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MANGROVES OF ANDHRA PRADESH; THEIR ETHNOBOTANICAL SIGNIFICANCE AND CONSERVATION STRATEGIES: A REVIEW

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Abstract

The Mangroves are a unique set of shrubs and trees which are found in the estuarine regions of the world. They are found in waterlogged conditions and they show a remarkable tolerance towards the salinity levels in the water. Due to their halophytic nature, they are also a host for a multitude of flora and fauna. It is not wrong to say that there is no dearth of commercial or ethnobotanical uses of the mangrove plants for the benefit of the human beings. Yet, their over-exploitation is a sure way to attract natural or climatic calamities that cannot be fought against. Effective conservation strategies have to be put in place for us to negate any coastline erosion, forest cover degradation and species extinction. There are multi-faceted solutions to combat the deforestation of mangrove forests. One of the solutions is to educate the local fisherfolk about the impending need to conserve mangrove forests. Remote sensing techniques using satellite imagery can be used to analyze and compare the extent of forest cover over the decades. It also helps if scientists show interest in continuing their observations and experiments on the mangrove forests, especially in Krishna-Godavari Deltaic regions of Andhra Pradesh, India, as there is lack of sufficient information about the nature of these mangrove forests and their pharmacopeial role in the world

Keywords: Mangroves, Forests of Machilipatnam, Fisherfolk, Ethnobotany, Sustainable Farming, Conservation Strategies.

Introduction

Mangroves are a group of trees and shrubs which are capable of withstanding the harsh climatic conditions of the shorelines. Mac Nae is credited with naming the mangroves first as "Mangals", although later the term was interchanged with "Mangrove" which was suggested by Lear and Turner. Their definition for the "Mangroves" was- "coastal ecosystem in a holistic manner, including its common habitat or inhabitant flora" [Kumudranjanet al., 1999]. The mangroves are also defined as a group of plants, either trees of shrubs, or palm or ground fern or grass, which grow above half of a meter in height and are found above the main sea level near the intertidal zones of coastal or estuarine regions. The mangroves are the only group of forests found near the confluence of the land and the sea [Udai Ram Gurjaret al., 2019]. The mangroves are primarily found near the tropical and sub-tropical regions of the world; between 24°N-38°S latitudes. They are near the tidal and inter-tidal regions where the temperature range is between 26-35°C

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The mangroves of India are a veritable repository of diverse flora and fauna. In India, Sunderbans of West Bengal, and Bhitarkanika of Odisha are touted as genetic paradises for Mangroves in the world. The famous Sunderbans are also home for Royal Bengal Tigers along with a couple of other endangered species of animals. It has been observed that the mangroves could be vastly classified in three categories in India viz., deltaic, backwater-estuarine and insular types. Around 58% of the mangroves are found along the Bay of Bengal, 29% on the west coast near the Arabian Sea and 13% near the Andaman and Nicobar Islands. Since the mangroves cover a significant area of land in the country, observing and studying these amazing forests would provide us with a much-needed insight into the complex interrelationships between man and the Mangrove forests [Kathiresan Kandasamy, 2017].

The mangroves are very resilient group of trees which can tolerate frequent changes in the water salinity levels, through various adaptations which evolved gradually over a period of time. They have pneumatophores, which are called breathing roots because of the presence of large lenticels on them which facilitate in the respiration process. The mangroves also have succulent leaves which can exude salt, sunken stomata and show viviparity to dispose of their seeds. All these attributes contribute to providing a safe niche for a variety of plants and animals. Above the water, the mangroves provide a canopy for several species of insects, birds, mammals and reptiles and mangrove associates. At water level, the pneumatic roots are a host for epibionts such as sponges, algae bivalves and tunicates. The soft substratum near the mangroves provides a niche for infaunal and epifaunal species and the detritus from the mangroves is a connecting link for the food web in this ecosystem [I. Nagel Kerkenet al., 2008]. Since, the mangroves are endowed with innumerable properties, they are one of the most productive ecosystems of the world. It has come to the notice of the scientific world that the mangroves also have several ethnobotanical values. Local communities, like the fisherfolk have finessed the use of several species of mangroves to treat common ailments like cold, fever or flu as well as diseases like epilepsy, diabetes etc. Some notable species of mangroves like Acanthus ilicifolius, Avicennia marina, Bruguieragymnorhiza, Clerodendroninerme, Derris trifoliata, Excoecariaallagocha, Rhizophora mucronate, Xylocarpus granatum etc., have ethnobotanical value in the tribal

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communities. A slew of experiments is now being conducted on the mangroves to prove their medicinal value in the treatment of disease like cancer and heart diseases as well [T. Pullaiahet al., 2016].

An abundance of natural forest products had encouraged the establishment of several human settlements near the mangrove forests of India. These human settlements primarily consist of fisherfolk who are dependent on the mangroves for their day-to-day basic needs. The advent of technology and also the increasing population of the country however, have paved a way for the gradual decrease in the forest cover along the coastal areas, which in turn lead to soil erosion and habitat destruction. Anthropological activities are now interfering with the conservation of these bountiful reservoirs of natural resources. Unrestricted and unchecked human activities would negatively impact the environment and the climate around these areas which would ultimately lead to the collapse of the mangrove ecosystem. It is mandatory now, to implement effective conservation strategies to overcome habitat lose and the Govt. of India has put in place several laws and regulations which prevent unmindful exploitation of forest resources [U. K. Sarkar et. al., 2016]. Active efforts put in by the Govt. and N.G.Os has contributed to a significant increase in the forest cover of mangroves in India, this assessment was also proved through remote sensing, which utilizes Landsat satellite data, post-clarification approach, and ground truth verification to map mangroves, their diversity and for the assessment of changes in protected and unprotected forest regions. Remote sensing would also help scientists in keeping a strict tab on the changing trends in wildlife conservation. Afterall, the natural wealth of resources in forests far outweighs the needs of man, only if he isn't greedy [M. Jayanthi et al., 2018].

Demography

The Mangrove cover of the world is spread over 123 countries and territories, with Asia having the most of it. India's contribution to the world mangrove cover is 3.3% over an area of 4921 sq km. The Sundarbans of the West Bengal occupies half of this area whereas Andhra Pradesh has close to the second largest mangrove forest cover in India. A total of 404 sq km of the forest cover is present in the Mangrove regions in Andhra Pradesh as of the year 2017 [Forest Survey of India, 2017].

