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Quest for Mangrovesin Anthropocene, South Odisha Coast;

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Abstract
Mangroves are estuarine swamps with foul smell, amphibian plenty, and mosquito panoramic flora that helpand sustain to mitigate climate change impacts, coastline protection, oxygen footprint, carbon sequestration and livelihoods worldwide to construct a productive and biological ecosystem. The South Odisha Coast (SOC) extends from Konark to Sonapur, Ganjam district of Odisha. The sandy stretch has been deprived of mangrove vegetation, and the coastline has been ransacked by ten intense storms from 2013 to 2024; otherwise, the ecosystem and devastations could have been possible. Literature reviews and ground-truthing in the Anthropocene (the human domination epoch) assess the issues, challenges, and feasibility of mangrove generation along the estuaries/creeks system of SOC. Necessary physicochemical studies of Soil, vegetation, and conducive environment include pH, electrical conductivity, soil organic carbon, and noxious heavy metals and radioactive metals. The GIS/RS methodology with ERDAS software has been used.History tells about the existence of mangrove ecosystems along the SOC. The areas conducive to mangrove generation have been researched, and a pertinent action plan has been suggested for growing mangroves in estuaries with a Public-Private partnership mode for coastal protection. Mangrove generation could help coastal protection, promotion of mangrove-based livelihoods, and biodiversity conservation to satisfy goals SDG 15., Life on Land (indicators 15.1.1 and 15.2.1)

Keywords: ***Anthropocene, Coastal vulnerability, estuaries, Mangroves, South Odisha Coast***

Introduction:

The Anthropocene isconsidered a geological event epoch that succeeded the Holocene epoch, in which all transformations were artificial.Homosapiens chrono-stratigraphically presided over the geo-bio-hydrosphere, including the atmosphere, somewhere during the mid-20th centuryCruzen, (2002)[1]; Waters et al. (2016)[2], Mishra et al., (2020)[3];Gibbard et al. (2022)[4],The coasts are the interface between 3 natural ecosystems: the atmosphere, the ocean, and inland fabric, where pure mangroves (PMN)and mangrove associates (MNA) and freshwater plants. Pure mangroves are salt tolerant (Halophytes) in tropical and subtropical inter-tidal zones, creeks and estuaries (25° N and 25° S lat.) in tropical and subtropical areas. Mangroves, a central floral kingdom, have encountered many challenges during the

Anthropocene by humans, climate change and natural disturbances, Mishra et al. (2018)[5]; Rudianto et al., (2020)[6]; Ferreira et al.,(2022)[7]; Nunes (2023)[8]; Nguyenet al., (2024)[9].
In addition to many well-known benefits in the dense, medium, and open mangroves in Odisha, the latent benefits include sequestering up to 8 MTs of CO2(@ 20 billion Tonnes of Carbon) 2-4 timesfaster than a mature tropical forest in one hectare of average mangrove area, a saviour of coastal habitats. About 7% of the globe's land mass is covered by mangroves, which have been lost by 50% in the last five decades.https://www.adgully.com/signature-makes-mangrove-plantations-in-odisha-on-world-earth-day-130892.html. In addition, mangroves serve as carbon sinks, natural water filters, natural disaster combating, augmenting coastal community's livelihood, ecotourism, aquaculture, ethnic/naturopathic medicines, timbers, and fodders etc. Mangrovesare among those that fix the parameters of carbon footprint, release more oxygen, and sequester more carbon thanother major coastal ecosystems. Globally, mangroves evolve about -42.8TgCy-1 (about 2.5 times the CO_2amount). The 7% mangrove losscould have been added an extra @10% to global CO2 release from tropical deforestation, Alongia et al., 2014[10]. Akram et al., (2023)[11].It has been estimated that the carbon burial rate in mangrove forests is 174 g C m−2 y−1, and in meadows, seagrass is 160–186 g C m−2 yr−1 Chen et al., (2017)[12].

Area and causes for investigation:

Odisha has a long coastline of about 549.5km with varying climates, topography, vegetation and coastal landforms comprising muddy, sandy and rocky beaches (Kanker et al., 2019[13]; Mishra et al., 2023[14]). South Odisha Coast (SOC) has become a hotbed for tropical cyclones and coastal erosion and a hotspot for anthropogenic activities, such as Gopalpur Port, fishing harbours, and ecotourism spots. The on-shore shall degrade further after the completion of projects like the Sabarimala project in Samuka City and the agglomeration of the Hotel industries. The golden sandy beach, dunes, the barrier spit of Asia's largest lagoon, Chilika, and mangrove vegetation shall be lost on the horizon.
The sheltered coastline, estuaries of the three rivers (mainly the Kushabhadra, the Rushikulya and the Bahuda), lower deltas, and barrier spits of Lagoon Chilika are comprised of two districts, Ganjam and Puri. The coastal expanse of about 150 km is biologically essential for the sandy/Rocky beach, the fragile outer channel of the lagoon ecosystem, and the Gokharakuda Olive Ridley hatchery, sheltering ground for Eurasian migratory birds and Irrawaddy dolphins. Geographically, the southern fringe is the confluence point of the Eastern Ghats belt Hills and the 85^0 ridge.

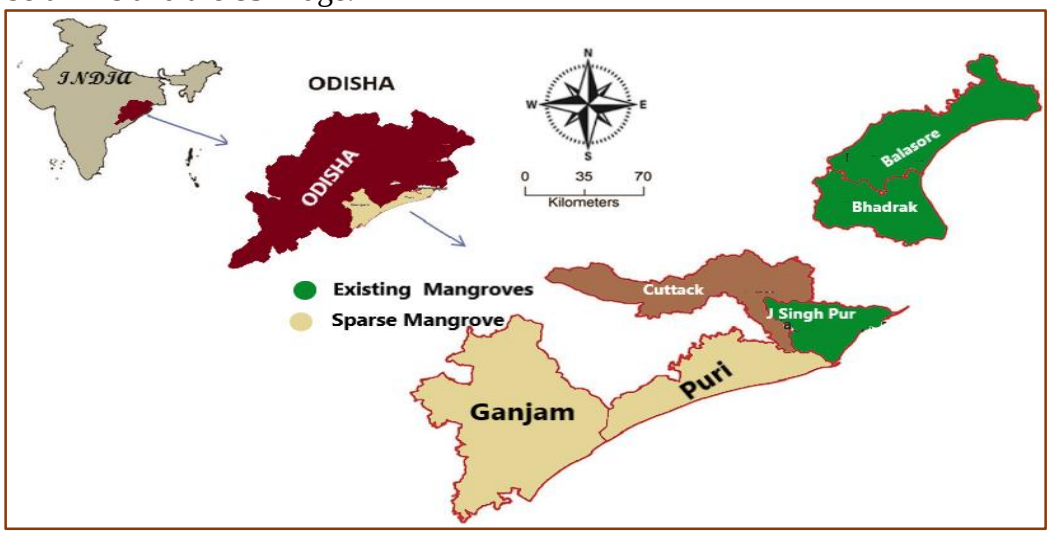


Fig 1: The study areamap of the coasts of Puri and Ganjam with sparse vegetation of Odisha

