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Vegetation mapping and management strategy of mangroves of Bhitarkanika wildlife sanctuary, Odisha: A remote sensing approach

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ABSTRACT

Mangrove forest of Bhitarkanika constitutes a specialized eco-geographical region enjoying a different ecological status quite distinct from inland forests. In India, the mangroves of Bhitarkanika inhabit a unique and vulnerable ecosystem harbouring very rich floristic composition and occupies second most important mangrove habitat in respect of wider species diversity and quality. In the present report, the status of land use and vegetation regarding their types with dominant species composition, crown density and spatial coverage has been assessed based on the image characteristics of remote sensing satellite data. The multispectral imagery exhibits that the mangrove forest of Bhitarkanika have been subjected to rapid destruction and degradation due to ruthless exploitation, mass encroachment for human habitation and conversion of mangroves to scrubs, agriculture lands, aquaculture sites, mud or tidal flats etc. In view of the importance and uniqueness of the ecosystem, a strategy has been developed for conservation and management of mangroves integrating the resource information generated from satellite data, Survey of India topographical maps and supplementary data. In view of the immense economic potentiality of genetic diversity of mangroves at species and ecosystem level, the establishment of a mangrove genetic resource centre has been prioritized to act as mangrove heritage site in Eastern India.

Key words: Bhitarkanika sanctuary, land use, management strategy, remote sensing, vegetation status

INTRODUCTION

'Mangrove' is a word of African origin, designates an ecosystem formed by the characteristic plant communities in the intertidal region between sea and land of tropical and subtropical coasts, estuaries, deltas, backwaters and lagoons. Being ecologically interesting, strictly habitat specific, highly resourceful, inhabiting vulnerable ecosystem and exhibiting peculiar morphological and anatomical adaptations, mangroves have drawn international attention for study and conservation (Misra and Mishra, 2015). Mangroves are imposing and unique in several aspects because they resist water-logging caused due to periodic submergence by tides, wide fluctuating salinity, high humidity, high solar radiation and strong winds - a combination of characters unfavorable for other plants (Banerjee, 1984).

The mangroves have enormous physical, biological and economic significance and play an important role in maintaining the coastal ecological balance. They have high economic potentiality and utilitarian value at ecosystem and component levels (Banerjee, 1987). The mangroves are considered to be important as they (i) provide a natural barrier against cyclones and storm surges (ii) play an important role in stabilizing the shoreline and

protecting inter-tidal landscape (iii) act against encroachment by sea to control coastal soil erosion (iv) consolidate sediments and mudflats and promote the formation of new islands (v) function as shelter, feeding platform and nursery for many useful plants and animals and represent an ideal breeding ground for a number of threatened animals, birds, estuarine fish, crab and other fauna. Mangroves play a significant role in the economy of the coastal people as they fulfill the fundamental needs such as food, fuel and shelter. Besides, they provide a wide range of goods and services including paper pulp, wood and charcoal production along with support for commercial and subsistence fisheries, salt production and many others (Carugati et al., 2018). The leaf and bark yield tannins, resins and plywood adhesives; flowers of some plants produce nectars and honey and several plant parts act as fodder and traditional medicines (Misra and Mishra, 2015; Carugati et al., 2018).

Distribution of mangrove vegetation in Indian coast is mainly concentrated in the eastern sector. Out of four major Indian estuaries such as Gangetic Sundarbans, the Mahanadi, Brahmani, Baitarani, the Krishna-Godavari and the Kaveri, the Mahanadi deltaic region between Dhamra and Devi river constitutes the second largest mangal formation and harbours the richest biological diversity in terms of species content and quality of mangroves. However, the mangrove vegetation is at present under threats of extinction at an alarming rate due to over-exploitation, habitat destruction through port construction and industrial developments, mass encroachment for habitation and agriculture practice. It has resulted in shrinkage of mangrove vegetation into a fragile state which needs immediate protection and conservation.

ODISHA COAST

Odisha state has a coastline of 480 km long stretching over Baleswar, Bhadrak, Kendrapada, Jagatsinghpur, Puri and Ganjam districts and is interrupted by several rivers and rivulets of which Mahanadi, Brahmani, Baitarani, Budhabalang, Rushikulya and brackish water Chilika lake deserve special mention. This interruption has greatly influenced the coastal vegetation of Odisha to give rise to richest genetic resources of mangrove communities. The tidal and littoral swamp forests of Odisha extend from Chandipur coast in Baleswar district to Gopalpur in Ganjam district either as continuous belt or in scattered patches along the creeks and channels of estuaries. The mangrove forests were confined to erstwhile two places namely Kanika and Kujang ex-zamindari areas of Kendrapada and Jagatsinghpur districts, respectively; the former being situated along the river Dhamara and the latter in the Mahanadi delta. Littoral scrub forest with some specific plants characteristic to deltaic swamps are distributed in salt marshes near Chandipur, Dhamara estuary, Satabhaya, Paradeep, Astaranga, rocky faces of Chilika lake and also a few more localities (Banerjee, 1984).