The mangroves of India are divided into three zones viz., 1) east coast, 2) west coast ad 3) Andaman and Nicobar Islands with Lakshadweep Atoll. These three zones in turn are divided into Deltaic, Coastal and Island habitats based on Thom's classification of estuarine habitats. There are several species of Mangroves spread over 12 habitats in India. The relative mangrove density (RMD) of these 12 habitats is calculated by the following equation: RMS= 100x[Fn+Gn+Sn)/N], where Fn represents, numbers of families, Gn and Sn represent Genera and species respectively and N=170 (sum of other families, genera and species of mangrove forests of all 12 habitats). By calculating the RMD, it was concluded that the Sunderbans has the highest RMD at 90% whereas, the Andaman and Nicobar Islands had the lowest at 9.4%. The vegetation near the inter-tidal regions is categorized into "Major mangroves", "Mangrove associates" and "Back Mangals" based on their salinity tolerance[R. N. Mandal et al., 2008].

The area of interest for the current study is near the coastline of Andhra Pradesh which extends over 974km and it is located between 13°.24'-19°.54 N latitudes and 80°.02'-86°.46' E longitudes. Krishna and Godavari estuarine regions are spread over an area of 585 sq km. Major mangrove forests of the area are present in Machilipatnam, Sorlagondi, Nachugunta, Yelichetladibba, Coringa, Kandikuppa, Salagondi, Yanam, Antarvedi, Repalle and Bandamuslanka. The focus of the study is mainly on Machilipatnam which is the headquarters of Krishna District of Andhra Pradesh. Its latitudinal location falls between 16°.10'N to 16°.17'N and the longitudinal location falls between 81°.09'E to 81°.13'E. The mangrove patches of the region are present near Gilakaladindi and nearby villages [Suseela Lanka, 2017].

Flora

There is immense diversity in mangrove plants. 46 true mangrove species have been identified in in India which belong to 14 families, and 22 genera which constitute 42 species and 4 hybrids [P. Ragavanet al., 2016]. Mangroves have adapted themselves so they could thrive in harsh climatic and environmental conditions [R. Ramasubramaniamet al., 2003]. Mangroves face enormous abiotic stress and the roots are the first parts to face abiotic stress in the soil in order to thrive in marshy conditions. They have undergone several adaptive strategies with respect to anatomy, biochemistry and physiology to withstand that stress. Genomic studies have revealed that specific genetic patterns are responsible this adaptive response in mangrove roots which are one of the secrets behind the resilient nature of the mangroves. [Nabi A. et al., 2011].

To properly evaluate the species density of mangroves in an area, it is necessary to set up main field stations, sub-field stations and their representative quadrants. Several parameters like Important Value Index (IVI), Maturity Index Values (MIV), Similarity Index (SI) and Coefficient Difference (CD) of the mangroves in the study areas are determined [Sandhya Srikanthet al., 2016].

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A study conducted in the year 1988 revealed that, the Mangrove population in Andhra Pradesh, especially near the Godavari Deltaic Complex consisted of trees belonging to the species Saueda maritima, Sauedamonoica, Excoecariaagallocha, Avicennia officinalis, Avicennia marina, Acanthus ilicifolius, Myrrostachyawightiana, Sonneratia apetala, Clerodendroninerma, Derris trifolia, Aegiceruscorniculatum, Lumnutzera racemose, Ceriopsdecandra, Dalbergia spinosa, Rhizophora apiculata, Ipomea tuba, Bruguieragymnorrhiza etc. All of these species can be broadly classified under the families, Myrsinaceae, Avicenniaceae, Rhizophoraceae, Euphorbiacea, Acanthaceae, Fabaceae, Chenopodiaceae etc., [M. Umamaheswara Raoet al., 1988 andSuseela Lanka, 2017]. A study conducted in the recent years revealed that in the southern east coast of Andhra Pradesh, the plant species Avicenniamucronata, Excoecariaagallochaand Aegicerascorniculatum were dominant in Nellore, Prakasam and Guntur districts. While, Kandeliacandel was newly recorded in these wetlands, Sonneratia apetala was confirmed to be present in Ponnapudi wetland of Nellore district [S. K. M. Basha et al., 2018].

To further prove the mangrove density and basal area measurements in the Coringa region of Andhra Pradesh, multivariate analysis (PRIMER) was conducted to reveal the presence of 6 different floristic groups of plants. Group-1 and Group-2 contained Sonneratia apetala, S. caseolari, and Avicennia alba. Group-3 contained Xylocarpusmekongensis, Rhizophora mucronata, R. apiculate and Bruguieragymnorrhiza. Group-4 species were Avicennia marina, A. officinalis and Excoecariaagallocha. Group-5 plants consisted of Lumnitzeraracemosa, Ceriopsdecandra, and Aegicerascorniculatum. Finally, Group-6 plant was Bruguiera cylindrica. Group-1 and -2 plants were found near low-lying swamps. Group-3 plants were typically present closer to the sea where there were high salinity levels. Group-4 were the most common in the Coringa forest while Group-5 plants were present closer to the Gauthami-Godavari estuary. Group-6 plants were under the direct influence of the Bay waters of the sea [B. Satyanarayana et al., 2009].

As mentioned above, the mangroves show diverse families and genera. There are the true mangroves, the associated mangroves and the halophytes. The halophytes show increased tolerance towards shifting salinity levels, and they are draught resistant. Hence, they are usually found in the transitional zones between the terrestrial plants and the mangroves. Halophytes are generally used as biofuels, for the extraction of certain vegetable oils and also as dietary supplements. As the mangrove cover is being erased for shrimp farming and fish nurseries, there is a significant decline in the density of the halophytes in the mangrove forests. It has been suggested that educating the local communities about the importance of these forests and with the help of the government, conservation strategies can be put in place to combat deforestation [G. M. Narasimha Rao, 2018].

Bioactive Compounds of Mangroves

Plants contain several nutritionally beneficial compounds, in addition to them, the plants also contain “bioactive compounds” which are non-nutrients. They bring about a specific biological response in animals and humans. Foods which contain bioactive compounds are marketed as functional foods. They provide health beyond the realm of basic nutrients provided by the plants [Vesna TumbasŠaponjacet al., 2015].

The bioactive compounds of Mangroves may serve as therapeutic precursors and industrial raw materials. Terpenoids and polyphenols of mangrove might potentially serve as antiviral, antibacterial, antifungal, antimalarial or anticancer drugs [Dahibate Nilesh L., et al., 2019].

