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Impacts of Climate Change on Indian Mangroves: A Review Paper

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Abstract: Mangroves are one among the important coastal habitats which are highly loaded with immense nutrient and always share it with adjoining coastal habitats. Interestingly this system supports number of endemic and endangered species throughout the tropical coast. India has more than 7500 km coastal line within this, it supports 4, 87,100 ha of mangroves and harbours 3985 species of flora and fauna. During late 80s India lost considerable areas of its mangrove cover due to several anthropogenic pressures. The ongoing climate change turned out to be a potential threat to the remaining Indian mangroves and other coastal ecosystem. Ironically there is no sound study till date about the impacts of ongoing climate change on Indian mangroves. The loss of mangroves will spread its impact on the adjoining system in a significant way. So, the mangrove loss will negatively influence the fishery resource of the tropical region and initiate regional and global socio-economical crisis.

Key words: Climate change · Coastal system · Mangroves · India

INTRODUCTION

From biodiversity, ecological and socioeconomic points of view, the coastal habitats are the most important one in this biosphere. For instance the intertidal zone out to the continental shelf break are estimated to provide over US $14 trillion worth of ecosystem goods and services every year. It was reported that more than one third of the world's population lives in coastal areas [1] and more than 10% of people live within 10 m of sea level [2]. Furthermore it deserves to mention that 70% of the Asian and approximately 20% of India's population depends on the coastal habitats for food and employment [3,4]. Coastal system is endowed with unique habitats such as coral reefs, sea grass beds, tidal flats and mangrove swamps. Interestingly all the habitats along the coastal line supports unique species throughout the world and most of the species are biologically and economically important.

Mangrove forests are one among the pivotal coastal systems around the world. Interestingly mangroves are one of the world's richest storehouses of biological and genetic diversity [5,6]. Moreover 90% of the marine species need to spend some stages of their life in this precious ecosystem. Furthermore it has been proved that 80% of the global fish catches are directly or indirectly dependent on tropical mangroves [7,8]. It is mainly due to the immense productivity, nutrient and suitable microclimate offered by mangroves since ages [9]. Especially the nutrient load is incomparable, for instance the Pichavaram mangroves of southern India alone produce 7,457 tones of leaf litter per year [10]. Moreover, dense mangroves always inhibit the speed and intensity of tropical cyclones and storms and minimize the damages [5]. Number of studies in different parts of the tropical regions elucidate the ability of mangroves against the impacts of cyclones [11-13]. In India, the 1999 super cyclone over 250 km of Orissa's coastline uprooted almost all the trees in the immediate vicinity of the coast and caused much damage to trees several kilometers inland. Notably mangrove forests and terrestrial trees in the shadow of mangrove cover remained intact [11]. The other most important benefits and uses offered by mangroves are presented in Fig. 1.

Indian mangrove has a long history that received attention right from the 17th century itself [14]. The first status report on Indian mangroves was submitted in 1987 to the Ministry of Environment and Forest, Government

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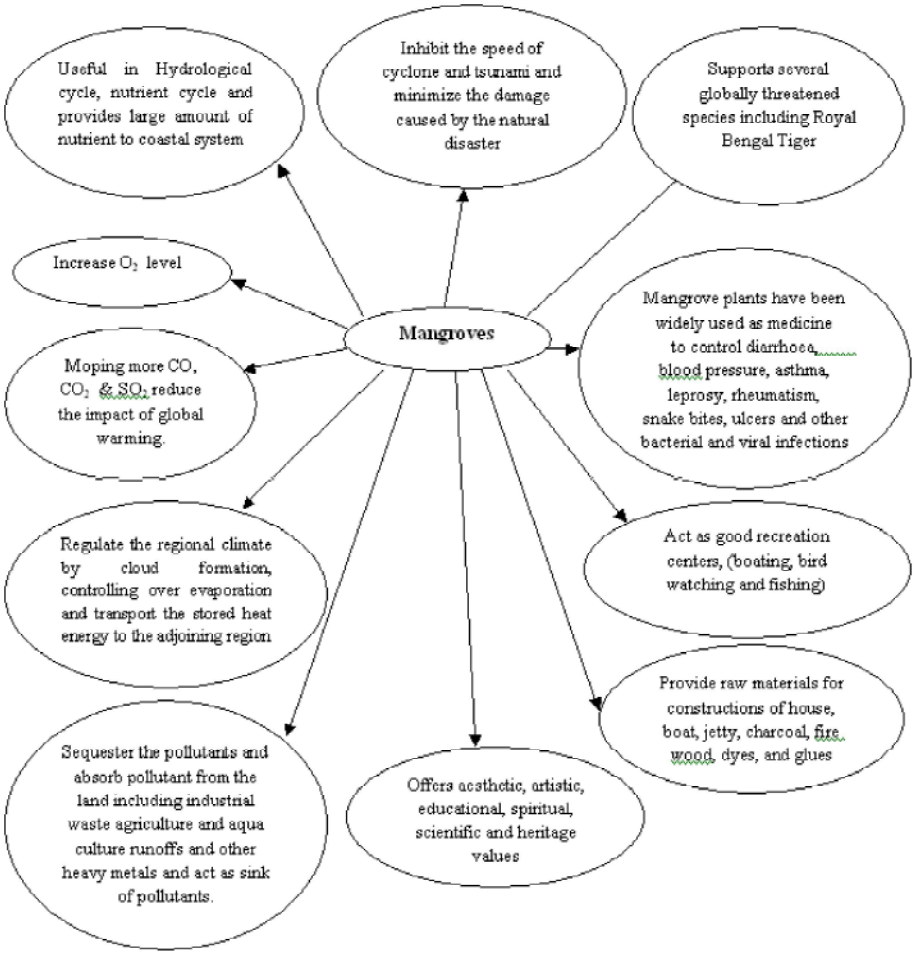

