# GeomorphologicChangesandEthnobotanyLossesof Indian Sundarbans in Anthropocene

ABSTRACT

People in theinter-tidalzones of the Ganga-Brahmaputra-Meghana Delta regions are reliant on mangroves for food, medicine, protection, and livelihood.The present Anthropocene epoch has a deteriorated impact on people'ssocietal, fiscal, and demography due to theclimate change loss ofagriculture and land use.The mangrove vegetation of Indian Sundarbans is decliningin the South 24-Praganna district, West Bengal,theworld'slargest estuarine forest, and the UNESCO Heritage, site.

Remote sensing (RS) and geographic information systems (GIS)techniqueswere used to download data of the Landsat 8 OLI from USGS/GLOVIS of SOUTH 24 Parganas, West Bengal and analysed by ERDAS IMAGINE applications forspeculation of theland use/land cover dynamics from the year 2015 to 2020. Ground truthing was conducted by site visits and compiled the medicinal use of plants to investigatethe sustenance of SDG-3 and SDG-14.2 and SDG14.5of life in the Sundarbans.

The distribution of various mangrove specieswas identified in the core, buffer and manipulation zones of the Sundarbans Biosphere Reserve, their stratification along the cross-sections, zoning, and useas folk medicines.Theresearch reveals mangrove vegetation is dwindling along the coasts of the South 24 Parganas. There is subsidence, emergenceand submergence of land in the archipelago of nearshore Islands. The mangrove losshas been transformed into settlements or agricultural land. Recommendations are made to sustain the inter-tidal vegetation.

Keywords: GBM Delta, Sundarbans, Mangroves, GIS, South-24-Parganas, Ethnobotany

**1.0 Introduction:**

The large deltas of the east coast (EC) of India are undergoing sinking, shrinking and subsidence, regionalsea level rise(RSLR), sedimentation, coastal erosion, and tidal inundations also the globally largest, Ganga Brahmaputra Meghana delta (GBMD).Mangroves,the halophytic plants grow in the transitional interface in Sundarbans in South 24 Parganas housed in the southern zone between the sea and the land. They are the tidal influencing areas comprising standalone flora (epiphytes, shrubs, ground ferns, grasses and trees) and brackish water fauna.It was a tiger reserve in the year 1973, declared as a wild sanctuary in the year 1977and later a national park in 1984. This mangrove ecosystemisof late Cretaceous origin [146 - 100 Mya]. Its expanse is ever-changing with the transgression and retrogression of the Bay of Bengal coast.The evergreen blue carbon ecosystem is inJeopardy due to Anthropogenicstress, climate changes in climateand is not compatible with Sustainable development goals, SDG 3 and SDG-14, (Rahman et al., 2020[1],Bera et al., 2022[2], Banerjee et al, 2023[3]).

**1.1 Anthropocene:** Homosapiens governed the biome,andfragmented the land, from states to districts grounded on nature's conformationin the Anthropocene (the human epoch) probably from 1950, and a larger scale from its golden spike period (1980). Presently, sustaining

human life has urged for an incremental menace to humans, biodiversity, ecology, and the environment due to population density, modernization, urbanization, industrialisation, and land use strategies, (Cruzen et al., 2000[4], Zalasiewicz et al., 2016[5]. Mishra et al, 2020[6], Waters et al., 2023[7],).

**1.2 Sustainable Development Goals:** SDGs 1 to SDG 17 wereofficially recognised by India among 193 membersof the United States on 15thSept. 2015.SDG 3 encouragespeople'shealth whereasSDG 14 promises to guard, reestablish and endorsesustainability of land-oceanusage of terrestrial ecosystems. The importance is emphasizedin sustainably dealingwith forests, combating desertification, Eco-system losses, and haltingsetbacks of degraded biodiversity loss, (Gera et al., 2018[8], Hassani et al, 2021[9], Mishra et al., 2023[10]).

**1.3 Sundarbans and mangrove forests:**Mangroves are halophytic plants that grow in the transition zones in coastal low-lying intertidal zonescomprising aerophytes, shrubs, coastal ferns, grasses and trees. The Indian coast covers 4992 sq. kmof mangroves out of 713789 $km^2$global figure.https://geographyhost.com/forest-cover-in-india-important-statistics/.TheSundarbans (India and Bangladesh),the archipelago of islands, are housed in the Ganga Brahmaputra Meghna delta (GBMD). The largest mangrove delta is housed inabout 10200 km2 (4200$km^2$ in India and the rest in Bangladesh)out of which about 2112.11 km2 of India'slower Gangetic delta (FSI, 2019[11] and https://sundarbanresidency.com/history.html). TrueMangrove covers 257.10sq. kmin the South 24 Parganas.The well-diversified vegetation hasdeveloped certain morphological, biological, physiological, andecological common adaptability to thrive along tropical coasts or creeks having climatological, biological, ecological,andeconomic importance.Sundarbans Wetland has an International Status, ranking 27th (*Ramsar Site no. 2370*). (Kuenzer et al.2011[12], Chakrabarti, 2015[13], Das etal. 2023[14]).

**1.4 Blue carbon:** Thecoastal system consisting of salt marshes, plankton, and seagrassecosystems,that efficiently storecarbon, maintain the carbon balance and are called blue carbon.Theecosystem pertaining to blue carbon shields the coast from erosion, augments accretion,and regulates oceanic water standards,marine life and forestry. Presently this ecosystem is in jeopardy due to its resource over-exploitation, pollution, and anthropogenic intervention initsgeomorphology.To sustain the role and maintain of concentration of $CO_2$ as per SDG-13 (climate action). It warrants devoted insistence to restorethe coastal blue carbon ecosystem to convert as a lasting carbon sink and to reduce carbon sequestrations.iucn.org/resources/issues-brief/blue-carbon. MNG and MNAecosystems can store and sequester huge quantities of blue carbon (Corg) but are area-specific.The CO2 emissions through coastal vegetation systems bearonly 0.2% of total global CO2 emissions but about 18% of CO2 emissions from the tropical coastal ocean (Alongi 2020[40]).The Sundarbans, mangrove forest stores around 26.62 Tg of blue carbon (Chanda et al, 2023[80]).

**1.5 STUDY AREA:**The Population of 24 Parganas (S) was 1.38million in 1951 whereas the present population has risen to 9.022million only in south 24 Parganas (North 24 Parganas not taken), (Mandal 2020[42]. Census India, 2011[43]).During the Meghalayan period (≈4.1k YBP) of the Holocene epoch, there were the Sundarbans mangroves. The Sundarbans, the largest mangrove, housebetween 88°55 E to 89° E and 21°30' N to23°30' N, i.e., between the Hooghly River (Kolkata) to Baleswar River (Khulna). TheIndian mangroves have an areaof about3800 km2.Sundarbans Biosphere Reserve (SBR) of India is located within 21°32′–22°

40′N and 88° 05′–89°51′E in districts of south 24- Parganas.The present study area is within 21° 32′–22° 14′N and88° 10′–89° 05′ E. Indian SBR has an area of about 2,400 km$^2$.

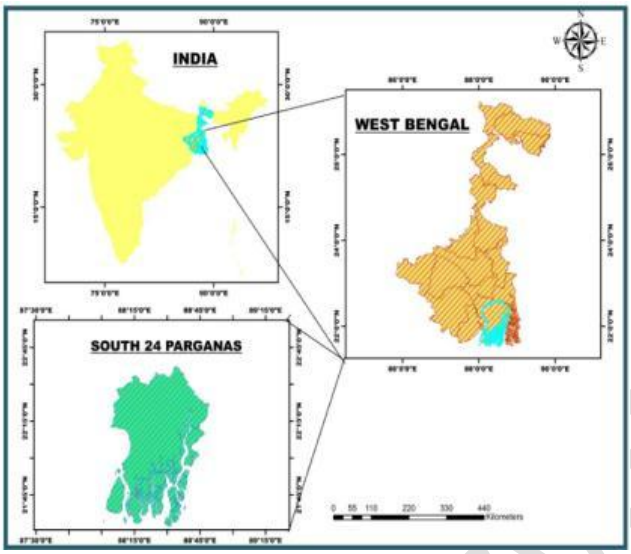



Fig I: The Index map of the South 24 Parganas district in West Bengal part of GBM delta

. (a)  (b) 

(c )  (d) 

Fig 2 (a): Sundari plant in Hooghly estuary(b): Knee roots in Passur or Pitamari (*Xylocarpusmekongensis)*mangroves(c) The Hental in Matla River in S-24-Parganas (d) Hental forests

The ‘Sundarbans’ are named afterthe main mangrove species ‘Sundari’ (Heritiera fomes) which is endangered due to cutting, and top-dying diseases. The other attraction of

Sundarbans is the Royal Bengal tiger (Panthera Tigris ssp. Tigris), which is endangered now, (Dutta et al., 2017[15]).The irrigation demand in Sundarbans is about 2784 MCum. The waterbodies (small or large) are 70000 in number and supplemented by 8,000shallow tube wells that cannot cater for the demand, (Das et al, 2015[16]). Food security is at stake for 87.5% of the low-income people in Sundarbans. Presentchangesin climatic, unsafe food security warrant an increase in the irrigation network,(Fig 2 a,b,c,d).

**2.0.0 Review of Literature:**

The 24-Parganas was established on 15th July 1757 by Mir Jafar, the first Nawab of Bengal.The South 24 Parganas was formed on 1st, March 1986. Which was later bifurcated into subdivisions- (Alipore and Diamond Harbour) and divided into 30 blocks (GoWB and South 24 Parganas website [47]).The Multidimensional RuralPoverty Index Score of the South 24 Parganas as per NITI Ayog, 2023 in the year 2015-16 and 2019-21 were 0.116 and 0.064 respectively. (NITI Ayog, TATA-2023[18])

Mangroves are developed in ≈150000 sq. km globally., (Kumar et al., 2022[17]). India shares 4975 km2, (0.15% of the globe) along the country'seast, west, and AN Islands. Coasts.The largest man-groves in West Bengal cover 42.45%, followed by Gujarat (23.66%) (FSI, 2019[11]). Indian Sundarbans have enumerated 27 pure mangrove species out of 46 true global and 40 mangrove The east coast of India has species, while thewest coast has 27 species (Sreelekshmi et al. 2020, [19], Nandi et al., 2021[20], Chanda et al., 2023[21]). MSL is a proxy for mangrove area delineation), (Payo et al.2016[22], Ghosh et al., 2018[23])

Geomorphologic study of Sundarbans and south Parganas is difficult for ground survey due to in accessibility and tough terrain. Remote sensing (RS) is one of the propertools for mapping and monitoring inaccessible topography, and natural resources(Nandy et al., 2011[24]; Sahana et al., 2015[25]; Kushwaha et al., 2018[26]; 2020, Thakur et al., 2021[27], Mishra et al, 2023[28][1]). The on-ground survey is hard, time-consuming, and laborious in mangrove tidal swamps, Remote sensing (RS) methodology can be conducted for the mapping and monitoring of the ground truthing and up-to-date information, (Giri et al., 2014[29], Mishra et al., 2021[30], Chanda et al., 2023[21]).

