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Review Article

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Global Scenario on Wetlands and Plant Adaptation Mechanisms in Water logging Condition: A Critical Review

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Abstract

Wetlands are shallow to intermittently flooded ecosystems that are commonly known as swamps, bogs, marshes and sedge meadows. Wetlands are sometimes described as "the kidney of the landscape" because they function as the downstream receivers of water and waste from both natural and human sources. Water logging is one of the major problems in wetlands that restrict oxygen movement from the atmosphere to the soil resulting in anaerobic conditions. For such type of conditions, plants and microbial species require special adaptations. This review summarizes a comprehensive overview of distribution, major types of wetlands in global level and in India (including Ramsar Sites of India). It also signifies different plant adaptation mechanisms in these adverse conditions.

Keywords: Plant adaptation, ramsar sites, swamps, waterlogging

1. Introduction

A wetland is an ecosystem that arises when inundation by water produces soils dominated by anaerobic process, which, in turn forces the biota, particularly rooted plants, to adapt to flooding (Keddy, 2010). Except Antarctica, wetlands are distributed in all the climatic zones ranging from tropics to tundra .Wetland definition, then, often include three main components: 1) Wetlands are distinguished by the presence of water, either at the surface or within the root zone. 2) Wetlands often have unique soil conditions that differ from adjacent lands. 3) Wetlands support vegetation adapted to the wet conditions (hydrophytes) and conversely, are characterized by the absence of flooding in tolerant vegetation.

The International Union for the Conservation of Nature and Natural Resources (IUCN) at the Convention on Wetlands of International Importance especially as Waterfowl Habitat, better known as Ramsar convention, adopted the following definition of wetlands (Navid, 1989) "as areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water is static of flowing, fresh, brackish or salt including areas of marine water, the depth of which at low tide does not exceed 6 meters". This definition was adopted at the first meeting of the convention in Ramsar, Iran in 1971. This definition does not include vegetation or soil and extends wetlands to water depths 6 m or more. These valuable uses of wetlands are now being recognized and translated into wetland protection laws, regulations and management plans. Since wetland requires water, the obvious place to begin is the distribution of water on earth. Table 1 show that a majority of the Earth's available water is in the oceans. A

Table 1: Mass of water in different forms on Earth

Sl. No.	Form	Mass ($\times 10^{17}$ kg)
a: Chemically bounds in rocks		
	Crystalline rocks	250000
	Sedimentary rocks	2100
b: Free water		
	Oceans	13200
	Ice caps and glaciers	292
	Ground water to a depth of 4000 m	83.5
	Freshwater lakes	1.25
	Saline lakes and inland seas	1.04
	Soil moisture	0.67
	Atmospheric water vapour	0.13
	Rivers	0.013

a. Does not cycle; b. Part of hydrological cycle; Source: Clapham (1973) much smaller amount is present as fresh water. Some wetlands from along the edges of oceans tend to be mangrove swamps in equatorial regions and salt marshes at higher latitudes. A majority of wetlands are, however, freshwater ecosystem. They occur where rain water accumulates on its way back to the ocean. This review was framed keeping in view the following objectives:

a. To highlight the basic wetland types in global level.

b. Current status of wetlands in World and in India, including Ramsar sites of India.

c. To reveal different plant adaptation mechanism in wetlands or waterlogging conditions with examples.

2. Status of Global Wetlands

The most recent estimate of global inland and coastal wetland area is 12.1 million km^2, an area almost as large as Greenland. Of this, 54% is permanently inundated and 46% seasonally inundated. Around 93% of wetlands are inland systems, with 7% being marine and coastal although this estimate does not include several wetland classes such as near shore sub tidal wetlands, which also fall into the Ramsar definition. Global areas of human-made wetlands are small in comparison: reservoirs cover an estimated 0.3 million km^2 and rice paddy 1.3 million km^2 (Davidson et. al., 2018; Davidson and Finlayson, 2018). The largest areas of wetlands (Figure 1) are in Asia (32% of the global area), North America (27%) and Latin America and the Caribbean (16%). Wetland areas in Europe (13%), Africa (10%) and Oceania (3%) are smaller (Davidson et. al., 2018). Continent wise examples of wetlands and their area are presented in Table 2.