Compared to the total of 61,294 sq km forest cover in Odisha, about 243 sq. km area is under mangroves, which are quite insignificant (FSI, 2017). However, they enjoy quite a divergent status and constitute a distinct and special type of forests among themselves. Interestingly, the flora is very rich and maximum numbers of mangrove species occur in Odisha coast in comparison to Sundarbans, Godavari, Cauvery and Andaman and Nicobar Islands (Banerjee, 1987). Occurrence of *Avicennia marina var. acutissima*, *Rhizophora stylosa*, *Sonneratia griffithii* and *Heritiera kanikensis* are new records for India and are of considerable phyto-geographical significance (Banerjee and Das, 1972; Banerjee, 1984 and 1987). However, *Nypa fruticans*, common in the Sundarbans and Andaman-Nicobar islands, reported by Haines (1921-25) from Mahanadi delta has been disappeared in due course from Odisha coast.

BHITARKANIKA: AT A GLANCE

Lying between 20° 28’ to 20° 50’ N latitude and 86° 38’ to 87° 10’ E longitude, the study area comprises of Bhitarkanika wildlife sanctuary and its neighborhood in Kendrapada district, which forms major part of mangrove forests of Odisha, India (Fig. 1). The sanctuary is bounded by Dhamara river in the north, the Hansua in the

west and the Bay of Bengal in the east and south. The river Dhamara (the confluence of Brahmani and Baitarani) in combination with Maipura, the tributary of Brahmani, constitutes the true arcuate delta criss-crossed by creeks and channels in Odisha coast. The landmass is about 2 to 10 m above mean sea level and is interrupted by a large number of meandering creeks and channels with mudflats/ tidal flats which provides an ideal niche for the formation of mangrove ecosystem. Bhitarkanika region is mostly covered with sediments of flood plain deposits. The soils are mostly clayed loam and highly slimy due to regular inundation through tidal action of the sea. The surface soil is composed of silt loam and clayey loam and about 3-4 m in depth. It has typical coastal tropical monsoon climate and average annual rainfall is about 1350 mm. The major rainy months are from July to September. The temperature varies between 10 - 45° C and humidity is high throughout the year (75 to 95%). Its prone to severe cyclonic storms almost every year during April to June and October to November.

Bhitarkanika was declared as wildlife sanctuary in 1975 to protect salt water crocodiles. The sanctuary covers 672 sq. km, out of which the core area of 145 sq. km has been notified in 1998 as National Park (Mohanty et al., 2004). The whole area including Gahirmatha coast in eastern flank of the sanctuary, functioning as a marine sanctuary since 1997 to protect olive ridley sea turtle. It has been accorded a wetland of international importance by its recognition as a Ramsar site in 2002 covering an area of 650 sq. km.

Bhitarkanika of Mahanadi delta in Odisha represents one of the finest patches of mangrove forest along the east-coast of India after Sundarbans and Andaman and Nicobar Islands. Compared to Sundarbans, the India's largest tract of mangrove forest, Bhitarkanika represents a wider species

