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Mangroves of India: A Synoptic Review on Ecological Functions and Economic Services

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Abstract: This paper deals with a synoptic review of the ecological and economic services of mangroves concerning India. The information was collected by visiting Internet search engines and published articles and reports. Mangrove forests live in two worlds at once, acting as the interface between land and sea. They exhibit unique adaptations. Mangrove ecosystems harbours a variety of flora and fauna. They provide a variety of services related to ecological and economic aspects. Anthropological pressures and natural calamities are the enemies of the ecosystem. Scientific knowledge of these habitats would help in better management so that productivity could be combined with sustainability and conservation.

Keywords: Mangrove Ecosystem, Ecological and Economic services.

I. INTRODUCTION

The term "mangrove" refers to a tidally influenced wetland ecosystem within the intertidal zone of tropical and subtropical latitudes. Mangrove also designates the marine tidal forest that includes trees, shrubs, palms, epiphytes, and ferns [1]. The distinctive community of plants and animals associated with mangroves is sometimes referred to as the 'mangal' [2]. Mangrove ecosystems are heterogeneous habitats with an unusual variety of animals and plants adapted to the environmental conditions of highly saline, frequently inundated, soft-bottomed anaerobic mud [3]. Not all mangroves are obligated to live in saline intertidal areas [4]. Plants that are confined to the mangrove are called true mangroves; plants that can also occur elsewhere are called mangrove associates. Mangrove associates never grow in true mangrove communities and may occur in terrestrial vegetation. The mangrove fauna includes terrestrial, marine, temporary, and permanent animal species, all of which have different adaptations to cope with the mangrove environment. They play a vital role in ecological as well as economic services.

II. DISTRIBUTION

Worldwide, 117 countries have mangroves with a total area of 190,000 sq. Km. An estimate suggests that in 1953, the Indian Mangrove area was 6000 Sq.Km. [5]. According to a status report of the Government of India publication, the total area of the mangroves in India was reckoned at about 6,740 km^2. This covered about 7% of the world's mangroves and 8% of the Indian coastline [6]. But Indian Remote Sensing Data showed that the total area of the mangroves decreased to 4,474 km^2 [7]. Now one can imagine the magnitude of depletion. Out of the total area, 57% of the mangroves are found on the East Coast, 23% on the west coast, and the remaining 20% on the Bay Islands like Andaman and Nicobar [8].
The mangrove habitat of India is broadly classified into three namely, Deltaic (Eastern Coast Mangroves), Estuarine & Backwater (Western Coast Mangroves), and Insular mangroves (Andaman & Nicobar Islands) [9]. Mangroves are prominent on the east coast of India because of the nutrient-rich soils brought in by rivers, Ganges, Brahmaputra Godavari, Mahanadi, Krishna, and Cauvery and a perennial supply of freshwater along the deltaic coast because of which on the shores of the Bay of Bengal only deltaic mangroves exist. On the other hand, the west coast is characterized by typical funnel-shaped estuaries of the rivers like Indus, Tapati and Narmada characterized by creeks and backwaters and hence the backwater estuarine type mangroves occur on the coasts of the Arabian sea [10]. There are 38 Mangroves sites in India [11]. The highest number of mangroves sites in a state is in Maharashtra that is 10 and the second on the list with 7 sites in Orissa [Table 1 and 2].

III. ECOLOGY OF MANGROVES

Mangrove forests live in two worlds at once, acting as the interface between land and sea. Mangroves help protect coastlines from erosion, storm damage, and wave action. The stability mangroves provide is of immense importance. They prevent shoreline erosion by acting as buffers and catching alluvial materials, thus stabilizing land elevation by sediment accretion that balances sediment loss. Vital coral reefs and seagrass beds are also protected from damaging siltation. The climate of the inter-tidal region acts as the most significant factor for the natural growth, development, and succession of the mangroves. Among these climatic factors' rainfall, regular wind flow, radiation, sedimentation play a very dominant role in the mangrove viability. The air temperature of the region may be governed by the geographic

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distribution of the different species of mangroves [12]. Atmospheric temperature fluctuation ranges between 20°C and 35°C. The rainfall conditions are more decisive for the sequence of mangrove distribution of the different zone in the tidal regions. Frequent rainwater-flashing wash out the surface salt and also leach down the salt particles and make the land suitable for the growth of the mangrove. Mangrove develops best in the region, experiencing abundant rainfall. The wind is the driving power of the air and its mechanical effect may cause damage to the system. The soil structure and soil salinity are the main agents, controlling the distribution of mangroves.

