ANALYSIS OF THE DISTRIBUTION PATTERN OF WETLANDS IN INDIA IN RELATION TO CLIMATE CHANGE

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ABSTRACT:

Wetlands provide immense environmental, economic, and social, benefits. Some of the wetland functions are surface water storage, groundwater recharge, storm water retention, flood control, shoreline stabilization, erosion control, and retention of carbon, nutrients, sediments and pollutants. According to the IPCC Second Assessment Report, changes in climate will lead to an alteration of the hydrological cycle and could have major impacts on regional water resources. Climate change may also lead to shifts in the geographical distribution of wetlands. Thus, the projected changes in climate are likely to affect wetlands, in their spatial extent as well as distribution and function. Wetland responses to climate change are yet to be understood thoroughly and are often not included in global models of the impact of climate change. India has a wide spectrum of wetlands ranging from high altitude alpine lakes, littoral swamps in the form of mangroves, corals and numerous types of inland wetlands. To understand the impact of climate change on wetlands, the first step is to have a spatial data base of existing wetlands. This paper highlights the wetland types and distribution in India created at 1: 250,000 scale using Resourcesat-1 (Indian Remote sensing Satellite-P6) Advanced Wide Field Sensor (AWiFS) data of 2004-05. A two step hierarchical classification was used to map the wetlands and categorise them into 25 classes. The total area under various wetland categories was estimated as 11.69 Mha. Since a wide range of wetland types exist, it is difficult to accurately predict whether they will continue to function as hydrological buffers for extreme events or provide other important ecological, social, and economic services. Therefore, only a general assessment of the relationships between wetlands and climate change is addressed in this paper. Increasing temperatures globally are likely to result in a warming of water temperatures in lakes and rivers. The greatest effect would be at high altitudes where biological productivity would increase. India has some of the very unique high altitude lakes spread across the Himalayas. Rare and endangered plant and animal species sensitive to small changes in temperature often have no alternative habitat, especially in isolated areas such as those in montane and alpine wetlands. On the other hand many coastal wetlands will have impact of salinity and change the homeostasis of ecosystem. The coral reefs are vulnerable to bleaching from sustained increase in Sea Surface Temperature (SST).

1. INTRODUCTION

Wetlands, one of the crucial natural resources are transitional areas of land that are either temporarily or permanently covered by water. Ramsar Convention defines wetlands as: ”areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters”. In addition, the Convention provides that wetlands: ”may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands”. Given these characteristics, wetlands exhibit enormous diversity and support a rich spectrum of plant and animal species, making them ecologically significance. Utility wise, wetlands directly and indirectly support millions of people in providing services such as food, fibre and raw materials, storm and flood control, clean water supply, scenic beauty and educational and recreational benefits. The Millennium Ecosystem Assessment estimates conservatively that wetlands cover seven percent of the earth’s surface and deliver 45% of the world’s natural productivity and ecosystem services provide benefits estimated at $20 trillion a year (Source : www.MAweb.org).

Irrespective of their significance, there has been a little attention given so far by policy-makers to the relationship between climate change and the conservation and wise use of wetlands. Rises in temperatures, changes in precipitation, and sea-level rise, are the main aspects of climate change that will affect wetland distribution and function. For most regions the projections for changes in precipitation and temperature, are highly uncertain. Further uncertainty includes the increase in frequency and intensity of extreme events, such as storms, droughts, and floods. The ability of wetland ecosystems to adapt to climate change will be highly dependent on the rate and extent of these changes.

India has a wide diversity of wetlands (MoEF, 1990, WWF, 1993). Mapping the wetlands following a meaningful classification system is a basic requirement to study climate change impact. This paper highlights the results of wetland inventory of India derived using satellite remote sensing data and analyses the broad aspects of climate change on different wetland categories in Indian context.

