A WebGIS BASED STUDY FOR MANAGING MANGROVES OF KRISHNA DELTA, ANDHRA PRADESH, INDIA

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ABSTRACT: Mangroves are one among the most productive ecosystem which provide a wide range of services to the coastal people, which includes the provision of food and timber products and coastal defense services by reducing risk from coastal hazards. Several research found that mangrove forests have been degraded throughout the world since 80s onwards due to anthropogenic factors and India is no exception for the same. The current study was conducted in the Krishna's wetland, which is located in Krishna district of Andhra Pradesh (AP), South India, India. The Mangroves of Krishna is second largest mangrove ecosystem in AP, fifth in East coast, eighth in India and it is rich in biodiversity but highly vulnerable because of anthropogenic and natural factors which makes this study area very scared. Information on Krishna mangroves and their geospatial information are owned by different institutions to build this geospatial dataset as open to access everyone. The WebGIS is a latest advancement and hybrid of GIS and Internet technologies for the dissemination of the geospatial datasets and its variations through the web. The main objective of the current study is to develop and demonstrate a WebGIS using open source software and integrate geospatial datasets of the mangroves of Krishna into WebGIS platform and to analyse and assess areas that are degraded by influenced parameters and in need of sustainable management.The result revealed that the area of mangroves in Krishna was decreased from 2,454 ha in 1990 to 1,363 ha in 2000 to 1,339 ha in 2011. On the other hand the areas of mangroves in the Krishna delta were increased to about 678 ha from 1990 to 2000 and 2,230 ha from 2000 to 2011. It may be pointed out that the variation in mangrove covers in the study area due to landuse conversion for different purposes and mangroves provides coastal defense services by reduce risk of coastal hazards. It is may be concluded that this WebGIS study is very useful and unique because it is sharing data through internet to everyone as it save money, time and data duplication, which are needed to different stakeholders such as researchers, decision makers, planners for the sustainable management of mangrove ecosystem.

Keywords: Mangrove Ecosystems, WebGIS, Spatial datasets, anthropogenic

1. INTRODUCTION

Mangroves are salt tolerant trees or shrubs, which occur in mudflats of intertidal zones of tropical and subtropical regions. They are the one among the most productive ecosystem and provide lot of benefits to the local community (Tomlinson 1986). Globally, 117 mangrove species were identified of which true mangrove species are seen in the core zone and they are about 54 species belonging to 20 general of 16 families and the rest of them were associate species as they were found in the transition zone between mangrove ecosystem and terrestrial ecosystems. Degradation of mangrove forests has become a serious problem throughout the world, mainly because of both anthropogenic and natural processes have induced major change in mangrove environment, increasing mangrove degradation in many places. Indian mangroves are also no exception for this degradation (Upadhyay et al., 2002; Selvam et al,2003). According to State of Forests Report (2011) Indian mangroves status reports has been preparing since the mid 80s onwards that has compared with assessments of the 90s, 20th and 21st centuries' which showed irregular variations. This variation is mainly

due to anthropogenic factors which includes clearing mangroves for domestic use (fuel wood, construction materials, fencing, etc.), converting mangrove land for aquaculture farming, salt pans, agriculture, urbanization, industrialization and infrastructures (Upadhyay et al., 2002). Apart from anthropogenic factor, the degradation also occurred due to natural processes such as tsunami, cyclone, storm surge, etc. To find out the changes in land use and land cover Remote Sensing and GIS are effective tools being used for mapping and monitoring throughout the world (Ramasubramanian et al.,2006; Satyanarayana et al.,2011; Jayakumaret al.,2013). But the results of all above studies had revealed that the output maps were in the form of books and reports, etc. These geospatial datasets can be able to access by only skilled GIS people who were addressed by only a few institutes such as research institutes and educational institutes. It is very hard to learn and handle by the unskilled stakeholders of GIS techniques which are difficult because of model complexity, tedious model calibration, poor in skill, lack of understanding and high costs of maintenance of the system. Though, it has a lot of benefits and advancement in technology, but the data cannot be fully utilized by the stakeholders unless otherwise if it is converted in a flexible form (Miller et al.,2004; Jayakumar 2014; Jayakumaret al.,2015).