Fig. 1: Benefits and uses offered by mangroves.

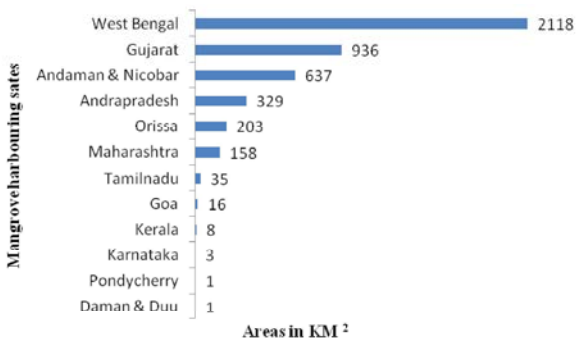

Fig. 2: Top mangroves suporting states of India based on the report of MOEF 2007

of India and after a decade another report entitled "Status Report on Mangroves of India" was published [14]. Inter alia Forest Survey of India [15]. stated that within the 7500 km coastal line, India supports 4,87,100 ha of mangrove wetlands, in that nearly 56.7% *i.e.* 2,75,800 ha is spread along the east coast region and 23.5% (1,14,700 ha) in the west coast region and the remaining 19.8% (96,600 ha) is found in Andaman and Nicobar islands. The major mangrove harboring states in India are provided in Fig. 2.

Current Status of Mangroves: Importance of mangroves was not properly recognized by the global community in the previous decades, which resulted in huge decline of mangroves throughout the tropical region. Losses of mangroves occur almost every country that harbours mangroves, on the other hand the developing countries which supported huge mangrove cover witnessed significant decline (>90%) [16]. Duke *et al* [17] disclosed that mangrove forests have been declining at a faster rate than inland tropical forests and coral reefs. To support this, Millennium Ecosystem Assessment MA [18],

Table 1: Flora and fauna species recorded from Indian Mangroves up to 2008.

Groups	Number of Species
Floral groups	
Mangroves	39
Mangrove associates	86
Sea grass vegetation	11
Marine algae (Phytoplankton + sea weeds)	557
Bacteria	69
Fungi	102
Actinomycetes	23
Lichens	32
Faunal groups	
Prawns and lobsters	55
Crabs	134
Insects	705
Mollusks	302
Other invertebrates	740
Fish parasites	7
Fin fish	543
Amphibians	11
Reptiles	82
Birds	419
Mammals	68
Total number of species	3985

Source: [6] .

reported, 35% of mangrove losses form 1980 to 2000 in the tropical region. Furthermore recent report by Global Marine Species Assessment declared, Southeast Asian countries alone lost 80% of its mangrove [19]. India also lost maximum cover during this period (e.g. Pichavaram mangroves South East Coast of India lost 80% of its mangrove cover [9]. Concerned over this large scale decline, United Nations General Assembly declared 2010 as the International year for biodiversity and 2011 for forest conservation mainly to highlight the importance of biodiversity values of forest.

Biodiversity Values of Indian Mangroves: Biological resources are the untapped capital of any country. Number of national and international research organizations emphasize that biodiversity is the most commercially important natural resources like oil and gold [20].

