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# Geoinformatics for Coastal Wetland Inventory of Krishna District, Andhra Pradesh

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## Abstract

Coastal wetlands include littoral zones, brackish water and estuarine regions, lagoons and coral reefs. These wetlands in the world being great ecological and economic significance, global efforts are being made to manage these resources on a sustainable basis. In addition, wetlands also play a major role in feeding and breeding areas for marine habitat and provide a stopping place for marine turtles. An attempt has been made here to map a reliable and precession thematic database for coastal geomorphology, land use and wetlands of Krishna district. For attain this, IRS LISS IV satellite data and SOI topgraphical maps on 1:25,000 scale are used. Geoinformatics tools like Remote Sensing (RS), Geographic Information System (GIS) and Global Positioning System (GPS) have been used for mapping. In recent years, RS & GIS have been proved for effective resources management and coastal environmental monitoring. Eighteen types of coastal wetlands are identified in the study area covering a total area of 1042 km$^2$. The generated spatial information on coastal geomorphology, land use and wetlands will aid in understanding the spatial distribution and extent which will ultimately help in further planning and taking in time appropriate decisions for sustainable development.

**Keywords**: Coastal wetlands, Land use, Geomorphology, Krishna Delta, Geoinformatics, Remote Sensing, GIS

## Introduction

India has a 7,500 km long coastline with numerous mangroves, lagoons, estuaries and swamps which supports rich living and non-living resources (Prasad et al., 2012). Coastal wetlands provide habitat for birds, spawning fish, and a diversity of amphibians, reptiles, insects, and plants. Mangroves make special type of vegetation found in wetlands. The pattern of wetlands that exists in a region is the outcome of continuous interaction between the given physical elements and human factor characterized by prevalent socio-cultural and economic environments. Mangrove areas today rated among the most productive ecosystems on the planet. Mangroves provide protective, productive and economic benefits to coastal communities like flood control, ground water recharge and shoreline protection. In the recent years, due to encroachment and improper usage of wetlands, they are either lost or are incapable of fulfilling their ecological functions.

Remote Sensing (RS) and Geographic Information System (GIS) in recent years have proved to be of great importance for effective resources management and coastal environmental monitoring. Geoinformatics tools like RS, GIS and GPS are extensively used for mapping, monitoring and management of Coastal Zone. These tools are used to identify boundaries of coastal wetlands, areal extent and condition of mangroves (Ramachandran, 1998). Importance of remotely sensed data for inventory, mapping, monitoring and management of coastal resources is well established (Naik et al., 2001). Nidhi et al., (2012) explained wetland delineation & mapping in coastal regions. Garg, (2013) demonstrated the use of geospatial technology for wetland assessment, monitoring and management in India. The present study attempts to provide a reliable and precession thematic database for coastal wetlands of Krishna district.

## Study area

The study area comprises the coastal belt of the Krishna district. It extends from Nagayalanka to Machilipatnam towards the upper limit, and from Gogileru creek to Sorlagondi and Nachugunta reserve forest, covering an area is about 2,256 km$^2$. The study area lies between 15°42' - 16°37' N latitudes & 80°49'

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- 81°35' E longitudes and having coastline is about 127 km as shown in Fig.1.