RS techniques have the potential to recognize, map, and monitor changes in the mangrove forests in coastal areas, using hyper-spectral satellite images and information for digital image processing to classify mangrove bowls, (Heenkenda et al., 2014[31], Datta et al., 2022[32], Doodee et al 2023[33], Sudirman et al., 2023[34]). Landsat TM,SPOT XS, IRS LISS-III, CARTOSAT-1 (2.5m), andSentinel-2, arecommon sensors used for Mangrove species.Identification is more helpful in high-resolution multispectral images than in coarser-resolution images. (Satyanarayana et al., 2011[35], Jia et al., 2016[36], Nandi et al., 2021[20]).

The effective management of a holistic blue carbon ecosystem can refurbish the strategy to bridgethe inmates to protect stakeholders'risk from deterioration of ecology, community, lifeline, society, and economy. There is a lag between coordination between its stakeholders, achieving suitable restoration goals and prescribing SOP (standard operating procedures),which are essential for the restoration of degraded mangrove areas.

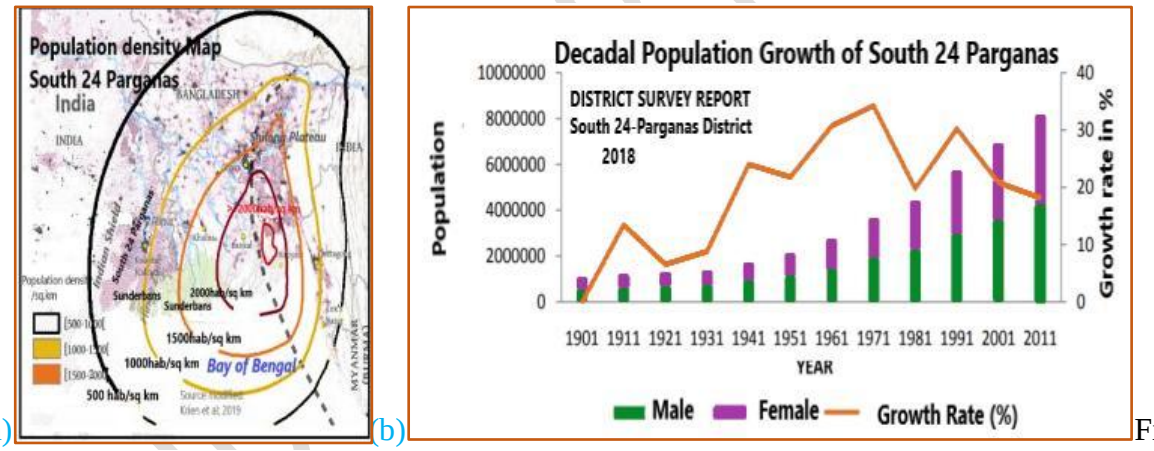
**2.1 Objectives:**

Since 2016, there have been few literature studies against land use change estimation literature availablefor the study area. The objectives of the present geospatial study to investigate:

1. The study of geomorphology of the Indian Sundarbans.
2. To access the multidimensional ethnobotanical folk drugs of the aboriginals of the area.
3. To speculate the functions of Sundarbans ecology, the current changes in the land use (LU) of South 24 Parganas in the last eight years (2015-2022).
4. The impact of the mangrove ecosystem on its stakeholders in the last two decades.

### 3.1 Ganga-Brahmaputra Meghana (GBM) Delta:

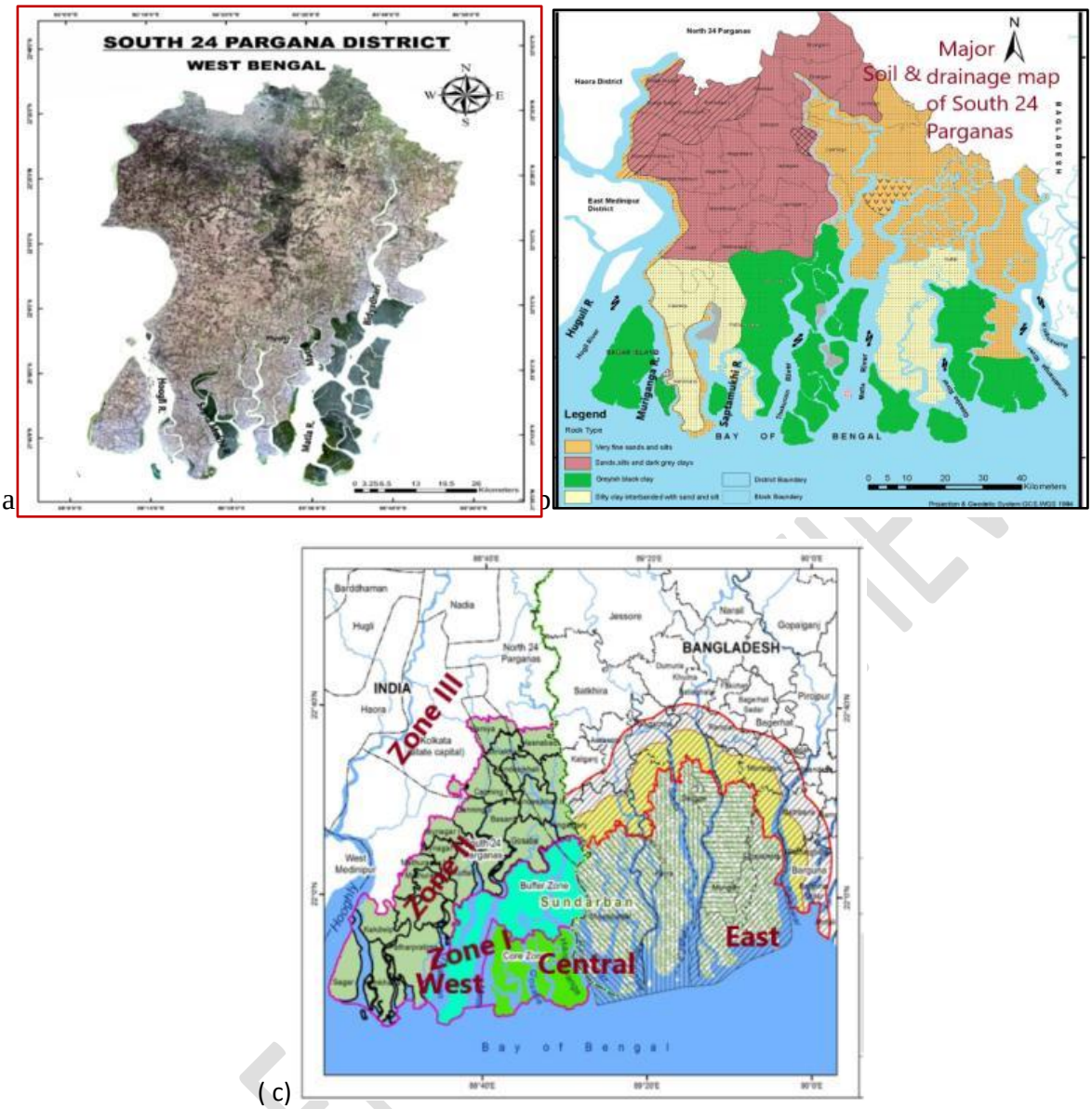
The GBM delta is the world's largest and wildest budding delta of Asia spread over six states, i.e., India, Bangladesh, Bhutan, China, Myanmar and Nepal. The GBM canopy covers 1.7 million km2 of India and Bangladesh. The delta covers an area of about 100,000 sq. kmand is fertile and agriculturally potential. The 355km longdelta runs parallel to the Bay of Bengal (BoB) coast. It is shaped by the regular deposition of sediment through GBM rivers(~1 BT/annum). The Ganga R. only carries about 150 to 590 MT/Y,the Brahmaputra 135 to 615 MT/y and the Meghana(6-12 MT/annum)have a decreasing trend (data 1960-2008).The ephemeral rivers and the longshore drift of about260km long swampycoasthavean average annual subsidence of 3-7mm/year (Steckler 2021,NASA [37],Rahman et al., 2018[38], Lovelock 2019[39], Alongi 2020[40], Mishra et al., 2017[41],).




(a) (b) Fig 3(a): Demographic study of South 24 Parganas Fig 3(b): The decadal population map of South 24 Parganas (source modified:https://s24pgs.gov.in/assets/webdoc/mediauplo)

### 3.2 South 24 Pargana (West Bengal)

The south 24 Parganas is a district (formed March 1st, 1986) adjacent to Kolkatacity of area 9960 km$^2$, comprising 8.153 million people (2011 Census). The district falls under Survey of India Topo Sheet No. 79B/2 to 6, 79B/10 to 12, 79B/15 and 16, 79C/1 to 6, 79C/9, andC/10.The lower partis housed in the Sundarbans, the largest mangroves of the globe. The connectivity is lacking due toa highly anastomosed drainage network, hilly land, and mangroves. The district is fed by the rivers Matla (wide estuary), the Raj Mangal (tidal estuary), the Saptamukhi (tidal estuarine), the Hooghly (260km long, treated as holy Ganga), the Vidyadhari(estuarine), the Thakuran (called Jamira, tidal estuarine) and the Piyali (a connector between Bidyadhari and Matla).




a b

( c)

Fig 4(a):GISTerrain map 24 Parganas (S),Fig4(b): The soil map of 24 Parganas(S) Rivers (Sou mod: GoWB; Dist. Survey Report -2018) Fig (c): Zoning of 24 ParganasS)(Sour: The World Bank, the IWA modified)

The South 24 Parganas district is trifurcated as (i) The marshy Sundarbans (Zone I) (ii) The Non-Sundarbans(countryside) (Zone II), and (iii) The Urban areas around Kolkata city, (Zone III).Zone II is composed of anastomosis of 1st-order drainages emerging the 2nd-order distributaries by bifurcation within both mangrove swamps, Levees, and marshes with mangrove associates. The Zone I areas are the coastal belt consisting of creeks and Sundarbans with pure MNG. Irrespective of zones, the land is highly fertile and has high yields of rice, timber, fish, honey, sugarcane, beetle nuts etc, (Bagchi 2017[44]). Indian Sundarbans in the phytosociological study had five zones but presently transformed into four zones (loss of a few species of mangroves). It is due to the impact of Tides (Low and High), Regional Sea level changes (RSLR), the impact of cyclones and human interventions, between 2017-2021(Chowdhury et al, 2023[45]).