The coast is vulnerable to regular cyclonic storms, floods, droughts in the hinterland, and high waves. Mangrove forests are among the most productive and biologically essential

ecosystems for combating climate change impacts, protecting coastlines from erosion and cyclonic storms, sustaining marine ecosystems and anthropogenic intervention on the coastline, promoting the ultimate economic health, and boosting the livelihoods of coastal inhabitants. The South Odisha coast (SOC) extends from the Bahuda River mouth to the Prachi River mouth, which has been deprived of mangrove vegetation for half a century.

Mangroves along Odisha coast in Anthropocene:

The Anthropocene has transformed the climate, Soil, sea, ecosystem, and biodiversity. Humans, as per their necessity, growth, and suitability, have changed the composition of mangrove species, given the current movement of the mangrove class in the country. The impact will lead to innovative mangrove forests that meet the necessities of the medicinal forestry demand of its stakeholders.

Odisha has six coastal districts: Balasore, Bhadrak, on the north coast; Kendra Pada (K-Pada), Jagatsinghpur (J Singpur), and Puri (part) on the central coast; and the south coast, coveringthe coasts of Puri and Ganjam.Fig 2(a)

a. b.

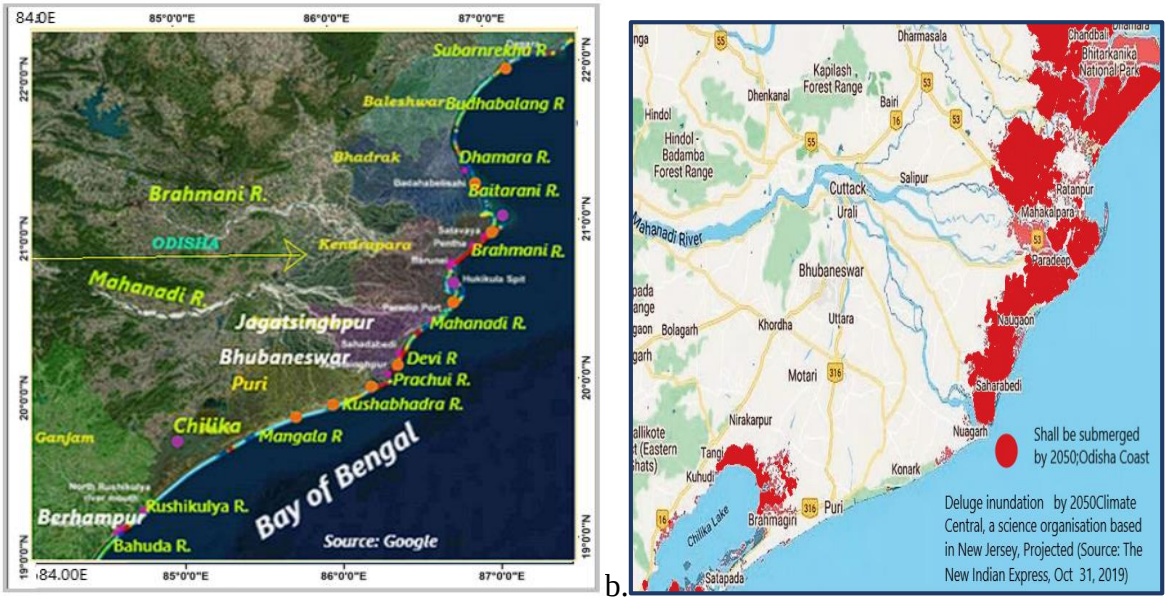


Fig 2 (a): The coastal map with the drainage system of Odisha with Chilika Lagoon (b) the projected inundation map of Odisha's coast by 2050

With the regular destruction caused by storm surges, intermittent high waves, floods, changes of strand lines, and floods added by anthropogenic stresses, the coastal lifeline is distracted and poses threats to the coastline. Generatingdune vegetation, especially mangroves,is the best way to protect against storms and high waves resulting from global warming, and regional sea level rise is the cause of the deprivation of true mangroves, Fig 2 (a-b).

Review of Literature:

To end hunger,Homosapiensmust achieve food security, improve nutrition and promote agriculture (Goal SDG -2).The mangrove'sexpanded poleward region shall increase life under water, reduce food scarcity and enrich biodiversity, ecology, and the environment during the Anthropocene epoch for sustained livelihood.They are due to high population density, modernisation, urbanisation, Industrialisation, and land use strategies,Cavanaugh et al., (2014)[15]; Zalasiewicz et al., 2016[16]; Mishra et al., (2020)[17]; Waters et al., (2023).[18]The Porewater exchange in salt pans can drivemore nutrient driving and generatemangrove-salt marsh ecotone better, Fortune et al., (2023)[19], Chen et al.(2024)[20].

Mangroves are a source of blue carbon ecosystems that support aquatic life and shelter many fish species, prawns, amphibians, shellfish, aquatic birds, phytoplankton, and zooplankton. They also maintain water quality by nutrient cyclingTailardatet al., (2018)[21]; Mishra et al., 2021[22]; Khan et al.,(2021)[23]; de Lacerda et al., (2022)[24].The threats, challenges and

players that caused mangroves to deteriorate during the Anthropocene are Urbanization, Tourism, Industrialization, salt pan activities, Timber/ charcoal making, Aquaculture (fish and shrimps), pollution, etc.Bimrah(2022)[25], Kusumaningrum et al, (2024)[26].

Asia, the storehouse of mangrove vegetation, has lost its global status, particularly in Indonesia, from 10.30 sq. km in 1990–2000 and 382.00 sq. km in 2010–2020. Indonesia lost 68 sq. km between 1990 and 2000 and 211 sq. km between 2001 and 2020 (FAO report 2020[27]). The India State of Forest Report (ISFR-21[28]), India's mangrove cover is 4,992 sq. km (bythe Mangrove Alliance, India is 4975sq. km), which is 0.15% of the country's area: where very dense 1475 sq. km (29.55%), Moderately dense 1481 sq. km (29.67%) and sparse open mangrove is 2036 (40.78%). Odisha state has a mangrove cover of 259 sq. km of mangrove forest cover (Anand et al.,(2020)[29], https://ecricc.org/status-of-mangroves/ and district-wise coverage is given in Fig3.