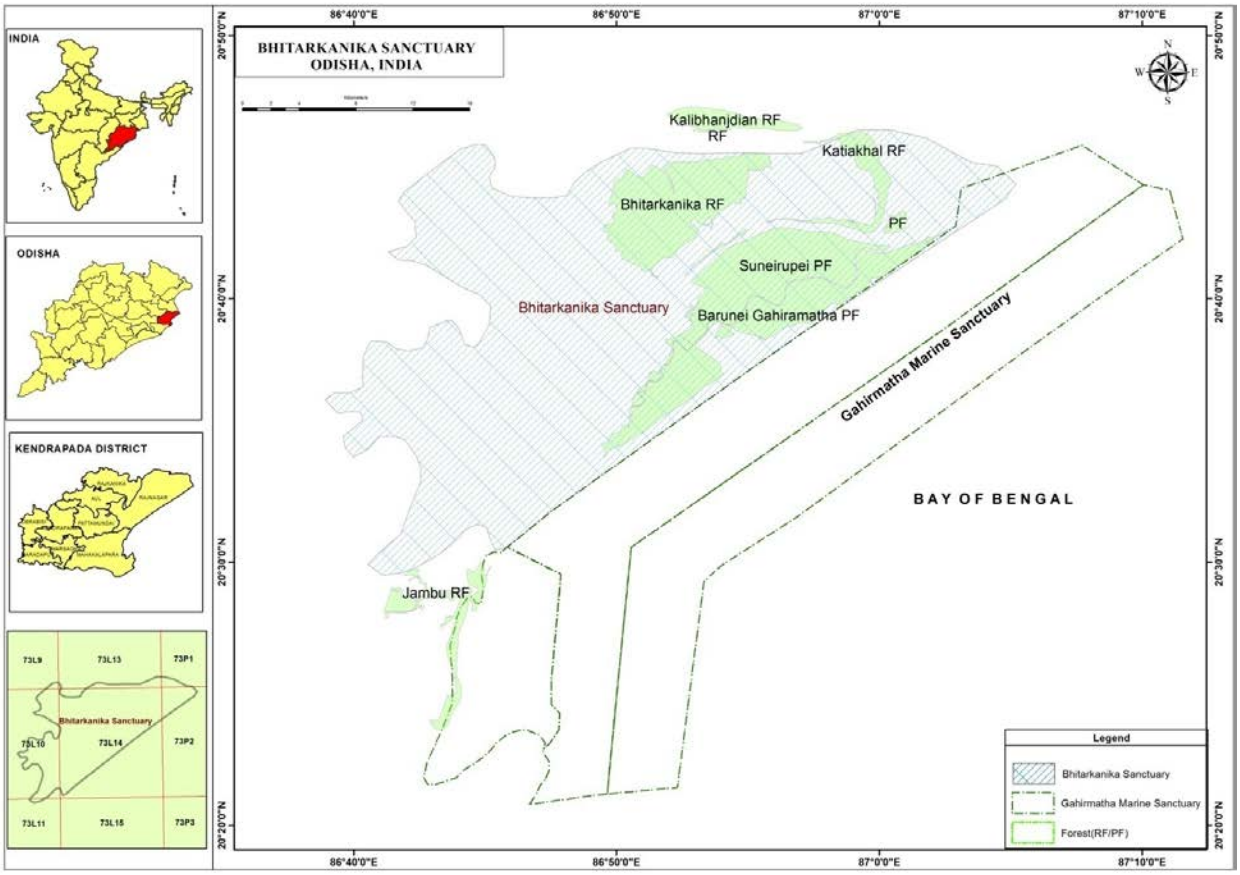

Fig. 1. Location map of Bhitarkanika wildlife sanctuary, Odisha

diversity of mangrove elements comprising of 62 species of vascular plants against 58 species in Sundarbans and out of a total recorded 64 species in India (Banerjee, 1987). The mangrove species are mostly concentrated along the network of creeks and channels and extend from the sheltered bay to the elevated banks of the upper riparian zone, where the composition of the mangrove community is high due the presence of semi-mangals and transitional mangals. Though several reports on the floristic and vegetational studies of mangroves of Odisha coast are available (Banerjee, 1984; Banerjee and Rao, 1985 and 1990; Choudhury, 1984; ORSAC, 1994; Roy, 1989; SAC, 2010). There is no/ very meager information pertaining to the conservation and management plan concerning multi-thematic approach using remote sensing technique.

DATA USED

Indian Remote Sensing Satellite F.C.C. imageries of IRS 1B LISS-II of 1995 and 1997 and IRS Resourcesat-1 LISS-IV of 2012 with 5.8 m spatial resolution in 1: 50,000 scales were referred for the study (Fig. 2). Image interpretation was carried out and the information was updated with available data to determine the status of land use/ vegetation types, crown density and spatial coverage under each type. Based on the image elements such as tone, texture, pattern, location and species association, an interpretation key has been developed (Table 1). Intensive ground truth was performed in the sampling sites of each vegetation/ land use category and in doubtful areas, and the ecological information with respect to floristic composition, crown density and species dominance in each category delineated on the map were collected and confirmed on the spot. Further, an exploration trip was undertaken for survey and