Table 2: The world's largest wetlands (areas rounded to the nearest 1000 km^2)

Rank	Continent	Wetland	Description	Area (km^2)
1	Eurasia	West Siberian low land	Bogs, mires, fens	2745000
2	South America	Amazon River basin	Flood plain forest and savanna, marshes, mangal	1738000
3	North America	Hudson Bay Lowland	Bogs, fens, swamps, marshes	374000
4	Africa	Congo river basin	Swamps, riverine forest, wet prairie	189000
5	North America	Mackenzie river basin	Bogs, fens, swamps, marshes	166000
6	South America	Pantanal	Savannas, grasslands, riverine forest	138000
7	North America	Mississippi River basin	Bottomland hardwood forest, swamps, marshes	108000
8	Africa	Lake Chad basin	Grass and Shrub savanna, marshes	106000
9	Africa	River Nile Basin	Swamps, marshes	92000
10	North America	Prairie potholes	Marshes, meadows	63000
11	South America	Magellanic moorland	Bogs	4400

Source: Fraser and Keddy (2005)

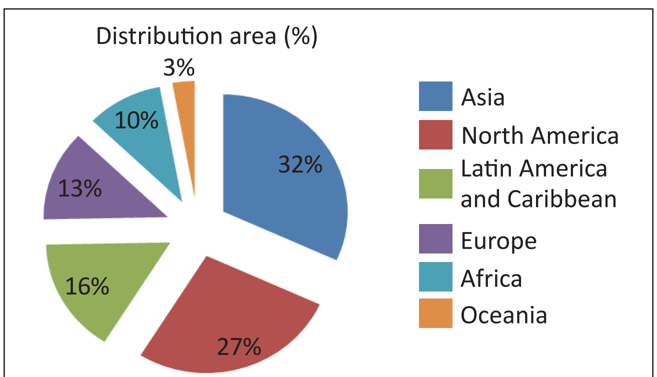

Figure 1: Regional distribution (%) of wetland area (Source: Davidson et al., 2018)

3. Types of Wetlands

3.1. Swamp

Swamp is a wetland that is dominated by trees that are rooted in hydric soils, but not in peat. Examples include the tropical mangrove swamps of Bangladesh and Myristica swamps of Western ghats. Tree species in such swamp forests are black spruce (*Picea marina*), black gum (*Nyssa sylvatica*), red maple (*Acer rubrum*), tall stilted mangrove (*Rhizophora apiculata*), willows (*Salix* spp) etc.

3.2. Marsh

Marsh is a wetland that is dominated by herbaceous plants that are usually emergent through water and rooted in hydric soils, but not in peat. Examples include cattail (*Typha angustifolia*) masrhes and reed (*Phragmites australis*), water spinach (*Ipomea aquatica*) etc.

3.3. Bog

A wetland dominated by Sphagnum moss, sedges, eriaceous shrubs or evergreen trees rooted in deep peat with a pH less than 5. Examples include West Siberian Lowland in central Russia.

3.4. Fen

A wetland that is usually dominated by sedges and grasses rooted in shallow peat, often with considerable groundwater movement and with greater pH (>6). Many occur on calcareous rocks, and most have brown mosses. Genera in such wetlands include Scorpidium or Drepanocladus. Examples of such wetlands include peatlands of Northern Canada and Russia.

3.5. Wet meadow

Such wetlands are dominated by herbaceous plants rooted in occasionally flooded soil. Examples include wet prairies along river floodplains, or herbaceous meadows on the shorelines of large lakes.

3.6. Shallow water

A wetland community dominated by truly aquatic plants. Examples include the littoral zones of lakes, bays in rivers and the more permanently flooded areas of prairie potholes (Plate 1).