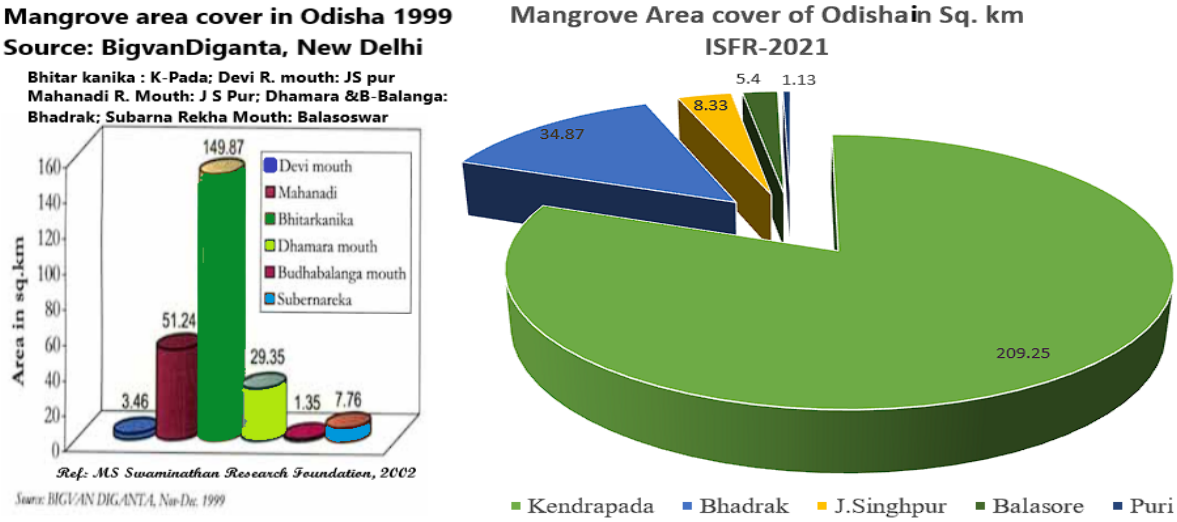


Fig 3: The mangrove status changes along the Odisha Coast estuaries from 1999 to 2021

Odisha's mangroves are rich in conserving biodiversity, stand as barriers to oceanic disturbances, provide livelihood providers, protect the coast from extreme events, and enhance the ecology and economy of its stakeholders. The M S Swaminathan School reports zero true mangrove vegetation along the south Odisha coast, i.e., the estuaries of the Prachi, the Kushabhadra, the Rushikulya, and The Bahuda rivers in districts Ganjam and Puri, in 1999. In contrast, the SOC in 2021 had 1.13 sq. km of a new generation of true mangroves.

Objective

South Odishacoast is in the trend of generation of new mangrove forests along its coasts at Prachi River estuaries, between outer channel and barrier spit at Arakhakuda and on the embankments of Palur channel near Gokhara Kuda (the Olive Ridley tortoise nesting ground). Present research. It is pertinent to have a detailed geophysical, Physio-chemical, oceanographic and eustatic investigation of the 200km SOC.,

1. Ancient History of the existence of mangroves along the SOC.
2. Change status of SOC in the 20th century and recent changes in the last 20 years.
3. Search for creeks andestuarine brackish water channels along SOC.
4. Finding Physio-chemical parameters conducive to mangrove growth in those channels.
5. The issues/ challenges confronted insapling and plantation management of mangroves.

Methods and methodologies:

The methodologies employed for data collection tools and organised action plansin the present study on the plea that:

Mangroves demand socio-economic standing, protection from erosion, and hazard mitigation in the surrounding coastal habitation and vegetation alongside the shoreline. The mangrove cover has been declining globally forabout two millennia.Odisha Forest Dept. initiated mangrove afforestation along four coastal districts: Jagatsinghpur, Kendra Pada, Bhadrak, and Balasore. However, proportionately, no attention is given to SOC generation and conservation.

1. Have ground truthing of the vulnerable landscapes feasible for ecosystem development.
2. Interviewed community leaders, SHG leaders, Misson Shakti women and FGDs with the stakeholders.
3. Desk Studies from previous literature and journals.
4. The conducive onshore areas for mangroves are degraded mud flats, creeks, estuaries, and grasslands, which are present in the SOC.
5. The laboratory and field tests use Soil and water samples along the coast.
6. A biophysical study of Soil, water, associated organisms, and Soil Organic Carbon content is necessary for interpretation in a mangrove landscape

The coastal shoreline of Puri and Ganjam district has been zoned as High, medium, low, and steady. The possible threats/challenges must be discussed with the community for redressal.Decision-making action plans are generated and communicated to society.

The coastal zone values:

The coastal zone values of SOC are richin biodiversity, multifaceted biological activity, fragile ecosystem, Rich in Flora, fauna, Avifauna and Aquafina, numerous brackish water and hatchery formany endangered marinespecies, resistive coastal interface forstorms, erosion and floods, high scenic values for tourism and recreation, rich in biological and natural resources (construction materials, housing, ethnobotany,coral reefs, sea-grass beds), cheap protein sources (fish, firewood, seafood, etc.), the source for transportation, navigation, local economy and livelihood.Above all, the mangrove forests in the littoralenvironment save carbon sequestration and conserve water and carbon footprints.

Threats along SOC:

The SOC suffers from attacks of Bay disturbances, tropical storms, storm surges, high waves, erosion/accretions, floods, climate change effects, and droughts, unsustainable harvesting of mangrove resources,which cause devastation along its coasts.The primarythreatthat the SOC is deprived of mangroves isdegradation arising from coastal urbanisation/developments, ecotourism, aquaculture, agriculture, overexploitation of mangrove vegetation, deforestation for firewood and timber and overall anthropogenic interventions like Ports, harbours, jetties, coast walls, sand mining, etc. The other associated threats are invasive species, the ports and jetties, sand mining, ecotourism, hotels in the ICZM zone, plastic/ ghost nets disposal, urban waste disposal (Solid /liquid), etc.

The physical threatshave stressed marine/ brackish water flora and fauna, including the surge in amphibians, high pollution, eutrophication, algal blooms, phytoplankton, threats to human settlement along the coast, deteriorating their economy, and deteriorated biological diversity. The socio-political fears arethat reducing marine resources shall lead to ban-period unemployment, resource scarcity, the transformations of mangroves to settlements, agriculture, habitat destruction, a backward economy, migration, and marginalisation. The fall in the economy has brewed societal unrest, political turmoil, and cultural degradation.