The south 24 Parganasis disaster-wise very sensitive. Cyclones with a return period of 4.62 years/cyclone, the flood of 22events, average lightning days/ year 48days, cold wave days of

20 days/year that confronted between 1969 to 2019 The av.rainfallof 1750mm/year, and the maximum temperatureof 48°C.(Edmonds et al., 2022[46],GoWB Survey Report 2018[47]).

**Sundarbans; The world's largest mangroves:**

Sundarbans is260kmlong coast along the shoreline withRhizophora mangroves species (largest Sundari),mangroveassociates,and saltwater swamps formed at the lower Ganges Delta, https://s24pgs.gov.in/historical_background.Sundarbans halophytes are under threat/endangered and are included under the Red List ofEcosystems (Sievers et al., 2020[48]). The evergreen Sundarbans canopy accommodates halophytes like the Sundari, Kakra, Keora, Garan, Hental, Golpata, Dhundul, Passur, Garjanvarieties, etc.The distributaries small or large like Malta, theHatania and Doania, the Go Saba, the Piyali, the Raiman gal, the saptamukhi, andthe Thakuran, and the muddy islands such as Sagar, Ghoramara, Henery, and the Locha Achara Islands situated in the district (Chakrabarti et. Al, 2015[13]).Species like rotundifolia, Aegialitis Heritiera fomes, S. Griffith, and Sonneratia apetala have turned up endemic due to Anthropogenic stress, westerly Tectonic uplift, and subsidence.The mangroves protect the inmate's livelihood and its ecosystem from devastating floods, tides and cyclonic storms. In the 21$^{st}$ century, thecycloneshad an impact on the south 24Parganasbut moderated by the mangrove ecosystem.They are Gonu (2007); Sidr (2007); Phailin (2013), Hudhud (2014), Mora (2017), Fani (2019), Amphan (2020); YAAS (2021); Sitrang (2022), and Mocha (2023)(Mishra et al, 2022[49])

**Indian Sundarbans:**

The Indian Sundarbans are part of the GBM subaqueous delta covering 19 blocks out of 30 blocks of the district.The Indian fabric of mangroves, a complexecoregion had6402 sq. km. in 2001 which has shrunk to 6385 sq. km in 2009, (erosion of 64.16 sq. km, accretion of 20.12 sq km) in a decade, (Ghosh et al., 2015[49]).Near thecoast, the forest enters the mangrove swamp; which sheltersmanydesolate animals, brackish water species, and amphibians like crocodiles. It is the last zoonotic sanctuary of the Royal Bengal tigers (≈400 in number) and 30000 spotted deer.The rare bovines existing are sheep (Garole breeds),Muscovy ducks (China Hans), etc.

**Ecosystem Services:**

The fiscal and livelihood services obtained fromSundar Banmangroves are added byfishing nurseries, aquaculture, fuel for the poor, honey, traditionalmedicines, etc. There is a transformation from wetland/foresttoaquaculture farming and agricultural fields. TheSouth 24 Parganas is enrolled on "The UNESCO World Heritage" list and named "The Sundarbans and SundarbansNational Park" respectively.

Sundarbans forestshouse 17 folk medicinal plants in itsMNG (true mangroves), 24 types of MNA (Mangrove Associates), 57 varieties of NMG (Non-Mangrove terrestrial species), 13 varieties of Fabaceae,5 species ofLamiaceae and Compositae (Islum et al, 2022[50]).The dominant *Mangrove Species in Sundarbans is Heritiera, Avicennia, Xylocarpus, Sonneratia, Bruguiera, Cereops, Aegicera, and Rhizophora. Nipa, etc.*

**Sundarbans Biosphere Reserve (SBR):**

People in the SBR area arefinancially backward and are directly reliant onbit-resources like fish, crabs,prawns, timber, honey, and fuel wood from SBR. Thiseco-region has high yields,

from land, rivers and diverse biodiversity. The weather remains humid and the activemonsoon (June to Sept.)providean average annual rainfall of 1750mm. The av. Maximum Temperature is 35 °C and water bodies areallochthonous types, tide-dominated mangrove wetlands. The mangroves are in theestuarine, funnel-shapedlinear tidal mud flats with anastomosed channels falling in BoB. Tidallevel in high tides also varies from 3 to 6.5 m seasonally and water pH from 7.2 to7.9. 24 numbers. The heart of the Sundarbans biosphere reserve has dwindled due to erosion, submergence and human over-exploitation of land, vegetation, and water resources.

The core area of SBR is restricted to human accesslest they deteriorate the ecosystem. The buffer area is admissible for honey, folk medicines collection, fishing, and limited dry wood cutting. Poaching and theft of forest products are prohibited from being protected by armed forest guards on patrol or in motorised boats. There is no nocturnal trespass within the river/forest. Forest bit houses and camps are set at vulnerable positionswithin the park.Location-wise the distribution of flora is in **Table 1.**

Table 1: The dominating MNG, MNA and NMG species found in Sundarbans

| # | Location of the place | Local name | Botanical Name |
|---|---|---|---|
| 1 | *Estuarine zone, Tidal zone,*banks, River mouths;swamps new sedimentation; sub-aqueous soil (Highly saline tolerant) | Jatbaen;<br>Pairabaen;<br>Kalabaen<br>Kripa<br>Garia<br>Tora | Avicennia officinalis<br>Avicenniaalba<br>Avicenniamarina<br>Lumnitzeraracemosa<br>Kandeliacandel<br>Aegialitis rotundifolia |
| 2 | Low salinity, Tidal current passing; channels in highland, Creeks in *Mid Estuarine zone* | Garjan<br>Goran<br>Math Goran<br>Bakul<br>Keora | Rhizophora apiculata<br>CeriopsDecandra<br>CeriopsTagal<br>BruguieracylindricaSonneratiapetala |
| 3 | *Inner estuarine Zone:* river inflow, less saline; elevated inland, Compact soil | Genwa<br>Kankara<br>Khalsi<br>Ora<br>Hental | Excoecariaagallocha<br>Bruguieragymnorrhiza<br>Aegicerascorniculatum<br>Sonneratia caseolaris<br>Phoenix paludosa |
| 4 | *Rare(R), endemic (E), Sporadic (S)* restricted to specific salinity | Amur (E)<br>Dhundul (E)<br>Passur (E<br>Sundari(R)<br>Golpata (R)<br>Palm-swamps (S) | Agaliadomestica<br>Xylocarpus granatum<br>Xyclocarpusmekongensis<br>Heritiera fomes<br>Nypafruticans<br>Palm-swamps |
| 5 | *Freshwater Mangroves*, dense and discontinuous, bushy and dwarf, even bushy | Hargoza<br>Ban Lebu<br>LataSundari | Acanthus ilicifolius<br>Merope angulates<br>Brownlowiatersa |

**Ethno-medicinal utility of Sundarbans mangroves:**

*arious reports say the common and popularly available MNG and MNA mangrove varieties available in Indian Sundarbans possess antiviral, antibacterial, antifeedant antioxidant,*

*antileukemia, antidiarrheal, and antitumor pharmacological properties and also* behave excellently as antioxidants, anti-microbial, antihyperglycemic, antinociceptive, and anti-malignant.Phytochemical studies revealed they contain chemical ingredientsi.e., saponins, glycosides, alkaloids, steroid tannins, flavonoids, gums, phytosterols, and antidiabetic, (Islam et al., 2022[51]) [**Table 2**].

Table 2: Majore mangrove species used as ethnobotany

| *Local name* | *Botanical name* | *Part used* | *Mode of attempt* | *Disease attempted /uses* | *Sources* |
|---|---|---|---|---|---|
| Sundari | *Heritiera fomes:* | Leaves, seeds, | Extraction by decoction | Diarrhoea, dysentery, colic, acidity, indigestion, constipation, stomach ache, bloating, lack of appetite and Gastrointestinal disorders | |
| | | woods, | Powder | Piles, Laxatives | |
| | | Stem bark | Paste | Eczema,abscess,boils,aches, rash, infections,scabies,itch, dermatitis,sores,scar,and warts | Mehmud et al, 2014[53] |
| | | Bark | decoction | Diabetes &Goitre | |
| | | Twig | Toothbrush | Toothache; oral infection | |
| Indian mangrove 8types | Avicennia (Officinallis L. or Marina) | Leaves roots & barks | Paste or decoction | Injuries or inflammation (alkaloids);cancer, diabetes, malaria, rheumatism, asthma, smallpox and ulcer | Patra et al., 2011[54]; Namaji et al, 2013[55] |
| Acanthaceae , JATbaen (such 8 varieties) | *Avicennia officinalis; Avicennia marina* | Leaves roots, flowersbark, twigs | Diabetic and diuretic, immunity developer | rheumatism, asthma, tumour, dyspepsia, paralysis | Thatoi et al, 2016[56] |
| Hental | Phoenix paludosa; Arecaceae | Upper soft part | Bark | To Control Cough | |
| Dhundul(tree) | Xylocarpus granatum | Bark | paste | dysentery, diarrhoea and other abdominal troubles, Febrifuges. | |
| | | Seed ash | seed ash+sulfur&coconut oil | Allergy; Itching | Alamgir et al, 2007[57] |
| | | Fruit | Direct or maceration | Antiinflamatory,antidiarrhoeal, | |
| Caw Phal (Climber) | Sarcolobusglobosus | Fruit, leaves | Extract or maceration | antimicrobial activity, rheumatism, dengue | Alamgir et al, 2007[57] |
| Math Garan | Ceriops tagal | Bark and wood | Extract and treat wood | Antioxidant and anticorrosive, Construction material, dying and tanning | Shamsuzzaman et al., 2021[58] |
| Genwa (blind your eye mangrove) | Excoecariaa gallocha | Leaves, flowers, twigs | Latex is poisonous so | antioxidant, antimicrobial, anti-inflammatory, analgesic, antiulcer, anticancer, anti-reverse,anti-filarial, transcripts, antihistamine-release, DNA damage protective, antidiabetic, antitumor | Mondal et al, 2016[59] |
| Garjan | Rhizophora mucronata | Leaves, flowers twigs | Extract or maceration | Antidiabetic and antioxidant activity; antifungal activity | Adhikari et al, 2016[60] |