Plate 1: (a) Swamp (Eastern coast, Odisha) (b) Marsh (Mangalajodi, Chilika lagoon, Odisha) (c) Bog (internet source) (d) Fen (Belghar, Balliguda, Odisha) (e) Wet meadow (Jajpur, Odisha) (f) Shallow water (Chilika lagoon, Odisha)

4. Wetland Scenario in India

National Wetland Atlas 2011, prepared by SAC, is the latest inventory on Indian wetlands. Entire Country was considered for assessment and a total of 201,503 wetlands were identified and mapped on 1:50,000 scale (SAC, 2011). Gujarat has the highest proportion (22.8%) and UT of Chandigarh has nearly negligible part of the total wetland area in the country. The States of Sikkim, Nagaland, Mizoram, Meghalaya and Jharkhand have more than 90% of the total wetland area as water spread area during post monsoon. Andhra Pradesh, Delhi, Karnataka, Manipur, odisha, Punjab, Tamil Nadu, Tripura and West Bengal have 15–59% of the wetland area under aquatic vegetation. Further, Andhra Pradesh, Gujarat, Karnataka, Orissa, Tamil Nadu, Uttar Pradesh and West Bengal account for nearly 3/4th of the total area under aquatic vegetation. The first scientific mapping of wetlands of the country was carried out using satellite data of 1992–1993 by Space Applications Centre (SAC), Ahmadabad. The exercise classified wetlands based on the Ramsar Convention definition. This inventory estimated the extent of wetlands to be about 7.6 mha (Garg et al., 1998). The estimates did not include paddy fields, rivers, canals and irrigation channels. The total wetlands area was estimated to be 15.26 mha (Table 3), which is around 4.63% of the geographical area of the country (ISRO, 2011).

Table 3: Category-wise wetlands distribution in India

Sl. No.	Wetlands category	Total wetland area (ha)	% of wetland area
1.	Inland wetlands-Natural	6623067	43.40
2.	Inland Wetlands-Man-made	3941832	25.83
	Total Inland	10564899	69.22
3.	Coastal wetlands-Natural	3703971	24.27
4.	Coastal wetlands-Man-made	436145	2.86
	Total-Coastal	4140116	27.13
	Sub-Total	14705015	96.36
5.	Wetlands (<2.25 ha)	555557	3.64
	Total	15260572	100

Source: Space Application Centre (SAC, 2011)

5. Ramsar Sites of India

The Convention on Wetlands of International Importance especially as Waterfowl Habitat is generally known as the Ramsar Convention. It owes its name after the town in Iran where it was adopted in 1971. It is the oldest and first inter-governmental conservation convention. India became a contracting party to the Ramsar Convention in 1981. The Chilika lagoon in Odisha and the Keoladeo National Park in Rajasthan are the first two wetlands designated as Ramsar sites in 1981. Since then, total 42 wetlands in the country have been designated as Ramsar sites by 2020. The latest Tsokar wetland in Ladakh has been declared as Ramsar site in November, 2020 (Table 5).

Though India has numerous wetlands of various types, there are certain criteria of selection of sites for Ramsar designation. As per the Article 2.2 of the Ramsar Convention, broadly the wetlands are categorized under two Groups under nine criteria (Table 4). Group A sites are selected under the Criterion 1 as "Sites containing representative, rare or unique wetland

Table 4: Criteria for declaring an area as Ramsar site

Group A of the criteria: Sites containing representative, rare or unique wetland types. Comprises only one criterion	
Criterion 1	A wetland should be considered internationally important if it contains a representative, rare or unique example of a natural or near-natural wetland type found within the appropriate bio-geographic region
Group B of the criteria: Sites of international importance for conserving biological diversity. This group comprises the rest of nine criteria which are based on species and ecological communities.	
Criterion 2	A wetland should be considered internationally important if it supports vulnerable, endangered or critically endangered species or threatened ecological communities
Criterion 3	A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular bio-geographic region.
Criterion 4	A wetland should be considered internationally important if it supports plant and/or animal species at critical stage in their life cycles or provides refuge during adverse conditions
Criterion 5	A wetland should be considered internationally important if it regularly supports 20, 000 or more waterbirds.
Criterion 6	A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or sub-species of waterbirds
Criterion 7	A wetland should be considered internationally important if it regularly supports a significant proportion of indigenous fish subspecies or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity
Criterion 8	A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend
Specific criteria based on other taxa	
Criterion 9	A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of wetland-dependent non-avian species

(Source: Murthy et al., 2013)

Table 5: List of all Ramsar sites of India (As on February, 2021)