The metabolites found in the mangroves and mangal associates belong to diverse chemical classes like aliphatic alcohols and acids, hydrocarbons, amino acids and alkaloids, carbohydrates, carotenoids, free fatty acids like poly unsaturated fatty acids (PUFAs), lipids, pheromones, phenolics and related compounds, phorbol esters, steroids, triterpenes, and their glycosides, tannins and other terpenes, their related compounds. In addition to this, gums, glues, alkaloids and saponins are also present. Chemicals such as amino acids, lipids and carbohydrates are important for primary vital metabolic functions of the plant, while secondary metabolic chemicals such as alkaloids, phenolics, steroids and terpenoids have ethnobotanical importance in the medical field [W. M. Bandaranayake, 2002].

One of the most studies mangrove plants is Rhizophora mucronata. Ernawati et. al., had once conducted an experiment on the fruits of R. mucronatato extract its bioactive compounds. Crude extracts of the fruit were prepared using methanol, ethyl acetate and n-hexane. Their phytochemical screening had shown the presence of compounds such as alkaloids, saponins, flavonoids, triterpenoids, and tannins in methanal extract, alkaloids, steroids, triterpenoids and tannins were present in ethyl acetate extract whereas n-hexane extract contained only the triterpenoids [Ernawatiet al., 2019].

There is a complex relation between a mangrove plant and its endophyte. This relation was studied between Avicennia marina and its endophytes. Different parts of the mangrove like the barks, leaves, roots etc., and its endophytes, mainly fungi were collected and their phytochemical analyses have isolated 123 compounds, most of which are novel compounds. The chemical investigations of A. marina have revealed the presence of compounds such as the terpenoids, steroids, naphthalene derivatives, Iridoid glucosides, phenylpropanoid glycosides, flavonoids, Abietane diterpenoid glucosides etc. Whereas, the chemical investigations of the

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endophytes revealed the presence of substances such as the Xyloketals, Xyloallenolides, and its precursors, cyclic peptides, various sphingolipids, xanthones and anthraquinones, steroids, esters, lactone and others. Most of the chemical compounds of the host and the endophyte differed, yet there are at least a couple of compounds which were structurally similar. The presence of such compounds suggests that some biogenetic relationships exist between the host and the endophyte, which could be analysed for further investigations about the workings of the complex interrelations between various components of nature [Feng Zhuet al., 2009].

Fauna

A blend of the sea and river waters provides suitable breeding grounds for several groups of animals. Animals belonging to Arthropoda, Mollusca, Pisces, Amphibia, Reptilia, Aves and Mammalia are most commonly found here. Because of this vast faunal diversity, we see that there are intermittent human settlements around these areas. The fisherfolk survive on the capture of local and exotic fish found in these areas as the presence of Mangroves naturally attracts huge populations of fish.

Approximately 543 species of fish are found in the Mangrove ecosystems of India, 13 species of Amphibians, 84 species of Retiles, 426 species of birds and 68 species of Mammals are also found in the mangrove forests of India. Along with the vertebrates, many water dwelling invertebrate species like prawns, lobsters, crabs, bivalves and gastropods are also found [Sahu S. C. et al., 2015]. Many species of prawns and crabs found in the areas are used in the local cuisine. In a study conducted near the Krishna estuarine region, it was found that a total of 76 fish species are present which in turn belong to 54 genera 34 families and 9 orders. The order Perciformes dominates the most of the fish species observed in the area. Some new additions were also made to the list of new species of fish found in the Krishna Estuarine regions. Notopterusnotopterus, Anguilla bengalensis, Acentrobius griseus, Gymnothoraxmeleargis etc., are among the 27 new species added to the record. Fish orders like Osteoglossiformes, Anguilliformes, Clupeiformes, Gonorhynchiformes, Siluriformes, Mugiliformes, Beloniformes, and Scorpaeniformes are also found in these areas [Krishna P. V. et al., 2019].

The mangrove forests are a niche for various fauna in the Coringa forest of Andhra Pradesh. Some animals like Smooth Indian Otters, Jackals, Monkeys and fishing cats are present. The forest is also home for an endangered species of Olive Ridley Sea Turtle which nests during the months of January-March every year. A number of birds, over 120 species are reported in these Mangrove forests, some of which are the little egret, pied kingfisher, grey heron, night heron, little stint, red shrank, crow pheasant, flamingos, sea gulls, Brahmini kite Little cormorant etc. [eastgodavari.ap.gov.in].

In an interesting study it was found that Free-living Nematode species thrived in the Coringa Mangrove Forest. These Nematodes belonged to 10 families and 11 genera and 11 species. The Nematode families are Xylidae, Desmodoridae, Cyatholaimidae, Comesomatidae, Linhomoeidae and Microlaminidae. Of these, the most dominant genera of Nematodes were Paraspherolaimus, Rhynconema, TerschellingiaandDaptonema. The meiofauna of Mangroves of Andhra Pradesh consisted of Nematodes, Oligochaetes and Harpacticoids. This may be due to the amount of silt and clay in the mud substratum which provides approximately 2 cm of the soil surface for colonization. It was also observed that the meiofauna density decreased with the increase in the tidal height along the mangrove shore [G. Sivaleela and R. Rajendar Kumar, 2016].

It may also be noted that the mangrove forests of Andhra Pradesh are also home for two species of fishing cats; Prionailurusviverrinusand Paradoxurus hermaphroditus. Commonly called as the Common Palm Civet. They are widely distributed in South and Sotheast-Asia and are categorized under Least Concern in the IUCN RED List of Threatened Species. They are small carnivores which are mainly nocturnal and slightly arboreal. Their habitat generally is around deciduous forests, although it has been observed that they are also found around mangrove forests but never within them. On a few occasions however, they also wander into the dense mangrove forests in search of prey or shelter. Common encounters between the fishing cats and human beings are near prawn cultures, fisheries or coconut plantations in the reserved forest areas. To prevent any game killing or accidental killing of Palm Civets, awareness programmes, radio-telemetry studies, responsible gap plantations and habitat restoration was recommended to conserve their population [Sathiyaselvam P. et al., 2016and GiridharMallaet al., 2019].

Due to the expansion activities near the mangrove forests, 40% of the assessed mangrove-endemic vertebrates are threatened globally. Strict measures have to be taken to prevent the complete annihilation of these animals from the world altogether. Conservation strategies pertaining to the wellbeing of the mangroves and their fauna will be further discussed in this paper [David A. Lutheret al., 2009].