A WebGIS is a hybrid of GIS and Internet technologies and has several advantages such as data transparency, independent platform, easy access, interactive, better visualization and cost effective and open source software used to build WebGIS, so no additional commercial software required (Jayakumar 2014; Jayakumaret al.,2015). When there is an involvement from stakeholders or local communities to address the environmental based problems which need to access WebGIS techniques would lead right solution at the earliest (Mansourian et al., 2011). Most of the stakeholders are students and scientists who have developed WebGIS for integrating geospatial datasets into it for addressing more environmental problems and solutions. Jayakumar (2014) developed WebGIS and integrated geospatial datasets of Godavari mangroves over 7 decades to assess the changes in mangrove forest and their impact in and around wetlands. Jayakumaret al.,(2015) described a WebGIS as a DSS for the management of land use and land over the change in Tiruvallur blocks of Tiruvallur district of TN (Tamil Nadu), India. Fang Yin et al.,(2009) developed a WebGIS and demonstrated a practical solution for sharing of geospatial datasets for the visualization through the web. KnoneForokoro and ZhongXie (2011) used WebGIS techniques to manage flood pastures in Lake Debo and WaladoDebo, Niger River, Mali. Paolo Manunta et al., (2008) applied WebGIS for the management of natural parks and to disseminate information in order to promote the tourist in Italia. According to Sakhare N.Pratapet al.,(2011) were developed a WebGIS and managed geospatial database of metallic mineral resources, forest cover, water resources, and land use and land cover in India. Dang ThuyBinhet al., (2015) had used WebGIS techniques to set up for the management of biodiversity data of reef fish. UsmanAkram et al., (2012) developed WebGIS and systemically mapped the wetland resources with their biological, social and ecological significance of Pakistan. Narasimharoet al.,(2014) explained of about WebGIS and integrated forest and tree resources for the planning and management of forestry sector. A WebGIS technique adopted for monitoring urban sewage pipelines to help stakeholders to take immediate action during the critical flooding situation. Above studies showed that WebGIS techniques have been used by the researchers for decision making for the sustainable management of natural resources.

In this study, a WebGIS technique is used to integrate geospatial dataset for monitoring mangroves of Krishna delta, which may be useful for the different stakeholders such as local communities and government official to take necessary action during critical time periods such as sea level rise, tsunami, coastal floods and cyclones etc...

1.1 Study Area

The present study was conducted in the delta of Krishna, which located between Krishna and Guntur districts of AP, India (Fig 1). Geographically, the mangroves of Krishna delta lie between 16° 30' and 17° 00' N latitudes and 82° 10' and 82° 25' E longitudes. This study

area is surrounded on the east by Bay of Bengal, on the North by West Godavari and Khammam district of Telangana, on the West by Nalgonda and Mahbubnagar districts of Telangana and on the South by Prakasam district. The most important economic activities of the coastal communities in the study area are agriculture, fisheries followed by trade and commerce. The River of Krishna is the fourth longest river in India and also second longest river in Andhra Pradesh, which originates in the Western Ghats near Mahabaleswar of WaiTaluk, Satara district of Maharashtra in the Western part of the state and merges into the Bay of Bengal at Hamasalladeevi in AP. There are ten major tributaries of the Krishna (Koyna, Bhima, Mallaprabha, Ghataprabha, Yerla, Warna, Dindi, Musi, Tungabhadra and Dudhganga rivers), which divides into two rivers Nadimeru and Gollamattapaya and total catchment area, length of the river are 258,948 sq km and 1,400 km respectively. According to Forest Department of Andhra Pradesh, the total area of Krishna mangrove wetlands is 15,263 ha and has the rich flora and fauna. It was declared in 1989 as the Krishna Wildlife Sanctuary (KWS), to protect the last surviving mangrove forests in the Krishna estuary. There are eight Reserve Forests (RFs) comprises by the mangrove wetland of Krishna namely Sorlagondi, Nachugunta, YelichetlaDibba, LankevaniDibba, Molagunta, Kottapalem, Kottapalem and Aduvuladivi as showedin fig 2. 12 true mangroves followed by 17 mangrove associates were identified so far and most dominated mangrove species are *Avicennia marina, Avicenniaofficinalis, Avicenniaalba, Rhizophoraapiculata, Excoecariaagallocha*and *Bruguieracylindrica*. The study area is in a tropical humid climate with hot summer and moderate winter. The maximum and minimum temperature varies from 23ºC to 33ºC and 19ºC to 23ºC throughout the year. The average highest temperature is 33ºC and hottest months include March, April, May and June. January is the coldest month and the highest temperature of the month is 23ºC. The average annual rainfall of the district is 110cm.