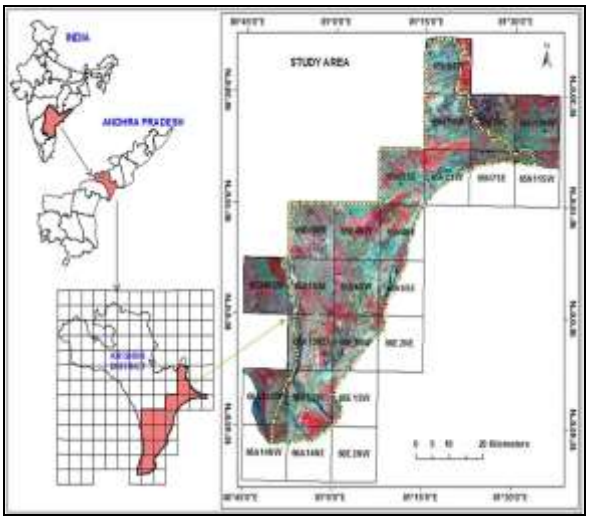


***Figure: 1. Study Area***

## Characteristics of the study area

The Krishna delta system originated from Vijayawada and extends to East and Western side of the River. The area of the Krishna Eastern delta enclosed between latitude 15°42' N-16°42' N and longitude 80°42' E - 81°36' E. The delta extended from Prakasam barrage constructed across the River Krishna. The barrage provides assured irrigation facility for nearly 4.88 lakh hectares of land both in Krishna and Guntur district areas. As far as the cropping pattern is concerned the predominant crop in the delta area is paddy and the other prominent crops are sugarcane, fruits and vegetables. The total geographical area of the delta is 6200 $km^2$, of which the Krishna Eastern delta occupies an aerial extent of 3980 $km^2$. Mostly the coastal landforms are treated that they would not have water shortage, as the depth to water table is shallow and the influence of river recharge will be quite adequate to maintain the ground water at safe levels with high potentials. But the fact is that out of 3980 $km^2$ of area in the Krishna Eastern delta 2541 $km^2$ (nearly 64%) is filled with brines/saline waters and over 630 $km^2$, (nearly 16%) is filled with brackish waters which are not suitable for drinking and irrigation of sensitive crops. The major part of the Krishna delta is a flat area with gentle slope towards Bay of Bengal. It has some undulations in the middle part of the delta in the form of deltaic lobes, beach ridges and flood plains. The highest elevation is about 16 meter above mean sea level near Vijayawada town and minimum is 3.50 m. level at Machilipatnam (Mallikarjuna et al., 2012). The general climatic conditions of the delta experiences are hot summers and cold winter. The delta region is influenced by tropical semi-arid (Dd) climate, receiving monsoonal rainfall. The rainfall of the delta is 910 mm with precipitation mainly in June through October. The temperature is 22 - 27.5 - 34ºC (Hema Malini, 1979).

## Materials and methods

Analysis was carried out by image processing of IRS LISS IV data (2005 and 2006) using ERADAS imagine 9.1 software. The Survey of India (SOI) topographical maps on 1:25,000 scale were scanned, geo-referenced and all the maps were subset and mosaic using the ERDAS Imagine environment. After applying necessary enhancement techniques, images were interpreted by using visual interpretation techniques. For mapping and segregation of units, on-screen digitization techniques are used for delineating Geomorphology, Land use and Wetlands of the study area in ArcGIS platform. Based on the information obtained from the satellite imagery and corresponding ground truth verification in the field, various categories of the wetlands have been identified. With support of the coastal geomorphology and coastal land use, different coastal wetlands have been categorized.

## Results and discussions

The intertidal wetlands of Krishna District contain productive habitats, including marshes, tidal flats, and beaches, which are essential to estuarine food webs. The distribution of these wetlands are sensitively barred for existing tidal conditions, wave energy, daily flooding duration, sedimentation rates (and types), and climate. The elevation of these wetlands in relation to mean sea level is critical for determining the boundaries of a habitat and the plants within it, because elevation affects the frequency, depth, and duration of flooding and soil salinity. For example, some marsh plants require frequent (daily) flooding, while others adapt to irregular or infrequent flooding (Teal et al., 1978). Wetlands have been delineated based on the characteristics of the geomorphology and land use.

## Coastal geomorphology

Coastal geomorphology by definition is the study of the morphological development and evolution of the coast as it acts under the influence of winds, waves, currents and sea level changes. Coastal geomorphological behavioural relates to landform features and land forming processes that are shaped by atmospheric, terrestrial and marine processes. In

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order to measure the geomorphological evolution of a stretch of coastline, it is necessary to analyze the system state in terms of nature of the coastline and its composition, Origin of the coast (antecedent conditions), Forces controlling and forcing mechanisms along the coast and behavioural characteristics of the coast.