Fisherfolk and Fisheries

Water availability in the coastal and inter-coastal regions is naturally abundant. This attracts several schools of fish during their breeding seasons. The physicochemical, geographical, biological and economical aspects of the waters present in the mangrove forests provide suitable environments for establishing fisheries. Livelihood of the fisherfolk around these areas depend on catching

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fish and various other water dwelling animals which can later be sold in the markets at reasonable prices. Most of the Mangroves in the area provide ethnobotanical medicines for their daily ailments. Since most of the income here is generated through fishing, it was thought that it would be beneficial to have a proper understanding about the early life history of the fishes living in the river waters. Careful observation of the fish population should be made with the help of local fishermen who would be able to identify the fish that they catch on a regular basis also, fine mesh-like fishing nets could be used near the nooks-and-crannies of the mangrove trees to snag any fish eggs and larvae. It is also necessary to calculate the physicochemical parameters of the water bodies. An observation like this would provide us insights into the nature of the water and its faunal diversity [K. Krishnamurthy et al., 1981]. Alongside fisheries, shrimp farm industries are also found along the banks of the Krishna river [F. Dahdouh-Guebaset al., 2006]. In an independent study conducted in the year 2018 on the fish species Lates calcarifer, it was seen that the fish thrived in integrated-mangrove-aquaculture-systems (IMAS) as opposed to the open-aquaculture-system without the mangroves (OAS). The experiment was conducted in suitable conditions for the fish to breed and grow. It was observed that the fish school population in the waters with the mangroves were higher in comparison to the waters without any mangroves in them. This proves that, integration of mangroves for fish farms would give a better yield in fish farming [Shanmugaarasu Venkatachalam et al., 2018]. Economically, marine fishery near Mangrove regions poses two distinct issues: 1) mangrove's effectiveness in increasing the marine fish production and 2) marginal effect of mangroves in the production of marine fishes per hectare. In relation to these questions, it was found that the 1) mangroves helped in significantly increasing the marine fish population and 2) the total marginal fish output for marine fish breeding in mangrove regions is 1.86 tonnes per hectare per year, which contributes to 23% of commercial marine fish output in India per year [Lavanya Ravikanthet al., 2017]. Despite their importance in fishing, there is not sufficient data to estimate neither the number of fishers engaging in mangrove associated fisheries nor the intensity of fishing associated with mangroves at a global scale[Philine S. E. zuErmgassenet al., 2020].

Fish breeding in the fisheries has its own slew of problems each of which would have to be addressed if healthy food is to be identified. One of the major problems with maintenance of fisheries is to avoid the fishes from getting infected via various fish pathogens. In these conditions, it is necessary to implement natural antimicrobial drugs to prevent bioaccumulation. Currently, fisheries are implementing synthetic drugs to treat various fish diseases. Since there is a dearth of information in properly administering natural drugs, scientists are now concentrating on conducting experiments on plant species. In one such experiment, infection by bacteria Aeromonas hydrophyla which is one of the most common pathogens in fish cultivation was considered as it is resistant to more than one type of antibiotics available in the markets in the present days. Experiments on the leaf extract of Rhizophora mucronatahave shown that the lowest concentration of methanol fraction extract to inhibit A. hydrophyla (KHM) growth was at 8.25±0.39 ppm, at the same time the lowest concentration of A. hydrophyla was at 32.99±1.56 ppm. On screening for the presence of bioactive compounds, flavonoids, tannins and alkaloid compounds were detected. It is thought that the presence of tannins and flavonoids gives the mangroves their antimicrobial properties [Panjaitanet al., 2018].

It must be duly noted however, that the fisherfolk of India still fall under economically backward sections despite aquaculture industry's booming success. Most of them still live-in kutcha houses and are not properly educated. There are also several other social aspects which do not give sufficient liberties to the fisherfolk to live a life of luxury. Because of the absence of collateral, they are not eligible to take any loans from state banks or national banks, so they are mostly forced to borrow money from money-lenders to pay for their fishing gear and equipment. To overcome an increasing mountain of debt, the fisherfolk would also have to do agriculture on the side to make their end meet [M. Haritha et al.,2017 and Bijayalakshmiet al., 2014].

Inshore and offshore fishing along the estuarine areas is a means of employment in the mangrove forests. The fishing communities rely heavily on the fish they catch for the day that could be marketed. The economical background of the fishing communities is far below the normal status of the rest of the backwards communities of the country. The advancement of technologies in the hamlets inside or near the forest areas is far outdated in comparison to the human settlements which are found closer to towns and cities. Due to these factors, the local human settlements would often have to depend on the natural supply of resources from within the forest. Huts are built using the timbre from the mangrove plants of the area. Along with fuelwood and meat, the local communities also sell natural honey in the local markets to make some money. Educating the fisherfolk about the importance of the mangrove forests, the ample supply of natural resources that they provide and sustainable living would prove beneficial in the protection of both the forests and the communities of people living in them [Syed Aimul Hussain et al., 2010].

It is also advisable to implement certain legal and non-legal criteria and indicators to help local communities in sustainably managing the mangrove forests. Bringing forth environment friendly laws and regulations has shown positive correlation between the local committees and the mangrove cover in the area [Debajit Datta et al., 2010]. These measures ensure that the local habitat and niches of the mangroves are conserved without converting the wetlands into lands for irrigation. Any disturbance in the fine balance between the tree density in the forest and the water levels in the area would prove to be stressors which would lead to land erosion along the coastal areas [P. Ragavanet al., 2020].

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Ethnobotanical Experiments

Plants play a huge role in the ethnomedical practices across several countries in the world. Each country and each region within the country has its own folklore medicine for the treatment of daily ailments. India, has a rich heritage of knowledge on medicinal plants and their usage in prevention as well as cure. A large number of these medicinal plants are endemic to specific areas and any knowledge about used to be passed from one generation to the next by word of mouth. With the advent of modern medicine, this traditional plant-based knowledge is slowly dwindling. Mangroves are such a group of plants which have several therapeutic uses in folklore medicine. Present day scientists, have however, picked up an interest in learning in detail about these wonderful group of plants which are exclusively found in the marshy areas. Some of the therapeutic activities of mangrove plants are; treatment for rheumatism, diabetes, inflammation, diarrhea etc. [P. Saranrajet al., 2015 and G. M. Narasimha Rao et al., 2014].

