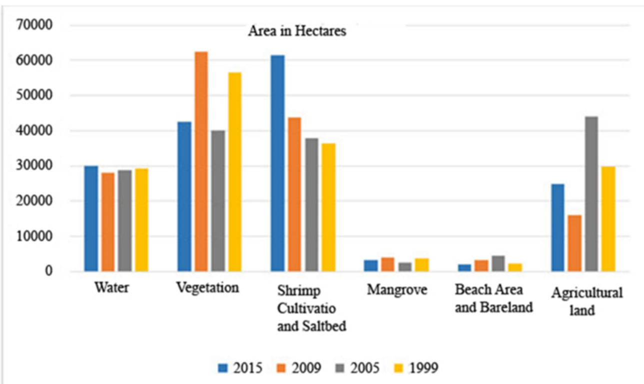

Figure 12: Comparison of Biophysical Parameters Based on Supervised Classification of the Study Area

Unsupervised thematic classified maps showed that the water bodies increased in this region from 1999 to 2009 and then declined again. The declining trend of water bodies indicates the erosion activities from 1999 to 2009. The fallow lands including beach also decreased from 2005 to 2015, indicates more agricultural activities including fisheries, salt production in this study area. On the other hand, the vegetated region was decreased but settlements area including vegetation increased in this area. Supervised classified thematic maps show that the shrimp cultivation and salt bed increased in this region from 1999 to 2015 and agricultural land has decreasing trend. The declining trend of beach area indicates may be the erosion activities from 1999 to 2009. On the other hand, the vegetated region was ups and down trend from 1999 to 2009. This vegetation includes vegetation around settlements and vegetation on hills both natural and planted. Salt beds expansion was dominant observed to the seaside and it encroaches towards inland. Mangrove forest seems to be constant. The analysis shows periodic ups and downs in the total area. This could be due to firewood collection or human intervention. Mangrove is a type of forest growing along tidal mudflats and along shallow water coastal area extending inland along rivers, streams and their tributaries where the water is generally brackish. Clearance of mangrove in this area causes loss of coastal habitat and aquatic resources increase erosion and vulnerability to natural disaster.

Conclusion

Various indices such as NDVI, NDWI, NDSI and classification approaches were introduced primarily for the assessment of biophysical (e.g., Land cover and Landuse) resource evaluation of the study area. Overall, water bodies were decreased of the study area in case of indices approaches of this study and consequently salinity also decreased in those area mostly in the northern part. The northern part was used mostly for shrimp farm and nowadays, these area are used as agricultural land. On the other hand, land or mixed or bared or vegetated area were increased from 1999 to 2009 and decreased from 2009 to 2015 overall, and subsequently salinity were also decreased in those area i.e., those area were used for shrimp or salt bed before. Unsupervised classified thematic maps showed that the water bodies declined, shrimp farm or salt decreased, fallow lands including beach were also decreased, indicating more agricultural activities in this study area. On the other hand, the vegetated region was decreased but settlements area including vegetation were increased in this area. Supervised classified thematic maps showed that the shrimp cultivation and salt bed increased significantly of the study area from 1999 to 2015. Otherwise, bared or beach land and vegetation area increased overall during the study period. This study inferred that the Landsat images is quite efficient to investigate and monitor the LULC of the most important tourist spot of Bangladesh i.e., Teknaf-Cox's Bazar area.

***Acknowledgements**: We are highly thankful to the Ministry of Science and Technology of the Government of the People's Republic of Bangladesh for research grant (Sl.202, gr. 127ES, dated 26/01/2015) and USGS archives for providing Landsat satellite imageries at free of cost.*

References

Aldakheel, Y. Y., Elprince, A. M. and Al-Hosaini, A. I. (2005). Mapping of Salt-Affected Soils of Irrigated Lands in Arid Regions Using Remote Sensing and GIS. *In Proceedings of 2nd International Conference on Recent Advances in Space Technologies*, IEEE: 467–472.

Brammer, H. (2002). *Land Use and Land Use Planning in Bangladesh,* The University Press Ltd. Dhaka.

Drummond, M. A., Auch, R. F., Karstensen, K. A., Sayler, K. L., Taylor J. L. and Loveland T. R. (2012). Land Change Variability and Human–Environment Dynamics in the United States Great Plains, *Land Use Policy*, 29: 710-723.