| | | | | | |
|---|---|---|---|---|---|
| Keora | Sonneratia apetala | Fruit, leaves, seed | Seed power/ extraction | Antibacterial, Anti-Diarrhoeal, Analgesic,Antioxidant, Cytotoxic Activities; asthmaulcers, febrifuge, swellings, sprains, bleeding, haemorrhages, piles | Hossain et al., 2017[61] |
| Kankra | Bruguieragymnorrhiza | bark; leaves | Extract | abortifacient;Liver disorders | Sur et al, 2016[62] |
| Khalsi (Odiya-Teluni) | Aegicerasconiculatum | Leaves, bark | decoction | Antidiabatic, , analgesic, asthma, Diarohea, and rheumatism. | Gurudeeban et al, 2012[63] |
| Pasur | Xylocarpus mekon-genesis (3species) | seeds, fruits, stem bark, leaf, twigs | Seeds power/ extraction, decoction | Anti-oxidant, anticancer, anti-diabetic, antimicrobial, anti-malarial, antifeedant, neuro-protective diarrhoea, cholera, dysentery, fever, viral infections | Nabeelah Bibi et al, 2019[64]; Dey et al., 2021[65] |
| Jele Goran | Ceriops decandra | Leaves | Extract | Antidiabetic, antimicrobial; inflammation, and cancer. | Mahmud et al., 2018[66] |
| Tora | Ding Hou & Tora Senna Tora | Leaves | Extract | Antioxidant, antibacterial, anti-inflammatory; bronchitis, itches, rheumatism, ringworm, leprosy, dyspepsia, liver & heart disorders. | Rahman et al., 2023[67] |
| Bhola | Hibiscus tiliaceus | Flowers | extract | Antibiotic;bronchitis, fevers, antihistaminic; coughs, ear infections, abscesses, postpartum disorders, skin diseases | Abdul Awal et al., 2016[68] |
| Golpata | Nypafruticans | Fruit | Extract | land scaping, antidiabetics and antioxidant, less toxic;healing gout, seeds creamy flavour | Yossuf et al., 2015[69] |

The tree Sundari in Sundarbans, a major medicinal plant is gradually becoming “endangered” on the IUCN Red List.

**LU/LCmethods and methodology:**

The present study has focused on investigating the LU/LC changes in the mangrove forest area dueto natural causes, and the hydrological regime,substantial variations in topography, salinity, erosion,and tidal current inundations, in spite ofspecies species-specific plantationto sustain the MNGand MNA. Baseline information is collectedasa pre-requisitefor identifying, mapping and estimating mangroves by experienced survey staff,hydrology, geomorphology, the amplitude of tides, inundation area, and the existence ofpredators. Due to their inaccessibility and inundation, it is a herculean task to conduct field surveys within the tidal swampy mangrove forests with tigers, crocodiles etc. So, GIS methodology is preferred but a species-specific afforestation program is necessaryfor Sundarbans for an exact survey,(Nandy et al. 2011[24],).

**GIS Methodology to detect LULC changes:**

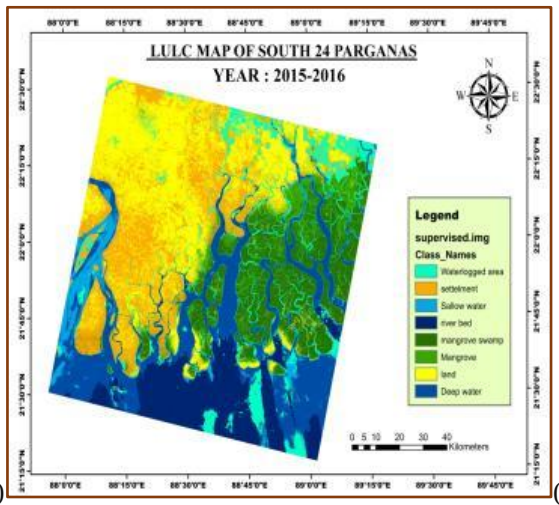
The remote sensing (RS) technique has increasingly emerged as an emerging innovative tool for mapping and timely change of land use (mangroves), though downloaded RS data cannot replace the field survey data, the classification and the change detection for planning, managing and monitoring land utilization. The RS claims the advantage of synoptic coverage, free/ low-cost, time-saving, accurate and repetitive coverage, during watershed, mangrove, coastal, and disaster management, (Crowley et al., 2020[71], Kumar et al., 2021[17] Mishra et al., 2022[72]).

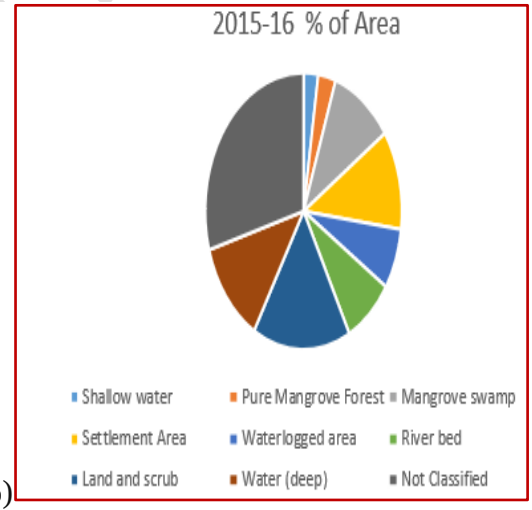
**Data-Processing:**

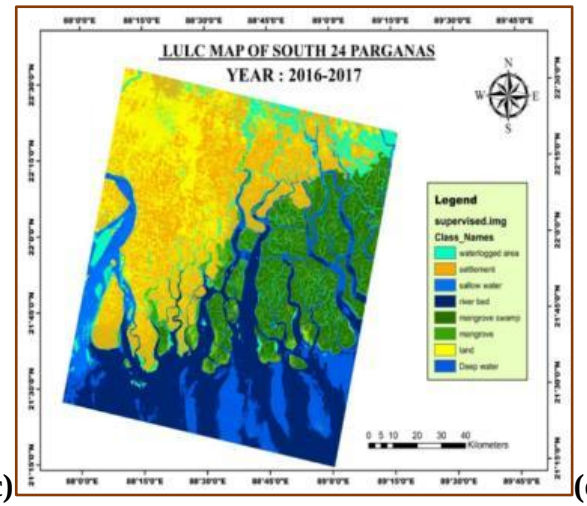
The Landsat 8 OLI data for continuous data for the year 2015 to 2022 of SOUTH 24 Parganasis downloaded either 2nd quarter of Nov. or the first quarter of Dec.) of the year. After completing the transfer from USGS/GLOVIS wasextracted in a zip file and was opened in TIFF files of diverse bands in ERDAS IMAGINE. The chronological processes followed are layer staking, subset imaging and supervised classification.Further, the steps are setting preferences (input and output directory), adding layers, inserting geometry, and identifying particular land features manually to have appropriate pixel accuracy. Then select the raster menu and select all signatures or classes. The Satellite image found five features- (i) Water bodies (ii) Agricultural land (iii) Vegetation (iv) Built and (v) Marshy land to have supervised classification and find the error data. To get an accurate supervised image decision rules can be tried one after other.

**Present setup**

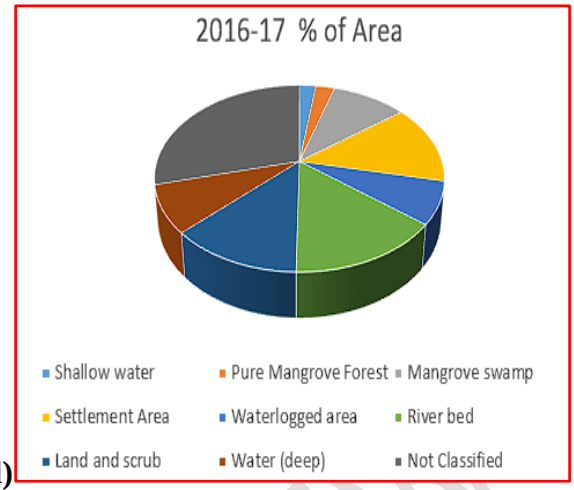
MNG occurred in the study area from the years 2015-16, 2016-17, 2017-18, 2018-19,and 2019-20 (for five years).The cloud cover pictures were not considered and the error in processing within <5% is accepted. The classification method is applied for data analysis. The classification matrix is used to analyze urban growth. Theclassified images are interpreted to obtain several pixels for calculating area. Temporal analysis helps in studying the change detection for analysingthe decrease in the number of waterand vegetation image pixels.In the process of fiveyearsof data analysis, we can be able to find out the major changes in terms of land surface /land cover, vegetation and many more then we can easily interpret the analysis processwith appropriate calculations and graphs that how much area gradually changed in percentage (%) is given below.

a) 

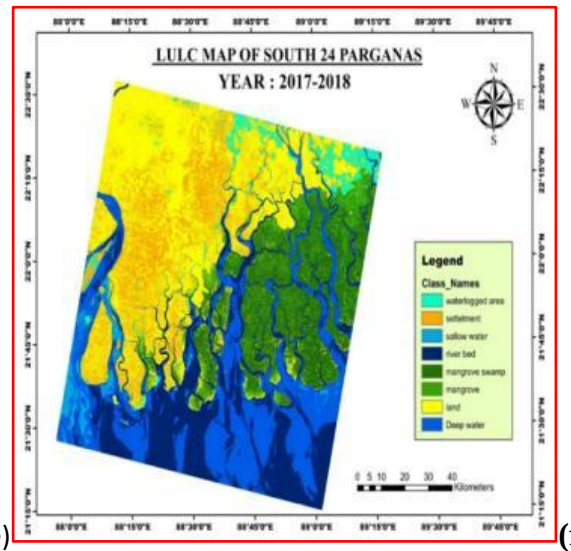

(b) 