In some of the experiments conducted on mangrove plants like Avicennia sp., Ipomea etc., it was observed that the bioactive compounds present in them could be broadly categorized into alkaloids, terpenoids, steroids, polyphenols etc., [G. Eswaraiahet al., 2019]. The presence of the bioactive compounds gives the mangrove plants their importance in Indian pharmacopoeia. Several local fishing communities would rely on the naturally sourced plant materials for their day-to-day lives. The flora present in the mangrove forests are used to treat common ailments like cough, cold, fever, dysentery etc., by using crude extract of a part of a plant or by using several parts of a plant [G. M. Narasimha Rao, 2020]. Apart from the conventional uses of the mangroves, scientists are now also concentrating on manufacturing drugs based on the bioactive compounds of the mangrove plants. Upon a thorough observation, it has been found that species of mangroves like Ipomea, Avicennia, Acanthus etc., can be used to synthesize effective super drugs. It has been found that these plants have the ability to act as antimicrobial, antifungal and also as anti-cancer drugs. Experiments were conducted on Ipomea tuba leaf extracts to identify bioactive compounds and also to evaluate their in-vitro antiproliferative activity against MCF-7 and HeLa cells. The results of the experiment showed that the reduction in cell viability is seen in both MCF-7 and HeLa cells [TirupathiChinnaVekateswaruluet al., 2020]. In another experiment conducted on the silver nanoparticles synthesized using the aqueous leaf extract of Rhizophora apiculata, the nanoparticles showed remarkable hepatoprotective effect. The liver plays a vital role in the removal of xenobiotics from our body, and so, it is subjected to harmful chemicals and microbes daily. Administering drugs which can help the liver in speeding up the process of ejecting unwanted materials from our body without undergoing stress is the need of the hour. The results from the experiment conclude that the silver nanoparticles from the aqueous leaf extract were successful in protecting the liver from the toxic effects of carbon tetrachloride [Hongru Zhanget al., 2019].

Leaf extracts of Rhizophora mucronataagainst human origin pathogens was observed in an experiment conducted by Elsa Lycias Joel and Valentin Bhimba. The active principal compounds such as, squalene (19.19%), n-Hexadacanoic acid (6.59%), phytol (4.74%), 2-cyclohexane-1-one-4-hydroxy-3.5, (4.20%) and oleic acid (2.88%) extracted through Column chromatography were analysed through GC-MS analysis. This mixture of substances has proven to be effective against bacterial growth. (Isolation and characterization of secondary metabolites form the mangrove plant Rhizophora mucronata).R. mucronata also possesses antioxidant properties which could be estimated through radicalscavenginf assays like the DPPH, NO and H_2O_2, primary and secondary metabolites. It was observed in an experiment that the radical scavenging activity of R. mucronata was greater in leaf extracts rather than either roots or the bark [Samanjit Kaur et al., 2018].

The mangroves can also act as antidiabetic drugs, implementation of these plants in the treatment of diabetes has shown positive results by bringing a balance in insulin production in type II diabetes by stimulating the β-cells or by regenerating them [V. Sachitanandamet al., 2019]. Vast reserves of active biotic compounds in mangrove plants such as Rhizophora mucronata have proven to be effective in the treatment of diabetes. Leaf extracts of R. mucronatahave significantly reduced the blood glucose levels in Streptozotocin-Nicotinamide Induced Type 2 diabetic rats. Regular administration of the extract had maintained the serum insulin at optimal levels. It was also observed that the serum lipid-levels had also decreased in a dose-dependent manner [Anjan Adhikariet al., 2018].

The acetonic extracts of bark of Rhizophora mangle (AERM) were used for the treatment of type 2 diabetes in an experiment. HPLC, flow injection analysis electrospray-iontrap mass spectrometry (FIA-ESI-IT-MS/MS) were done to identify the bioactive compounds. High-fat diet (HFD)-fed mice were used as the animal model for this experiment. The mice were fed AERM 5 or 50mg/kg/day orally for 4 weeks to evaluate insulin homeostasis using insulin tolerance kit. Hepatic steatosis, gene expression and triglycerides were also evaluated. In the phytochemical studies it was found that AERM consists of quercetin, catechin, and chlorogenic acids derivatives. These metabolites have nutritional benefits, since they had considerably increased the insulin resistance in mice which resulted in hepatic steatosis reductions due to the inhibition of hepatic mRNA levels of CD36. In-vitro assays on α-amylase showed an inhibitory α-amylase activity and AERM also partially reverses insulin resistance and hepatic steatosis related to obesity in the mice. This is in concurrence with the traditional usage of R. mangle in the treatment of obesity and diabetes [Leonardo Mendes deSouza Mesquita et al., 2018].

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Rhizophora stylosa is a mangrove plant endemic to Indonesia. It is locally called the Coffee and Tea Mangrove and theyare used for brewingbeverages. Crude extracts were prepared to analyse the presence of various bioactive compounds in their fruits. DPPH assay was run to analyse its radical scavenging activity. Tea mangrove showed the strongest activity, upon its fractionation using different polarities, acetone and methanol fractions were estimated to have high antioxidant activity. Six fractions were prepared from the acetone fraction of which only fractions A2 and A3 indicated any antioxidant activity. These were subjected to further purifications. Fraction A3 (caffeine) and A2 gave AS1 (N, N-dimethyl-L-alanine), AS2 (quercetin-3-O-galactopyranoside), AS3 (dodecanoic acid) and AS4 which was similar to AS2 in NMR spectroscopic results. The methanolic fraction could not exhibit clear peaks in HPLC chromatography, hence precipitation was done to purify it and the precipitate was analysed using NMR spectra. It was found that the methanolic fraction contained typical polymer of condensed tannins, with procyanidin and prodelphinidin units [Dewi Indah Mirantiet al., 2018].

Jayanta Kumar Patra, Swagat Kumar Das and HrudayanathThatoi had conducted experiments in the antidiabetic, anticancer and antibacterial activities of Sonneratia apetala along with phytochemical profiling. All four solvents of Sonneratia apetala viz., acetone, ethanol, methanol and aqueous extracts have shown strong antioxidant properties. In vivo anticancer activity of methanol leaf extract showed 34% inhibition against EAC cells in Swiss Albino mice. All the leaf extracts exhibited α- glucosidase inhibitory activity depending on the dosage, indicating effective anti-diabetic properties. The extracts also exhibited promising antimicrobial activities. The phytochemical profiling through partial extraction of methanolic extract of leaf and bark have has revealed the presence of lead compounds for several bioactivities of the plant extracts [Jayanta Kumar et al., 2015].

The antimicrobial activity of the mangrove leaf extracts can also be done by monitoring their seasonal variability. Species of mangrove plants belonging to the genera Ceriops, BruguieraandLumnitzerawere taken for the experiment. Crude methanolic leaf extracts were prepared and the zone of inhibition for the bacterial species like Bacillus aureus, B. subtilis, Staphylococcus aureus, Escherichia coli and fungal pathogen Candia albicans was observed, it was noted that the zone of inhibition for the leaves collected during the rainy season showed more antimicrobial activity against the leaves collected during the summer and the winter seasons [Vijay Kumar Kovvadaet al., 2019].