2. METHODOLOGY

2.1 Data Collection: The topographical maps, satellite data and WebGISopen source software were used for the study.The topographical maps at 1:50,000 scale of 66 A/13&14 and 66 E/1&2 were purchased for the year of 1976 from Survey of India (SOI). The satellite data of Landsat-5 TM (Thematic Mapper) data of 1990, and Landsat-7 ETM + (Enhanced Thematic Mapper Plus) data of 2000 and ResourceSat-1 LISS-III (Linear Imaging Self Scanning Sensor) of 2011 (cloud free data of 2010 not available) were downloaded from the U.S. Geological Survey (USGS) website (<http://glovis.usgs.gov>) and Bhuvan website (<http://bhuvan.nrsc.gov.in>). The downloaded Remote sensing data were imported to ERDAS IMAGINE 2011 software. Before the analysis, these images were corrected for distortion and adjusted to the correct scale using ground control points and rectified using Geographical Projection with WGS 84 datum. In order to assess temporal variation in the study area, all the images were visual interpreted by using onscreen digitization techniques and delineated the most important coastal wetland classes such as dense mangroves, degraded mangroves, sparse mangroves, sand, water bodies, aquaculture, agriculture, mud flat and casuarinas. Finally, these three decade areas of Krishna mangroves data were used to assess the changes in the region. The digital datasets of wetland classes were verified with ground truth survey using GPS and Google Earth maps and then finalized mangroves wetland maps.
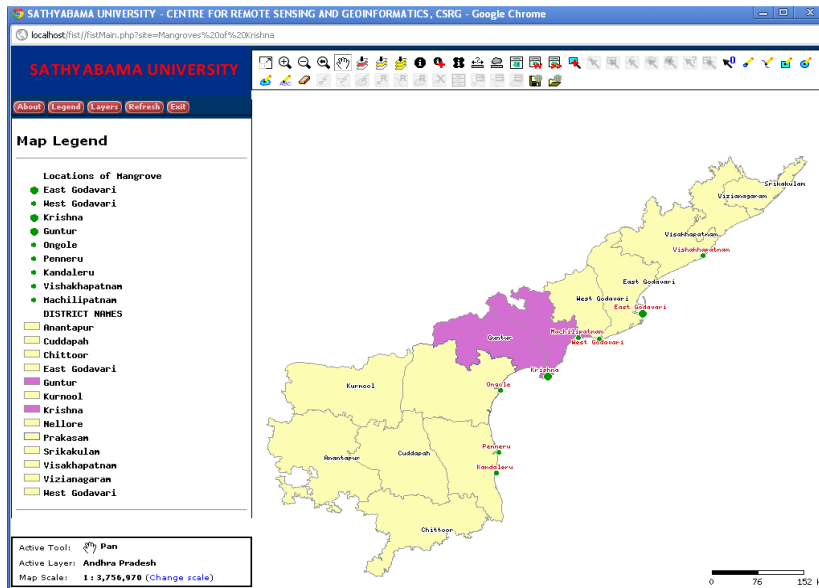
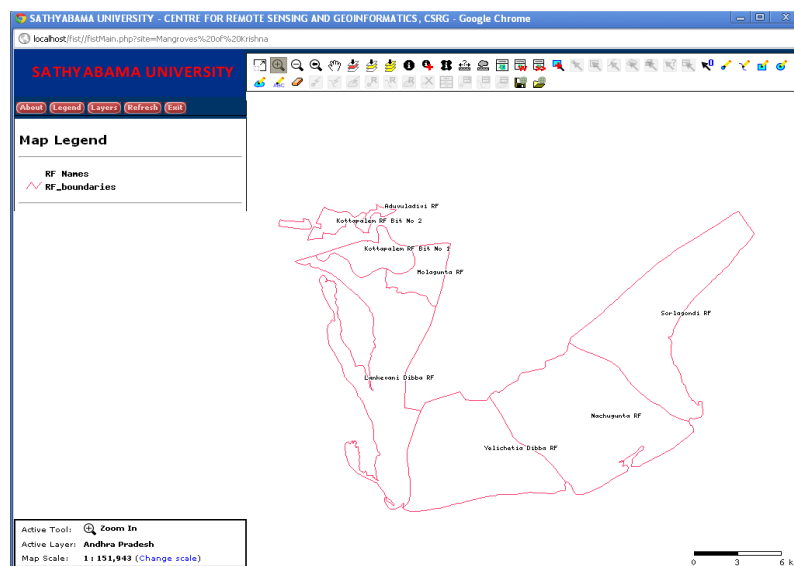*Figure 1. Study Area Map of Krishna Mangroves Delta*