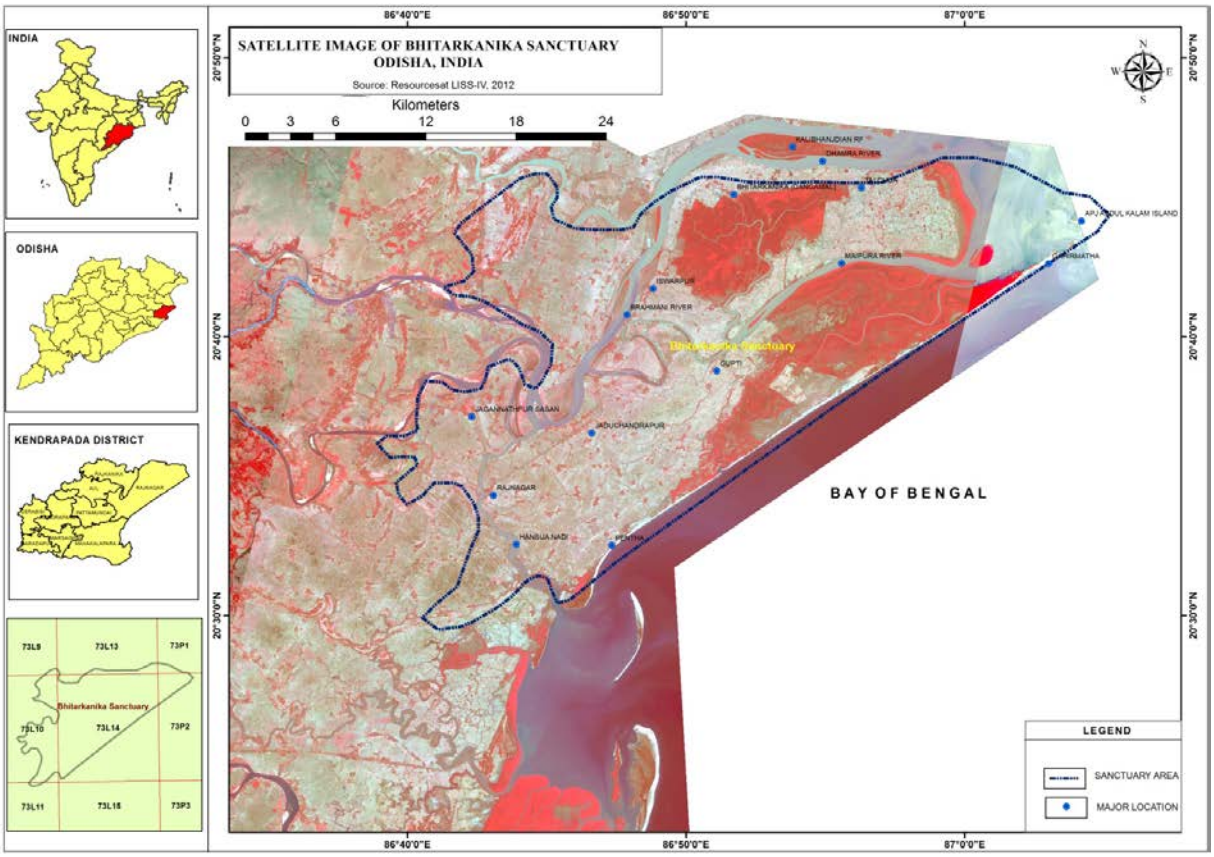

Fig. 2. Satellite image of Bhitarkanika wildlife sanctuary

germplasm collection of medicinal and aromatic plants and crop wild relatives during March, 2013. Survey of India topographical maps in 1: 50,000 scales were used in the field for locating for ground truth areas and to correlate the ground information with satellite images. Thematic information on environmental parameters such as physiography, soil types and surface texture, salinity, slope erosion status etc were collected with respect to each land use category from secondary sources and confirmed on the spot. The areal extent under each vegetation/ land use class was calculated and recorded. Integrating all resource parameters into the account, a general strategy was developed for conservation and management of mangroves of Bhitarkanika and adjoining regions.

Table 1. Interpretation key for vegetation mapping

Vegetation/ land use	Density (canopy %)	Tone	Texture	Pattern	Location	Dominant species
Dense mangrove	> 40	Bright red	Smooth	Contiguous	Intertidal/ silted creeks	*Sonneratia apetala, Avicennia marina, Ceriops tagal, Rhizophora apiculata, R. mucronata, Brownlowia tersa, Heritiera fomes, H. littoralis, Kandelia candel*
Open mangrove	10-40	Medium red	Smooth-medium	Contiguous to non-contiguous	Fringes of creeks/ islands	*Avicennia alba, A. officinalis, Aegiceras corniculatum, Bruguiera gymnorrhiza, Cerbera manghas, Ceriops decandra, Excoecaria agallocha, Phoenix paludosa*
Degraded Mangrove/ scattered scrub	< 10	Reddish brown	Medium-coarse	Frequent openings	Disturbed sites	*Stunted growth of Caesalpinia nuga, Phonix paludosa, Acanthus ilicifolius, Sarcolobus carinatus, Tamarix dioica, T. ericoides, Clerodendrum inerme, Intsia bijuga, Salvadora persica*
Mud flat/ tidal flat	< 10	Light grey	Coarse	Patchy	Estuaries/ sea water intrusions	*Acanthus ilicifolius, Ammania baccifera, Acrostichum aureum, Sueda maritima Myriostachya wightiana, Salicornia brachiata, Sesuvium portulacastrum, Porteresia coarctata, Scirpus littoralis*
Sand/ Bar	< 10	White/ (brown tinge)	Smooth	Narrow strips	Elevated foreshore	*Pandanus tectorius, Spinifex littoreus, Hydrophyllax maritima, Bulbostylis barbata, Ipomoea pescaprae, Cyperus arinarius, Zoisia pungens*
Agriculture land	-	White	Smooth	-	Encroachments and settlements	*Oryza sativa* and horticultural crops; field bunds: *Heliotropium curassavicum, Carissa spinarum, Hemidesmus indicus, Launea sarmentosa, Pandanus tectorius*
River/ creeks	-	Blue	Smooth	Dendritic	Low lying channels	Nil

LAND USE/ VEGETATION TYPES

Based on the vegetation density, degree of deforestation, physiography and overall spectral signature, eight vegetation or land cover types were identified in the mangrove forests of Bhitarkanika. The thematic details in respect of each land cover/ vegetation category are discussed below.

Dense mangrove forest

Occupying an area of 134 sq. km, the dense mangroves are mainly confined to the inner estuarine banks particularly in the central zone of Bhitarkanika, Satabhaya, Kalibhanjadian Reserve Forest, Suneirupei Protected Forest and south of Talchua point. The vegetation density is more than

40 per cent tree canopy cover and the trees attain maximum height of 25 m. The formation of two distinct tiers of canopy with stratified foliage density is the characteristic feature of this type. These might be the factors where the chlorophyll absorption is high resulting in dark red tone, smooth textural value and contiguous pattern. Species such as *Avicennia marina, Brownlowia tersa, Ceriops tagal, Heritiera fomes, H. littoralis, Kandelia candel, Rhizophora apiculata, R. mucronata, Sonneratia apetala* and *Xylocarpus moluccensis* constitute the dominant trees of top storey. The small trees, large shrubs and lianas form the second storey of which *Kandelia candel, Hibiscus tiliaceus, Bruguiera gymnorrhiza, Cynometra iripa, Flagellaria indica* and *Phoenix paludosa* are predominant. In this forest type, the soils are rich in humus and low to moderately saline. The soil texture is silty clay-loam and the slope is 1-3% with slight erosion status.

Open mangrove forest

This type of forest spreads over an area of 2.25 sq. km. This is mostly found along the fringes of defunct creeks, in small islands and forest peripheries where the vegetation density is less than 40 per cent canopy cover. The plant growth is stunted, uneven and the height of the trees reaches up 5 m. The floristic composition is very poor compared to the dense forests. Stunted growth of trees such as *Avicennia alba, A. officinalis, Aegiceras corniculatum, Bruguiera gymnorrhiza, Cerbera manghas, Ceriops decandra, Excoecaria agallocha, Phoenix paludosa, Salvadora persica* in association with shrubs like *Acanthus ilicifolius, Phoenix paludosa, Thespesia populneoides, Aegialitis rotundifolia* and *Sarcolobus carinatus* are found to occur in this type. The soil texture is silty loam with medium salinity content. The slope is 1-3% with moderate to severe erosion status.

