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Ecology of Mangroves: A Comprehensive Review

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Mangroves are a unique type of coastal ecosystem found in tropical and subtropical regions. They are dense forests of salt-tolerant trees and shrubs that thrive in intertidal zones, where land meets the sea. These ecosystems are characterized by their ability to withstand harsh conditions, such as saline water, tidal fluctuations, and muddy, oxygen-poor soils.

Characteristics:

Mangroves exhibit Viviparity mode of reproduction, where seeds germinate within the tree before falling to the ground. This is an adaptive mechanism to overcome the challenge of germination in saline water. Some mangrove species secrete excess salt through their leaves, while others block the absorption of salt at their roots. Mangrove plants have special roots like prop roots and pneumatophores, which help impede water flow and provide support in the challenging tidal environment (Kathiresan and Bingham, 2001).

Status of Mangroves cover in India

According to the Indian State Forest Report 2021, Mangrove cover in India is 4992 sq. Km which is 0.15% of the country's total geographical area. Sundarbans in West Bengal are the largest mangrove forest regions in the world. It is listed as a UNESCO World Heritage Site. Besides the Sundarbans, the Andamans region, the Kachchh and Jamnagar areas in Gujarat too have substantial mangrove cover (Anon, 2021).

Influence of Environmental factors on Mangrove vegetation

The structure and functions of mangrove ecosystems, and therefore the composition and distribution of species and growth patterns of mangrove organisms, depend heavily on the following environmental factors:

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- **Coastal Physiography:** Mangroves generally dominate coastal zones with mudflats and tidal estuaries deltas (Lugo and Snedaker, 1974). Topography is an important factor affecting the characteristics of mangrove structure, especially species composition, species distribution and the size and extent of mangrove forest. Along the submerged shoreline, mangroves form a narrow fringe to shelter the narrow coastal plains around mountainous islands. Characteristics of coastal plains, such as area, extent and location, are related to tidal inundation, sedimentation, and sediment characteristics. Mudflats and estuaries influenced by streams or rivers are generally associated with fertile mangrove areas supporting a vast diversity of plants and animals, as is seen in the Sundarbans Forest in Bangladesh and India.
- **Climate:** Light, temperature, rainfall and wind all have a strong influence on the mangrove ecosystem. Apart from playing a significant role in the development of plants and animals, they also cause changes in other physical factors such as soil and water. Light is vital for photosynthesis and growth processes of green plants. It also affects the respiration, transpiration, physiology and physical structure of the plants. Light intensity, quality and duration are factors known to be important to plants. In general, mangrove plants are long-day plants and require high intensity of full sunlight.
- **Rainfall:** The amount, duration and distribution of rainfall are important factors determining the development and distribution of plants and animals. In addition, rainfall & other environmental factors such as air and water temperatures, salinity of surface and groundwater which, in turn, affects the survival of mangrove species. Normally, mangroves thrive in areas with a range of 1,500-3,000 mm of annual rainfall. However, they can also be found in areas with rainfall as high as 4,000 mm per year distributed over a period of 8-10 months in a year.
- **Temperature**: Temperature is of importance to physiological processes such as photosynthesis and 35 Ecology and Management of Mangroves respiration. However, there is little evidence of the relationship between temperature variation and the growth of plants in mangroves. Study in Australia and found that Avicennia marina sprouted fresh leaves at temperatures of 18-20°C and observed that the higher the temperature, the lower the rate of new leaf production.

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- **Wind:** Wind has a number of effects on the mangrove ecosystem. Not the least of these is the influence of wind on waves and currents in coastal areas, which cause coastal erosion and changes in mangrove structure. Plants often depend on winds as agents of pollination and seed dissemination. Wind can also increase evapotranspiration of plants. Strong winds are capable of impeding plant growth and causing abnormal physiological characteristics.
- **Tides:** In coastal areas, tides determine the zonation of plant and animal communities found within the mangroves. Tidal duration has a great influence on salinity changes in mangrove areas. Salinity of water is high during high tide and decreases during low tides. Moreover, water salinity varies during spring and neap tides. During spring tides, highly saline water intrudes further into the mangrove areas than during neap tides. Changes in water salinity due to tides are one of the factors limiting species distribution in mangroves, especially horizontal distribution. Tides also contribute to the exchange of mass between fresh water and salt water and thereby affect the vertical distribution of mangrove organisms.
- **Waves and Currents:** Waves in coastal areas are mostly created by wind. Coastal waves are important because they can cause coastal erosion and suspension of sediment. At sandy or muddy beaches, waves carry particles of sand and sediment out to the sea. Larger or coarser particles will precipitate, accumulate and form a sandy beach or sand bar. Another type of wave mostly found outside the bays is the tidal bore, which occurs when water at high tide flows into rivers with high velocity. Once it reaches the shallow areas, this water runs into the river currents, causing higher levels of water and waves in the river. These waves look like walls of water intersecting the river. Most tidal bores occur at the mouth of the bays or narrow rivers or tidal water channels where currents are temporarily blocked. Tidal bores depend on the volume of freshwater flowing into the bays and which temporarily obstructs the influence of high tide.
- **Salinity**: Salinity and interstitial water salinity are important to growth rate, survival rate, and zonation of mangrove species. Mangroves usually exist and thrive in estuaries with a range of salinity between 10-30 ppt. However, several mangrove species can grow in very high salinity. In Australia, *Avicennia marina* can grow in areas where