Figure 2. Reserve Forests Boundaries of Krishna Mangroves Wetland

2.2 Building a Web Based Monitoring and Management Platform: In order to develop a Web based GIS, a following open source software was downloaded; MS4W, (<http://www.maptools.org/ms4w/>),
FIST(<http://190.136.181.39/fist/fistMain.php?site=example_world_win>)and PostgreSQL (http://www.postgresql.org/download/). The downloaded software was installed into the server system. The multi-tier architecture has been used and it consists of three tiers, they are application tier, middle tier and a data management tier (Fig 3). Three steps have been followed to work with open source based WebGIS. Firstly, the application tier called as client side components used to send requests to the server and to view the results. Secondly, middle tier is the heart of any solution and consists of the server side components, including the Web server and application server. Finally, the data management tier accountancy for the organization of both spatial and attribute data in the application. In some case, one

server is used as a data management tier and middle tier. In other cases, each tier can be on a separate server.
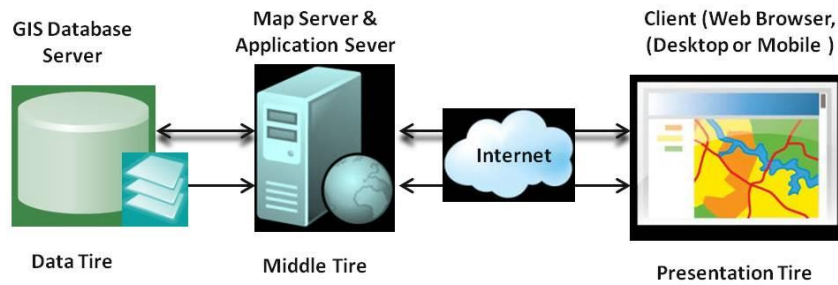

Figure 3. Basic System Architecture

3. RESULTS AND DISCUSSION

In this study, a WebGIS was developed using open source software, which is easy, simple to handle and to understand with friendly interface and one of the most effective tools for monitoring and analyzing of mangrove ecosystem for better management. This study, geospatial datasets over the 3 decades between 1990, 2000 and 2011were integrated into WebGIS platform which allows a regular change from district to villages' level depiction which are unique to WebGIS. The WebGIS proved that it has the capability of disseminating mangroves information via the internet and web browser to stakeholders. The stakeholders are students, researchers, academicians, volunteers, planners, policy makers, NGOs, Forest officials, decision makers and publics. The advantage of WebGIS includes interaction with temporal datasets, visualization, query, analysis, thematic maps display and export in the form of PDF, conversion of digital data into tables. Apart from these advantages, the WebGIS techniques also manage ownership problem, controlling duplication of datasets and makes these datasets, as data standardization and saves money and time and user friendly website to access at anytime from anywhere throughout the world. These benefits may offer stakeholders to take decision for the sustainable management of mangrove ecosystems at the grass root level. A similar study from Jayakumar and Malarvannan (2015) was conducted in Tiruvallur Block, Tiruvallur District, Tamil Nadu, India in which they had developed WebGIS techniques by using Open Source software and explained of about the advantages of WebGIS for the better management of urban land use and land cover over the period of 25 years during 1988-2013.