Avicennia officinalis, a mangrove plant, has several ethnobotanical uses in traditional medicinal practices. Experiments conducted its leaf and bark ethanolic extracts have also shown its effectiveness as an antioxidant, antimicrobial, carbohydrate metabolizing enzyme inhibition and its cytotoxic potential. The bark extract had inhibited the activity of α-amylase and α-glucosidase based on a dose-dependent manner at an IC_{50} value of 0.66 and 0.71 mg/ml respectively. The leaf extract on the other hand and exhibited the inhibition at an IC_{50} value 0.29 and 1.19 mg/ml respectively. The radical scavenging activity of the ethanolic bark extract was estimated through DPPH, ABTS and superoxide radicals and the results were found at IC_{50} values of 112, 114 and 82 µg/ml respectively while the IC_{50} values of the ethanolic leaf extracts were at 200, 41.9 and 207.6 µg/ml respectively. The antiproliferative activity of the bark and leaf ethanolic extracts on the TC1 murine cell lines were also estimated in a dose dependent manner. Antimicrobial activity against Bacillus subtilis, Escherichia coli, Pseudomonas aeruginosa and Candida albicans was also noted [Swagat Kumar Das et al., 2018].

Crude methanolic extracts of plants, Launaeasarmentosa, Bruguiera cylindricalhave shown antibacterial activity to some extent against both gram -ve and gram +ve bacteria. It was observed that the crude extracts of L sarmentosawere successful in their antibacterial activity against both the bacterial strains whereas the crude extracts of B. cylindrical were resistant to the bacterial strains [Milat S. M., et al., 2017].

Mangrove plant Bruguieracyclindricalleaves were shown to possess in-vitro thrombolytic, membrane stabilizing and cytotoxic activities after analysing their phytochemical properties. The phytochemical screening of the methanolic leaf extracts revealed the presence of carbohydrates, glycosides, tannins, phenols, mucilages and gum. The in-vitro thrombolytic activity in 10mg/ml concentration of the plant extract showed moderate clot lysis at (14.51 ± 1.87%) while streptokinase showed 59.73 ± 0.97% clot lysis. The methanolic leaf extracts have shown significant anti-inflammatory properties at a concentration of 10 mg/ml by both, heat induced heamolysis and hypotonic solution, i.e., 23.60 ± 0.89% and 18.53 ± 0.91% respectively. Vincristine sulphate and the crude methanolic extracts showed moderate cytotoxic properties at LC_{50} value of 16.628. Further studies have to be conducted to enable production of efficient drugs for medical purposes [Safiqul Islam et al.,2017].

The mangrove plant Bruguieragymnorrhizais traditionally used in the treatment of diarrhoea, fever, diabetes, diabetes etc. It's antioxidant, analgesic and antidiarrheal activities were estimated in the laboratory conditions using ethanolic extracts of leaves and stem. The antioxidant activity was analysed through DPPH, reducing power, nitric oxide and H_2O_2 scavenging assays. The polyphenol content was estimated using FolinChiocalteu's reagent, and aluminium chloride colimetric assay was used for flavonoids. HPLC

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analysis indicated the presence of vanillic acid and other phenolic compounds. Both leaf and stem extracts showed significant ($P<0.01$) antidiarrheal and analgesic activity. No toxicity was exhibited upon administration [Imtiaz Mahmudet al., 2017].

Owing to the stress induced conditions of their natural habitat the halophytes are endowed with stress associated bioactive molecules, most of which are yet to be discovered. If experiments are to be conducted on the natural antioxidant resources in plants, antioxidant capacity (AC) and total phenolic content (TPC) are two parameters which could be employed. In a study conducted on approximately 100 halophytic and non-halophytic plants commonly used as herbal teas, nutrients and phytochemicals with a special interest in the phenolic metabolites were screened. Most of the medicinal plants showed high AC levels. In general, halophytes showed higher content of AC and TPC in comparison to the non-halophytes. The experiment also showcased five medicinal halophytes, Thespesia populneoides, Salvadora persica, Ipomea pes-carpes, Suaedafruticosaand Pluchea lanceolata which displayed significantly higher levels of AC than the synthetic antioxidants (BHT and BHA). Phytochemicals like phenols (42.3-63.9 mg GAE g^{-1}), tannins (8.7-20 mg TAE g^{-1}), flavonoids (12.3-37.1 mg QE g^{-1}), proanthocyanidins (15.8-22.4mg CE g^{-1}), carotenoids (0.07-0.84 mg g^{-1}), saponins (11.2-28.4 mg DAE g^{-1}) and alkaloids (0.64-1.1 mg g^{-1}) reflect the therapeutic benefits of these plants. HPLC analyses revealed the presence of phenolic compounds such as chlorogenic acid, gallic acid, catechin, and quercetin which are responsible for the higher AC. In addition to these compounds, carbohydrates, proteins, lipids and minerals were also screened and their levels were estimated [M. Qasimet al., 2017].

While the mangrove plants have proven to be effective therapeutic drugs for modern medicines, there is also a need to focus on the various endophytic and epiphytic mangrove associates which also contain innumerable therapeutic activities. In an experiment conducted by Dong-Bo Xu et. al., on mangrove Actinomycetes, 73 novel compounds and 49 known compounds were isolated. Substances such as alkaloids, benzene derivatives, macrolides, 2-pyranones, cyclopentenone derivatives, dilactones, and sesquiterpenes were isolated and identified. The active compounds isolated from the Actinomycetes also possess antibiotic, antitumor, anti-fibrotic, antiviral and antioxidant activities [Dong-Bo Xu et al., 2014].

In addition to these properties, the mangrove associate actinomycetes also have antiangiogenetic properties, enzyme inhibition and can also act as a probiotic [S. K. Chand Basha et al., 2017].

Mangrove ecosystem provides a niche for a wide range of mangrove-associated bacteria and fungi. Culturable fungi and bacteria collected from Mangroves all over the world have shown a divergence from the general bacteria found elsewhere in the world. The endophytic fungi like Penicillium brocaeMA-231, obtained from Avicennia marina in China have shown the presence of several cytotoxic compounds like brocazines A, B, E and F. They show remarkable anticancer activity against human cell lines like MCF-7, HepG2 etc. [Elena Ancheevaet al., 2018].