The tidal fluctuations have a major role for mangrove habitats most mangroves grow well in between the Mean High Water Spring Tide (MHWST) and Mean Sea Level (MSL). Along with the west coast, the tidal amplitude changes from south to north. Tides are also affected by freshwater discharge, particularly, floods during monsoon seasons [13]. Based on salinity, five zones of mangrove distribution are considered, these are the euhaline, polyhaline, mesohaline, oligohaline and limnetic zones. The west coast is characterized by the rocky substratum and hence the absence of mangroves in the mouth region. On the other hand, the same euhaline zone along the estuaries of the east coast, which is a delta region, shows the presence of luxuriant mangrove forests as observed in the Gangetic, Mahanadi, and Godavari deltas.

IV. FLORA AND FAUNA

The floristic composition includes angiosperms like true mangroves and associated mangroves. This vegetation in turn supports a variety of algae, bryophytes, and ferns. The Indian mangroves comprise approximately 59 species in 41 genera and 29 families. Of these, 34 species belonging to 25 genera and 21 families are present along the west coast. There are about 25 mangrove species, which have restricted distribution along the east coast and are not found on the west coast [9]. There are approximately 16 mangrove species reported from the Gujarat coast, while Maharashtra has about 20 species, Goa with14 species, and Karnataka 10. There are hardly three to four species of mangrove that are rarely found along the Kerala coast [14]. The associated mangrove flora is quite common to both the coasts, with minor variations in distribution.

The wildlife of Indian mangrove forests is quite diverse and interesting. Apart from the famous Royal Bengal tiger and estuarine crocodile, there are different kinds of monkeys, fishing cats, snakes, and wild pigs. The mangrove swamps of India are favored by a variety of birds, both migratory and resident. There are different types of faunal communities in mangrove waters that are dependent on the water component in one way or the other. The fishes are represented by several species like mudskippers, carangids, clupeids, serranids, mullets, hilsa, seabass, milkfish, etc. The detritus system consists of fungi and other microorganisms. Microbial organisms like bacteria and fungi play a very important and dominant role in the decomposition of mangrove foliage, regeneration of nutrients, and mineralization.

V. MANGROVE ADAPTATIONS

The mangroves exhibit very unique modifications to survive in estuarine habitats. The mangrove community is the biotic part of this ecosystem. Mangroves, which can live in the most inundated areas, prop themselves up above the water level with stilt roots, and can then take in air through pores in their bark (lenticels). Some mangroves live on higher ground and make many specialized root-like structures called pneumatophores for breathing. These “breathing tubes" typically reach heights of up to 30 centimeters. The roots also contain wide air-filled cavities to facilitate oxygen transport within the plant [15]. Columnar trunks of certain mangroves are flanged or buttressed with a short plate-like protuberance, called plank buttresses. The main function is to increase the surface area at the base of the trunk as support.

Mangroves exclude salt by having rather impermeable roots which are highly suberized, acting as an ultra-filtration mechanism to exclude sodium salts from the rest of the plant. The water inside the plant shows that 90%, and in some cases of high salinity, up to 97%, of the salt, has been excluded at the roots. Any salt which does accumulate in the shoot is concentrated in old leaves which are then shed, as well as stored away safely in cell vacuoles [16]. Some Mangroves secrete salts directly, they have salt glands at each leaf base. Because of the limited availability of freshwater in the salty soils of the Intertidal zone, mangrove plants have developed ways of limiting the amount of water that they lose through their leaves. They can restrict the opening of their stomata and can vary the orientation of their leaves. By orienting their leaves, the mangrove plants can reduce evaporation from their leaf surfaces.

The biggest problem that mangroves face is nutrient uptake. Because the soil that mangroves live in is perpetually waterlogged, there is not much free oxygen available. Since the soil is not particularly nutritious, mangroves have adapted by modifying their roots [15]. Prop root systems allow mangroves to take up gasses directly from the atmosphere and various other nutrients, like iron, from the soil. They quite often store gasses directly inside the roots so that they can be processed even when the roots are submerged during high tide.

All mangroves have buoyant seeds that are suited to dispersal in water. Unlike most plants, whose seeds germinate in the soil, many mangrove plants are viviparous, i.e., their seeds germinate while still attached to the parent tree [17]. Once germinated the seedling grows either within the fruit or out through the fruit to form what is called a propagule, which

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can produce its food via photosynthesis. When the propagule is mature it drops into the water where it can then be transported great distances.