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salinity is as high as 85 ppt. *Avicennia officinalis* can grow in areas with a maximum salinity of 63 ppt.

- **Dissolved oxygen:** Dissolved oxygen is extremely important for the existence of plants and animals in mangroves, especially in the processes of respiration and photosynthesis. It also plays an essential part in the decomposition of litter in the mangrove ecosystem. Thus, it is one of the factors controlling species composition, distribution and growth. Oxygen concentration in mangroves varies over 24 hours, being the lowest at night and highest during the day. Mangrove plants, especially those with pneumatophores *Sonneratia* spp., need dissolved oxygen for their respiration. Mangrove animals also need a considerable amount of oxygen. In some areas where dissolved oxygen 1.0-2.0 mg/l, aquatic organisms can still survive because they can adapt themselves to low oxygen content. During low tides, bivalves like those in Ostreidae family, close their valves and turn to anaerobic respiration. &a rosea come up from their holes to breath during low tides.
- **Soil Mangrove**: Soils are formed by the accumulation of sediment derived from coastal or river bank erosion, or eroded soils from higher areas transported down along rivers and canals. Some may originate corn the sedimentation of colloidal materials and particulates. Sediments that have accumulated along the coast and in mangroves have different characteristics, depending on their origin. Sediment from rivers and canals is fine muddy soil, while coastal sediment is mainly sand. The degradation of organic matter deposited through time is also part of mangrove soils.

Importance of Mangroves

Mangroves reduce wave damage: Mangroves reduce wind and swell waves, preventing erosion and damage to structures like dikes and sea walls. During rising tides, waves can enter mangrove forests. Over 100 metres of mangroves, they lose energy as they pass through the tangled above-ground roots and branches, resulting in a rapid decrease in height of 13-66 %. As this happens, waves lose their ability to scour the seabed and transport sediments. Mangroves reduce wind across the water's surface, preventing waves from propagating or re-forming. Waves that travel through more obstacles in a higher density experience the fastest rate of reduction. Thus, waves in shallow water are attenuated more quickly by mangroves with aerial roots than by those without. Clearly, low branches and closely spaced arching prop roots

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provide a more substantial barrier to waves than sparse areas with few or no aerial roots. Waves may cross above aerial roots as the water gets deeper, but the Asian Nypa palm's dense fronds or lower branches can block waves in a similar way. The most likely mangroves to be successful in lowering wave heights are those with a complex structure of low branches and dense aerial roots, along with a variety of species varying in size and age.

Mangroves in binding the soil: Every coastline experiences changes due to waves and currents; sometimes they bring sediments to the shore, but other times they cause erosion and the loss of land. Mangroves typically improve sedimentation and lessen erosion in areas where they are found. The mangrove vegetation lessens wave energy and slows water flow across the soil's surface, which lessens the water's ability to eject sediments from the mangrove area. Simultaneously, the slower water flows may cause suspended sediments to settle out of the water, leading to a rise in the amount of sediment deposited. The organic matter that the mangroves themselves produce, which includes both dead leaves and woody materials as well as living roots, is abundant in typical mangrove soils. This is evident in many coastal regions, including those in the Gulf of Thailand, northern Java, and Guyana, where mangroves have been replaced with aquaculture or agriculture. These coasts, which were once steady or even advancing, are currently receding at a rate of several metres annually.

Biodiversity Conservation

Mangroves provide a unique habitat for a wide variety of plant and animal species, serving as breeding, nursery, and feeding grounds for numerous marine and terrestrial organisms. For example, sundarban hosts the Royal Bengal tiger, Irrawady Dolphin, Rhesus macaque, Leopard cats, Small Indian civet. Coastal Protection: Mangroves act as natural buffers against coastal erosion, storm surges, and tsunamis. Their dense root systems and tangled network of prop roots stabilize shorelines and reduce the impact of waves and currents. During hurricanes and cyclones, mangroves can absorb and dissipate a significant amount of energy, protecting inland areas and human settlements from devastating damage. Carbon Sequestration: Mangroves are highly efficient carbon sinks, sequestering large amounts of carbon dioxide from the atmosphere and storing it in their biomass and sediments (Duke *et al.*, 2014). Fisheries and Livelihoods: Mangroves support fisheries by providing nursery areas for fish and shellfish, enhancing fishery productivity and contributing to livelihood and local food