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2. DATA AND METHODOLOGY

Mapping and analysis was carried out for entire India including the islands. Resourcesat-1 AWiFS data of 2004/5 was used to map the wetlands. AWiFS provide data in 4 spectral bands; green, red, Near Infra Red (NIR) and Short wave Infra Red (SWIR), with 56 m spatial resolution. The spatial resolution is suitable for 1:250,000 scale mapping. Two date data, one acquired during March-May and another during September-November were used to capture the pre-monsoon and post-monsoon hydrological variability of the wetlands respectively. On screen digital interpretation of the data was done to map the wetlands. A two step hierarchical classification system was followed to map the wetlands into 25 classes. The database was organised in GIS environment using a well defined spatial framework for India (Anon, 2005). Spatial layers of bio-geographic zones, river basins and agro-climatic zones were created using published maps and literature. Administrative boundary layers of country, state and district were also organaised in GIS environment. These layers were used for analysis of wetland distribution. Spatial distribution layers have been generated for various aspects. The broad steps of the procedure are:

- Geo-referencing of satellite data
- Generation of spatial framework in GIS environment on the basis SOI graticule grids for database creation and organisation.
- Preparation of wetland maps from satellite data using on-screen interpretation techniques
- Creation of a digital database for each of the thematic layers as per the spatial framework.
- Mosaicing/edge matching of all these maps to create seamless database
- Preparation of maps and statistics on wetland distribution

3. RESULTS

3.1 Wetlands in India

The total area under wetlands in India was estimated to be 11689909 ha (11.69 Mha). This accounts for 3.66 per cent of geographic area of the country. Wetlands belonging to different classes are shown in Table 1. The major wetland types are River/Stream, Inter tidal mud flats, Reservoirs, Tanks, Lake/ponds and Mangrove forest. India has some of the unique wetlands like mangroves (403278 ha) and corals (106235 ha). Area under different wetland classes in India is shown in Figure 1. State-wise distribution shows that Gujarat has highest area under wetlands (2853838 ha), followed by West Bengal (1199864 ha) and Andhra Pradesh (1088975 ha). However, if per cent geographic area is taken into consideration, Lakshadweep leads the list with 54.38 per cent area under wetlands (mainly coral reefs), followed by Gujarat (15%) and West Bengal (14%).

Sr. No.	Wetland Type			Area (ha)
	Level I	**Level II**	**Level III**	
1	**Inland Wetlands**	**Natural**	Lake/ponds	469817
2			Ox-bow lakes/cut off meanders	142158
3			Waterlogged	404937
4			Playas	44434
5			Swamp/marsh	259198
6			River/Streams	2929620
7		**Man-made**	Reservoirs	1512011
8			Tanks	1492342
9			Waterlogged	160046
10			Abandoned quarries	5245
11			Ash pond/cooling pond	8119
12	**Coastal Wetlands**	**Natural**	Estuary	17480
13			Lagoon	190196
14			Creek	137011
15			Backwater(kayal)	453206
16			Bay	575
17			Tidal flat/mud flat	2331528
18			Sand/beach/spit/bar	53240
19			Coral reef	106235
20			Rocky coast	8428
21			Mangrove forest	403278
22			Salt marsh/marsh vegetation	221273
23			Other vegetation	73126
24		**Man-made**	Salt pans	112097
25			Aquaculture ponds	154309
Total				**11689909**

Table 1: Type Wise Area Under wetlands in India Based on IRS AWiFS Data of 2004-05

Natural wetlands accounted for 71 per cent of total wetlands. Area under inland wetlands (natural and man made) is about 7.42 Mha and that of costal wetlands is 4.26 Mha accounting for about 64.0 and 36.0 per cent of total wetlands respectively. (Table-2 and Fig.2).

Since, size is an important criterion for impact assessment; wetlands were categorized into five classes based on their aerial extent. Analysis revealed that there are 118 very large wetlands (>10000 ha) occupying 49 per cent share followed by 6690 belonging to large ones (100 -10000 ha) as shown in Table-3 and Figure 3.