There are some key functional tools available alike GIS software they are zoom in, zoom out, overview map, pan, navigation tool, measurement tools, graphics, etc. The geospatial datasets of administrative boundaries, baseline data and mangrove wetlands maps for 1990, 2000 and 2011 were arranged in three numbers of folders for better understanding of spatial variation in the study area. The first folder has been holding administrative boundaries (state, districts and RFs boundaries and mangrove users in and around wetland). The second and third folders have been covered wetland maps for 1990, 2000 and 2011 respectively. Based on the user choice, the user can navigate within the map after clicking on the desired folders and files, when the user requires more details he has to go functionality tools available on the top of the main map section. Suppose if the user wants to see the spatial variations of mangrove of Krishna cover change either in 1990 or in 2000 or in 2011. The user has to select desired mangrove wetland folder, in which listed layers of mangrove of Krishna and its associated features in different colors by clicking the check box that would show the spatial variation in the respective time periods within the wetland. The maximum user zoomsthe wetland features that would get more information like km to meter level difference in mangroves cover which help to the stakeholders to take necessary action to manage the mangroves for the future. Similarly a WebGIS technique was used by Jayakumar (2014) and demonstrated for the management of mangroves in Godavari delta. In that study the author

was highlighted that the public participation from different stakeholders which may be helpful in the planning process through bottom-up of approach.

For an example how to query the area of mangroves wetland features and its associate features changes in the Krishna mangroves wetland from 1990 - 2011. When the users want to see the geospatial database of mangroves and its associates features, he must select the layers of 3rd folder, then the system shows a result of the requested in a small window. Mangroves of Krishna wetland of 2011 details are selected; they are displayed in the map, which is shown fig. 4, the mangrove user villages and RFs boundaries as used as a reference line over 2011 wetland maps. The agriculture, sand, dense mangrove, degraded mangroves, mud flat, spare mangroves, aquaculture, water bodies and casuarinasis represented by yellow, orange, dark green, red, gray, light green, sky blue, dark blue and brown colors respectively. It is easy to find the areas of coastal wetland features in 2011, which help users to anticipate the amount of mangroves covers in the near future as well.

This WebGIS study would be considered as a decision support system for users with regard to the area of mangrove of Krishna because this technique displays all the spatial and temporal changes of the study area (administrative, baseline datasets, wetlands maps of 1990, 2000 and 2011).
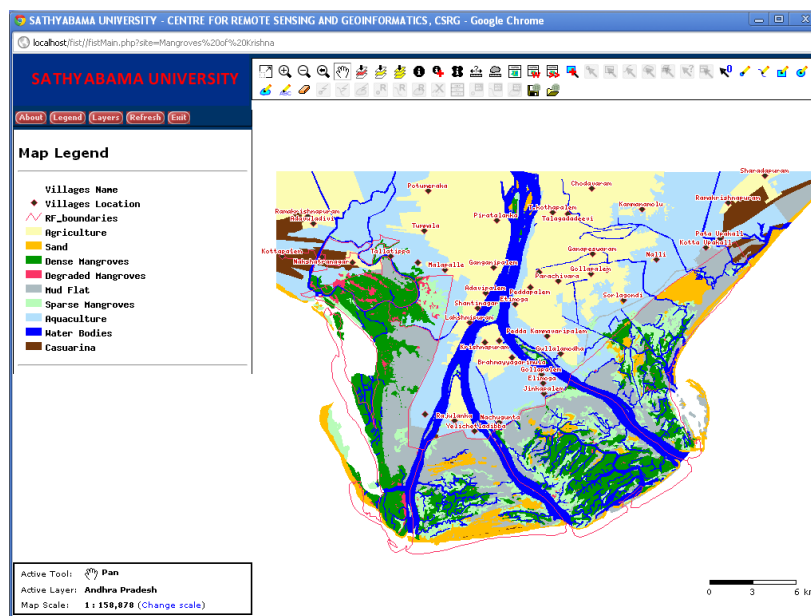