Degraded mangrove forest/ scrub

Spreading over an area of 21.06 sq. km., this kind of vegetation is found as secluded patches inside the Satabhaya forest, Suneirupei forests, Gopalpur P.F. and Bhitarkanika R.F. where over-exploitation and encroachment are prevalent. The vegetation density is less than 10 per cent canopy cover and plants reach a height 1-3 ft. At many places, the stands become discontinuous and almost barren. The species like *Azima tetracantha, Caesalpinia nuga, Phonix paludosa, Acanthus ilicifolius, Sarcolobus carinatus, Tamarix dioica, T. ericoides, Clerodendrum inerme, Intsia bijuga, Salvadora persica, Derris trifoliata, Pandanus tectorius* and *Colubrina asiatica* are the dominant elements of this vegetation type. The texture of soils is clay loam to sandy loam. The slope of landform is 1-3% with severe erosion status.

Mud flat/ tidal flat

Salt marsh/mud flats are wide expanse of fine grained soft materials consisting of clay, silt, ooze etc and cover an area of 48.43 sq. km. These are highly rich in nutrients, thus support the growth of tidal marsh vegetation. Mud flats are inundated/ submerged during daily low/high tides and are found mostly in estuarine areas of composite delta fronts of Maipura and Dhamra rivers. These are formed due to high outflow and deposition of sediments carried away by rivers from the catchment. At many places, these tidal/mud flats are vegetated with scanty patches of a number of species such as *Acanthus ilicifolius, Ammania baccifera, Acrostichum aureum, Myriostachya wightiana, Porteresia coarctata, Phoenix paludosa, Salicornia brachiata, Sesuvium portulacastrum, Sueda maritima, S. nudiflora, Scirpus littoralis, Cyperus malaccensis* etc. Vast patches of tidal or mud flats along the river Dhamara, at the confluence of the river Baitarani and along the sea front from Dhamara estuary to Balimunda are being reclaimed for agriculture and shrimp culture purposes. The soil texture is silty-clay with very high saline content. The slope is 0-1% with very severe erosion.

Sand/ bar

Covering an area of 5.06 sq. km., these temporary marine deposits of varying width along the foreshore are formed in shallow epi-continental areas as a thin narrow strip by the action of low tide waves and currents. Their extent is increasing day by day, restricting the flow of water to sea through the channels. These sandy beaches along Gahirmatha and Satabhaya offer suitable habitat for mass nesting

of Olive Ridley sea turtle, *Lepidochelys olivacea*, an endangered animal species. The elevated foreshore of the beach at few places is occupied with a thin cover of vegetation composed of species such as *Azima tetracantha, Bulbostylis barbata, Cyperus arenarius, Hydrophyllax maritima, Ipomoea pescaprae, Pandanus tectorius, Pedalium murex, Sesuvium portulacastrum, Spinifex littoreus* and *Zoisia pungens* etc. The soil texture is sandy with high salinity in the beach areas. The slope of landform is 0-3% and erosion status is very severe.

Agricultural land

These lands presently under paddy cultivation which were once occupied with mangroves of various species. But over the years, due to over-exploitation and subsequent mass encroachment by the local inhabitants, the area was converted to the agricultural land. The texture of surface soil is clay loam or sandy loam with low salinity and the slope of landform is 1-2% with slight erosion status.

CONSERVATION AND MANAGEMENT

On account of immense biotic interference and multiple uses of mangrove species, the genetic resources are under threats of extinction. Apart from the natural threats such as cyclones and floods, the Bhitarkanika mangrove ecosystem suffers from rapid destruction and degradation due to over-exploitation, mass encroachment for human habitation and conversion of mangroves to agriculture lands, aquaculture sites and mud or tidal flats. The hectic search for new land for paddy cultivation and shrimp culture are the two major factors at present which brought once luxuriant mangrove vegetation to almost a disaster. Besides this, the mangroves of Odisha have not received adequate attention and remain totally ignored and neglected. As per remote sensing mapping estimates, it is revealed that the interesting plant communities have reached a fragile state causing a great shrinkage in the density and area and the spatial distribution of mangrove cover in Odisha for different years is indicated in Table 2.