Indian mangrove supports a unique group of fungi, microbes, plants and animal species including crustaceans, mollusks, fishes, waterbirds and a number of endangered mammals like fruit bats, dolphin and the Royal Bengal tiger [5]. It was reported that Indian mangroves support 3985 species of flora and fauna that includes 919 (23%) flora and 3066 (77%) of fauna (Table 1). Interestingly 2 million water birds of about 200 species over-winter in Indian coast heading back to colder northern climes in April [16] and among them most of the species effectively utilize the Indian mangroves [21]. No other country in the world supports so many species in the mangrove ecosystem alone and most of the species are endemic to this habitat [6]. Notably Indian mangroves support numerous endangered flora and fauna (Table 2). Ironically such an important ecosystem is in continuous jeopardy and in recent decades this vital ecosystem is facing unimaginable threat due to continuous human intervention throughout India and faces a profound

Table 2: Endangered flora and fauna recorded in India mangroves up to 2005.

Species name	IUCN status	Source
Plants		
Acanthus ebracteatus	Endangered	[67]
Acrostichum speciosum	Endangered	[67]
Cynometra ramiflora	Endangered	[67]
Excoecaria indica	Endangered	[67]
Lumnitzera littorea	Endangered	[67]
Nypa fruticans	Endangered	[67]
Rhizophora annamalayana	Endangered	[67]
Rhizophora lamarckii	Endangered	[67]
Rhizophora stylosa	Endangered	[67]
Scyphiphora hydrophyllacea	Endangered	[67]
Sonneratia griffithii	Endangered	[67]
Invertebrates		
Cardisoma carnifex	Endangered	[68]
Gelonia erosa	Endangered	[68]
Uca tetragonon	Endangered	[68]
Macrophthalamus convexus	Endangered	[68]
Pilodius nigrocrinitus	Endangered	[68]
Fishes		
Boleophthalmus dussumieri	Endangered	[68]
Scartelaos viridis	Endangered	[68]
Reptiles		
Crocodilus porosus	Endangered	[69]
Varanus bengalensis	Endangered	[69]
Varanus. salvator	Endangered	[69]
Varanus. flavescens	Endangered	[69]
Lepidochelys olivacea	Endangered	[69]
Lissemys punctata	Endangered	[69]
Trionyx gangeticus	Endangered	[69]
Trionyx. hurun	Endangered	[69]
Batagur baska	Endangered	[69]
Python molurus	Endangered	[69]
Birds		
Pelecanus philippensis	Endangered	[69]
Theskiornis melanocephalus	Endangered	[69]
Ardea goliath	Endangered	[69]
Mammals		
Panthera tigris	Endangered	[69]
Platanista gangetica	Endangered	[69]

Fig. 3: Climate change variables and its impacts on mangrove wetlands.

emergency. Moreover natural calamities such as cyclone and tsunami are the great challenges to this system. Above all, it has been predicted that the ongoing climate change could be the greatest threat to the existing global mangroves [22]. and 100% of the mangrove forests could be lost in the next 100 years if the present situation continues everywhere [17]. Different climate variables and its impacts on mangroves are provided in Fig 3.

Mangroves and Climate Change: The ongoing global climate change is recognized as a great threat to natural habitats and ravage species survival [23,24]. Worldwide researchers investigate the ecological and hydrological impacts resulting from the ongoing climate change in several important habitats. It was recognized that the issue of climate change is a great challenge to wetland conservation and the restoration. Especially climate change will significantly alter many of the world's coastal wetland habitats [24,25]. Considering the global importance, coastal marine environments are a major focus of concern regarding the potential impacts of anthropogenic climate change [26].

It was predicted that the ongoing global climate change is expected to intensively alter the air and water temperatures, ocean and atmosphere circulation, sea-level rise, the intensity and incidence of hurricanes and the timing, frequency and magnitude of precipitation [27]. In natural conditions, coastal wetlands have the ability to adjust the rising seas and changes in local storm patterns, but unfortunately combination of climate changes and human activities jointly alter natural conditions and disrupt coastal wetland hydrology, biogeochemical cycling and other processes [28].

It was established that various extreme climatic events can significantly affect most of the wetlands species (e.g. Plankton, Benthic animals) [29], which also can significantly affect the demographic rates in the given year [30 and the productivity of the wetland. But unfortunately limited studies related to mangroves are available and especially there are no case studies in India. To support this, a recent international conference on climate change and sustainable agriculture held in the Indian capital concluded that there are no conclusive studies in India on the prospective impact of climate change on several fronts including coastal habitats and admitted that the knowledge and understanding of implications of climate change at the national level is inadequate and fragmentary or still in its infancy [31]. So, the foregoing review is highlighting the impacts of extreme climate on Indian coastal system. It is needless to state that mangroves are one among the coastal systems and the numbers of problem which affect the coastal system are applicable to mangroves also.