S Gayathri et. al., had conducted an experiment on bioprospecting aspects of endophytic bacteria of mangrove leaves. The experiment had been conducted on the leaves of 5 mangroves and 2 salt-marsh plant species. 104 bacterial isolates were observed of which 36 fast growing isolates were selected and screened for biological activities. 77% of the 36 bacterial isolates have shown antimicrobial activity, and 94.9% isolates exhibited pectinase, 58.3% protease, 52.7% insulinase and invertase activities. Endophytic bacteria also help in the plant growth promoting activity such as, ammonia and acetoin production (22 and 25 bacterial isolates), 26 isolates exhibited nitrogen fixing activity, 6 isolates showed phosphate solubilization activity and 7 isolates produced indole acetic acid. Around 20 endophytic bacteria exhibited sensitivity towards antibiotics such as streptomycin and trimenthoprim, while 31 isolates showed resistance towards vancomycin and bacitracin. These statistical data prove that the mangroves are sources for bacteria with bioprospecting potential which could further be elucidated [S. Gayathri et al., 2010].

Streptomyces cheonanensisVUK-A, a mangrove endophytic bacterium has two bioactive compounds, namely 1) 2-Methyl butyl propyl phthalate and 2) Diethyl phthalate. Their structures were elucidated through ^{1}H NMR and ^{13}C NMR spectroscopies, FTIR and EIMS. The antibacterial activity of these two compounds was tested against a variety of bacteria and fungi and it was proven that they were active against all the bacteria tested and compound 1 has shown the best activity against Proteus vulgaris. Compounds 1 and 2 have shown activity against dermatophytes and fungi yet compound one was most effective against the fungus Candida albicans. Compound 1 also showed promising cytotoxic activity against cell lines such as MDA-MB-231, OAW-42, HeLa and MCF-7, the highest level being against HeLa cancer cell lines [UshakiranmayiManhamuriet al., 2016]. More research is yet to be done to prove the effectiveness of the mangroves as effective drugs in the treatment of various diseases.

Bioaccumulation of Heavy Metals

Heavy metal toxicity is known to cause serious health problems to people who might unknowingly consume them. While it is a well-known fact, we must also keep in mind that ecotoxicity of heavy metals in the soil or in the water would also cause devastative problems to plants and other organisms. The heavy metals or trace metals might invariably enter these organisms and from them,

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through bioaccumulation, they would finally reach the animals which are at the highest rung in the food pyramid. It is therefore, important for the scientists to analyze the chemical make-up of the edaphic and hydrographic factors in which the mangrove forests are present. There are several pollution indices which would allow us to estimate the presence of trace metals in the environments, which are; contamination factor (CF), pollution load index (PLI), enrichment factor (EF), geo-accumulation index (I-geo), potential ecological risk index (Eif), and potential toxicity response index (RI). It was found in a study that trace metals like Cd and Fe show very high contamination across the Indian coast whereas, Co, Cr, Cu, Mn, Ni, Pd and Zn indicated moderate contamination in the mangrove forests. Pichavaram, Coringa-Gaderu, Manakudy and Vellar estuary mangroves showed high risk of trace metal contamination, while the Sundarbans, Muthupet and Goa estuarine mangroves showed low risk of contamination. Other trace metals like Al and as might also be present along the coasts of areas affected by tsunami, like Pichavaram. Due to the presence of trace metals in the affected areas, it is imminent for the people and the Government to take necessary actions to curb any seepage of trace metals into the environment further before it is too late [Prabhat Ranjan et al., 2017].

It has been proposed in another study however, that select species of the mangroves like Rhizophora mucronatacan be used as bio-indicators for the presence of heavy metals in the mangrove forests. Tests were conducted to examine the presence of heavy metals like Zn, Cd, Cu and Pd. The results showed that the concentration of the trace metals in the sediments changed seasonally between 0.07-0.85 mg/kg for Cd, 0.43-17.46 mg/kg for Pb, 2.88-14.87 mg/kg for Cu and 7.80-38.37mg/kg for Zn. The levels of contamination of trace metals in the plant tissues are as follows: (0.10-0.62) Cd, (6.20-26.57) Pb, (0.76-4.35) Cu and (1.75-61-67) Zn. Based on this data, we can say that the heavy metal profiles ranged like this: Zn>Pb>Cu>Cd. It was also observed that Pb concentration was consistently greater both in the sediments as well as in the plant tissues in all seasons, followed by Zn, Cu and Cd. In addition to this, the levels of Pb increased from the sediments to the plant tissue due to bioaccumulation and translocation. The concentration of the heavy metals in the mangrove forests of Muthupet showed greater levels than the recommended standard levels set by the WHO, although, the levels of contamination fell below the levels suggested by the sediment quality guidelines. As R. mucronataspecies showed better accumulation and translocation rate of Lead, it could be used as an efficient bio-indicator for monitoring the pollution of lead toxicity in the mangrove ecosystem [A. Ganeshkumaret al., 2019].

Conservation Strategies and Remote Sensing

The mangrove ecosystem is a unique wetland along the coastlines. They can help mitigate natural calamities and they are also a means of livelihood for the human settlements within these forests. The mangroves are self-sustaining forests, they normally do not require any human intervention to propagate themselves. In the recent years, the Interu Mangrove swamp along the Krishna estuarine region had been subjected to erosion and severe degradation owing to the anthropogenic activities. Aquaculture industry is setting up fisheries along the shores of the Krishna river to grow fish and they are also establishing shrimp farms along the way. This increase in the controlled production of only a few varieties of fish adversely affecting the local diaspora of the fish, other animals and plants which might rely on the existence of a certain species of animals for their survival. [Madhusudan Rao K. et al., 2015].

Seasonal variability and physicochemical parameters of the river and sea waters also play an important role in the mangrove cover of any given area. It was noted in a study that the temperature variation in Gauthami-Godavari estuarine regions only varied between 26-31C, the pH values ranged from 7-8.3, the salinity levels ranged from 0.23-31.82 psu, dissolved oxygen values ranged from 2.36-6.82 mgl-1. The hydrographical parameters also change with respect to the seasonal and spatial variations. The concentration of nutrients such as nitrite, ammonia, nitrate, phosphate and silicate also exhibit a fluctuation from the riverine waters to the estuarine waters, their levels being more in the riverine waters rather than in the estuarine waters. This observation was supported again by studying the parameters during different seasons. The presence of nutrients in the water was significantly more during the rainy season in comparison to the other seasons. [T. Umamaheswara Rao et al., 2015].

Annual estimates of the Net Ecosystem Exchange (NEE) should also be done to keep a tab on the carbon dioxide accumulated through a year in the mangrove forests, these annual tests would give us a glimpse into the efficacy of carbon sequestration and accumulation in the mangrive forests. Carbon sequestration in the forests would help in reducing the global carbon emission, thereby reducing the carbon footprint globally. The study was conducted in the Sundarbans mangrove forests, and it was proved that the mangrove forests act as effective carbon sinks [Suraj Reddy Rodda et al., 2016].