Table 2. Distribution of mangrove vegetation in Odisha coast

Period	Area (Sq. km)	Mapping source	Data used
1972-75	234	NRSA	LANDSAT-1 MSS
1980	227	NRSA	LANDSAT-1 MSS
1984	218.75	ORSAC	MKF-6 (SALYUT-7)
1985	217.12	ORSAC	LANDSAT TM
1989	210.93 207	ORSAC/ NRSA NRSA	IRS – 1A KATE-140 pan photo
1993	199.19	ORSAC	IRS- 1B
1995	195	FSI	IRS-1B LISS-2
1996	239	ORSAC/ SAC	IRS- 1B LISS-2
1997	211	FSI	IRS-1B LISS-2
1999	215	FSI	IRS-1C/1D LISS-3
2001	219	FSI	IRS-1C/1D LISS-3
2003	203	FSI	IRS-1D LISS-3
2005	217	FSI	IRS-1D LISS-3
2009	221	FSI	IRS-P6 LISS-3
2010	233	SAC, ISRO	IRS-P6 LISS-3
2011	222	FSI	IRS-P6 LISS-3 and A-WiFS
2013	213	FSI	IRS-P6 LISS-3 IRS-Resourcesat II LISS III
2015	231	FSI	IRS-P6 LISS-3 IRS-Resourcesat II LISS III
2017	243	FSI	IRS-P6 LISS-3 IRS-Resourcesat II LISS III

The mangrove ecosystem rehabilitation programmes are being carried out world-wide for three reasons: conservation of ecosystem with their biological diversity, multiple use systems for high sustainable yield and protection of coastal areas. In this context, a strategy has been developed for conservation and management of the mangroves of Bhitarkanika by integration of major resource

parameters such as landuse pattern, vegetation cover and density, soil types and texture, salinity, slope and erosion status (Table 3). The information on the vegetation cover and density with land use pattern, slope or erosion status of wetlands of Odisha including mangroves of Bhitarkanika were interpreted from spectral data in conjunction with topographical maps and ground truth whereas other resource parameters such as soil texture, salinity, tidal inundation etc were obtained from field verification and supplementary data (Chari and Mitra, 1989; ORSAC, 1996, 1998; SAC, 2010).

Table 3. Strategy for conservation and management of mangroves of Bhitarkanika

Present land use	Vegetation density	Soil texture	Salinity	Slope (%)	Erosion status	Area (sq. km)	Proposed plan
Dense mangrove forest	>40%	Silty clay-loam	High to medium	2-3	Slight	126	Core zone
-do-	>40%	Silty clay-loam	High	1-2	Slight to moderate	8	Research zone
Open mangrove forest	10-40%	Clay-loam	Medium	1-3	Moderate to severe	2.25	Re-establishment zone
Degraded mangrove or scrub	<10%	Sandy loam	Low to medium	1-3	Severe	21.06	Re-establishment zone
Mud flat or tidal flat	-	Silty clay	Very high	0-1	Very severe (inundated)	48.43	Re-establishment zone
Sand per bar	-	Sandy	High	0-2	Very severe	5.06	Re-establishment zone
Agriculture land (encroached)	-	Sandy-loam	Low	1-2	Slight	82	Agro-forestry zone
Rivers/ Creeks/ Camp sites	-	-	-	-	-	-	Eco-tourism zone

The entire area was divided into five different zones, each with distinct objectives, activity and management plan, which were based on the latest land use pattern, vegetation status with crown density, soil type or texture, slope and erosion status (Fig. 3). The zones are described below.

Core zone

The inner dense forest of Bhitarkanika wildlife sanctuary and adjoining regions with its rich biological diversity comprises the core zone which occupies an area of 126 sq. km. This zone represents the closed high forest community due to its thick crown and stratified foliage density. Thus, the forests of this zone are to be provided adequate protection from biotic interference and there will be no activity of any sort of entry into the area. This may be a protected habitat, the conservation and management may be left to the nature alone.

Research zone

This is an isolated dense forest zone in the north of the sanctuary covering an area of 8 sq. km in Kalibhanjadian R.F., which may serve as a bench mark for future studies. The forest profile has three tiers of plant strata comprising of trees in the upper,

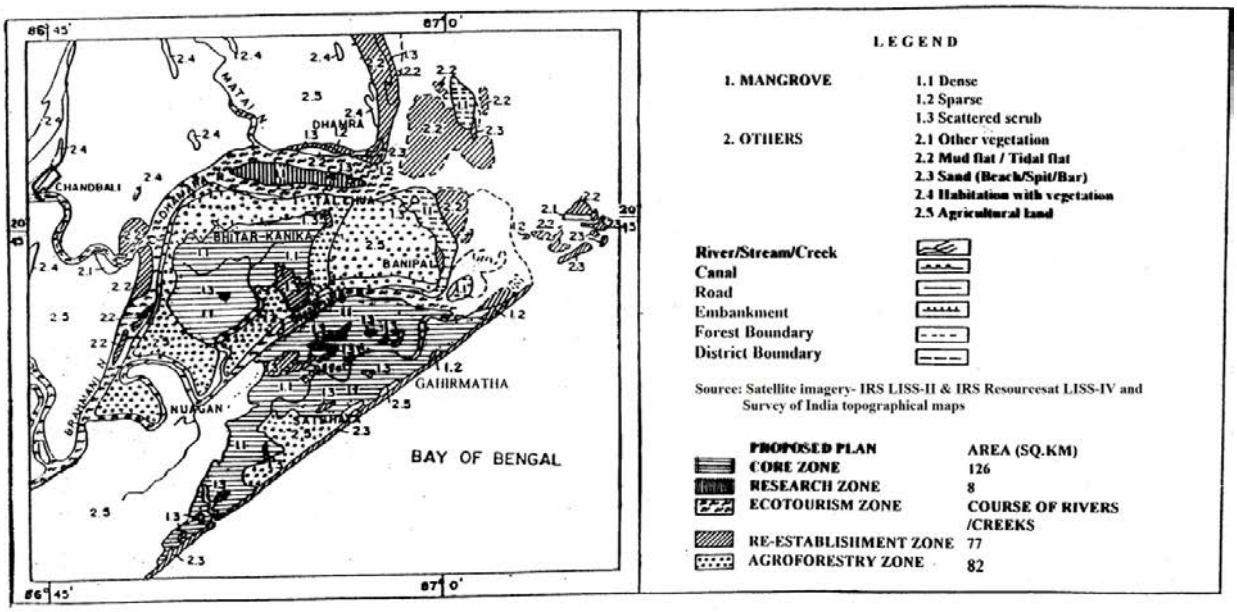

Fig. 3. Strategy for conservation and management of mangroves of Bhitarkanika wildlife sanctuary