Increasing CO_2: Climate change events are accelerated mainly due to the dumping of green house gases such as CO, CO_2 and CH_4. Especially elevated level of CO_2 together with other green house gases result in global mean temperature rise and which will yet again result in a cascade of physical and chemical changes in marine systems [26]. The atmospheric concentration of CO_2 has increased 35% from a pre-industrial level from 280 parts per million by volume (ppmv) in 1880 to 379 ppmv in 2005 and it is expected to rise further [32].Moreover, it was reported that roughly half of the CO_2 released by human activities between 1800 and 1994 is now stored in the ocean. The continuous entry of atmospheric CO_2 is expected to substantially decrease marine pH and expected to change the saturation horizons of aragonite, calcite and other minerals essential to calcifying organisms [33, 34].

It was found that for some mangrove species, the response to elevated level of CO_2 may be sufficient to induce substantial change of vegetation along natural salinity and aridity gradients [35]. However, the impact of more CO_2 on mangroves is poorly understood and there is a less understanding in this area till date in India. On the other hand the annual automobile sales trend in India gets increasing in an alarming way [36]; Fig. 4), which will further increase the anthropogenic gases in the Indian environment. It is worth to mention here that India is the fifth largest crude oil consumer in the world and during 2009-10 India's motor sprit consumption was estimated to 1, 28,18, 000 tonnes (Fig. 5).

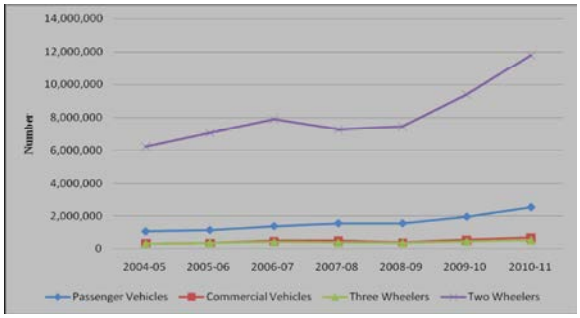

Fig. 4: The growth of automobile industry in India between 2004 and 2011. Source (SIAM 2011).

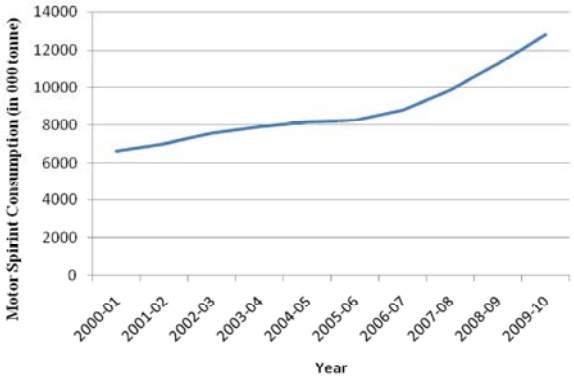

Fig. 5: Motor spirit consumption trends in India for the lost one decade. Source . (www.indiastat.com)

Increasing Temperature: Increasing CO_2 level in the atmosphere resulted in increasing global mean temperature [26]. Between 1906 and 2005, the global average surface temperature has increased by 0.74°C (±0.18 °C) and it is further expected to increase 1.1-6.4°C at the end of this century [32].

Several studies emphasize the negative impacts of rising temperature on species. The increasing temperature not only affects the biodiversity but also devastates the entire system. For instance, as a result of warming seawater, the world oceans are expanding, which coupled with freshwater input from 'ice-melt' and thermal expansion of the oceans is causing sea level to raise both at regional and global scale [37]. This will strongly affect the mangrove forest (refer sea level rise heading of this paper).

Furthermore it is stated that increasing temperature affects physiological processes ranging from protein damage to membrane fluidity to organ function [38]. Especially the marine organisms are highly prone to increasing temperature, because many coastal organisms already live close to their thermal tolerances [39,40]. So, naturally further increase in temperature can