An attempt has been made to study and map the diverse coastal geomorphic features along the study area and marked by geomorphic features resulted from various coastal and land ward processes. The geomorphic units under different heads namely, features formed by present day wave action, features formed due to sea level oscillations and features formed by rock and sea water interaction have been identified. The features were confirmed using field data as well as the earlier investigations carried out in this part of the coast (Anand Rao et al., 2006; Nageswara Rao, 1985; Nageswara Rao and Vaidyanadhan 1978; Babu, 1975). All the significant features have been mapped and these features are recorded for the benefit of future researchers. The predominant geomorphic feature is Young Deltaic Plain contributes 19.43% an account of 437.52 $km^2$ followed by Supra tidal Flat is contributes 361.92 $km^2$ i.e. equal to 16.07%. High tidal Flat and Intertidal Flat units were occupied 267.37 $km^2$ (11.87%) and 205.94 $km^2$ (9.14%) respectively. Statistical extent of each geomorphic landform of the study area is given in Table 1 and its spatial distribution shown in Fig.2 & Fig.3.

***Table 1. Statistical distribution of Coastal Geomorphic Landforms in Krishna District***

| S.No. | Geomorphic Unit | Area in $km^2$ | % to Total |
|---|---|---|---|
| 1 | Bay | 5.38 | 0.24 |
| 2 | Beach | 10.05 | 0.45 |
| 3 | Beach Ridge | 103.19 | 4.58 |
| 4 | Channel Bar | 28.58 | 1.27 |
| 5 | Flood Plain | 38.57 | 1.71 |
| 6 | High tidal Flat | 267.37 | 11.87 |
| 7 | Intertidal Flat | 205.94 | 9.14 |
| 8 | Moderate Deltaic Plain | 642.6 | 28.53 |
| 9 | Point Bar | 11.24 | 0.50 |
| 10 | Ridge Swale Complex | 33.13 | 1.47 |
| 11 | River | 66.56 | 2.96 |
| 12 | Shoal | 0.9 | 0.04 |
| 13 | Spit | 1.86 | 0.08 |
| 14 | Sub tidal Flat | 8.83 | 0.39 |
| 15 | Supra tidal Flat | 361.92 | 16.07 |
| 16 | Tidal Creek | 28.35 | 1.26 |
| 17 | Young Deltaic Plain | 437.52 | 19.43 |
| | **Total** | **2252** | **100** |