shrubs and climbers in the middle and herbs in the ground tier. The area will be solely used for taking up research work on different aspects. Suitable institution are to be entrusted for conducting basic research on biodiversity assessment, germplasm conservation and propagation of vulnerable and rare plants such as *Rhizophora stylosa, Sonneratia griffithii, Cerbera manghas, Heritiera littoralis, Avicennia marina var. acutissima and introduction of Nypa fruticans, Acanthus volubilis and Lumnitzera racemosa*. Based on the limits of salinity tolerance of different species, large scale experiments may be undertaken for natural or artificial regeneration for different environmental conditions. The other parameters on functional dynamics such as productivity, tropic relationship, energy flow, nutrient cycling and overall generation of scientific data base may be included. Such studies would help us in understanding the relative importance of various components of ecosystem.

Re-establishment zone

All activities relating to regeneration and rehabilitation of mangroves may be taken up in degraded and unstocked mangrove areas such as mangrove scrubs, salt marshes, intertidal flats or mud flats, encroachments and other suitable locations. Since most of the mangrove species are viable to natural regeneration rather than artificial felling, hence the natural soil condition of the lands and tidal inundation should be the prime criteria to be considered before preceding the plantation programme. Revegetation of non-mangrove species in these degraded areas may cause unusual hazards and thus the ecological condition may disappear. Therefore, the mangrove species best suited to different site conditions and plants of wide salinity tolerance may be selected for revegetation. The source of plantation may be either from naturally grown seedlings or from mature propagules/ seeds. These degraded mangrove sites may act as congenial habitat for plant regeneration because the soils are rich in nutrients needed for the plant growth.

Eco-tourism zone

The eco-tourism zone may be open to the visitors who are interested in boating, wildlife and nature studies. The tourists may be allowed to have only guided tours in this area and all the rivers, nalas, major creeks, guest houses, rest sheds, observatories watch towers and related facilities may be included in this zone.

Agro-forestry zone

The encroachment area presently under seasonal agriculture inside the mangrove forest belts may be considered as agro-forestry zone which in turn may be used for agriculture and forestry purposes to provide suitable alternatives for the livelihood of the local people for production of food grains, timer, fuel wood, fodder etc with a view to reduce their dependence on the mangrove forests. In the peripheral areas along river banks and seaward fringes, artificial plantations of *Casuarina equisetifolia, Calophyllum inophyllum, Anacadium occidentale* and *Barringtonia acutangula* may show promising success. Silviculture practice of many economically important trees may be carried out to get maximum benefit from this ecosystem. Adequate environmental awareness should also be generated among the local people about the potentiality of the forest and not to exploit the mangrove trees for fuel and other purposes.

Besides this, the mangrove forests of Bhitarkanika need urgent protection from Government agencies like that of Sundarbans in West Bengal. Immediate steps are to be taken for formation of a Mangrove Development Board by the State Government which should give priority to protect and conserve the fast disappearing vegetation. Unless very stringent measures are taken to protect and maintain this precious ecosystem, the mangroves will be completely wiped out within few decades resulting in serious ecological imbalance and loss of genetic diversity. Therefore, conservation of mangrove ecosystem is necessary not only for the sake of preserving natural environment for their intrinsic value and for conservation of genetic diversity but also for gaining a better understanding of the coastal dynamics which may play a protective and productive role in the Bhitarkanika mangrove belt.

ECONOMIC IMPORTANCE

The mangrove forests have enormous economic potentiality and utilitarian value at ecosystem and component levels. The mangrove ecosystem acts as a coastal stabilizer, barrier and protective green belt to disperse the energy of cyclones, tidal bores, winds and storms in general. It functions as a feeding ground and nursery for many useful plants and animals such as providing shelter to seedlings of many species and representing an ideal breeding ground for a number of fishes, crocodiles and prawn fauna. Innumerable pneumatophores, stilt roots and stem buttresses of mangrove trees or shrubs act as substratum for a number of fish food organisms during high tides. Besides these, mangroves serve useful purposes in the coastal region viz. i) afford vegetation cover in the critical intertidal zone that would not exist otherwise and plays a crucial role in cushioning impacts of tides and fury of strong sea winds ii) prevents soil erosion iii) even though at lesser rate they produce detritus and nutrients and iv) consolidate sediments, mud banks and mud flats which promote the formation of permanent islands and significantly create a habitat suitable for colonization by animals.