LULC MAP OF SOUTH 24 PARGANAS
YEAR : 2016-2017
Legend
supervised.img
Class_Names
waterlogged area
settlement
sallow water
river bed
mangrove swamp
mangrove
land
Deep water
0 5 10 20 30 40
Kilometers

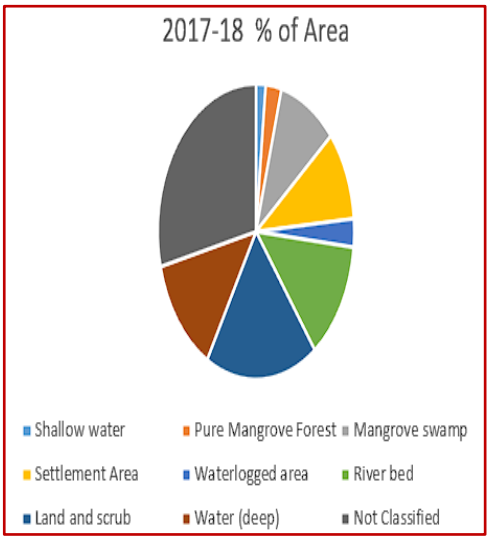
(c)


2016-17 % of Area
Shallow water
Pure Mangrove Forest
Mangrove swamp
Settlement Area
Waterlogged area
River bed
Land and scrub
Water (deep)
Not Classified

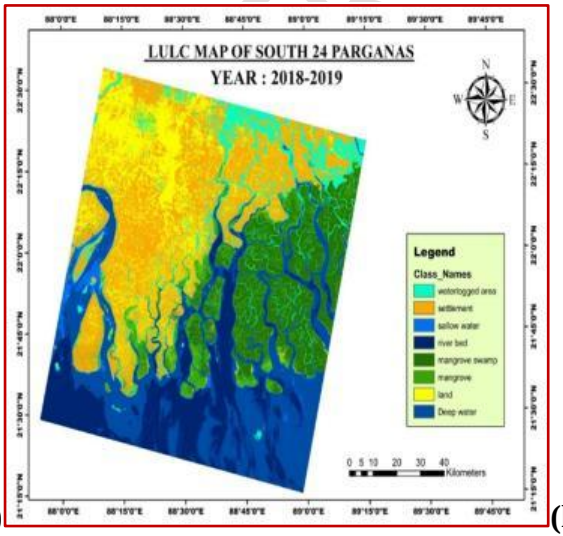
(d)


LULC MAP OF SOUTH 24 PARGANAS
YEAR : 2017-2018
Legend
Class_Names
waterlogged area
settlement
sallow water
river bed
mangrove swamp
mangrove
land
Deep water
0 5 10 20 30 40
Kilometers

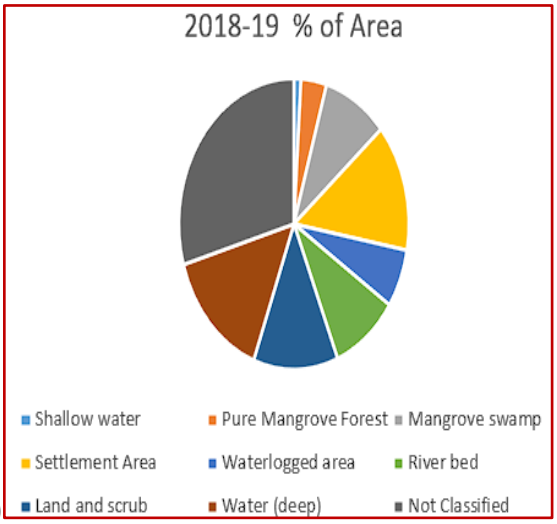
(e)


2017-18 % of Area
Shallow water
Pure Mangrove Forest
Mangrove swamp
Settlement Area
Waterlogged area
River bed
Land and scrub
Water (deep)
Not Classified

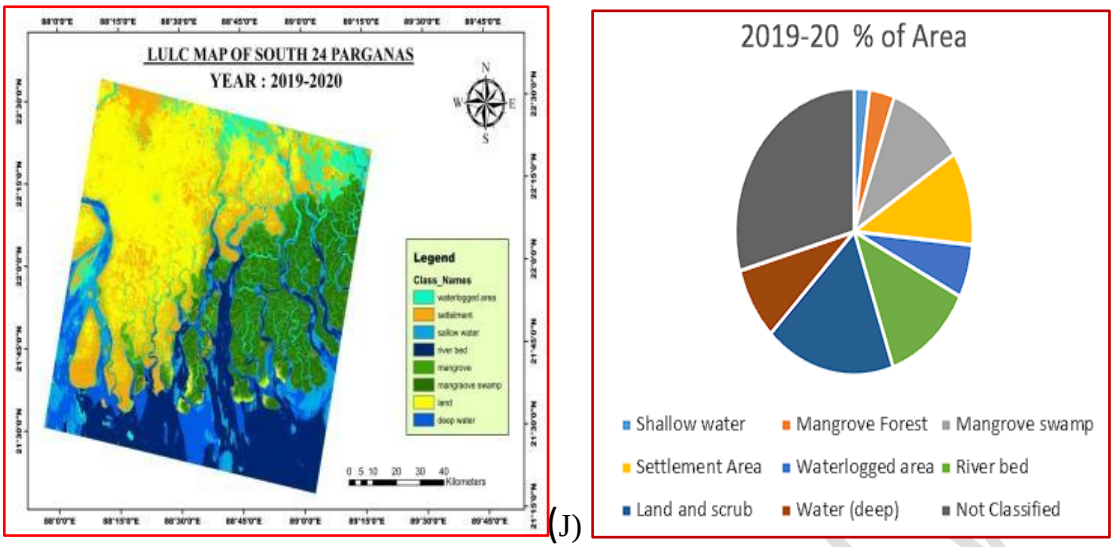
(f )


LULC MAP OF SOUTH 24 PARGANAS
YEAR : 2018-2019
Legend
Class_Names
waterlogged area
settlement
sallow water
river bed
mangrove swamp
mangrove
land
Deep water
0 5 10 20 30 40
Kilometers

(g)


2018-19 % of Area
Shallow water
Pure Mangrove Forest
Mangrove swamp
Settlement Area
Waterlogged area
River bed
Land and scrub
Water (deep)
Not Classified

(h)




(i) (J)

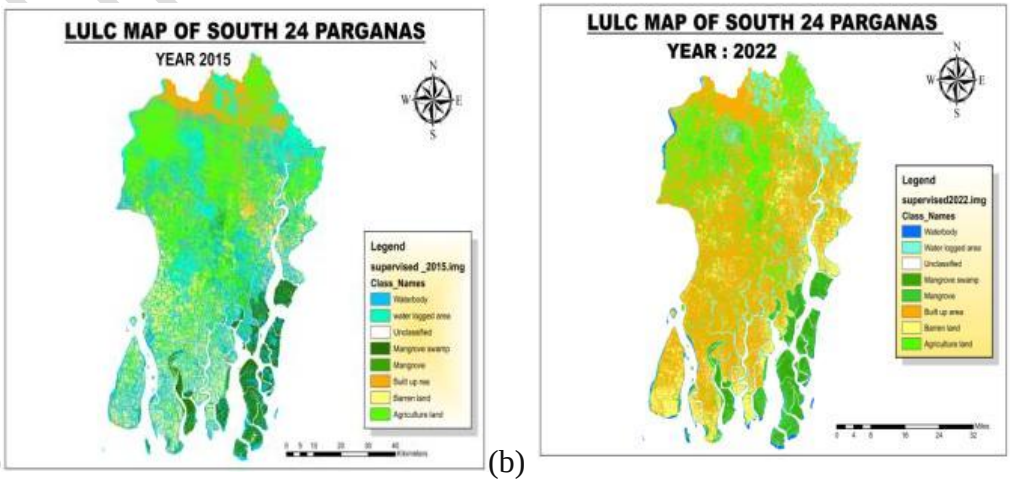
Fig 5 (a) to (J): The year-wise areas for land use for mangroves, mangrove associates and inland taxa in Sundarbans, S-24-Parganas.

The result reveals that as the Sundarbans area is populous, People have exploited the edges of the land for either settlements or agriculture at the cost of mangroves or mangrove Swamps, (Fig 5((a-f) and (Table 3)

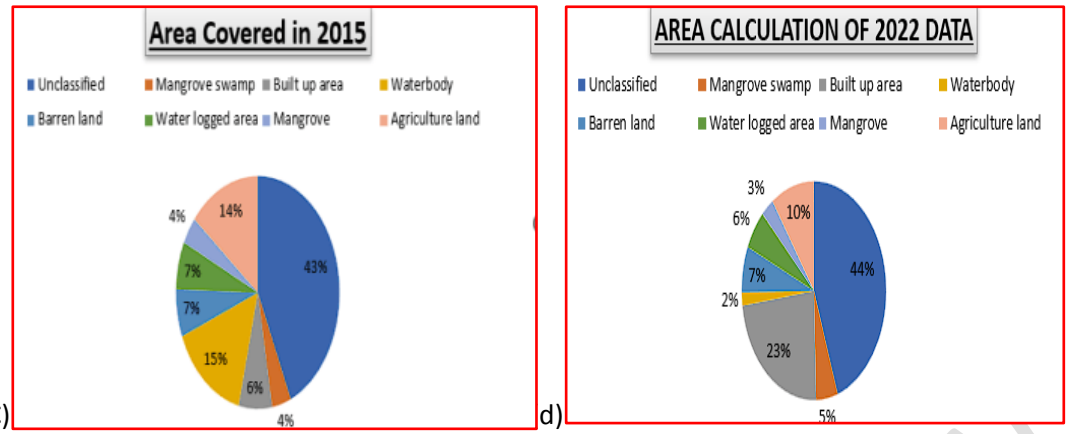
**T**able 3: The land use and land cover of theclassified study area in % of South 24 Parganas

| Class | 2015-16 | 2016-17 | 2017-18 | 2018-19 | 2019-20 |
|---|---|---|---|---|---|
| Classified | % of Area | % of Area | % of Area | % of Area | % of Area |
| Shallow water | 2.4 | 2.2 | 1.6 | 1.0 | 2.1 |
| Mangrove Forest | 2.9 | 2.5 | 2.6 | 3.6 | 3.4 |
| Mangrove swamp | 10.2 | 9.9 | 9.6 | 9.1 | 9.4 |
| Settlement Area | 11.6 | 13.8 | 10.8 | 14.2 | 10.6 |
| Waterlogged area | 7.1 | 7.3 | 3.1 | 6.5 | 6.0 |
| River bed | 8.1 | 14.6 | 13.1 | 9.4 | 12.2 |
| Land and scrub | 16.1 | 12.5 | 17.5 | 11.9 | 17.7 |
| Water (deep) | 12.1 | 8.2 | 10.9 | 14.8 | 09.2 |
| Not Classified | 29.5 | 29 | 28.8 | 29.5 | 29.4 |

**Considering the mangrove forest,** The LULC map for Sundarbans in south 24 Parganas wasconstructed and the corresponding land utilisation changes were calculated**.**




(a) (b)




( C) d)

Figure 6 a-d: Land use area changes in % for various features between the year 2015 and 2022

It is inferred from the satellite data study that one per cent of the study area has been converted from mangrove forests to mangrove swamps. The causes may be attributed to either increase in settlement area 5 (a to d).