Sl. No.	States	Name of site	Area in (km^2)
1.	Andhra Pradesh	Kolleru lake	901
2.	Assam	Deepor Bel	40
3.	Bihar	Kabartal wetland	26.20
4.	Gujarat	Nalsarovar bird sanctuary	120
5.	Himachal Pradesh	Pong dam	156.62
6.	Himachal Pradesh	Renuka	0.2
7.	Himachal Pradesh	Chandertal	0.49
8.	Jammu and Kashmir	Surinsar-mansar	3.5
9.	Jammu and Kashmir	Wular lake	189
10.	Jammu and Kashmir	Tsomoriri	120
11.	Jammu and Kashmir	Hokera wetland	13.75
12.	Kerala	Sasthamkotta	3.73
13.	Kerala	Vemband Kol wetland	1512.5
14.	Kerala	Asthaimudi	614
15.	Ladakh	Tso Kar wetland complex	95.77
16.	Madhya Pradesh	Bhoj wetlands	32.01
17.	Maharastra	Lonar lake	4.27
18.	Maharastra	Nandur Madhamaleswar	14.37
19.	Manipur	Loktak lake	266
20.	Odisha	Bhitarkanika mangrooves	650
21.	Odisha	Chilka lake	1165
22.	Punjab	Ropar lake	13.65
23.	Punjab	Keshopur-miani community reserve	3.439
24.	Punjab	Nangal wildlife sanctuary	1.16
25.	Punjab	Kanjili lake	1.83
26.	Punjab	Harike lake	41
27.	Punjab	Beas conservation reserve	64.289
28.	Rajasthan	Keoladeo Ghana NP	28.73
29.	Rajasthan	Sambhar lake	240
30.	Tamil Nadu	Point Calimere Wildlife and bird sanctuary	385
31.	Tripura	Rudrasagar lake	2.4

Table 5: Continue..

Table 5: List of all Ramsar sites of India (As on February, 2021)

Sl. No.	States	Name of Site	Area in (km^2)
32.	Uttar Pradesh	Sandi bird sanctuary	30.85
33.	Uttar Pradesh	Samaspur bird sanctuary	79.94
34.	Uttar Pradesh	Parvati Agra bird sanctuary	7.22
35.	Uttar Pradesh	Nawabganj bird Sanctuary	2.246
36.	Uttar Pradesh	Sarsai Nawar jheel	16.13
37.	Uttar Pradesh	Saman Bird Sanctuary	52.63
38.	Uttar Pradesh	Sur Sarovar	4.31
39.	Uttar Pradesh	Upper Ganga river	265.9
40.	West Bengal	Sunderbans wetland	4230
41.	West Bengal	East Kolkata Wetland	125
42.	Uttarakhand	Asan Conservation Reserve	4.44

types". Group B sites are sites of international importance for conserving biological diversity.

Table 5 reveals that out of 42 Ramsar sites of India, Uttar Padesh having highest (7 number) of sites followed by Punjab (6 numbers) and Jammu and Kashmir (4 numbers). As per total geographical area the Sundarban Wetland is largest wetland in India (4230 km^2) followed by Vemband Kol Wetland (1512.5 km^2), and Chilika lake (1165 km^2), whereas Renuka wetland of Himachal Pradesh is the smallest wetland in India having geographical area of 0.2 Km^2. The Ministry of Environment Forests and Climate Change (MoEF and CC) Government of India notified the Wetlands (Conservation and Management) Rules in December 2010 which was a positive step towards conservation of wetlands in India. Recently, on the occasion of World Wetland Day 2021, Ministry of Environment Forests and Climate Change (MoEF and CC) Government of India decided to set up India's first Wetland centre named as 'Centre for Wetland Conservation and Management at National Centre for Sustainable Coastal Management in Chennai, Tamil Nadu.

6. Wetland Soil Properties and Plant Adaptation Mechanisms

6.1. Physio-Chemical changes in soil due to waterlogging

Thousands of plants have adapted to life in water or wetlands, with a significant proportion of them occurring only in wetlands and shallow water. Many wetlands are readily identified by vegetation and traditional method. One of the major problems in wetlands is water logging, that restrict oxygen movement from the atmosphere to the soil as a result anaerobic conditions occur when the redox potential of soil reaches +300 to +250 milivolts (mV) (Faulkner and Patrrick, 1992).