Challenges along SOC:

Challenges: Mangroves during the Anthropocene are combating many challenges, such as climate change, Regional Sea Level Rise (RSLR), deforestation, urbanisation, Industrialisation, pollution, eutrophication, and other anthropogenic interventions. Other challenges that can be addressed are community participation, financial instruments, and

biodiversity loss. The anthropogenic interventions are the Sagar Mala project, illegal cutting for stakeholder use, ecotourism, fishing, birdwatching, kayaking, etc. Fig 2(a) and Fig 2(b).

Growth of mangroves in Odisha

In 1944, Orissa had about 500 sq. km of mangrove forestsin different Zamindaries, but they were depleted gradually, leaving aside 211 sq. km by 1997 and, over time, only 211 sq. km. left.The Government of Odisha (GoO),State Forest Dept. from 1952, planned to plant mangroves in estuaries, creeks, and salt pans along its coastal land as part of part II of the Integrated Coastal Zone Management Project (ICZMP). Odisha had 258.98 sq. km of mangrove in 2021, which was 5.18% of India's total mangrove cover. These mangrove forests constitute a dense 80.43 sq. km, moderately dense 94.31 sq. km, and open (sparse) 84.24 sq. kmas per https://lib. icimod.org/record/35490#:~:text=Mangroves,Panda et al, (2013).[30] Das (2022)[31].

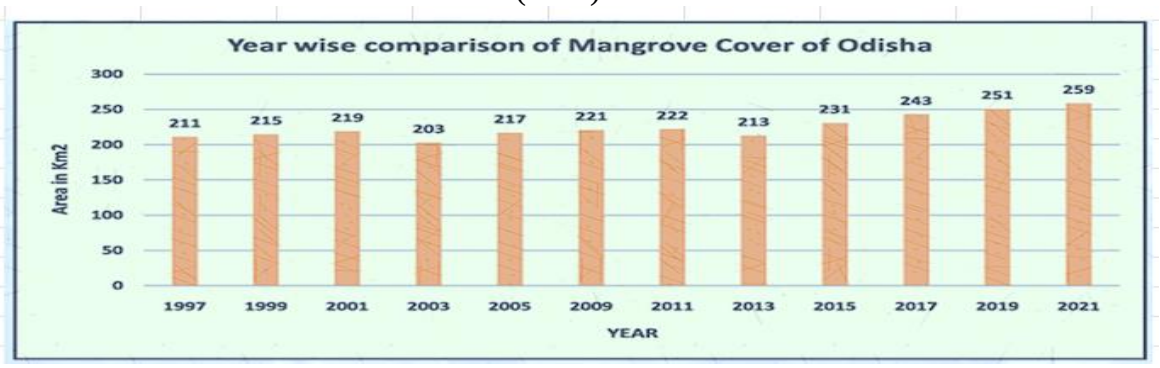


Fig 4: The annual growth of mangroves along the Odisha coast (Source: F&E Dept, GoO)

In-situ site survey

The onshore line of the Puri coast has been divided into two fragments. The river estuaries have mangroves up to the Prachi River mouth (Keluni Muhan). The southern rivers and waterbodies are the Kushabhadra R., the Nuanai, the Mangala Rivers, the Chilika Lagoon, the Rushikulya and the Bahuda Rivers. A large salt pan exists at Rambha. The rest of the intermediate coasts have dunes backed by sweet water swamps (Tampara, Samang or Sur Lakes) with MNA or dune vegetation up to Gopalpur.The dead salt marsh in Huma can have mangroves (Fig 5)

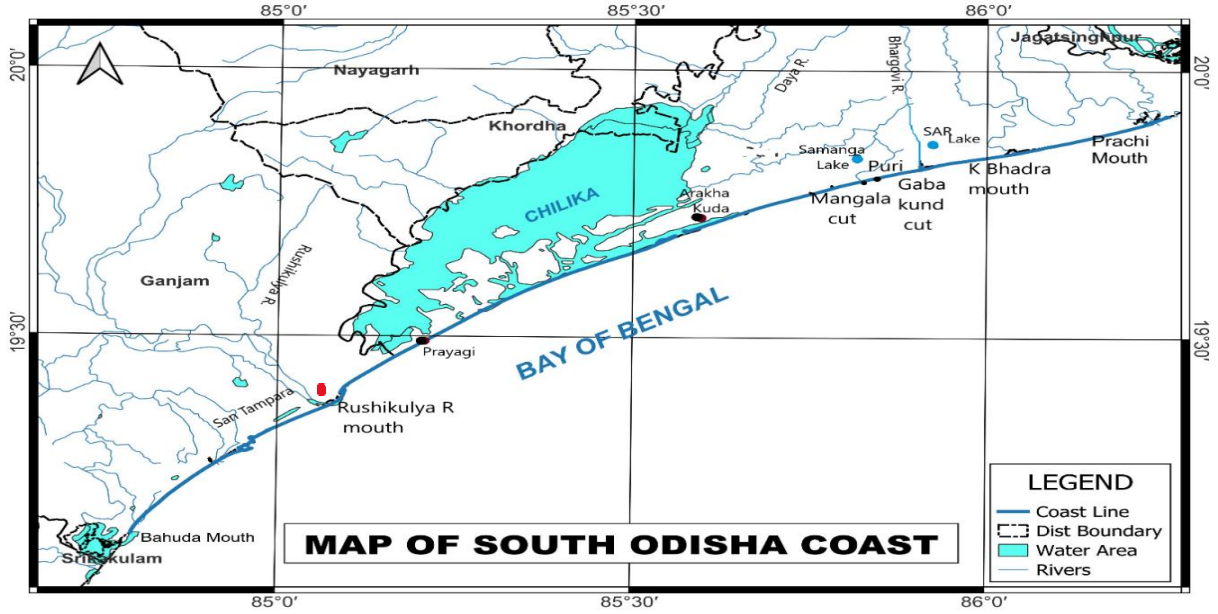


Fig 5: The map of the south Odisha coast with estuaries, Rivers, lagoons and Lakes

The southern SOC have sporadic rock cliffs of EGB Hills that plunge into the shoreline from Prayagi to Sonapur. The coast was retrograded by 2 to 3 km during the past due to climate change, the dysfunctioning of coast-parallel rivers, the Sunamunhi, the Bhargavi, and the Prachi, and a few other coast perpendicular creeks along with urban drains joining the BoB.**Types of MNG statistics:**

According to Champion & Seth Classification (1968), the mangrove forests in coastal swamps are Littoral Forest, mangrove scrub, mangrove forest, saltwater mixed forest (Heritiera) and Brackish water mixed forest (Heritiera) types. However, the Indian State of Forest Report (ISFR) has classified mangrove forests based on canopy density as very dense (>70%), Moderately dense (40%<FC<70%) and open forest (10% < FC < 40%). The suitability of the class/species of mangroves, general classification of mangroveOdiya local names (Table 1) :