Figure 4. Mangroves of Krishna Wetland of 2011

It's invaluable for the users those whom working on the coastal zone managements. Additionally, the functional tools and they are the major function for the users such as interaction, querying, analyzing which lead mitigation, conservation, monitoring and remediation. For example, East coast of India is worst due to natural hazards include cyclone, storm, floods, tsunami and earthquake, etc. It is must require an attention in the future activities in the coastal area as it highly vulnerable and this kind of WebGIS study would help fast remedial measure during emergency periods. This was similar to Jayakumar and Malarvannan (2016) used WebGIS techniques for the management of shoreline changes, in which they had felt that this kind of the study may be reduce the risk hazards because of the public participation approach.

3.1 Mangrove Wetland Map of 1990

The mangrove wetland map of Krishna was prepared using Landsat-5 TM of 1990 satellite data. The major wetland features, namely dense mangroves, degraded mangroves, sparse mangroves, mud flat, sandy, aquaculture, agriculture, casuarinas and water bodies were

mapped and then they were added into WebGIS platform. This spatial map of mangrove of Krishna in WebGIS is shown in fig. 5 at that period of time aquaculture have come forward and mangroves were degraded and most of the land use under agriculture and water bodies. The WebGIS based map shows that the extent and distribution of mangroves in Western, Southern and Eastern parts of Krishna delta and sparse and degraded mangroves are observed both within and around the RFs boundaries.

3.2 Mangrove Wetland Map of 2000

Landsat-7 ETM+ of satellite data was used to derive mangroves of Krishna wetland map for 2000 which was incorporated to WebGIS (Fig.6). The spatial map in WebGIS depicts the coastal wetland features such as dense mangroves (10,239 ha), degraded mangroves (1,363 ha), mud flat (12,111), aquaculture (20,758 ha), sand (3,159 ha), casuarina (3,184 ha), agriculture (10,941 ha) and water bodies (13,757 ha). It is pointed out that the spatial extent of the aquaculture, mud flat and casuarinas were high at the time period in the study area.
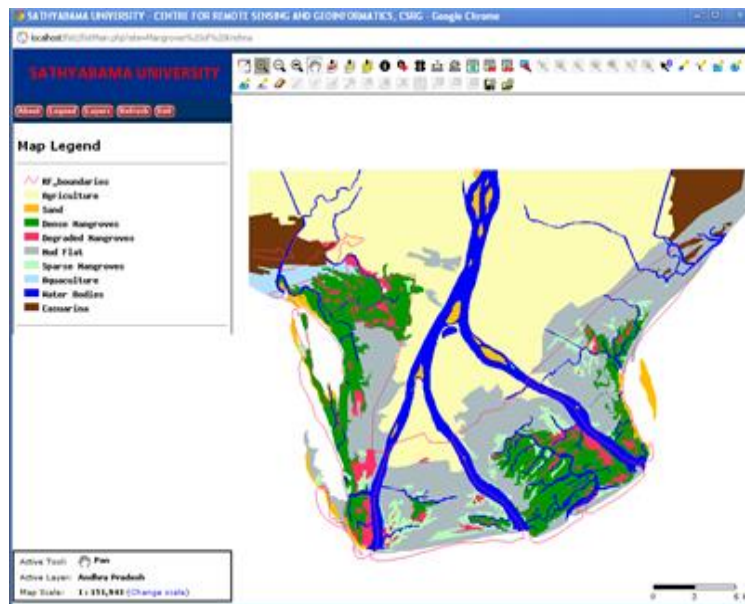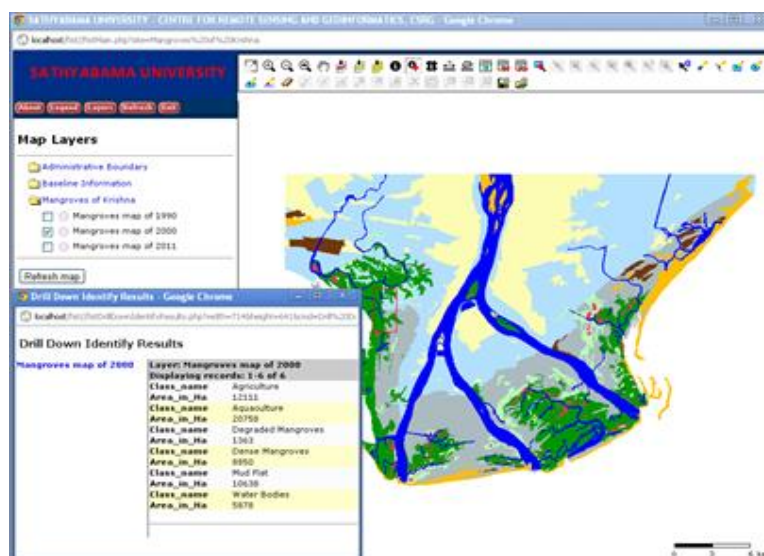