Table 4: land use changes in % for various features in Sundarbans in South 24 Parganas, WB.

| Class | 2015 | 2022 | % change (+/-) |
|---|---|---|---|
| Classified | % of Area | % of Area | |
| Mangrove Forest | 4 | 3.0 | (-) 1.0 |
| Mangrove swamp | 4 | 5 | (+) 1 |
| Settlement Area | 7 | 24 | (+) 17 |
| Waterlogged area | 7.1 | 6.0 | (-) 1.1 |
| Agricultural land | 15 | 10.0 | (-) 5 |
| Land and scrub | 7 | 7 | 0 |
| Waterbody | 16 | 2 | (-)14 |
| Not Classified | 40 | 43 | -- |

The structure of the result of the analysis indicates that within seven years the built-up area and the transformed water bodies (ponds) to agricultural land. have surged by (17%), the cause being a rise in population. Due to the slamming of the extremely severe cyclonic storm Amphan 2020, there was great devastation to Sundarbans.

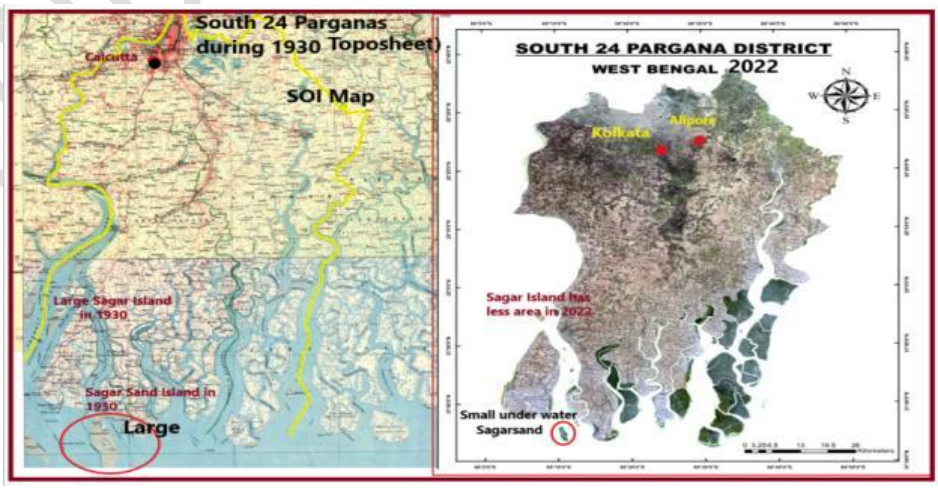



Fig 7: The various islands existing (1930) within Indian Sundarbans are downsized in 2022

The topographical maps of 1930 of the Survey of India have been compared with the 2022 present map. Some larger islands within the IndianSundarbans have been identified but later submerged totally or partly confirming coastal inundation by the BoB. The record reveals that 54 islands in the Indian Sundarbansare emerging, vanishingorhelplessto submergence,(**Table-5**), https://www.Sundarbanaffairswb. in/home/page/islandsofsundarban.

Table 5: The status of various Islands under the Indian Sundarbans, India

| # | Status of Islands | Name of the Islands |
|---|---|---|
| 1 | Islands disappeared from the present map | Lohachara, Bedford, Kabasgadi and Suparibhanga etc. |
| 2 | Islands under slow disappearance (vulnerable islands) to erosion are | Sagar, Ghoramara, Dakshin Surendranagar, Mousuni, Namkhana, Sagar sands,Dhanchi, Dalhousie, Bulchery, Bhangaduni, Mousini Lothian, Baliakhal Lothian, and Jambudwip |
| 3 | Islands emerged (in 1970 and later submerged in 2010). | South Talpatti after the Bhola (1970) cyclone, on the territory line and unhabitable. |
| 4 | Enlargement | Islands enlarging in eastern and northern margins of Indian Sundarbans Islands |
| Source: Mandal 2015[73],www.sundarbanaffairswb.in/home/page/islands_of_sundarban | | |

Spatial changes in the territory and outskirts are noticed in Sundarbans**.** The archipelago of islands mostly submerged or rarely emerged depending upon RSLR, littoral drift, and sedimentation in the estuaries. The area of the Islandswas estimated from old SOImaps revealingthatIndian Sundarbansmangroves inclusive of the waterbodies and drainage channels in the areawere in 1773(10064Km$^2$), in 1873 (7894Km$^2$), 1973 (4277km$^2$),and 2016 (3576Km$^2$)@ 5.63%loss/year excluding the area of the riverine channels. (ISFR 2011-2021(74), Unikrishnan et al, 2007[75], Mishra et al, 2017[76]).

**Discussion**

Mangroves grow along the sea-landinterface. The mangrove forests are built up with diurnaltidal inundation.The Indian Sundarbans formed over a subaerial, subaqueous and tidal GBM delta. Mangroves survive within the elevation of the alluvial fans, paleo deltas and the Pleistocene terraces, and the fringe of the littoral drift or offshore current along the EC. The Himalayan rivers are ephemeral and carry huge amounts of sediment. The littoral sediment and the inland fluvial sediment get deposited along the flood plains, which act as a catalyst for the sustenance ofMNG and MNA, (Mishra 2017[76]).

Mangroves generally thrive in the most traumatic and unreceptive settings of highly saline, large tidal fluctuations, raisedsurface air temperature (SAT), high humidity, strong gusty winds and silty anaerobic soil. These are climate-tolerant plants and shrubs, that can protect stakeholders from erosion, adverse climate and cyclones, and there is insistent dwindlingin the mangrove population. The various human services provided by these unique lifelinefloral kingdomurge for its sustainable existence from nature and human cruelty. Its degradation**is** far higher in Asia than in other tropical and subtropical regions.

Human-based challenges are overfishing, tourism, food, medicine, fuel, shelter, deforestation, and construction materials are anthropogenic. Nature-based forces are subsidence, submergence, climate change, meteorological extremes, and ownership of land holdings of the swamps and mangroves. The main redressal actions are people's awareness, education, economic growth, clear landownership, distinct plans and proposals, the PPP mode development, participatory forest management,

The present study aims to detect theLU changesfrom 1773 to 2016 and especially (2015–2020) of Indianmangrove zones using the RStechnique,The diminishing trend in Indian mangroves and Drainage Channels are inferred.The changes perceived are mangrove swamps, and fallow lands, transferred to agriculturalfields, settlements, and waterbodies. It is high time to protect our coastalwealtheither by legal interventions, people's participation, community involvement or PPP mode as one step to complywith SDG-15 i.e., life on land.

Regularly forming nurseriesintermediatebackwaterinundation and species-specific afforestation are to be adopted to keep the mangrove forest sustainable. Baseline information about the rejuvenation of the existing mangroves is a criterionto identify, map, and estimatefuture mangroves' status. The constraint duringthe sustenance of maintenance of mangroves is strenuous and inaccessibleto conduct field surveys amidstcoastal creeks,swampsand mangrove forests.

The Sundarbansin South 24 Parganashavetried replantation programmes but are futilefor adequate knowledge, communication, and documentation forthe restoration of mangrove ecology.The national policy of food security (SDG-2) in changing climate, surged irrigation potential, and harnessing more water resources are essential. This is possible with morerainwater harvesting structures, rejuvenation and renovation of defunct and depleted drainage channels and recharging of UG aquifers are warranted.

SDG-15 cannot be ignored as the protection, restoration and promotion of forests demand its sustainable usage of telluric ecosystems. Actions are tomanage the forest's sustainability, fightagainst desertification, stop and reverse gearthe degradation and cease biodiversity loss to adhere to SDG-15.

Mangroves, thatensembles as significantasylumsto coastal/estuarine bio-diversity. They act asthe bio-shields to extreme onshore events like gusty winds of cyclones, High tides, coastal erosion, high floods, and tsunami waves. These bio-shields never betray their ecosystem, zoonotic, sheltering avifauna, andbiomass-dependantstakeholders and even add tothe blue-carbon ecosystem, (ISFR 2021[74])

**CONCLUSION:**

Human activities have in recent years become recognised as a major force in shaping the biosphere. The land use/land cover pattern of a region is an outcome of natural, socioeconomic factors and their utilization by man in time and space. Land is becoming a scarce resource due to immense agricultural and demographic pressure. Remote sensing (RS) and geographic information systems (GIS) techniques provide effective tools for analyzing the land use dynamics of the region as well as for monitoring, mapping and management of natural resources. The objective of the present study is to analyze the land use/land cover dynamics from the year 2015 to 2020. This project is mainly to study the satellite image and how it has changed in five years from date.

In the last 5 years duration (2015–2020) mangrove coverage hasdeclined significantly and been replaced by waterbodies. The S-24-Parganas have lands in swamps and creeks available for mangrove plantations. Urbanization andagriculture land use/land cover features have a high rate of conversion against other land usages.

The apocalyptic future sea level rises in the study area, sediment-rich and active delta under erratic climate change, global warming andanthropogenic attack to nature has already deteriorated (≈75%) and cannot recoup. The presentSouth 24 Parganas milieuscannotrecuperatelike the 19th-century biome but only can be maintained as it is today.

The district of South 24 Parganas houses the active delta of the Ganges, where its formation is still an ongoing process. The Sundarbans mangroves and their sustainabilityby adopting community contributionand spending social capital is the onlysuccessful techniqueto preserveUNESCO's World Heritage,and its vastbio-diversity of coastal lands, brackish water flora,fauna, avifauna, and aqua fauna.