The bio-geographic classification of India recognizes 10 bio-geographic zones ranging from the Trans-Himalaya to the Islands. These zones indicate an unique set of geo-physical and hydro-climatic conditions as well as distinct geological origins. They also have unique floral and faunal elements. The Himalaya and Gangetic plains are examples of two adjacent extremely different zones. The map prepared by Wildlife Insitute of India has been used for analysis (Rogers and Panwar, 1988). Bio-geographic zone wise wetland area is given in Table 4. Zone 8 (East coast)

accounts for 35.8% of geographic area under wetlands. About 7.7% of geographic area of Island-Andaman is under wetlands. Gangetic plain (3.9%) and Brahmputra valley has about 3.8% area under wetlands. Graphical distribution is shown in Figure 4.

Sr. No.	Wetland Type	Area (ha)
1	Inland : Natural	4250164
2	Inland : Man-made	3177763
3	Coastal : Natural	3995575
4	Coastal : Man-made	266407
	Total	11689909

Table 2: Area Under coastal and Inland Wetland Types in India

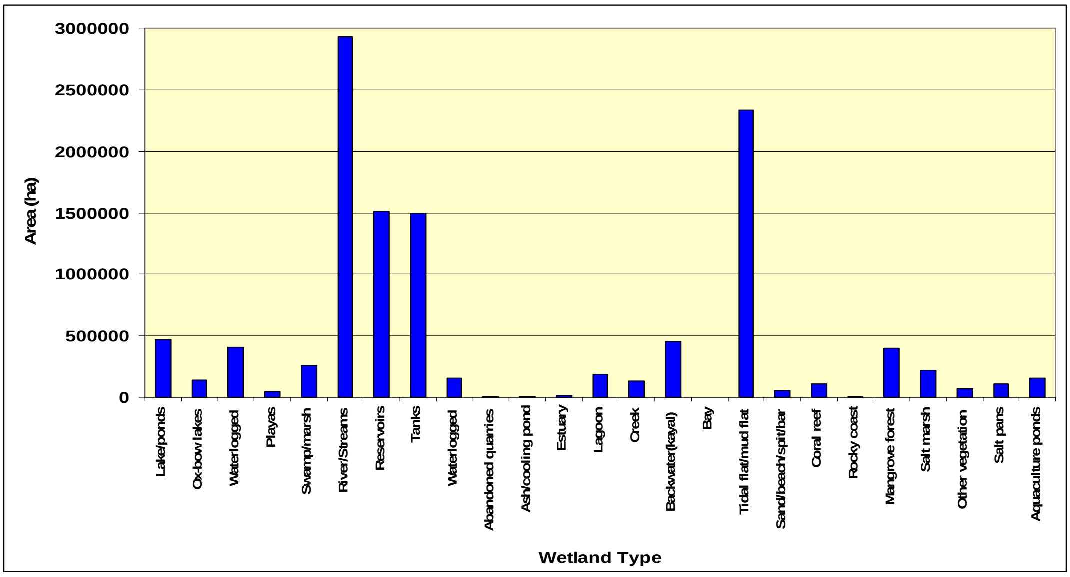

Figure 1: Area Under Different Wetland Classes in India (2004-05)

Sr. No.	Class	No. of Wetlands	Area (ha)
1	Very Large (> 10000 ha)	118	5859580
2	Large (100 - 10000 ha)	6690	4270651
3	Medium (25 - 100 ha)	10772	545684
4	Small (1 - 25 ha)*	71660	1013994
5	Very Small (< 1 ha) #	-	-
	Total		11689909

Table 3: Number and Area of Wetlands Under Different Sizes

** Less than minimum mapable unit (62.5 ha on 1:250,000 scale) assumed to be approximately 15 ha.# AWiFS data not suitable for mapping*