Table 1: The classification of Mangroves depending on various species

Class of Mangroves	Conducive inundation	Family	Species Type	Local name
Class I	All Tides	Rhizophoraaceae	Rhizophora Stylosa Rhizophora apiculata	Rai
Class II	All Medium environment	Avicenniaceae Sonneratiaceae Rhizophoraceae	Avicennia alba Avicennia marina Sonneratia alba Rhizophora mucronata	Dhalabani Singalabani Keruana Rai
Class III (Wide spread)	Normal High Tides	Rhizophoraceae Melliacea Combretacea Euphorbiaceae	Rhizophora spp Ceriops tagal Xylocarposgranatum Lumnitzeralittorea Exoecarisagalloche	 Garani Shisumar Churanda Guan

The SOC coast is classified as category II. The Coastal track of SOC has rare mangroves but sparse Mangrove associates (glycophytes) with inland strata. Present species are Aegicerascorniculatum (Kharsi), Salvadora persica (Miriga), Pandanus (Kia), Pongamia pinnata (Karanja), and Caesalpinia bonduc (L.). Roxb (Gila, a climber), Moringa oleifera (Drumsticks), Murrayakoenigii (Curri patta) etc.

The ephemeral mangrove ecosystem consists of 71 location-specific species in Odisha based on RSLR, salinity, type/shape of the coastal swamp, and anastomosis of the inland channels with soft substrate adjacent to the coast (Fig 6 a-f).


a


b

c  d. 

e.  f. 

Fig6: (a) Prachi R. estuary; (b)Available open areas in estuaries of SOC;(c) Dunes only mouth of the debouching channel(d) The newmangrove;Chilika; (e) Gokhara Purl Ganjam (f) Near Palur canal

The SOC can grow Sonneratia apetala (Keruan),Aegialitis Rotundifolia (Banarua). Avicennia alba (Dhala Bani), Avicennia officinalis (Badabani), Bruguiera parviflora (Kaliachua), and A. marina in Chilika, particularly in the mouth region of the outer channel.https://odishamangroves.in/.

Mangroves in meadows:

The SOC has meadows used as salt marshes (salt pans) along two river estuaries: Devi River (110ha at Astaranga), Mangala Jodi (Chilika), and Rushikulya R. mouth (30 ha at Huma). These meadows are nutrient filters and have a good nitrogen cycle for salt marsh–mangrove interfaces and Benthic habitats. An example is the recent luxuriant development of mangroves (5 years old) at Gokhara Kuda, where mangroves can growFig 7(a-d).

a.  b. 

c.  d. 

Fig 7 (a-d): Conducive for mangroves in *Coarctata*meadows(a) the salt marsh at Palur canal(Ganjam) (b) Mangrove at the Prachi River mouth(c) the open plantations Keluni Muhan, Sutan Puri(d) The salt marsh at Huma.

Role of communities in SOC:

About 1.13 sq. km of sparse mangrove forest occurs in Puri District, per the India State of Forest Report 2021. However,a site visit in Oct 2023 found dense, medium and open mangroves that had been luxuriantly grown in the DeviRiver estuary. Duringfield visits between 2021-2023, a long stretch of new mangrove plantations is seen along the Prachi River estuary, Keluni mouth, and the Palur Channel towards the south of the Chilika lagoon. The Credit goes to land donors and the constant support of the Vana Samrakshana Samithi(VSS) members and the Forest Dept (FD). The role of Women Self Help Groups (WSG) in raising seedlings for FD is commendable, The Hindu,July 27, 2023 07:22 am.

History of Mangroves along SOC

Mythology/legendsnarrate the Holocene mangrove ecosystem along the SOC coast, showing that mangroves existed before Chilika Lagoon, which is from the Meghalayan period. History and radio-carbon studies also reveal that the entire coastal front was filled with Luna Jungles, either MNGs or MNAs, during pre-Holocene days. Khandelwal A., 2008, studiedsediments of core CHI 9 of ≈13,500 y.b.p(at the northern sector of Chilika) mentioned that Chilika Lagoon was anestuarine or lower delta with fresh water undergrowth. In the active period, Greenlandian and Northgrippian had pure mangrove jungles backed by mangrove associates.

With the increase in the sea level after about 9,500 YBP, the area became an estuary with mangrove vegetation. Slight variations in the sea level between about 5,000 and 2,500calyears b.p. are not visible in our pollen profile. However, the regression after about 2,000calyears b.p. caused a barrier spit and sand ridges to form, resulting in a giant lagoon, Chilika Lake. Marine influence diminished, and the freshwater impact from the rivers increased. Mangrove vegetation disappeared and was replaced by freshwater vegetation.

Geo-physical changes SOC Coast: For the last two decades, it has been observed that the dense MNGs and the MNAs are fading along with the vast dunes of vegetation. The regular landfall of intense cyclonic storms along Odisha's coast, Anthropogenic interventions along the coastal front, and climatic changes with regional sea level rise (RSLR) have a deteriorating impact on the coastline, Fig 8 (a-f)

Fig 8 (a.-f.):The present status of anastomosed estuaries and lagoons along SOC**(a)**Rushikulya estuary **(b)**Channels behind barrier spit of the Chilika lagoon c. Nuanai Mouth (**d.)**The Kushabhadra River mouth e. The Prachi River mouth f. The Devi River estuary

It is observed that if the river mouths before joining the sea are anastomosed (Creeks, drainage channels, lakes, and Islands), mangroves' growth is luxuriant at Devi R. and Keluni River mouth. If the rivers join the sea without any bends but directly, there is less chance of mangrove survival and relatively sparse Mangrove associates.

c  d. 

Fig 9 (a-d): Trials are made about the feasibility of mangrove growth along the coasts of SOC.

Suitable criterion considered:

Suitable criteria for the pre-feasibility study along the Puri Coast in the tropics are coast-parallel anastomosed channels with brackish backwater, alluvial muddy Soil, Low oxygen, wide tidal range, and High hydrogen sulphide (FAO criteria). Other wants considered are high humus, red crabs, snails, and similar inland biodiversity.Conducive conditions for the growth of mangroves are the accretional coast, estuaries, and creeks in the SOC.Mangrove growth is favourable when the estuary has brackish backwater, red crabs, and dead conch cells. The land must be covered with reed grasses, including indigo bush and Arundo donax, Fig 9(a-d)

Mangrove Ecophysiology: SOC is found in the mangrove ecosystem, which is located in the tropics. It has a favourable environmental gradient, such as a temperate zone, and favourable soil salinity.