**Reference:**


1. Rahman, MM, Ghosh T., Salehin M., Ghosh, A., Haque A., Hossain, MA., Das, S., Hazra S.. et al. (2020). Ganges-Brahmaputra-Meghna Delta, Bangladesh and India: A Transnational Mega-Delta. In: Nicholls, R., Adger, W., Hutton, C., Hanson, S. (eds) Deltas in the Anthropocene. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-030-23517-8_2
2. Bera, B., Bhattacharjee, S., Sengupta, N. et al. Significant reduction of carbon stocks and changes in ecosystem service valuation of Indian Sundarbans. Sci Rep 12, 7809 (2022). https://doi.org/10.1038/s41598-022-11716-5
3. Banerjee S, Chanda A, Ghosh T, Cremin E, Renaud FG. A Qualitative Assessment of Natural and Anthropogenic Drivers of Risk to Sustainable Livelihoods in the Indian Sundarbans. Sustainability. 2023; 15(7):6146. https://doi.org/10.3390/su15076146
4. Crutzen, Paul J., and Eugene F. Stoermer. 2000. "The Anthropocene." Global Change Newsletter 41: 17–18.
5. Zalasiewicz J, Williams M, Waters CN, Barnosky AD, Palmesino J, et al. 2016. Scale and diversity of the physical technosphere: a geological perspective. Anthr. Rev. 4:9–22
6. Mishra S. P., July 2020; Human Evolution/Extermination up to Present Anthropocene:India; Journal of Shanghai Jiaotong University; JSJ.U-2222.14-F (1).pdf; ISSN:1007-1172; 16 (7); 115-133
7. Waters, C. N., Turner, S. D., Zalasiewicz, J., & Head, M. J. (2023). Candidate sites and other reference sections for the Global boundary Stratotype Section and Point of the Anthropocene series. The Anthropocene Review, 10(1), 3–24. https://doi.org/10.1177/20530196221136422
8. Gera R, Narwal R, Jain M, Taneja G, Gupta S. Sustainable Development Goals: Leveraging the Global Agenda for Driving Health Policy Reforms and Achieving Universal Health Coverage in India. Indian J Community Med. 2018 Oct-Dec;43(4):255-259.
9. Hassani H, Huang X, MacFeely S, Entezarian MR. Big Data and the United Nations Sustainable Development Goals (UN SDGs) at a Glance. Big Data and Cognitive Computing. 2021; 5(3):28. https://doi.org/10.3390/bdcc5030028
10. Mishra SP, Mohapatra SK., Sethi KC. (2023) The Values and Blue Carbon Ecosystem of the Chilika Lagoon through Ages, India. Environ Sci Arch 2(2):164-184
11. FSI 2019. Mangrove resources of the country. India State of Forest Report 2019. Forest Survey of India, Ministry of Environment, Forest and Climate Change, Government of India, Dehradun
12. Kuenzer C, Bluemel A, Gebhardt S, Quoc TV, Dech S. Remote Sensing of Mangrove Ecosystems: A Review. Remote Sensing. 2011; 3(5):878-928. https://doi.org/10.3390/rs3050878
13. Chakrabarti, P., Nag, S. 2015. Rivers of West Bengal: Changing Scenario. Geoinformatics and Remote 811 Sensing Cell, Govt. of West Bengal, Kolkata: 265p.
14. Das I, Chanda A, Akhand A, Hazra S. Carbon Biogeochemistry of the Estuaries Adjoining the Indian Sundarbans Mangrove Ecosystem: A Review. Life (Basel). 2023;13(4):863. doi: 10.3390/life13040863

15. Dutta MK, Bianchi TS., Mukhopadhyay SK (2017) MangroveMethane Biogeochemistry in theIndian Sundarbans: Frontiers in Marine Science 4, DOI: 10.3389/fmars.2017.00187
16. Das, S.; Bhadra, T.; Hazra, S., Water for Agriculture in a Vulnerable Delta: A Case Study of Indian Sundarbans, NASA Astrophysics Data System (ADS), 2015-12-01
17. Kumar D, Dhaloiya A, Nain AS, Sharma MP, Singh A. Prioritization of Watershed Using Remote Sensing and Geographic Information System. Sustainability. 2021; 13(16):9456. https://doi.org/10.3390/su13169456
18. NITI Ayog, (2023). National multidimensional poverty index India, a progress review 2023.
19. Sreelekshmi, S., Nandan, S.B., Kaimal, S.V., Radhakrishnan, C.K. and Suresh, V.R., 2020. Mangrove species diversity, stand structure and zonation pattern concerning environmental factors—A case study at Sundarbans delta, east coast of India. Regional Studies in Marine Science, 35, p. 101111
20. Nandy, S., Tamang M., Kushwaha SPS., (2021), Plant Diversity Assessment in Indian Sundarbans Mangroves: A Geoinformatics Approach. Ch-5, In book: Sundarbans Mangrove Systems, DOI: 10.1201/9781003083573-5
21. Chanda A, Akhand A. Challenges towards the Sustainability and Enhancement of the Indian Sundarban Mangrove's Blue Carbon Stock. Life. 2023; 13(8):1787. https://doi.org/10.3390/life13081787
22. Payo, A., Mukhopadhyay, A., Hazra, S. Ghosh, S. Ghosh, S. Brown, RJ, Nicholls, L. Bricheno, J. Wolf, S. Kay, A.N. Lázár, and A. Haque. 2016.Projected changes in the area of the Sundarbans mangrove forest in Bangladesh due to SLR by 2100.Climatic Change: 1–13. https://doi.org/10.1007/s10584-016-1769-z
23. Ghosh T., 2018. Dynamics of the Sundarbans Mangroves in Bangladesh Under Climate Change. Ch-26, from the book: Ecosystem Services for Well-Being in Deltas; R. J. Nicholls et al. (eds.), https://doi.org/10.1007/978-3-319-71093-8_26
24. Nandy, S., Kushwaha, S.P.S., Dadhwal, V.K., (2011). Forest degradation assessment in the upper catchment of the river Tons using remote sensing and GIS. Ecological Indicators,11(2), pp. 509–513
25. Sahana, M., Sajjad, H., Ahmed, R. (2015). Assessing spatio-temporal health of forest cover using forest canopy density model and forest fragmentation approach in Sundarbans reserve forest, India. Model. Earth Syst. Environ. 1, 49, https://doi. org/10.1007/s40808-015-0043-0
26. Kushwaha, SPS, Nandy, S., Shah, M.A., Agarwal, R. and Mukhopadhyay, S., 2018. Forest cover monitoring and prediction in a Lesser Himalayan elephant landscape,Current Sci., 115(3), 510–516
27. Thakur, S., Mondal, I., Bar, S., Nandi, S., Ghosh, PB., Das P., De, TK, (2021). Shoreline changes and their impact on the mangrove ecosystems of some islands of Indian Sundarbans, North-East coast of India, Journal of Cleaner Production, 284, 124764, https://doi.org/10.1016/j.jclepro.2020.124764.
28. Mishra, S.P., Mishra, S., Bera, D.K. (2023). Anthropocene Lithology and Hydropower search through North Eastern Ghats Hills, Odisha. Water productivity journal, 3(1): 75-104. DOI: 10.22034/wpj.2023.170350
29. Giri, S., Mukhopadhyay, A., Hazra, S., Mukherjee, S., Roy, D., Ghosh, S., Ghosh, T., Mitra, D., (2014). A study on abundance and distribution of mangrove species in Indian Sundarbans using RS technique. J. of Coastal Cons., 18(4), 359–367
30. Mishra, SP., Barik, KK., Pattanaik, SK., (2021). The Vulnerability and Management to the Blue Carbon Ecosystem: Coastal Odisha, International Journal of Lakes and Rivers., ISSN 0973-457014(1); 43-70.
31. Heenkenda MK, Joyce KE, Maier SW, Bartolo R. Mangrove Species Identification: Comparing WorldView-2 with Aerial Photographs. Remote Sensing. 2014; 6(7):6064-6088. https://doi.org/10.3390/rs6076064
32. Datta, D., Bairagi, M., Dey, M. et al. Spatially explicit estimation of soil organic carbon stock of an estuarine mangrove wetland of eastern India using elemental analysis and very-fine resolution satellite data. Ecol Process 11, 30 (2022). https://doi.org/10.1186/s13717-022-00370-4
33. Doodee MDD, Rughooputh SDDV, Jawaheer S., (2023). Remote sensing monitoring of mangrove growth rate at selected planted sites in Mauritius. S Afr J Sci.;119(1/2), DOI: 10.17159/sajs.2023/13716
34. Sudirman N., Salim, HL., Rustam, A, Ati1 RNA, Hermina R., Marini Y, Suryono1et DD, (2023). IOP Conf. Ser.: Earth Environ. Sci. 1148 012041, doi:10.1088/1755-1315/1148/1/012041
35. Behera S.,Mohamad K. A., Idris I., Husain M., Dahdouh F., Assessment of mangrove vegetation based on remote sensing and ground-truth measurements at Tumpat, Kelantan Delta, East Coast of Peninsular Malaysia,thor. Int. J. of RS, Sensing,2011,32, 1635 – 1650,