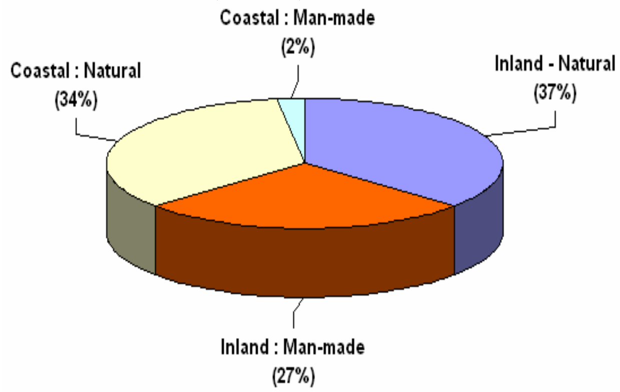

Figure 2. Percent Share of Man-Made and Natural Wetland Types in India (2004-05)

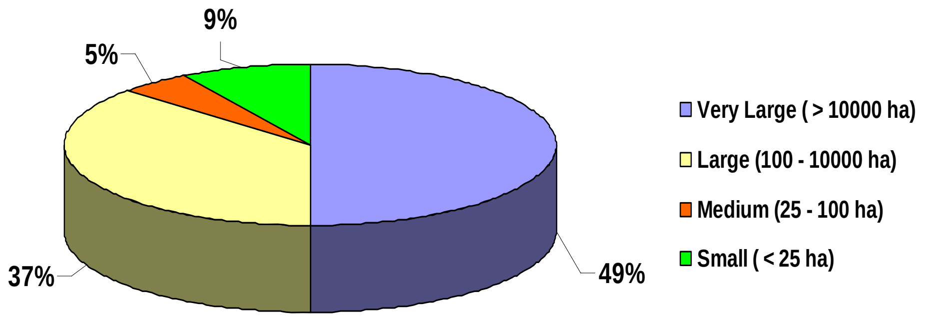

Figure 3. Percent Share of Wetland of Different Sizes in India

Sr. No.	Biogeographic Zones	Geographic Area (ha)	Total Wetland Area (ha)	Percent wetland area
1	Trans Himalaya - Ladakh Mountains	18393982	245166	1.33
2	Himalaya - West Himalaya	20396030	177927	0.87
3	Desert - Kachchh	19032015	232337	1.22
4	Semi-Arid - Gujarat Rajputana	50961676	1309550	2.57
5	Western Ghats - Western Ghats Mountains	13040390	251234	1.93
6	Deccan Peninsula - Central Highlands	134347297	3255652	2.42
7	Gangetic Plain - Lower Gangetic Plain	34240009	1345512	3.93
8	Coasts - East Coast	11696546	4192217	35.84
9	North-East - Brahmputra Valley	16496362	626992	3.8
10	Islands - Andaman	691826	53322	7.71
	Total	319296134	11689909	3.66