In an independent study done on the biochemical markers for carbon sequestration in two species of mangrove plants viz., Avicennia marina and Rhizophora mucronata. The biochemical markers for carbon sequestration are carotenoids, anthocyanin, flavonoids, phenols, tannins and leaf surface wax. Levels of carbon sequestration are estimated by comparing these parameters. Any plant which shows an increase in carbon sequestration is superior in converting atmospheric carbon dioxide into biomass. Mangroves are efficient in carbon sequestration; they remove the CO_2 from the atmosphere and store it in the form of biomass. They respond well to higher levels of CO_2; hence they show a greater accumulation of biomass under these levels. From these analyses we can conclude that the mangrove wetlands are one of the world's most productive ecosystems and any decrease in the mangrove forest covers of the

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world would significantly increase the global carbon footprint, which would, in turn, result in catastrophic climate changes [Kathiresan Kandasamy et al., 2018].

Transcriptomic analysis for the roots of Avicennia officinalis was done in an experiment to determine their response to salt treatment to identify salt-responsive genes. It was seen that of the 6547 genes that were differentially regulated, 1404 and 5213 genes were either up- or down-regulated in response to salt treatment. In genomics study it was seen that, 93 key salt tolerance-related genes were present of which 47 genes were up-regulated. Genes which function on the regulation of ABA, ethylene and auxin were either up-regulated or down-regulated based on the water salinity levels. Understanding the activity of the salt-tolerance related genes would give us an insight into the mechanism regulating the salt tolerance in mangrove plants. This would in turn, help us in selecting a mangrove or a halophyte for plantation drives along the estuarine regions [Pannaga Krishnamurthy et al., 2017].

The conservation of mangrove forests is the need of the hour to tame any natural calamities that might happen in these areas. Mangrove forests along the coastal areas help in mitigating adverse natural disasters like tsunamis or typhoons. A study conducted in the year 2005 after the tsunami struck the east coast of India, declared that the presence of mangrove forests had reduced the disastrous impact of the tsunami on the human settlements in these areas. It was also proposed that any human settlements should be built in raised platforms 1km away from the shoreline preferably behind defense mangrove forests [Kandasamy Kathiresanet al., 2006].

Mangroves are generally described as social-ecological systems (SESs). Their study would give us an insight into the interaction between man and nature, and resource utilization. To further understand this complex relation, adaptive cycle (AC) heuristic could be combined with SES. This would enable the scientists to extrapolate the data linking the spatial-temporal dynamics and the multi-dimensional character of the mangroves.The AC heuristic gives an understanding about the connectedness of the mangrove SES with that of the mangrove's accumulated capital using parameters such as natural, built, human and social. Complex data obtained from the SES and AC would help us mitigate unwanted calamities in the future by analyzing the data from the past. This would enable future stakeholders of this ecosystem to thrive positively and also it would be comfortable for forest officials to go for interactive adaptive planning of the mangrove forests [Farid Dahdouh-Guebaset al., 2020].

To plan excellent conservation strategies, it is necessary to understand the various threats and vulnerabilities that the mangrove forests face in the current world. Application of remote-sensing technique and Geographic Information System (GIS) for comprehensive data base approach is needed to review the threats of extinction that many wild animals and plant species face due to anthropogenic activities [S. Ghoshet al., 2015].

Remote sensing of the mangrove forests through satellite imaging is one of the best means to keep a track of the increase or the decrease in the forest cover of the areas in which the mangroves are seen. To remotely monitor the mangrove forest covers, several methods could be implemented to extract optical data from the satellite imagery. Landsat 4,5,6,7 and 8 TM and ETM could be used to obtain a comprehensive data over a longer period of time. Some of the methods used for the evaluation of the satellite imagery are; K-means clustering, Gabor filtering, Otsu's method, Texture and colour segmentation, colour based pixel classification, SVM Classification, Pixel threshold on Natural color image and SIFT [Kubo Sumiko et al., 2017]. Any of these methods could be used according to the need of the experiment being carried out. A careful observation of the satellite imagery gives us insights into the role of deforestation and construction of dams in the mangrove forests. Satellite imaging near the Krishna-Godavari deltas (K-G Deltas) has shown that there was significant forest cover in the 1970s which went down from 17,966 ha to 16,110 ha by 1990. But we see a significant rise in the mangrove forest cover after 1991, owing to the decision taken up by the Govt. of Andhra Pradesh to plant native mangrove plants in the deforested areas [A. Kavya et al., 2018]. The forest cover had increased significantly over the decades but there is still some degradation in the forest areas. The areas with darker patches in the image would be the ones which were cleared by the local communities for the construction of their huts. Areas with lighter patches signify salt encrustation on the banks and on the land due to increased salinity levels. Mangroves cannot thrive in areas with salt alone in the water. This problem could be addressed by building lesser dams near the river basins and carefully diverting the river waters along these areas. The salinity in the water would then be mitigated with the help of the fresh waters of the rivers. Mangrove degradation in an area could occur due to three factors viz., anthropogenic, coastal erosion and aquaculture. Maintaining a balance between these factors would harmonize the mangrove areas and significantly increase their carbon stock [Sushma Reddy et al., 2016 and P. Rama Chandra Prasadet al., 2017]. It should also be noted that due to the geomorphological landforms like spits and burs, there is a change in the niches of the mangrove forests. The endemic plant and animal species are more or less concentrated in one area due these landmasses and human habitation in these areas would directly affect the species endemism in these areas. Reforestation drive can use suitable mangrove species to increase the forest cover [Rehman K. N. et al., 2018]. It has been observed that the forest cover had increased manifold beyond the reforested areas due to the spreading of the propagules of the mangrove plants. The mangrove seeds could germinate on the banks of the river in locations which were suitable for them [Kandasamy Kathiresanet al., 1996].

Conclusion

Mangrove solve many environmental problems. They offer productive, proactive and social functions. Urbanization, population explosion and lack of awareness is leading to the conversion of mangrove regions into urban spaces. Various case studies in the present study area, Gilakaladandi, Machilipatnam, have given evidences about the loss of mangrove regions.

The present paper illustrated various aspects of mangroves and the general consensus is that, the policymakers and decision makers have to take requisite decisions on the sustainable conservation for the future generations.

Despite consistent efforts by the Swaminathan Research Foundation, N.G.O.s, and several research organizations, the mangroves are still left unprotected. The research team and the authors would like to educate the children in the present study area by providing the, various educational manuals which will help them in sustaining and protecting the environment. Creation of awareness among the small children will lead to sustainable protection of mangroves.

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