Conducive environment: InSOC, barrier spits/coasts are backed by anastomosed channels, estuaries and creeks with brackish backwater sources, most favourable for mangrove development with red crabs, conch cells, and marine grasslands, defunct salt pans, Fig 10(a-d)

(a)  (b) 

(c)  (d) 

Fig 10 (a-d): Conducive edaphic factors from ground zero to transformations of pure mangroves

Multi-Stressenvironment adaptations: The channels, estuaries, and creeks backing the coastline are flood-tolerant embankments with an organic matter-rich hypoxic substrate and interstitial water osmolality with cellular salt segregation. Other favourable environments are propagule dispersion from nearby mangroves.

Salinity and Nutrients with structural development: SOC is considered to have impressive growth if the mangrove variety is dwarf rather than stunted like Sundari. The SOC coast has different water use efficiency and photosynthesis of scrubs, dwarf, and stunt mangroves. The shrubs and dwarfs may be tried along SOC, mainly withRhizophora forests.

Global carbon fluxes and climate change: The estuarine coast is conducive in soil organic carbon (SoC), temperature, regional sea level rise, rainfall, etc., and lies within the climate gradient of south and north stretches, indicating the possibility of mangrove SOC growth Lugo et al.,(2014)[32]; Mishra SP., (2018)[33]

The initiatives for mangroves

Various sites, from the Devi River Mouth to the Bahuda River mouth along the SOC coast, were surveyed, and staff from the State Forest Department and the adjoining communities interacted with them. Along the interface, with the help of the Vana Samrakshana Samithi(VSS) members, the Forest Department (FD), and Women Self-Help Groups (WSG), some NGOs, and some wetland people have participated in mangrove forest generation.

The Government of Odisha (GoO) transformed the ownership of mangrove forests from the Zamindars to the State Forest Department (OSFD) in 1952. The OSFD has tried to preserve the mangrove forests as per the Coastal Regulation Zone (CRZ) Notification, 2011, Ministry of Environment and Forests (MOEF&CC), amended 22.03.2016)CRZ-I,–A, notification. For Mangroves, if the area is more than 1000 sqm, a buffer of 50 m mangroves shall be provided;http://www.environmentwb.gov.in/pdf/CRZ-Notification-2011.pdf.

Mangrove plantation has been prioritised along onshore and on kaputt salt pans with the assistance of people from the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) and Compensatory Afforestation Fund Management and Planning Authority (CAMPA) Fund and other sources.

The True Mangrove Species

The SOC coast can be expected to have the potential to plant *Rhizophora(*Rai), *Coecaria*(Bandari or Kalia Chua), *Sonneratia* (Orua, Keruana), NypaFruticans(Mangrove Palm), Kandelia candle (L.) Druce, (Sinduka) *Sonneratia apetala* (Keruan), and *Aegialitis rotundifolia* (Banarua). *Avicennia alba*(Dhala Bani),*Avicennia officinalis* (Badabani), and *Bruguiera parviflora* (Kaliachua) have grown in the northern/ southern part of the SOC.Species like *Ceriops decandra and Sonneratia alba*grow in sweet water along the Odisha coast buthave a competitive growth in saline settings, such as the Odisha Forest dept. GoO.

The river mouths of the Devi R. and the Prachi,creeks, drainage channels, lakes, and Islands have mangrove growth and mouths along SOCFig 8 (a and b).The SOC coast is becoming vibrant and affecting the coastal landform and the ecosystem. However, the formation of lateral channels is conducive to the growth of mangroves by the sides of these channels (Fig. a-d) (Mishra et al., 2023[34]).

Climatic factor: SOC experiences a humid, tropical climate, receiving about 1400mm of rainfall annually. Warm air frequently damages naturally growing grasses, shrubs, and Pandanus tinctorius. After the slam of the extremely severe cyclonic storm, "Fani," the area's flora, fauna, and topography were massively destroyed, reducing the height of the vegetation. Tourism growth along the coastal front has deteriorated the beach landscape due to vegetation cutting.South Coastal Odisha (SOC) is a hotbed for cyclonic storms (CSs) formed in the Bay of Bengal (BoB). About 44% of cyclones formed in BoB slam the Odisha Coast. About 75% of the total CSs during pre/post-SW monsoon hit within the Visakhapatnam—Paradip coast, causing devastation either during landfall or passing near the offshore. The woes and fatalities increase if the CS is added to the high frequency of 10 severe cyclones in the last 12 years.

Edaphic factor: There are two main types of Soil in this region of the Bay of Bengal coastal zone: sandy Soil and sandy loam. The pH of different soils is generally alkaline (pH>7.0). During high tides, soil salinity rises parallel to the adjacent marine water. After ebb tides, the salinity depletes due to the inflow of river water. The favourable places that can be selected for the plantation of Mangroves are red crabs, Crunch, and jellyfish, Fig 7 (a-d).

Estuarine Fallow lands for mangroves.

Some estuaries in SOCare housed in the lower deltaic regions. The OSFDhas undertaken massive Casuarina/cashew-nutplantationsbounded by sandy onshore areas. Severe cyclonic storms like Phailin, Hudhud, Fani, and Amphan have ransacked the vegetation, Fig 11(a-b).

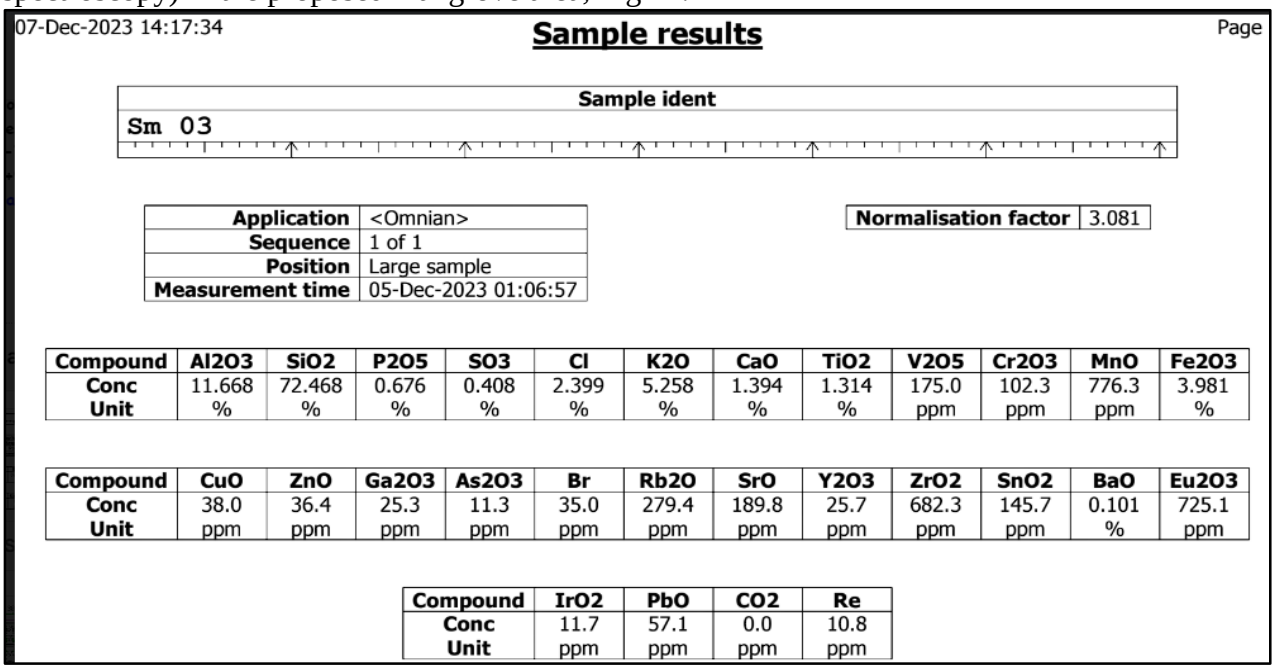
Fig 11 (a -d): Proposed nursery areas for mangrove planting (under tidal submergence)