Soil oxygen deficiency poses the main ecological problem for plant growth as it affects plant functions such as stomata opening, photosynthesis, water and mineral uptake and hormonal balance (Kozlowski, 1984). Waterlogging or flooding also causes changes in the soil environment which affect plant growth and survival. Soil temperature is lower in flooded soils than in well drained soils. Lower temperatures may influence soil chemistry, nutrient release, phytotoxin production, organic matter decomposition and plant growth (Ponnamperuma, 1976). Alternate flooding and drying may causes significant cracking in clayey soils. Such activity may affect root growth and restrict root penetration. Flooding also alters the pH of soil. Acid soils attain a higher pH status when flooded while alkaline soils decrease in pH (Ponnamperuma, 1984).

6.2. Plant adaptation to flooding and water logging

Life in permanently or periodically aerobic soils or substrates is more difficult than living in mesic soils due to oxygen deficiency, the nature of a highly reduced environment (low redox potential) with soluble phytotoxins and other conditions. Prolonged flooding during the growing season typically kills most woody species, with seedlings being most vulnerable. Aquatic plants are the best adapted and most specialized of the wetland plants, since they spend their entire lives in water.

A wide range of adaptations make it possible for plants to grow in water or wetlands. These adaptations include physiological responses, morphological adaptations, behavioral responses and others (Table 6).

7. Description of Some Adaptation Mechanism of Plants

7.1. Hypertrophied stems or buttressing

Some wetland species growing under extended flooding conditions exhibit a noticeable swelling of the lower stem. Such swelling increases the surface area and often is coupled with the presence of hypertrophied lenticels that collectively improve gas exchanges (Hook et al., 1970). The diameter of the stem from ground surface to some distance above is greatly expanded. In herbaceous plants this condition is called simple hypertrophied stems, while in trees it is called buttressed trunks or buttressing. In herbs, the enlargement of cortex and collapse of some cells create air filled spaces (aerenchyma) that lead to an expansion of the stem (Kawase, 1981). Example: Water willow (*Decodon verticillatus*) and rattlebush (*Sesbania drummondii*).

In trees and shrubs, the swelling is not due to aerenchyma, but to larger cells and lower density wood (Penfound, 1934; Kawase, 1981). Ethylene producton during anaerobiosis may be responsible for this (Kozlowski,1982) developed after 3 weeks of flooding. In mangroves root buttresses are the

Table 6: Different plant adaptation mechanism		
Morphological adaptations and Responses	Physiological adaptations and responses	Other adaptations
Stem hypertrophy (buttressed tree trunks)	Transport of oxygen to roots from lenticles and or leaves	Seed germination under water
Large air-filled cavities in center of roots and stems	Anaerobic respiration	Viviparous seeds
Aerenchyma tissue in roots and other plant parts	Increased ethylene production	Growth dormancy (during flooding)
Hollow stems	Reduction of nitrate to nitrous oxide and nitrogen gas	Root elongation
Adventitious roots	Malate production and accumulation	Long lived seeds
Pneumatophores and Aerial root tips	Metabolic adaptations	Root mycorrhiza near upper soil surface
Succulent roots and Succulent leaves	Reduction of NADH	Additional cell wall structures in epidermis or cortex

Source: Tinner, 1991

characteristic features of *Heriteria* spp and *Xylocarpus* spp (Naskara and Mandal, 1999). Examples of other buttressing plants include Red maple (*Acer rubrum*), White ash (*Fraxinus americana*) and Arjun (*Terminalia arjuna*).

7.2. Fluted trunks

Some wetland trees exhibit flared bases or fluted trunks, presumably to provide for support in unstable substrates, such features also may create more surface for production of hypertrophied lenticles during periods of prolonged flooding. These structures have been observed in American elm (*Ulmus americana*), Pin oak (*Quercus palustris*), Bald cypress (*Taxodium distichum*).

7.3. Shallow root system

Higher water tables and accompanying anaerobic significantly influences root growth. Since oxygen is the prime limiting factor in wetlands, the anaerobic environment essentially forces plants to seek oxygen near the surface and thereby also avoid phytotoxins present in the subsoil. As a result, plant roots for most wetland species grow horizontally or upwardly (negative geotropic) to form extensive root systems near the surface.