Because of varying species composition and degrees of genetic diversity, the uses made of mangrove products and of the ecosystem as a whole vary from place to place. Like the terrestrial tropical rain forests, mangals play a significant role in rural economy providing a wide variety of goods and services including timber and fire wood production, support for commercial and substance fisheries, aquaculture, salt production and many others. The mangrove tree wood is highly prized for fuel wood, charcoal production and valuable timbers. The leaves and barks yield various extractives such as tannins and resins. Quite a good number of mangrove elements are economically important as sources of construction materials, edible fruits, pot herbs, fibres, pulps for paper, perfumes, fodder and in traditional medicines. The soil is best used as a fertilizer. The flowers of *Aegiceras corniculatum, Ceriops decandra, Sonneratia apetala, Brownlowia tersa, Avicennia alba* and *A. officinalis* produce profuse nectar and thus these plants act as excellent bee forage. About 25-30 quintal of honey is collected annually from the Bhitarkanika wildlife sanctuary area alone. The stem and leaves of *Phoenix paludasa* is used for roofing and thatching of houses and manufacture of ropes and brooms by the local inhabitants. The

species like *Phragmites karka*, *Porteresia coarctata* and *Myriostachya wightiana* are good source of fodder for local cattle. On the sea-ward fringe, beach and dune fixing plants like *Ipomoea pescaprae, Sesuvium portulacastrum, Salicornia brachiata, Spinifex littoreus* and *Zoisia pungens* perform the useful function of consolidating the sandy sea front. On the shallow water mass where salinity is low, *Porteresia coarctata* (=*Oryza coarctata*) is tolerant of some degree of water salinity and it has been domesticated or hybridized with *Oryza sativa* to produce cultivated varieties of rice for cultivation at salinity affected soils. High grade of tannin can be extracted from the bark of *Brugueria sexangula, Rhizophora mucronata, R. apiculata, Sonneratia apetala, S. caseolaris, Aegiceras corniculatum, Kandelia candel, Xylocarpus granatum* etc. The leaves of *Flagellaria indica* and *Myriostachya wightiana* are extensively used for basket making by local people (Misra and Mishra, 2015).

MANGROVE GENETIC RESOURCE CENTRE: AN URGENT NEED OF THE DAY

Mangrove ecosystems are reservoirs of plant and animal species and many biological aspects are still imperfectly known and not fully understood. The plant resources not only dominate the habitat and characterize the ecosystem, but also provide economic resource, which has been widely and variously used by the coastal inhabitants since ages. A number of mangrove plants are used as medicines in traditional healthcare and also as antimicrobial and antiviral agents. Many fungal endophytes isolated from mangrove species have produced some bio-active metabolites of pharmaceutical and industrial importance.

Mangrove genetic resources have been the subject of interest for plant taxonomists, ecologists, physiologists, biochemists, geneticists and breeders. Mangroves of Bhitarkanika region of Odisha coast harbor many plant genetic resources of wild relatives such as *Porteresia coarctata* (Fig. 4), *Canavalia maritima, Hibiscus tiliaceus* (Fig. 5), *Phoenix paludosa, Polyalthia korintii, Vigna trilobata* etc. have shown importance with stress tolerant genes and form the wild gene pool for crop improvement studies. Rare or endangered medicinal spp. like *Mucuna gigantea* (Fig. 6), *Cerbera odollam* (Fig. 7), *Salvadora persica, Xylocarpus granatum* and other important species like *Acanthus ilicifolius, Bruguiera parviflora, Caesalpinia nuga, Ceriops tagal, Excoecaria agallocha, Salicornia brachiata* and *Tylophora tenuis* represent the untapped wild species for production of new bioactive compounds of pharmaceutical importance. Bio-prospecting of mangrove ecosystem to conduct crop improvement programme along with isolation of high valued products like drugs, enzymes, microbial bio-fertilizers, bio-feed products of industrial utility is the need of the day. Besides, systematic research should be carried out for survey and inventorisation of plant genetic resources associated with mangrove gene pool at macro-, micro- and molecular level. There is an urgent need to collect, characterize, multiply and conserve the plant genetic resources and disseminate the scientific information about mangroves for education, research and promoting awareness among students, teachers, nature lovers, forest officials and general public (FSI, 2017; Carugati et al., 2018). Even now our studies on the mangroves of Odisha coast are far from adequate (SAC, 2010; Misra and Mishra, 2015). In view of this, Bhitarkanika mangrove forest in Odisha has a great potential for establishment of a mangrove genetic resource center to act as mangrove heritage site in Eastern India.

CONCLUSION

Indian Remote Sensing Satellite data was very much useful for assessing the vegetation status of mangrove vegetation with their dominant species composition, density and spatial distribution. The multispectral imagery showed that the mangrove forests of Bhitarkanika and its neighborhood was deteriorated to a great extent, mainly due to over exploitation, mass encroachment, reclamation for agriculture and lack of management. In this context, a general management strategy has been developed for Bhitarkanika Mangrove biodiversity using remote sensing technique and supplementary/ ancillary data. In view of the enormous economic potentiality of genetic diversity of mangroves at species and ecosystem level, the establishment of a mangrove genetic resource centre has been prioritized to act as mangrove heritage site in Eastern India.

Fig. 4. *Porteresia coarctata*, a wild relative of paddy occurs on mud flat of mangroves

Fig. 5. *Hibiscus tiliaceus*, a crop wild relative in Bhitarkanika mangrove forest of mangroves

Fig. 6. *Mucuna gigantea*, an endangered medicinal plant found in Dhamara river bank of mangroves

Fig. 7. *Cerbera odollam* a vulnerable medicinal plant in Dangmal mangrove area of mangroves

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