Steps for identifying, quantifying, and reducing these dependencies on mangrove forests have been taken to replace the mangrove associates (sporadic), but they have become successful. This is possible by providing alternate sources of livelihood and employment generation through eco-development programmes.

The Laboratory supports

These indicators help measure the intervention's effectiveness and urge nature-based solutions rather than structural resolutions. The development of appropriate interventions: As part of the Baseline study, data that guide the growth of suitable mangrove plantations and dune vegetation were collected and gathered. This data will help detect the target population's requirements and provide insights to develop effective interventions.The following laboratory tests with ground verification were conducted to identify the appropriate intervention area.

Table 4: The assessment of the nonmetal/metals/heavy metals and REEs in Soil (XRF spectroscopy) in the proposed mangrove area, Fig 12.



07-Dec-2023 14:17:34 **Sample results** Page

Sample ident

Sm 03

Application	<Omnian>
Sequence	1 of 1
Position	Large sample
Measurement time	05-Dec-2023 01:06:57

Normalisation factor	3.081

Compound	Al2O3	SiO2	P2O5	SO3	Cl	K2O	CaO	TiO2	V2O5	Cr2O3	MnO	Fe2O3
Conc	11.668	72.468	0.676	0.408	2.399	5.258	1.394	1.314	175.0	102.3	776.3	3.981
Unit	%	%	%	%	%	%	%	%	ppm	ppm	ppm	%

Compound	CuO	ZnO	Ga2O3	As2O3	Br	Rb2O	SrO	Y2O3	ZrO2	SnO2	BaO	Eu2O3
Conc	38.0	36.4	25.3	11.3	35.0	279.4	189.8	25.7	682.3	145.7	0.101	725.1
Unit	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm

Compound	IrO2	PbO	CO2	Re
Conc	11.7	57.1	0.0	10.8
Unit	ppm	ppm	ppm	ppm

Fig 12: The sample results from the X-ray fluorescent Oscilloscope of the collected soil sample

Compatibility for mangrove plantation

From the literature review and the Indian Standard codes about Mangrove plantations, the followingphysicochemical property ranges and theirconditions are needed to generatemangroves—the suitability of mangroves in the lands as per laboratory results in Table 5.

Table 5: The fitness of Phisco-chemical parameters for the growth of mangroves (Odisha coast)

#	Parameters	IS code followed	Observation value (250)	Conducive range mangrove	Reference
1	pH value	IS 3025(part 11)-2022	6.82	6.7 and 7.3 at 230C	Su et al., 2020
2	Temperature		15–25°C	29-350C	For mangroves
3	Climate	Tropics / Sub-tropics	Lati: 19° 51' N; & Long: 86° 04' E	25º North and 25º South	
4	Electrical Cond. (EC)	IS 3025(part 14)-2022	10350µS at 250	ranged 16.23 to 33970 µS/cm	Rahman et al., 2013

5	Turbidity (NTU)	IS 3025(part 10)-2023	246 NTU	5.44-10.67 NTU	Tori man; WASJ 28(9) 2013
6	Salinity		varies	3 to 27 ppt	Smithsonian
7	Biological oxygen demand (BOD)	IS 3025(part 44)-2023	41 at 270C for three days)	2.65-4.46 at five days	Mizwar et al 2020 IOP: Earth Env. Sci. 448 012126
8	Soil Organic Carbon (SOC)	(CRZ) Notification (2019)	Av 2 mg/gm(proposed site)	Ranges from 0.4 to 1.5%,	(Rahman et al., 2021)

Vulnerability Assessment:

The present nation's goals (SDGs) are to coordinate and allow for integrating climate justice and environmental resilience across India by applying a humanitarian approach, locally lead adaptation and resilience, with other ecosystem links, and community nature-based solutions with advocacy, Spalding et al.(2014)[35], Pfiegner et al., (2018)[36]

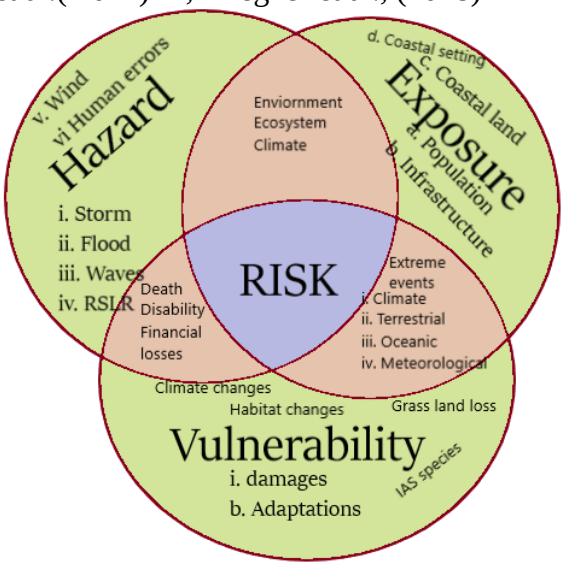


Fig 9: The risk analysis considers the hazards, exposures, and vulnerabilities along SOC.