7.4. Strut and stilt roots

Rhizophora species (Rhizophoraceae family) (personal observation, Plate 2) produce lateral roots from the hypocotyls and bases of the stems which form arch and reach after coming in contact with substratum. Some of which produce innumerable fibrous absorbing or nutritive roots and others form another arch, and the process continues.

Besides the family mangrove (Rhizophoraceae), stilt roots are observed in Avicenia spp, Lumnitzera spp and Acanthus spp.

7.5. Prop roots

Rhizophora produces lot of relatively thin unbranched positively geotropic roots arising from branches at various heights even at 8 to 10 meters. They appear to show branching after their tips are damaged by mollusks or some other agencies. After reaching the ground they also produce innumerable fibrous roots for absorption of water and nutrients.

7.6. Pneumatophores

Pneumatophores can be seen in Mangroves, as these mangroves grow on saline mudflats of the coastal area where the soil is very wet with poor oxygen and other glasses content. In this case, some lateral roots of mangroves become specialized as Pneumatophores. Pneumatophores are lateral roots that grow upward (negative geotropism) for varying distances and function as the site of oxygen intake. They project some centimeters above the low-tide level. They have small openings (lenticels) in their bark so that air can reach the rest of the plants' root system. Examples of *Xylocarpus granatum* (personal observation, Plate 2), *Laguncularia racemosa*, *Avicenia* spp. *Xylocarpus* spp and *Lumintzera* spp. Pneumatophores helps in exchange of gases between atmosphere and underground roots (Singh and Odaki, 2004).

7.7. Horizontal roots (Knees)

In several species like Bruguiera spp., *Ceriops tagal*, Lumnitzera spp. etc. come above the surface of the soil due to bending and again after some height curve towards soil forming knee like structure. Each branch travelling towards the ground becomes apogeotropical and produces fine branches for adsorption of water and minerals. (Singh and Odaki, 2004).

7.8. Pneumatothodes

Negatively geotrophic erect roots from the fibrous horizontally spreading roots of (*Phoenix paludosa)* is known as Pneumatothodes. The Pneumatothodes looks like pencil and attain a height of 20 cm in very compacted clay soil (Naskara and Mandal, 1999).