Foley, J. A., DeFries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., Chapin, F. S., Coe, M. T., Daily, G. C., Gibbs, H. K., Helkowski, J. H., Holloway, T., Howard, E. A., Kucharik, C. J., Monfreda, C., Patz, J. A., Prentice, I. C., Ramankutty, N. and Snyder P. K. (2005). Global Consequences of Land Use. *Science,* 309: 570-574.

Garedew, E., Sandewall, M., Söderberg, U. and Campbell, B. (2009). Landuse and Land-cover Dynamics in the Central Rift Valley of Ethiopia, *Environmental Management*, 44(4): 683-694.

Gao, B.C. (1996). NDWI - A Normalized Difference Water Index for Remote Sensing of Vegetation Liquid Water from Space, *Remote Sensing of Environment*, 58: 257-266.

Giri, C., Zhu, Z. and Reed, B. (2005). A Comparative Analysis of the Global Land Cover 2000 and MODIS Land Cover Data Sets, *Remote Sensing of Environment*, 94: 123-132.

Guerschman, J. P., Paruelo, J. M., Ingrid, C. B. (2003). Land Use Impacts on The Normalized Difference Vegetation Index in Temperate Argentina, *Ecological Applications,* 13(3): 616–628.

Huang, C., Asner, G. P. (2009). Applications of Remote Sensing to Alien Invasive Plant Studies ,*Sensors,* 9(6): 4869-4889.

Hansen, M. C. and Loveland, T. R. (2012). A Review of Large Area Monitoring of Land Cover Change Using Landsat Data, *Remote Sensing of Environment*, 122: 66–74.

Jensen, J. R. (2007). Remote Sensing of the Environment: An Earth Resources Perspective, 2nd Edition. Pearson Prentice Hall.

Kausher, A., Kay, R.C., Asaduzzaman, M. and Paul, S. (1996). Climate Change and Sea-level Rise: The Case of the Coast, *In: Warrick R.A., Ahmad Q.K. (eds) The Implications of Climate and Sea–Level Change for Bangladesh*, Springer, Dordrecht:335-405.

Kibria, G. and Yousuf, H.A.K. (2017). Climate Change Impacts on Wetlands of Bangladesh, Its Biodiversity and Ecology, and Actions and Programs to Reduce Risks, *Wetland Science*:189-204.

Liu, J. (2001). Integrating Ecology with Human Demography, Behavior, and Socioeconomics: Needs and Approaches. *Ecological Modelling*, 140: 1–8.

Lambin, E. F., Geist, H. J. and Lepers, E. (2003). Dynamics of Land-Use and Land-Cover Change in Tropical Regions. *Annual Review of Environment and Resources*, 28(1): 205- 241.

Lambin, E. F. and Meyfroidt, P. (2011). Global Landuse Change, Economic Globalization, and the Looming Land Scarcity. *PNAS,* 108: 3465-3472.

Lillesand, T. M., Kiefer, R. W. and Chipman, J. W. (2004). *Remote Sensing and Image Interpretation,* Fifth ed, New York, John Wiley and Sons.

Mcfeeters,S. K. (1996).The Use of the Normalized Difference Water Index (NDWI) in the Delineation of Open Water Features*, International Journal of Remote Sensing*, 17: 1425-1432.

Prenzel, B. (2004). Remote Sensing-Based Quantification of Land-Cover and Land-Use Change for Planning, *Progress in Planning*, 61, 281–299.

Rahman, H. and Khan, Y.A. (1995). Landslides and Stability of Coastal Cliffs of Cox's Bazar Area, Bangladesh, *Natural Hazards*, 12: 101-118.

Rouse, J. W. Jr., Haas, R. H., Well, J. A. and Deering, D. W. (1974). Monitoring Vegetation Systems in the Great Plains with ERTS,*NASA special publication*, 351: 309.

Tilley, D. R., Ahmed, M., Son, J. H. and Badrinarayanan, H. (2007). Hyperspectral Reflectance Response of Freshwater Macrophytes to Salinity in a Brackish Subtropical Marsh, *Journal of Environmental Quality*, 36(3): 780–789.

Verburg, P. H., Neumann, K. and Nol, L. (2010). Challenges in Using Land Use and Land Cover Data for Global Change Studies, *Global Change Biology*, 17: 974-989.