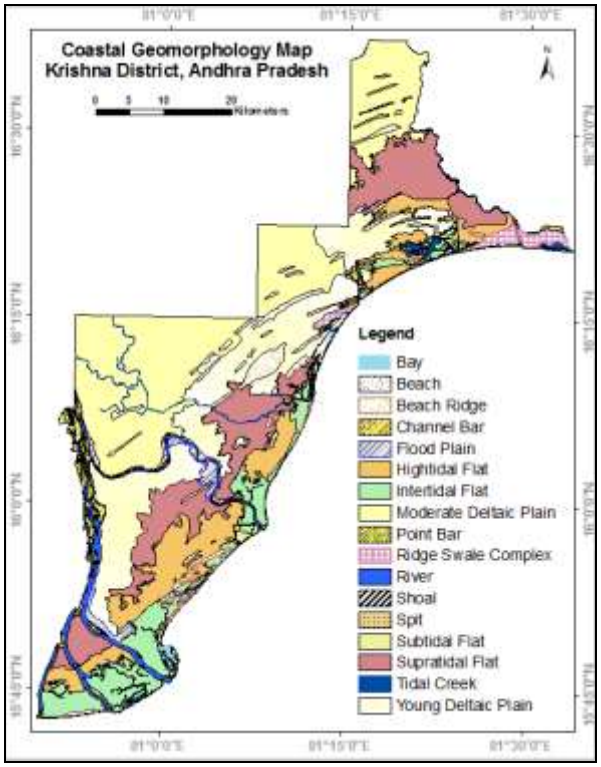


***Figure: 2. Coastal Geomorphology Map of study area***

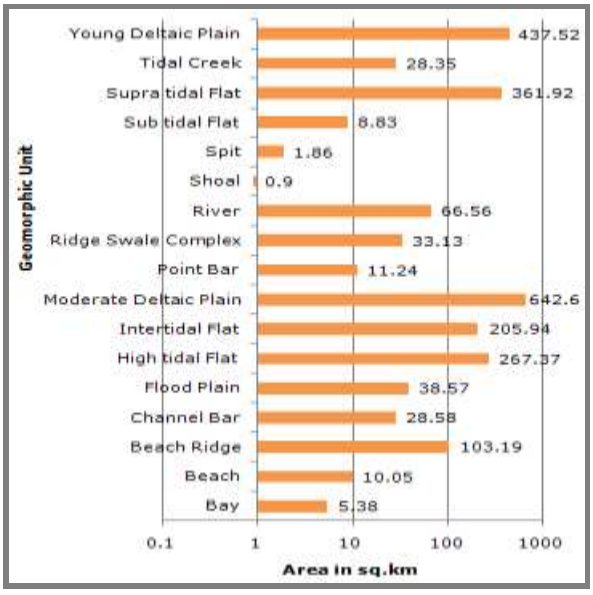


***Figure: 3. Graphical representation of Coastal Geomorphology***

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## Coastal land use

Coastal land use is one of the most required information for assessing the status of natural resources and the coastal environment. It is also essential for zonations of the coast as well as for making a sustainable coastal zone management plan. Land use / land cover changes may influence carbon fluxes and green house gas emissions, and modify land surface characteristics which may influence the climatic processes. The land cover modification and conversion may alter the properties of the ecosystems, biodiversity and their vulnerability to climate change. Thus the study of land use changes in coastal areas is essential for understanding the global environmental changes (SAC, 2012). In view of the dynamic nature of the coastal zones, it is necessary to regular monitoring of coastal land use in order to realize integrated plans for sustainable conservation of coastal areas.