Figure5.Mangroves of Krishna Wetland of 1990

*Figure 6. Mangroves of Krishna Wetland of 2000*

Figure 7. Mangroves of Krishna Wetland of 2011

3.3 Mangrove Wetland Map of 2011

IRS ResourceSat-1 of (LISS 3) satellite data was used for delineating the wetland features Krishna mangroves for the year of 2011 (Fig. 7). This geospatial dataset of Krishna mangroves was incorporated into WebGIS platform that shows that mangroves area have been increased to 9,150 ha followed by degraded mangroves of 1,339 ha, sparse mangroves of 1,373 ha, aquaculture of 14,838 ha mud flat of 8,999 ha as showed in table 1. Apart from this, agriculture, casuarina, water bodies and sand demonstrate irregular changes. The spatial extent and distribution of mangroves represent about 23% expansion and that occurred in all the directions and found very high in the first 3 RFs. This expansion is mainly because of Mangrove Restoration Program conducted by M S Swaminathan Research Foundation, Forest Department (AP) and local NGOs in the early 20th century. Apart from this, the local people of Guntur and Krishna districts realized mangroves protective role after the tsunami and they had started the restoration/afforestation in and around RFs boundaries. It may be pointed out that due to this activity the sparse mangroves seen in the fringe wetland and they are growing stage.

3.4 Changes of Mangrove Vegetation between 1990, 2000 and 2011
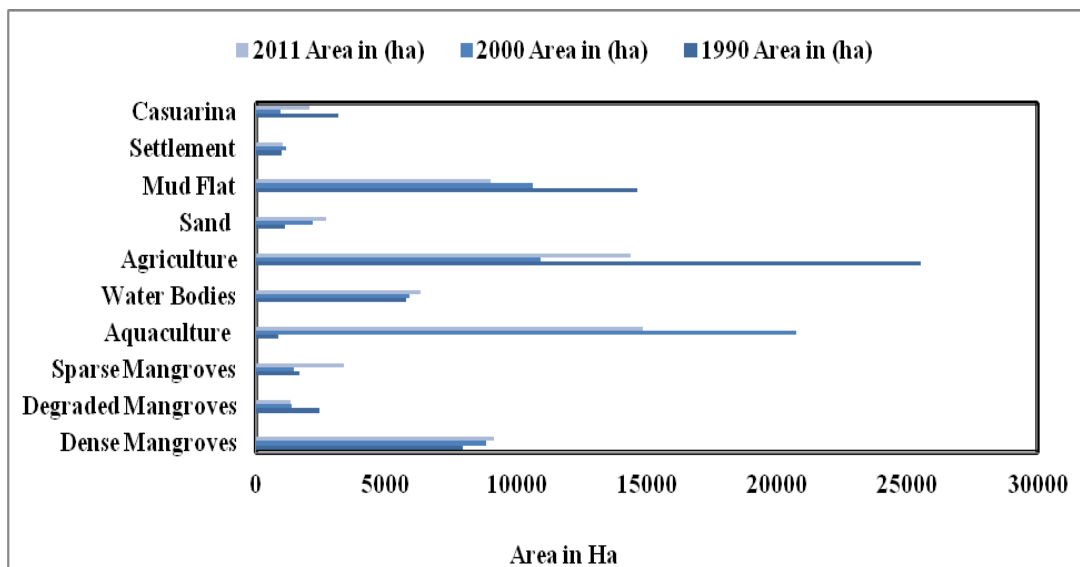
The mangrove of Krishna is highly dynamic and threatened by both anthropogenic and natural activities they played a key role for the last three decades, this was captured clearly by assisting with geospatial techniques and datasets of Krishna mangroves added into WebGIS. The total area of mangroves of Krishna wetlands is about 64,200 ha of which RFs covers an area of about 24,953 ha out of this the total area of mangrove extent is 15,263 ha declared by APFD (1989). As per the current study the extent of mangrove area is only about 9,615 ha and 10,293 ha and 12,523 ha respectively, during 1990, 2000 and 2011 (Table 1). The areas of degraded mangroves were declining to about 2,454 ha, 1,363 ha and 1,339 ha respectively in 1990, in 2000 and in 2011 (Fig. 8).