VI. ECOLOGICAL AND ECONOMIC SERVICES

Ecological and socioeconomic values offered by the mangroves are innumerable, immeasurable, and incomparable. So conserving the mangroves should be a priority in any nation's conservation programs. The status and species composition of mangrove forests is a basic requirement and a prerequisite for the management and conservation of mangrove resources. It is necessary to collate comprehensive species-specific information for the mangroves of India, in the absence of which it will be difficult to set up conservation priorities [9]. Thus, the comprehensive information on diversity in mangroves of India provided here will help in the long-term monitoring of mangrove species in the country and formulating species-specific conservation strategies. The mangrove wetlands offer refuge and nursery grounds for juvenile fish, crabs. shrimps, and mollusks. Mangroves are also prime nesting and migratory sites for hundreds of bird species. Additionally, crab-eating monkeys, fishing cats, monitor lizards, sea turtles, and mud-skipper fish utilize the mangrove wetlands. Mangrove ecosystems have traditionally been sustainably managed by local populations to produce food, medicines, tannins, fuelwood, and construction materials. For millions of indigenous coastal residents, mangrove forests offer dependable, basic livelihoods and sustain their traditional cultures [18].

The services and values can be divided into two types—direct and indirect. Direct value refers to harvestable products for personal use or sale in local and international markets. Indirect value refers to services or uses which do not use up the resource. Wood is used for the construction or repair of houses, firewood, or charcoal. Leaves or seeds as fodder. Saponins released from some mangrove species are used as poisons. The viviparous seedlings are also boiled and eaten [19]. Many mangrove species are exploited for their medicinal usage. The bark of mangrove trees is harvested as a source of tannin for the tanning industry. Mangrove sap is, however, still used by East Africans to make the black dye for cloth. Mangrove trees are exploited for the lignocellulose for the manufacture of chipboard, pulpwood (newspaper and cardboard), or synthetic materials.

Mangroves, if they retain the full diversity of species, have great potential for yielding products that humankind can exploit in the future. This is the new world of bioprospecting. The numerous species used in folk medicine are a starting point for exploration for scientific medicinal usage [20]. Experiences have proved that the presence of mangrove ecosystems on coastline saves lives and property during natural hazards such as cyclones, storm surges, and tsunamis. These ecosystems harbor a variety of flora and fauna. They are breeding, feeding, and nursery grounds for many estuarine and marine organisms. Mangrove wildlife is a major tourist attraction.

Detritus decomposition is an important ecological role of the mangroves. The detritus, besides forming a food source, is also consumed by the juveniles of a variety of bivalves, shrimps, and fishes, which migrate into the mangrove environments in their life cycle for better feeding and protection [21]. Ecosystem value includes productivity, energy flow, trophic relationship, and nutrient cycling. The major ecological role of mangroves is the stabilization of the shoreline and prevention of shore erosion. The dense network of prop roots, pneumatophores, and stilt roots not only gives mechanical support to the plant but also traps the sediments. A summary of ecological and economic services of mangroves is presented in table 3.

VII. THE THREATENED ECOSYSTEM

Mangroves are the rainforests by the sea. Most of the subtropical and tropical coastline is dominated by mangroves. However, over the past several decades, the global area in mangroves has increasingly diminished because of a variety of human activities [22]. Anthropological pressures and natural calamities are the enemies of the ecosystem. Growing industrial areas along the coastlines and discharge of domestic and industrial sewage are polluting these areas. With the exploitation of mangroves for their economic value, often the environment is degraded to some extent or almost totally wiped due to indiscriminate harvesting of raw materials for wood, charcoal, chipboard, or pulpwood. Apart from this, indiscriminate fishing and sand mining added much to the erosion of these ecosystems.

VIII. CHALLENGES AND SOLUTIONS

Now the importance of these ecosystems is recognized and realized and efforts have been initiated at the International and National levels. Because of the uniqueness of the mangrove ecosystems, they are frequently the object of conservation programs including national Biodiversity action plans. At the Global level Mangrove Action Group has been set up to monitor and initiate conservation measures. In our country, National Mangrove Committee has been set up. The Central government enacted a law-Coastal Regulation Zone (CRZ) to control and monitor the coastal zones in the country [23]. In Karnataka, the forest department has already implemented many projects including plantation work in estuaries. However, the mangroves are said to be a global heritage with local importance. They should be exploited on a sustainable

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basis. Massive awareness programs have to be initiated so that they should reach all the individuals, communities without discrimination into rich-poor, child-adult, urban-rural, male-female, etc. Our recent experience of Tsunami already alarmed the significance of these unique ecosystems.