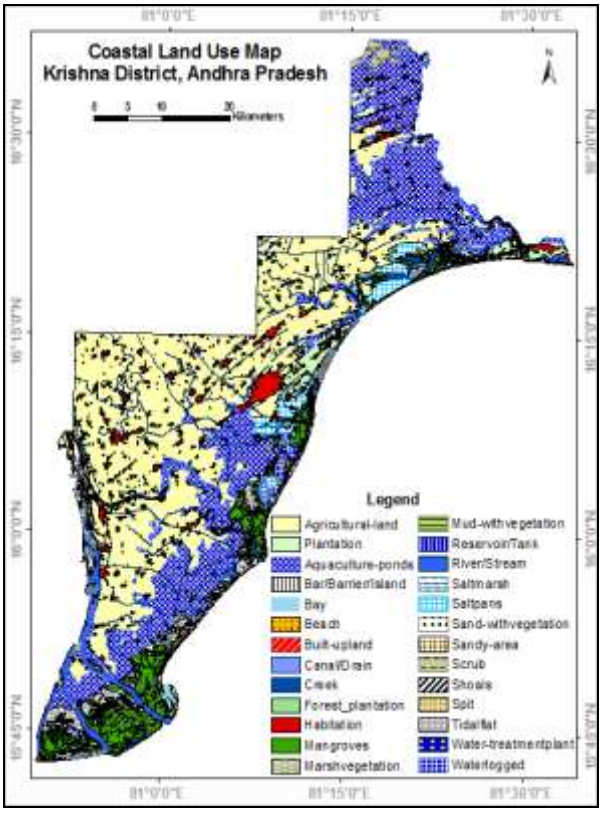


***Figure: 4. Coastal Land Use Map of Study Area***

Coastal Land use classification was done through on-screen digitization by using visual image interpretation techniques. Twenty six land use categories were identified in the study area (Table 2). The land use classes constitutes of agriculture land, Plantation, aquaculture ponds, Forest plantation, Mangroves, Marshy vegetation, Saltpans, Scrub, Tidal flats, Waterlogged, etc. According to the land use map (Figure 4), agricultural land is predominantly occupied with 45% with an area is 1018.56 km$^2$. This area is intensively cultivated and irrigated. The area occupied by aquaculture ponds is 526.53 km$^2$ which is account of brackish water shrimp culture areas (23.38%). The Mangroves category occupied is about 6.69%. 104.53 km$^2$ area occupied by habitation which is represents by human settlements. Machilipatanam is the only city and it act as district headquarters. The rest of the land use categories were presented in Table-2 and the spatial distribution of coastal land use classes shown in Fig.4 & Fig.5.

***Table 2. Statistical distribution of Coastal Land use in Krishna District***

| S. No. | Land use unit | Area in km$^2$ | % to Total |
|---|---|---|---|
| 1 | Agricultural land | 1018.56 | 45.23 |
| 2 | Plantation | 44.19 | 1.96 |
| 3 | Aquaculture-ponds | 526.53 | 23.38 |
| 4 | Bar/ Barrier/ Island | 0.51 | 0.02 |
| 5 | Bay | 4.68 | 0.21 |
| 6 | Beach | 8.73 | 0.39 |
| 7 | Built-upland | 0.24 | 0.01 |
| 8 | Canal/Drain | 17.06 | 0.76 |
| 9 | Creek | 25.44 | 1.13 |
| 10 | Forest plantation | 1.79 | 0.08 |
| 11 | Habitation | 104.53 | 4.64 |
| 12 | Mangroves | 150.67 | 6.69 |
| 13 | Marshy vegetation | 9.04 | 0.40 |
| 14 | Mud-with vegetation | 2.87 | 0.13 |
| 15 | Reservoir/Tank | 9.23 | 0.41 |
| 16 | River/Stream | 78.26 | 3.48 |
| 17 | Salt marsh | 27.16 | 1.21 |
| 18 | Saltpans | 64.73 | 2.87 |
| 19 | Sand-with vegetation | 3.75 | 0.17 |
| 20 | Sandy-area | 23.59 | 1.05 |
| 21 | Scrub | 34.1 | 1.51 |
| 22 | Shoals | 1.38 | 0.06 |
| 23 | Spit | 2.74 | 0.12 |
| 24 | Tidal flat | 75.22 | 3.34 |
| 25 | Waterlogged | 16.29 | 0.72 |
| 26 | Water-treatment plant | 0.69 | 0.03 |
| | **Total** | **2252** | **100** |

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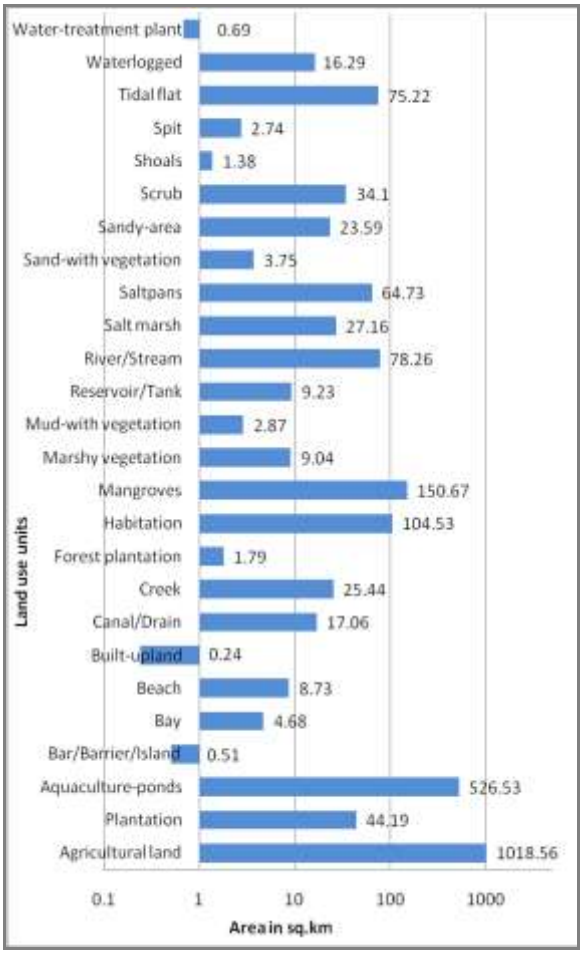