It is assessed that about ~34% of coastal vegetation, including ~23% of mangrove forests, is highly vulnerableto the Indian Ocean. Since the Ganga-Brahmaputra-Meghana (GBM), the Mahanadi and the Godavarideltas are sinking, shrinking and subsiding more susceptible to mangrove risk and vulnerability,Unikrishnen et al. (2007)[37],Mishra et al. (2017)[38], Syvitski et al., 2022[39], Mishra et al., 2023[40].The risk assessment zoning of Puri and Ganjam districtsof SOC have been done for the change rate of shoreline, ESLR, wave height, regional elevation, geomorphology, etc, as low, medium, and high. The Coastal Vulnerability Index (CVI), designated for various coastal variables, isin Table 6,

Table 6: The Riskzoning of the South Odisha Coast (SOC), Puri and Ganjam

Parameter change rate	Zoning			Puri coast	Chilika barrier spit	Ganjam Coast
	Low	Medium	High			
	(Accretion)	(Erosion)	High Erosion			
Shoreline (m/y)	>0y	-10 to 0	>10	High	medium	Low
RSLR (mm/y)	<0	0to1.0	1.0 to 2.0	High	High	High
Wave amplitude(m)	<1.25	1.25 to 1.40	>11.4	Medium	Medium	Medium

Tidal range (m)	0-2.5	2.5 to 3.5	>3.5	medium	Low	Low
Landscape(other than Mangroves)	Submerging coast	Estuaries, dunes, creeks,	Sandy Beach, sandy spits	Medium	Low	Low
Tsunami run-up(m)	0 to 1.0	1.0 to 2.0	>2.0	High	High	High
Cyclone slamming	26%	39%	35%	Medium	High	High
Overall vulnerable	2.1 to 4.75	4.75-9.5	>9.5	Low	Low	Low

Source: Kumar et al., (2010)[41], Murali et al (2018)[42], Hazra et al, (2022)[43],

Tectonic displacement damages coastal vegetation and mangroves. Humans continuously endeavour to change the old vs. new mangrove species according to community needs and combat climatic changes, and modern people are the players in the biogeographical changes.

Discussion:

Themangrovespread changes directly based on regional sea level rise (RSLR), climate change, global warming, etc. The effect of temperature rise, Maiden Jullian oscillations (MJO),Oceanic Nino Index (ONI), (ENSO), the Indian Ocean Dipole (IOD),etc. These parameters regularly make environmental changes in the lands and seas. This will involve competition and reassembly of communities of halophytic species and possible displacement of non-halophytic species. However, Peterson et al. (2012)[44]reported that the mangrove-salt-marsh ecotone enables mangrove generation like Avicennia in a degraded salt marsh or the salt pans periphery.

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Conservation and generation of mangroves are used for sustainable management practices on the south Odisha coast. The works ahead are (i) Afforestation and Reforestation in open and degraded fallow land. (b) Sustainable livelihoods reduce ecosystem stresses such as plastic waste, ghost nets, ecotourism, and fish management onshore. (c) Increase the dimensions of protected and biodiversity conservation areas by banning human interventions like encroachment and destruction. (d) The onshore and offshore pollutions and climate change actionsoverexploitation of Mangrove species, plying ofmotorised boats, (e)Promoting awareness among the people, (f) promoting national and international agencies to collaborate and share forcreation and preservation of the mangrove ecosystem like WWF, HCLF, Wetland International etc., (g) strictly adhering to laws enforced by state and central governing authorities against resource exploitation, illegal cutting, land conservation, grazing and pisciculture within the mangrove areas. (h) involving community stewardship in promoting the mangrove plantation, watching/warding off their national property to save the coast's future.

Works ahead along SOC coastline

All the coastal beneficiaries must protect the vast reserve Balu Khand area (Puri to Konark) and the other mangrove-associated forest blocks, estuaries, emerged estuaries/ mudflats, etc. After the extremely severe cyclonic storm slam, the Phani, the coastal flora and fauna shattered, and the Odisha State Forest Department (OSFD) intended to grow casuarina trees to restore the reserved forest. Local people extensively use casuarina trees as firewood, destroying the forest daily for domestic use.

It is high time to make available proper legal actions against encroachment, prawn culture ponds, and unsustainable use of forest/ Sanctuary lands. They must be booked under section 26(A) of the Wildlife (Protection) Act, 1972. Regular demolition of these prawn gherries must be done as they are the land for mangrove areas in CRZ-I.

Massive plantation programmes are to be initiated to encourage the afforestation of degraded mangrove areas and banks of backwater areas like estuaries or creeks. Odisha has plans to raise mangrove plantations along its coast to act as a natural barrier against cyclones and storm surges. The state government has also proposed to plant casuarinas in the coastal belt.
Developing mangrove areas along the coastal zone as per the Integrated Coastal Zone Management Project (ICZMP) Phase-II, as the Government and Mangrove Initiative for Shoreline Habitats & Tangible Incomes (MISHTI) plan is to create and preservemangrove forests to build onshore resilience in the nearshore and also in the buffer Zone. The union budget provision for 2023-24 involves mangrove plantations along the salt marshes and backwater areas along the coastline.This scheme, announced in the 2023-24 budget, will involve mangrove plantations along the coastline and on saltpan lands.
The HCL Foundation, ECRICC and Wetland International have taken promising initiatives to promote ecological health, prevent devastation during natural disasters, and support local livelihoods to augment the sustainable development of vulnerable coastal areas.The UNDP also planned to plant more than 1,000 hectares of mangroves over three years to minimise the impact of cyclones and storm surges.
The OSFD and MS Swaminathan Research Foundation (Part 3) have prepared the state mangrove Atlas, which needs to be updated annually. Digitised GIS has made the work faster and more economical. A continuous record of mangroves and the aspect ratio is needed for future initiatives. Eviction of encroachment to mangrove wetlands should be identified,and steps should be taken to reduce community dependencies by providing alternate livelihood and sources of employment generation to the community stakeholders through the Mangrove Mitra Programme (MMP) and Management Action Plans (MAPs)

Conclusion

Mangroves' canopy has one foot on land and the other in the water; the land of amphibians in brackish water, withering heat, suffocating mud, and crouching sun. Mangroves are the most resourceful and operative natural ecosystem that can mitigate and adapt to global change in tropical and subtropical coasts as per SDGs(1, 2,8, 13, 14 and 15). As mangrove forests are absent along the South Odisha Coast, further research is needed to findSoil Organic Carbon's physicochemical properties and the brackish water's salinity and pH in the anticipated estuarine and saltmarsh landscapes along the Coast of SOC.
Awareness programmes and community interactions have been pivotal through focus group discussions and with the stakeholders are essential. The scientific analysis and biometric information are compared and analysed. The findings are: (i) Mangrove generation should not be tried along erosional coasts and sweet water estuaries. (ii) The salt marshes and meadows peripheries are conducive for mangrove generation. The conclusion is that mangrove growth can occur along the depositional onshore estuaries/creek’scoastline of SOC.

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