Figure 8. Landuse/Landcover changes over the period of 31 years

This was pointed out that the increasing mangroves and decreasing degraded mangroves within the wetland mainly due to the afforestation program from MSSRF, APFD, local people and NGOs.

Sl. No.	Land use /Land cover classes	1990	2000	2011	Change during Different time periods (ha)		
					1990-2000	2000-2011	1990-2011
1	Dense Mangroves	7948	8850	9150	-902	-300	-1202
2	Sparse Mangroves	1667	1443	3373	224	-1930	-1706
Total Mangroves		**9615**	**10293**	**12523**	678	2230	2908
3	Degraded Mangroves	2454	1363	1339	1091	24	1115
4	Aquaculture	863	20758	14838	-19895	5920	-13975
5	Water Bodies	5765	5878	6319	-113	-441	-554
6	Agriculture	26535	12111	15448	14593	-3456	11137
7	Sand	1128	2200	2686	1072	-486	-1558
8	Mud Flat	14656	10638	8999	4018	1639	5657
9	Casuarina	3184	959	2048	2225	-1089	-1864
	Total	**64200**	**64200**	**64200**			

Table 1. Wetland features changes areas in ha for the years of 1990, 2000 and 2011

The average rate of mangroves increase in the wetland in a year is 94 ha but if there is no interference from both man-made and natural then the original mangrove area of 15,263 will cover in another 29 years. It may be feasible with an involvement of the restoration program by local people, APFD and others with the support of RS and GIS and WebGIS techniques would play a crucial role in the planning and implementation of restoration work. Apart from the mangrove forest cover changes, the other major wetland classes such as salt pans, aquaculture farming, casuarina plantation, mud flat, sand, agricultural and water bodies also are in dynamic areas. These variations mainly because of anthropogenic factors in which land use and land cover conversion near agriculture, water bodies, mud flat, sandy and casuarina regions for salt\shrimp farming. Additionally, the natural disaster of tsunami also uprooted some casuarina trees on the coastline. A study by Gnanappazham (2007) confirmed that the degradation of mangrove forest mainly due to anthropogenic and natural factors which induce changes in the mangroves of Pichavaram wetland.

4. CONCLUSION

The mangrove of Krishna wetland is highly dynamic which undergoes significant changes due to anthropogenic and natural causes. The changes in the mangrove wetland are either with the external forces are due to the pressure within the system. WebGIS was used in the present study, which is hybrid of GIS and internet technology and which can store a large volume of a geospatial datasets and also called as it is a powerful tool for mapping and monitoring mangroves in the Krishna delta. Online GIS or Web based GIS is an effective and easiest way to monitor the changes in the mangroves of Krishna delta. Apart from this, the GIS also offers several benefits to users such as interaction, visualization, manipulation, editing and exporting maps through internet with web browser at any time and at any location. In this study open based WebGIS has demonstrated in mangrove environment and the major advantage includes reducing cost and time, controlling data duplication which make data standardization and user friendly interface. The regular updates on mangrove forest which gives immediate attention by users for scientific findings and updates which speed up the evaluation and analysis process during the disaster periods at micro level. It may be concluded that WebGIS techniques offer spatial mapping and effective monitoring of mangrove wetland, which also supports public participation interactively using the internet at any location and the technique will be of immense use for planning and management of mangrove wetland for sustained development.

5. ACKNOWLEDGEMENT

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