***Figure: 5. Graphical representation of Coastal Land Use***

## Coastal wetlands

Human interference with natural sediment processes and relative sea level rise are resulting in the drowning of 100 km$^2$ of wetlands every year (Gagliano et al., 1981; Nummedal, 1982). Wetlands are defined as transitional landforms between terrestrial and aquatic eco-systems where the water table is usually at or near the surface or the land is covered by shallow water (Mitsch & Gosselink 2007). Generally wetlands retain water during dry periods and keep the water table high and relatively stable. Wetlands play a major role during periods of flooding; they mitigate floods and trap suspended solids and nutrients, thereby increasing the soil nutrient factor and fertility.

From the analysis, Eighteen types of wetlands are identified in the study area covering a total area of 1042 km$^2$ includes brackish water aquaculture, bar, beach, creek, tidal flat, mangroves, waterlogged areas and marsh vegetation etc. All the above said features are of prime importance which are spatially and temporally variable in nature. The major wetland category is brackish water shrimp culture, occupying an area of 526.53 km$^2$ which is about 50% of the total wetlands of the study area. The next major land form are mangroves having an aerial extent of 150.87 km$^2$ and it accounts 14.48% (Table 3). From the analysis, it is shown that the area under brackish water shrimp culture is extremely high as much of the coastal wetlands are encroached by the local people.

The increasing trend of this brackish water aquaculture is causing severe threat to coastal environment and also to the meager coastal fresh water aquifers, much of the mangrove areas are being encroached systematically for cultivation of brackish water shrimp culture. Further these wetlands are also play a major role in feeding and breeding areas for marine habitats and provide a breeding place for marine turtles and some fish habitats also. The spatial distribution of coastal wetland categories are shown in Fig.6 & Fig.7.

***Table 3. Statistical distribution of Coastal Wetlands in Krishna District***

| S.No. | Wetland Unit | Area in km$^2$ | % to Total |
|---|---|---|---|
| 1 | Aquaculture-ponds | 526.53 | 50.54 |
| 2 | Bar/Barrier/Island | 0.51 | 0.05 |
| 3 | Bay | 4.68 | 0.45 |
| 4 | Beach | 8.73 | 0.84 |
| 5 | Creek | 25.44 | 2.44 |
| 6 | Mangroves | 150.87 | 14.48 |
| 7 | Marsh vegetation | 9.04 | 0.87 |
| 8 | Mud-with vegetation | 2.87 | 0.28 |
| 9 | Reservoir/Tank | 9.23 | 0.89 |
| 10 | River/Stream | 78.26 | 7.51 |
| 11 | Salt marsh | 27.16 | 2.61 |
| 12 | Saltpans | 64.93 | 6.23 |
| 13 | Sand-with vegetation | 3.75 | 0.36 |
| 14 | Scrub | 34.16 | 3.28 |
| 15 | Shoals | 1.38 | 0.13 |
| 16 | Spit | 2.74 | 0.26 |
| 17 | Tidal flat | 75.22 | 7.22 |
| 18 | Waterlogged | 16.29 | 1.56 |
| | **Total** | **1041.81** | **100** |