Table 4: Biogeographic Zone Wise Wetland Area

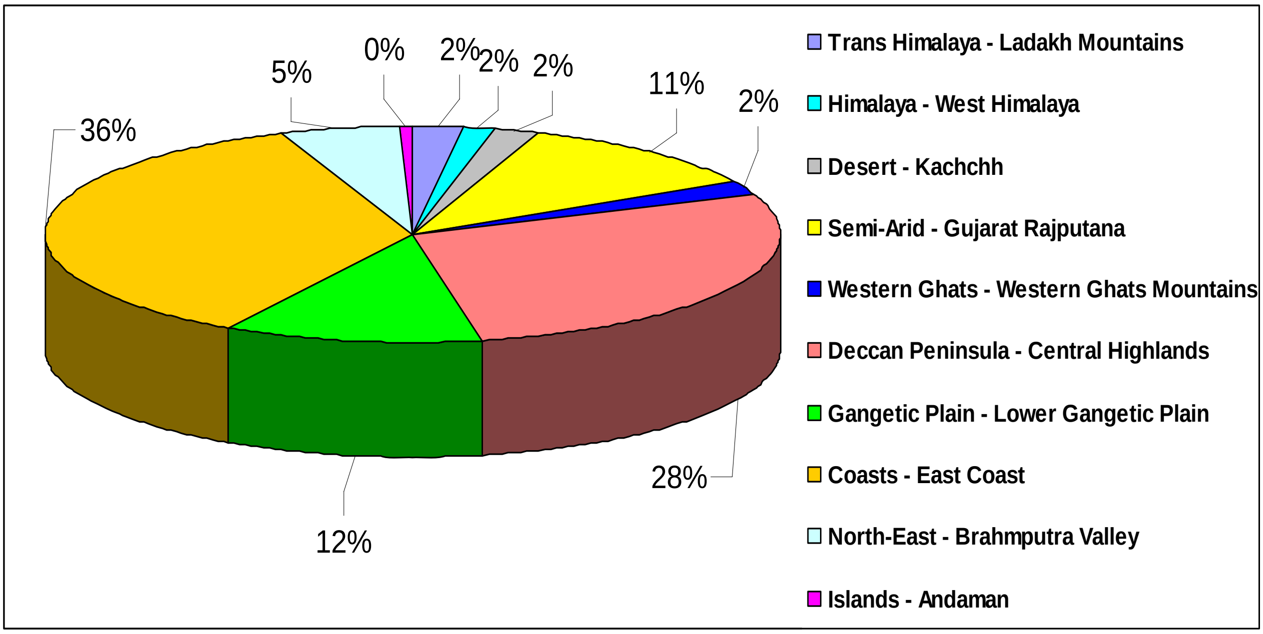

Figure 4. Bio-Geographic Zone Wise Wetland Distribution Pattern

3.2 Analysis of Impact of Climate Change

Changes in precipitation, sea-level rise and increases in temperature, are some of the important aspects of climate change that has direct impact on the wetlands. The wetland statistics generated along with their spatial distribution derived using remote sensing data enables to assess the dimensions of impact.

3.2.1 Coastal wetlands: Coastal region has been projected as the most vulnerable target of climate change due to sea level rise, flooding etc (Boorman, 1990). IPCC (1996) estimates that sea levels will rise between 1, 5 and 9 meters in the coming decades due to thermal expansion of ocean water and melting of glaciers and ice caps. Already since pre-industrial times, sea levels have risen globally between 1, 2, and 5 meters. This will have direct impact on the coastal wetlands.

India has large number of coastal wetlands which account for around 36 per cent of total wetlands. These wetlands range from coral reefs of Gujarat, Anadaman and Nicobar, Lakshdweep, Gulf of Mannar followed by inter tidal mud-flats that spans most of the coast and mangroves of varying densities, and breeding habitats of turtles of Orissa coast. Rise in sea level would result engulfment of these wetlands or at least make these wetlands very vulnerable. Increased coastal flooding, loss of habitats, an increase in the salinity of estuaries and freshwater aquifers, and changed tidal ranges in rivers and bays, transport of sediments and nutrients, patterns of contamination in coastal areas are amongst the main effects of coastal region. Coastal wetland flora and fauna generally respond to small, permanent changes in water levels. Accelerated rates in sea level rise will likely result in shifts in species compositions, a reduction in wetland productivity and function. The degree to which they are able to adapt to these changes will depend to a great extent on the ability for species to 'migrate' to alternative areas. Increased sea levels will likely force wetland systems to migrate inland. However, this migration path could be obstructed by inland land uses or by the ability of these systems and their components to migrate in time sufficient to survive. For example, many coastal and estuarine wetlands will be unable to migrate inland due to the presence of dikes, levees or specific human land uses close to the coastal area.

3.2.2 Mangrove ecosystem: India harbors some of the largest and most diverse mangrove ecosystems of the world. The magrovess along the Bay of Bengal has evolved over the millennia through natural deposition of upstream sediments accompanied by intertidal segregation. The physiography is dominated by deltaic formations that include innumerable drainage lines associated with surface and subaqueous levees, splays and tidal flats. There are also marginal marshes above mean tide level, tidal sandbars and islands with their networks of tidal channels, subaqueous distal bars and proto-delta clays and silt sediments. The delicate balance of fresh water and sea water supports the diversity of these ecosystems be it the famous Sunderbans or the Bitarakanika. The effect of sea level rise and change in freshwater runoff from the catchment due to change in precipitaion will have direct impact on the species composition and diversity. Threat to loss of area due to sea level rise, erosion are additional impacts.