36. Jia M, Liu M, Wang Z, Mao D, Ren C, Cui H. Evaluating the Effectiveness of Conservation on Mangroves: A Remote Sensing-Based Comparison for Two Adjacent Protected Areas in Shenzhen and Hong Kong, China. Remote Sensing. 2016; 8(8):627. https://doi.org/10.3390/rs8080627
37. Steckler, MS., Bar O.; t Jaman, H.. ; Mondal, DR. ; Grall, C., et al., 2021. Recent measurements of subsidence in the Ganges-Brahmaputra Delta, Bangladesh.https://ui. adsabs.harvard.edu/abs/2021,EGUGA.23.6562S/abstract
38. Rahman M., Dustegir M., Karim R., …. 10 authors, Akter M.,, (2018). Recent sediment flux to the Ganges-Brahmaputra-Meghna delta system. The Science of The Total Environment 643(1-2):1054-1064, DOI: 10.1016/j.scitotenv.2018.06.147
39. Lovelock CE. Duarte CM. 2019 Dimensions of Blue Carbon and Emerging Perspectives Biol. Lett.152018078120180781; http://doi.org/10.1098/rsbl. 2018.0781
40. Alongi DM. Global Significance of Mangrove Blue Carbon in Climate Change Mitigation. Sci. 2020; 2(3):67. https://doi.org/10.3390/sci2030067
41. Mishra SP., (2017). Management of the sediment transported by the south Mahanadi Deltaic rivers to the Chilika lagoon. Int. J. of Adv. Res. 5 (Jun). 1005-1020]. DOI:Article DOI: 10.21474/IJAR01/4503
42. Mandal JK., 2020. The scenario of population growth South 24 Parganas, Dist West Bengal, India. International Journal of Research in Social Sciences, 10(4), 10-26
43. Census of India 2011- National Population Register & Socio-Economic and Caste Census.ppt.
44. Bagchi E., 2017. Development of Basic Infrastructure: An Analysis of South 24 Parganas District in WB, India. Bulletin of Geogr. Socio-economic Series / No. 36 (2017): 33–60, DOI: 10.1515/bog-2017-0013
45. Chowdhury A, Naz A, Sharma SB, Dasgupta R. Changes in Salinity, Mangrove Community Ecology, and Organic Blue Carbon Stock in Response to Cyclones at Indian Sundarbans. Life (Basel). 2023 Jul 11;13(7):1539. doi: 10.3390/life13071539.
46. Edmonds, C., Mehtta, M., Noy, I., Banik, P. (2021). The Climate-(Ir)Resilient Society of the Indian Sundarbans. In: Brears, R.C. (eds) The Palgrave Handbook of Climate Resilient Societies. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-030-42462-6_95
47. Government of West Bengal, 2018. District survey report South 24-Parganas District; Sathi Planners Private Limited; Prepared As Per Ministry of Environment, Forest And Climate Change Notification S. O. 3611 (E),25th July 2018
48. Sievers, M., Chowdhury, MR., Adame, MF., Bhadury, P., Bhargava, R., Buelow, C., et al., 2020. Indian Sundarbans mangrove forest is considered endangered under the Red List of Ecosystems, but there is cause for optimism. Biological Conser., 251, 108751
49. Mishra SP., Ojha AC, MishraS., Sahu DK., 2022. Cyclogenesis and Odisha Coast, the Hotbed. Agriculture Association of Textile Chemical and Critical Reviews Journal (2022) 71-85, DOI:://doi.org/10.58321/AATCCReview.2022.10.01.85
50. Ghosh, A., Schmidt, S., Fickert, T., & Nusser, M. (2015). The Indian Sundarbans mangrove forests: History, utilization, conservation strategies and local perception. Diversity, 7, 149–169.
51. Islam ATMR, Hasan MM, Islam MT, Tanaka N. Ethnobotanical study of plants used by the Munda ethnic group living around the Sundarbans, the world's largest mangrove forest in southwestern Bangladesh. J Ethnopharmacol. 2022 Mar 1; 285:114853. doi: 10.1016/j.jep.2021.114853.
52. Mondal M., Paul S., Bhattacharya S., Biswas A., 2020. Micro-level Assessment of Rural Societal Vulnerability of Coastal Regions: An Insight into Sagar Island, West Bengal, India. Sage, Asia-Pacific Journal of Rural Development 30(1–2) 55–88, 2020, DOI: 10.1177/1018529120946230
53. Mahmud I, Islam MK, Saha S, Barman AK, Rahman Mmet.al.,. Pharmacological and Ethnomedicinal Overview of Heritiera fomes: Future Prospects. Int Sch Res Notices. 2014;2014:938543. doi: 10.1155/2014/938543
54. Patra, K.J., Dhal, K.N. and Thatoi, N.H. (2011) In Vitro Bioactivity and Phytochemical Screening of Suaeda maritima (Dumort): A Mangrove Associate from Bhitarkanika, India. Asian Pacific Journal of Tropical Medicine, 4, 727-734. http://dx.doi.org/10. 1016/S1995-7645(11)60182-X
55. Namazi R, Zabihollahi R, Behbahani M, Rezaei A. Inhibitory Activity of Avicennia marina, a Medicinal Plant in Persian Folk Medicine, against HIV and HSV. Iran J Pharm Res. 2013 Spring;12(2):435-43.
56. Thatoi, H., Samantaray, D., Das, SK., (2016). The genus Avicennia, a pioneer group of dominant mangrove plant species with potential medicinal values: a review, Frontiers in Life Science, DOI: 10.1080/21553769.2016.1235619

57. Alamgir M., Rob, DC Kundu, JHK, Joy, MM. 2007. Bioactivity of two medicinal plantsXylocarpus granatum Koen. (Meliaceae) and Sarcolobusglobosus Wall. (Asclepiadaceae) of Sundarbans mangrove forest M, Sarder Oriental Pharmacy and Experimental Medicine20077(4), 379-384 1
58. Shamsuzzaman M, Kalaiselvi K, Prabakaran M. Evaluation of Antioxidant and Anticorrosive Activities of Ceriops tagal Plant Extract. Applied Sci.. 2021; 11(21):10150. https://doi.org/10.3390/app112110150
59. Mondal S, Ghosh D, Ramakrishna K. A Complete Profile on Blind-your-eye Mangrove ExcoecariaAgallocha L. (Euphorbiaceae): Ethnobotany, Phytochemistry, and Pharmacological Aspects. Pharmacogn Rev. 2016.10(20):123-138. doi: 10.4103/0973-7847.194049.
60. Adhikari A, Ray M, Das AK, Sur TK. Antidiabetic and antioxidant activity of Rhizophora mucronata leaves (Indian Sundarbans mangrove): An in vitro and in vivo study. Ayu. 2016 Jan-Mar;37(1):76-81. doi: 10.4103/ayu.AYU_182_15.
61. Hossain SJ, Islam MR, Pervin T, Iftekharuzzaman M, Hamdi OAA, Mubassara S, Saifuzzaman M, Shilpi JA. Antibacterial, Anti-Diarrhoeal, Analgesic, Cytotoxic Activities, and GC-MS Profiling of Sonneratia apetala (Buch. -Ham.) Seed. Prev Nutr Food Sci. 2017 Sep;22(3):157-165. doi: 10.3746/pnf.2017.22.3.157.
62. Sur TK, Hazra A, Hazra AK, Bhattacharyya D. Antioxidant and hepatoprotective properties of Indian Sunderban mangrove Bruguieragymnorrhiza L. leave. J Basic Clin Pharm. 2016 Jun;7(3):75-9. doi: 10.4103/0976-0105.183262
63. Gurudeeban S, Satyavani K, Ramanathan T, Balasubramanian T. Antidiabetic effect of a black mangrove species Aegicerascorniculatum in alloxan-induced diabetic rats. J Adv Pharm Technol Res. 2012 Jan;3(1):52-6. doi: 10.4103/2231-4040.93560
64. Nabeelah Bibi S, Fawzi MM, Gokhan Z, Rajesh J, Nadeem N, R.R. RK, R.D.D.G. A, Pandian SK. Ethnopharmacology, Phytochemistry, and Global Distribution of Mangroves—A Comprehensive Review. Marine Drugs. 2019; 17(4):231. https://doi.org/10.3390/md17040231
65. Dey, D, Quispe, C., Hossain,R., Jain, D., Khan, RA., Janmeda, P., Islam MT., et al., 2021. Ethnomedicinal Use, Phytochemistry, and Pharmacology of Xylocarpus granatum J. Koenig", Evidence-Based Complementary and Alternative Medicine, 2021, 1- 16, https://doi.org/10.1155/2021/8922196
66. Mahmud I, Shahria N, Yeasmin S, Iqbal A, Mukul EH, Gain S, Shilpi JA, Islam MK. Ethnomedicinal, phytochemical and pharmacological profile of a mangrove plant Ceriops DecandraGriffDin Hou. J Complement Integr Med. 2018 Jun 22;16(1). doi: 10.1515/jcim-2017-0129.
67. Rahman MM, Al Noman MA, Khatun S, Alam R, Shetu MMH, Talukder EK, Imon RR, Biswas MY, Anis-Ul-Haque KM, Uddin MJ, Akhter S. Evaluation of Senna tora (L.) Roxb. leaves as a source of bioactive molecules with antioxidant, anti-inflammatory and antibacterial potential. Heliyon. 2023 19;9(1): e12855. doi10.1016/j.heliyon. 2023.e12855.
68. Abdul-Awal SM, Nazmir S, Nasrin S, Nurunnabi TR, Uddin SJ. Evaluation of the pharmacological activity of Hibiscus tiliaceus. Springerplus. 2016 Jul 29;5(1):1209. doi: 10.1186/s40064-016-2891-0.
69. Yusoff NA, Yam MF, Beh HK, Abdul Razak KN, Widyawati T, Mahmud R, Ahmad M, Asmawi MZ. Antidiabetic and antioxidant activities of Nypafruticans Wurmb. vinegar sample from Malaysia. Asian Pac J Trop Med. 2015 Aug;8(8):595-605. doi: 10.1016/j.apjtm.2015.07.015.
70. Crowley, M.A., Cardille, J.A. Remote Sensing's Recent and Future Contributions to Landscape Ecology. Curr Landscape Ecol Rep 5, 45–57 (2020). https://doi.org/ 10.1007/s40823-020-00054-9
71. Kumar AP., Gnanappazham, L., Selvam,V., Ramasubramanian R., Kar CS., (2015). Developing a spectral library of mangrove species of Indian east coast using field spectroscopy, Geocarto Inter, 30:5, 580-599. DOI: 10.1080/10106049.2014.985743
72. Mishra, SP., Mishra, A., Kumar, C., Sahu, D. K., & Mishra, S. (2022). Distressed Lives and Livelihood in Biosphere Reserves during Anthropocene; Similipal Forest Blaze -2021. Current Journal of Applied Science and Technology, 41(25), 17-27. https://doi.org/10.9734/cjast/2022/v41i2531772
73. Mondal BK., 2015. Nature of Propensity of Indian Sundarbans. International Journal of Applied Research and Studies (I JARS), 4(1)
74. India State of Forest Report (ISFR), 2011 to 2021, Forest Survey of India, Dehradun, https://fsi.nic.in
75. Unikrishnan AS., Shankar D., (2007), AreSealevel risetrends along the North Indian coast consistent with global estimate. Global planet change, 57, 301-307
76. Mishra S. P., 2017, Stochastic Modelling of Flow and Sediment of the Rivers at Deltahead, East Coast of India, American Journal of Operation Research, Scientific Research, Vol. 7 (6), PP. 331-347, DOI: 10.4236/ajor.2017.76025