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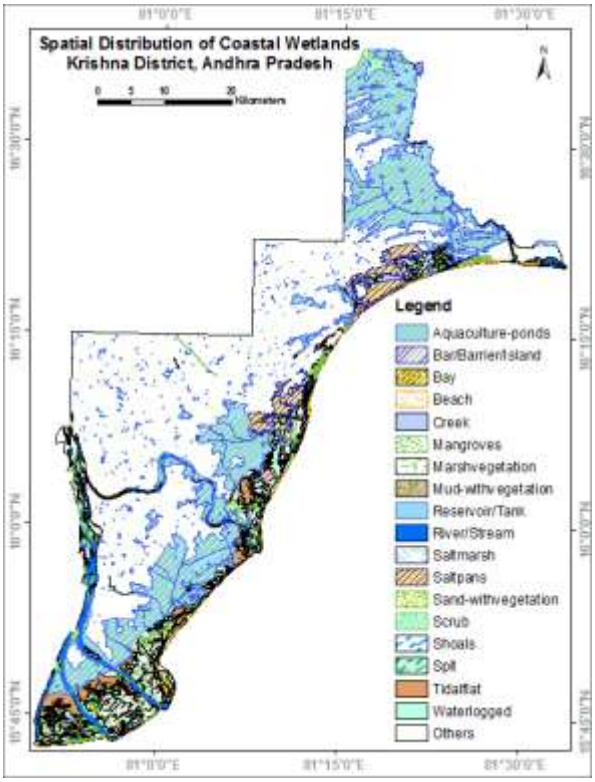


*Figure: 6. Coastal Wetland Map of Study Area*

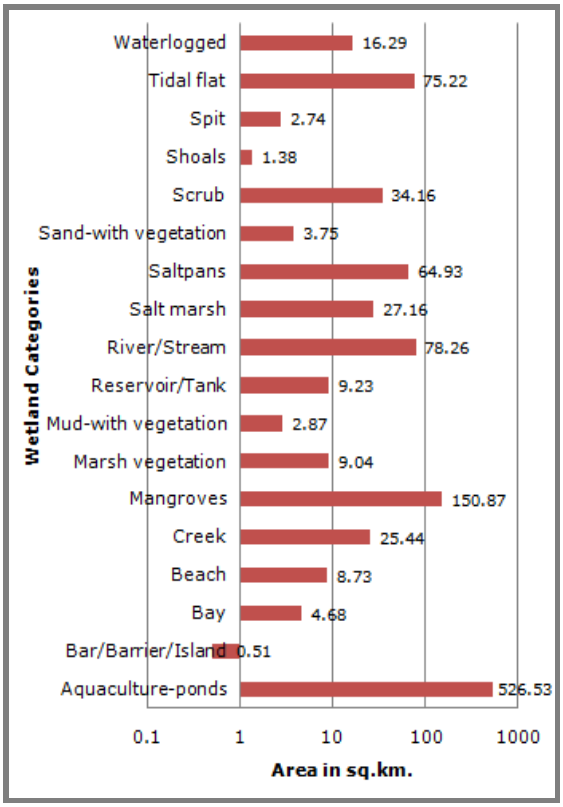


*Figure: 7. Graphical representation of Coastal Wetlands*

## Conclusions

The geomorphic processes of erosion and sedimentation, periodic storms, flooding and sea level changes continuously modify the coastal zones. Human activities greatly influence such natural processes. The coastal zone is receiving attention due to pressure of growing population and developmental activities, which are major concern to coastal zone management. Thus, the information on coastal areas related to coastal geomorphology, land use and wetlands are prerequisite. Scientific data on coastal wetlands, land use, geomorphic landforms, and shoreline and water quality are required periodically to ensure an environmentally effective and sustainable coastal zone management practices. Coastal land use and wetlands are the most required information for assessing the status of natural resources and the coastal environment. It is also essential for zonations of the coast as well as for making a sustainable coastal zone management plan.

Geospatial techniques have proved to play a critical and significant role in coastal wetland inventory, monitoring and management of such dynamic landforms, which are subjected to marine and fluvial processes. The generated information on coastal geomorphology, coastal land use and coastal wetlands will aid in better understanding the spatial distribution and extent which will help in further planning and taking in time appropriate decisions for sustainable development of the coast. Also the local people should be made aware of the importance of the wetlands and its changes.

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