negatively alter the performance and survival of marine organisms. For instance, several planktons and larval forms of several marine organisms are particularly susceptible to thermal effects [41], particularly young benthic stages of many organisms are more vulnerable to stress than their adults [42]. It is a well known fact that Indian mangrove supports unique group of fungi, plankton and other benthic community (Table 1) which might face potential risk by the increasing temperature. Furthermore rising temperature also affects the timing of ontogenetic transitions. So the ongoing climate change may decouple changes in the larval environment from the cues used by the adult population [43]. Field [44] and Ellison [45], emphasized that the mangrove might face the species composition change and changes in the flowering and fruiting periods. Moreover the mangrove plants need an ideal temperature for photosynthesis (28-32°C). So, photosynthesis is significantly reduced when leaf temperatures reach 38-40 °C [46,47], which will affect the net productivity. Continuous monitoring and detailed analysis indicate that the maximum temperature has been increasing during the last century over all the regions of India. The coastal region which supports mangroves will show a maximum increase of 0.6°C [48]. Extreme temperature events also have increased in the recent past in several parts of the country and the highest temperature varied between 45 and 50°C in several parts of the east coast [48], which supports 56.7% on country's mangroves.

Sea Level Rise: Global sea-level rise is one of the more certain outcomes of global warming, it is already taking place (12-22 cm occurred during the 20th century) [32]. The most obvious consequence of sea level rise will be an upward shift in species distributions. For example, intertidal habitat area may be reduced by 20-70% over the next 100 years in ecologically important zones [49]. Climate modeling clearly pointed out that larger changes in sea level have led to mangrove ecosystem collapse [50, 51]. In the future, landward migration of fringing mangrove species, such as *Rhizospora mangle*, will likely be limited due to coastal development and associated anthropogenic barriers [52, 53]. So sea level rise will be the greatest threat to Indian mangroves.

Cyclones: Recent evidence suggests that human induced global warming has already increased both the intensity and the frequency of cyclones that can cause severe damage to coastal life [54]. Muniyandi [55] (1986) stated that almost every alternative year Indian mangroves are affected by major cyclones. Recent data disclosed that severe cyclonic storms crossing east coast shows an increasing trend [48].

The increased intensity and frequency of tropical cyclones naturally increase the damage to mangroves through defoliation, uproot of trees and tree mortality. In addition to causing tree mortality, the nature of the soil sediments also get modified [56-60]. Moreover, it will lead to ecosystem conversion [61]. And it has been established that a cleared mangrove forest had failed to recover even after several years mainly due to changed hydrodynamics, salinity and acidity, as well as low nutrient levels and poor essential substrates [62].

Poor Rain Fall: Globally, rainfall is predicted to increase by about 25% by 2050 in response to climate change. However, the regional distribution of rainfall will be uneven [63]. A recent assessment of IPCC highlights the significant increase of precipitation in parts of Central Asia and poor in parts of Southern Asia for the forthcoming years [64].

Naturally the poor rainfall and increased evaporation will lead to the rise in salinity in mangroves (refer [65]). For the impacts of salinity on mangroves) and decreasing net primary productivity of mangroves, growth and seedling survival, altering competition between mangrove species, decreasing the diversity of mangrove zones and causing a notable reduction in mangrove area which is due to the conversion of upper tidal zones to hyper saline flats [44].

CONCLUSIONS

The ongoing climate change is a looming danger for the pivotal Indian coastal systems, especially the mangroves which are highly vulnerable to climate change. Adverse effects on mangroves extend its serious consequence to the adjoining fragile and important ecosystems such as coral reef and sea grass bed. It was reported that mangrove is the only marginal ecosystem which share the resources with the adjoining ecosystem [66]. Moreover, the ecological and socioeconomic values offered by the mangroves are innumerable, immeasurable and incomparable. So conserving mangroves might be a vital agenda in any nation's conservation programs. Practically conserving the mangroves from ongoing climate change is not an easy task and on the other hand it is high time to adopt a road map to minimize the damages.

As far as India is concerned, we have not started to analyze/estimate the impacts of climate change on mangroves. Unfortunately India is one among the countries which dumps huge quantity of CO_2 in atmosphere by combustion of fossil fuel from almost all the energy need sectors. Reports stated that flourishing of automobile industry in India is quadrupled over the past 15 years, which will result in further more dumping of anthropogenic gases. Apart from that, highly populated Indian metro cities are located on coastal line (e.g. Mumbai, Chennai and Calcutta) which will accelerate the pollution load resulting in vanishing mangroves. For instance, the mangroves in some places of the Indian state Maharashtra are almost extinct due to continuous human exploitation.

For a viable conservation, linking individuals and populations in conservation oriented action plans and making them to understand about the local-scale impacts to broader-scale changes, will improve their understanding of the biological consequences of climate change on mangroves [26]. Apart from that considerable reduction in CO_2 is a vital at least at the regional scale, unless the conservation of the mangrove from ongoing climate change will be a pipe dream.

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