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security. Water Quality Improvement: Mangroves act as natural filters, trapping and removing pollutants and excess nutrients from coastal waters before they reach the open ocean. Their role in purifying water contributes to the health of marine ecosystems and helps maintain the balance of fragile coastal ecosystems. Tourism and Recreation: Mangroves offer recreational opportunities such as eco-tourism, bird watching, kayaking, and nature-based activities, which can promote sustainable economic growth for local communities (Acharya, 2002).

Threats for mangroves

Destruction and Fragmentation of Habitat: Mangroves are frequently cleared for a variety of reasons, such as infrastructure development, urbanisation, aquaculture, and agriculture (Gilman *et al.*, 2008). These actions cause mangrove habitats to become fragmented and disappear, which affects the biodiversity and ecosystem function of these areas. One major concern is the conversion of mangroves into commercial uses, such as shrimp farms. Climate Change and Sea Level Rise: Mangroves are seriously threatened by the rising sea levels brought on by climate change. Extreme weather events like storms and cyclones are another effect of climate change that can seriously harm mangrove forests. Pollution and Contamination: Mangrove habitats are contaminated by pollution from industrial discharges, agricultural runoff, and improper waste disposal (Adame *et al.*, 2021). The plants and animals in these ecosystems are negatively impacted by heavy metals, plastics, and other pollutants. Absence of Integrated Management: Mangroves are frequently managed independently, failing to take into account their connections to nearby ecosystems such as seagrass beds and coral reefs (DasGupta and Shaw, 2017). Effective conservation requires integrated management strategies that take the larger coastal ecosystem into account.

Government Initiatives Related to Mangrove Conservation:

- **UNESCO Designated Sites:** The inclusion of mangroves in Biosphere Reserves, World Heritage sites and UNESCO Global Geo-parks contributes to improving the knowledge, management and conservation of mangrove ecosystems throughout the world.
- **Cultural advantage and community participation:** Eg. Bon Bibi is forest goddess worshipped by people of Sundarbans. In this it helps to reduce encroachment and poaching of resources.

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- **International Society for Mangrove Ecosystem (ISME):** The ISME is a non-governmental organization established in 1990 to promote the study of mangroves with the purpose of enhancing their conservation, rational management and sustainable utilization.
- **Blue Carbon Initiative:** The International Blue Carbon Initiative is focused on mitigating climate change through the conservation and restoration of coastal and marine ecosystems. It is coordinated by Conservation International (CI), IUCN, and the Intergovernmental Oceanographic Commission-UNESCO (IOC-UNESCO). **International Day for the Conservation of the Mangrove Ecosystem:** UNESCO celebrates this day on July 26 with the aim of raising awareness about mangrove ecosystems and to promote their sustainable management and conservation.
- **Mangroves for the Future Initiative:** IUCN and UNDP developed a unique initiative to promote investment in coastal ecosystem conservation called the "Mangroves for the Future (MFF)". The member nations include Bangladesh, Cambodia, India, Indonesia, Maldives, Myanmar, Pakistan, Seychelles, Sri Lanka, Thailand, and Vietnam.
- **National Mangrove Committee:** The Government of India set up a National Mangrove Committee in 1976 which advises the government about conservation and development of mangroves. The IUCN and The Nature Conservancy have laid down a global scientific map for the purpose of mangrove restoration and it needs to be implemented effectively.
- **Ramsar wetland conservations** and protocol should be upheld to boost conservation of mangroves.
- **National Mangrove Committee:** The Government of India set up a National Mangrove Committee in 1976 which advises the government about conservation and development of mangroves.
- **MISHTI** (Mangrove Initiative for Shoreline Habitats & Tangible Incomes) and **Sustainable Aquaculture in Mangrove Ecosystem (SAIME) initiative**

Way Forward

Using AI algorithms and high-resolution cameras, drone technology can be used to monitor the health of mangroves and identify illicit activities like logging or encroachment.

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Using this method can aid in timely and effective surveillance over large regions. Mangrove Adoption Programme: Start an initiative that is driven by the public that allows people, businesses, and institutions to "adopt" a mangrove patch. In order to promote a sense of ownership and group responsibility, participants would be in charge of the upkeep, defence, and restoration of the area they had adopted. Investing in research and development on mangroves can lead to innovative uses of these plants, such as phytoremediation for the treatment of contaminated water or the creation of new medications using extracts from the plants. This may result in novel approaches to utilising the special qualities of mangroves for sustainable growth.

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