There is an increasing awareness regarding the importance of these great coastal habitats. However, the biodiversity of these habitats is being threatened and their long-term productivity endangered. Scientific knowledge of these habitats would help in better management so that productivity could be combined with sustainability and conservation. It is evident from the literature that these ecosystems are under immense anthropogenic pressure. The baseline studies of these fragile ecosystems are essential. The ecosystem has a very large unexplored potential for natural products useful for medicinal purposes and salt production, apiculture, fuel, and fodder, etc. Sustainable exploitation is the only way to conserve these ecosystems.

TABLE 1. STATE AND UNION TERRITORIES WITH MANGROVE SITES

State/Union Territories	Mangrove sites
West Bengal	Sunderbans
Orissa	Bhaitarkanika, Mahanadi, Subernarekha, Devi, Dhamra, Chilka
Andhra Pradesh	Coringa, East Godavari, Krishna
Tamil Nadu	Pichavaram, Muthupet, Ramnad, Pulicat, Kazhuveli
Andaman & Nicobar	North Andamans, Nicobar
Kerala	Vembanad, Kannur
Karnataka	Coondapur , Honnavar, Karwar
Goa	Goa
Maharashtra	Achra-Ratnagiri, Devgarh-Vijay Durg, Veldur, Kundalika-Revdanda, Mumbra-Diva, Vikroli, Shreevardhan, Vaitarna, Vasai-Manori, Malvan
Gujarat	Gulf of Kutchh, Gulf of Khambhat, Dumas-Ubhrat

(Source: Annual Report MoEF & CC 2020-21)

TABLE 2. STATUS OF MANGROVE AREA

(area in sq km)

S.No.	State/UT	Very Dense Mangrove	Moderately Dense Mangrove	Open Mangrove	Total	Change with respect to ISFR 2017
1.	Andhra Pradesh	0.00	213.00	191.00	404.00	0.00
2.	Goa	0.00	20.00	6.00	26.00	0.00
3.	Gujarat	0.00	169.00	1,008.00	1,177.00	37.00
4.	Karnataka	0.00	2.00	8.00	10.00	0.00
5.	Kerala	0.00	5.00	4.00	9.00	0.00
6.	Maharashtra	0.00	88.00	232.00	320.00	16.00
7.	Odisha	81.00	94.00	76.00	251.00	8.00
8.	Tamil Nadu	1.00	27.00	17.00	45.00	-4.00
9.	West Bengal	996.00	692.00	424.00	2,112.00	-2.00
10.	A&N Islands	398.00	169.00	49.00	616.00	-1.00
11.	Daman & Diu	0.00	0.00	3.00	3.00	0.00
12.	Puducherry	0.00	0.00	2.00	2.00	0.00
Total		**1,476.00**	**1,479.00**	**2,020.00**	**4,975.00**	**54.00**

(Source: Annual Report MoEF & CC 2020-21).

TABLE 3. MANGROVES: ECOLOGICAL AND ECONOMIC SERVICES

Ecological function	Economic goods and services	Value type
Flood and flow control	Flood protection	Indirect use
Storm buffering/sediment retention	Storm protection	Indirect use
	Improved water quality	Indirect use

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Water quality maintenance/nutrient retention	Waste disposal	Direct use
Habitat and nursery for plant and animal species	Commercial fishing and hunting	Direct use
	Recreational fishing and hunting	Direct use
	Harvesting of natural materials	Direct use
	Energy resources	Direct use
Biodiversity	Appreciation of species	Non-use
Carbon sequestration	Reduced global warming	Indirect use
Natural environment	Recreation and tourism	Direct use
	Existence, bequest, option value	Non-use

(Source: Salem, Marwa E., and D. Evan Mercer. 2012.)

CONCLUSIONS

Mangrove ecosystems are the wetland ecosystems in the intertidal zone of tropical and subtropical latitudes. Mangrove ecosystems harbor a variety of flora and fauna. They provide a variety of services related to ecological and economic aspects. Anthropological pressures and natural calamities are the enemies of the ecosystem. The mangrove habitat of India is broadly classified into three namely, Deltaic (Eastern Coast Mangroves), Estuarine & Backwater (Western Coast Mangroves), and Insular mangroves (Andaman & Nicobar Islands). The floristic composition includes angiosperms like true mangroves and associated mangroves. This vegetation in turn supports a variety of algae, bryophytes, and ferns. The mangroves exhibit very unique modifications to survive in estuarine habitats. The mangrove community is the biotic part of this ecosystem. Ecological and socioeconomic values offered by the mangroves are innumerable, immeasurable, and incomparable. So conserving the mangroves should be a priority in any nation's conservation programs. The status and species composition of mangrove forests is a basic requirement and a prerequisite for the management and conservation of mangrove resources. Scientific knowledge of these habitats would help in better management so that productivity could be combined with sustainability and conservation.

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