3.2.3 High altitude wetlands: India has a large number of high altitude wetlands known as alpine wetlands, which are unique in terms of biodiversity, besides its role in mountain hydrology. Increasing temperatures are likely to result in a warming of water temperatures in lakes. The greatest effect would be at high altitudes where biological productivity would increase. Rare and endangered plant and animal species with sensitivity to small temperature changes often have no alternative habitat, especially in isolated areas such as those in montane and alpine wetlands.

3.2.4 Coral reefs: Coral reefs have been given specific attention under climate change scenario due to their sensitiveness to growing environment (IUCN/UNEP, 1993). India has good number of corals and atolls classified under natual wetlands. Atolls defined as "...an annular reef enclosing a lagoon in which there are no promontories other than reefs and islets composed of reef detritus" and "...in an exclusively morphological sense,.a ring-shaped ribbon reef enclosing a lagoon in the center." The remains of an ancient atoll as a hill in a limestone area is called a reef. As noted above, reef-building corals can thrive only in warm tropical and subtropical waters of oceans and seas, and therefore atolls are only found in the tropics and subtropics.

Coral reefs are the most biologically diverse marine ecosystems, but are very sensitive to temperature changes. Short-term increases in water temperatures in the order of only 1 to 2 ^{o}C can cause "bleaching" of coral. Sustained increases of 3 to 4 ^{o}C above average temperatures can cause significant coral mortality. A rising sea level and increasing storm surges also could harm corals. Many available studies indicate that even slow-growing corals can keep pace with the "central estimate" of sea-level rise (approximately 0.5 cm per year). Also, recent research suggests that increasing concentrations of carbon dioxide in the atmosphere negatively affect coral reef growth due to change in pH of sea water. Generally speaking, climate change will affect these coral reef systems one way or other (Bijlsma, 1996).

3.2.5 Inland natural wetlands: Inland natural wetlands constitute 37 per cent of total wetlands and include classes like rivers/streams, lakes/ponds and waterlogged areas. Inland natural wetlands will be affected in different ways by shifts in the hydrological cycle due to changes in precipitation, evaporation, transpiration, runoff and channel flow. Arid and semi-arid areas are especially vulnerable to changes in precipitation as a decline in precipitation can dramatically affect wetland areas.

3.2.6 Carbon cycle: Wetlands play an important role in the global carbon cycle. The carbon pool contained in wetlands globally is estimated to be up to 230 Gton out of a total of about 1943 Gton. Assessment of Indian wetlands in direction has not been done. However, conserving, maintaining, or rehabilitating wetland ecosystems can be a viable element to an overall climate change mitigation strategy.

Due to their anaerobic character and low nutrient availability, wetland carbon stocks increase continuously and are source of methane production and emission. When the wetlands are drained, mineralisation generates considerable methane emissions. When wetlands are converted to agricultural land, large quantities of CO_2 and NO_2 are released while methane emission is reduced sharply.

CONCLUSION

Wetlands are important natural resources. India has a large diversity of wetlands starting from the alpine wetlands in Himalaya, mangroves in the coastal region to corals in sea and near shore. Hydrological regime is the key process of wetland formation and status. Change in temperature, precipitation projected under climate change scenario has a direct bearing on the hydrological regime. Thus, the projected changes in climate are likely to affect wetlands, in their spatial extent, distribution, function and ecological aspect including flora/fauna composition and concentration. Wetland responses to climate change are still poorly understood. This paper has shown the potential of geospatial tools like remote sensing and GIS in mapping and updating database of wetlands. Analysis showed that high altitude wetlands, coastal wetlands and mangroves and corals are some of the most sensitive classes that will be affected by climate change. This will have serious ecological impact. The inland natural wetlands which occupy single most dominant position, will have impact on its hydrological regime due to changes in runoff, evapo-transpiration. Particular impact on the arid/semi arid region is highlighted like the Gujarat state which leads in wetland area.

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