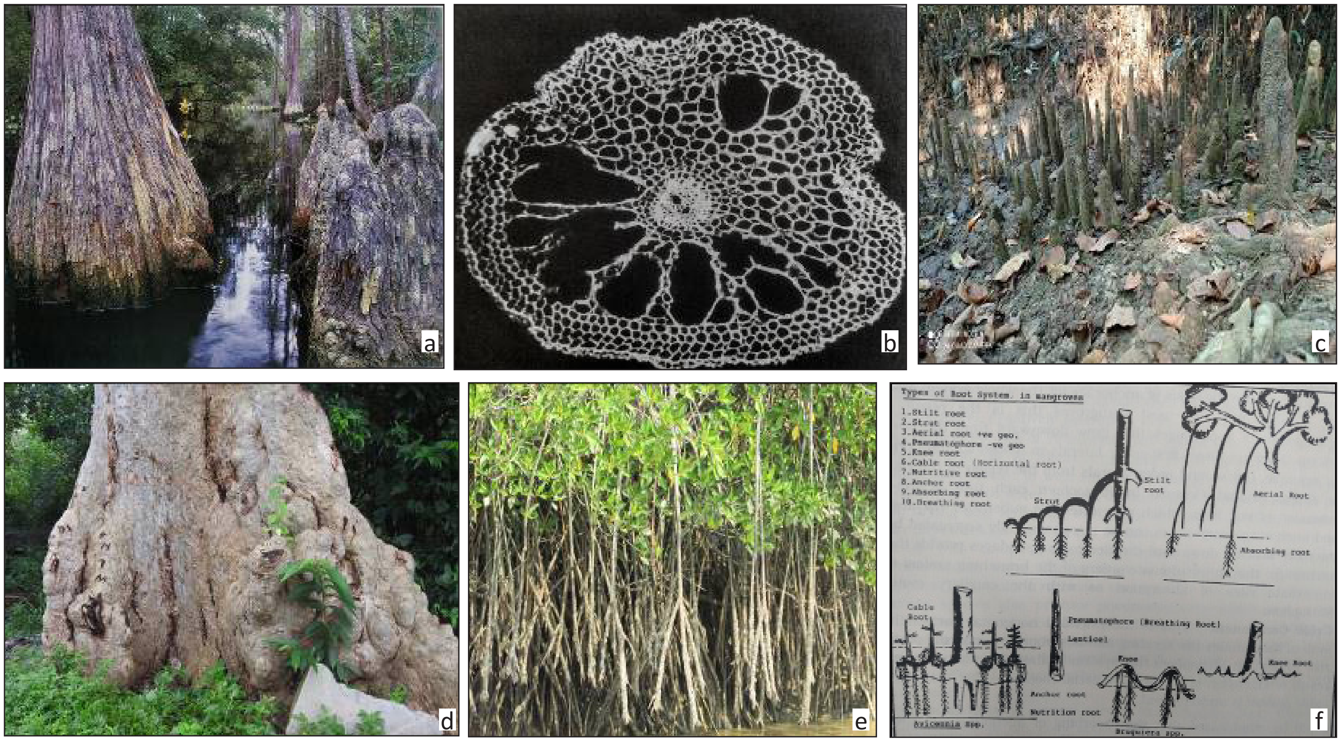

Plate 2: (a). Fluted trunk in Bald cypress (b). Aerenchyma tissue in root of smooth cord grass (*Spartina alterniflora*, Tinner, 1999) (c). Pneumatohpres in *Xylocarpus* spp, Bhitarkanika National Park, Odisha (d). Buttressed stem of Arjun tree (Deopur, Chhattisgarh) (e). Stilt roots of *Rhizophora* spp (f). Various types of root system in Mangroves (Singh and Odaki, 2004).

7.9. Hollow stems

Many wetland herbs posses hollow or chambered stem that favor growth in wetlands. Hollow or chambered stems may improve aeration to the roots as well as accumulate carbon dioxide important for photosynthesis (Billings and Godfrey, 1967). Thus, the presence of hollow stems in these graminoids might help explain why they are often dominant in wetlands.

7.10. Aerenchyma

The presence of aerenchyma (air-filed) tissue in many wetland herbs, especially marsh plants helps these plants grow in anaerobic or anoxic soil. An internal system of large air spaces is needed to transport atmospheric oxygen to the roots, thereby creating an oxidized environment around the roots (oxidized rhizosphere). This reduces resistance to oxygen movement for respiring cells, decreases the amount of respiring tissue, facilitates diffusion of oxygen-containing air to organs lacking oxygen and still provides sufficient structural support (Voesenek and Van der Veen, 1994). It also aids in releasing carbon dioxide and methane to the atmosphere (Wetzel, 1990).

7.11. Salt regulation mechanism (Mangroves)

The saline environment of marsh ecosystems create a formidable challenge for plants living in the coastal tract. High salinity soils are characteristic of salt marshes. As salt water from the ocean inundates and recedes from the system in a daily cycle, sodium chloride is deposited into marsh soils where evapotranspiration amplifies soil salt concentration (Larcher, 2003). The high concentration of sodium chloride in salt marshes has negative consequences for plants in two primary ways i) it affects osmoregulation; and ii) it has ion specific effect that can be toxic and can disrupt ionic balance (Larcher, 2003).

8. Halophytes Adopted following Salt Regulation Mechanism

8.1. Salt filtration or salt exclusion

In some mangrove plants like Avicenia, Bruguiera, Kandelia and Ceriops species have some sort of ultra filtration mechanism in their roots enabling only selection of ions (Scholander, 1968). Their Xylem sap has NaCl (Sodium Chloride) content between 0.02 to 0.05%. Rhizophora species, have specialized cells in roots which block sodium while allowing essential elements such as potassium to move freely in the plant.

8.2. Salt excretion or salt secretion by salt glands

Mangrove species like Avicenia and Aegiceras spp have salt glands on their leaves which secrete excess salts on surface of leaves. NaCl in the xylem sap of these plant is normally 10 times that or salt exclusion types. However, the precise mechanism of salt secretion is not understood, but it does require energy and can be stopped by metabolic activity.

8.3. Salt accumulation

Sonneratia spp and some others *Lumnitzera* and *Excocaria* spp have been found to have excessive amount of ions in their organs and thus they absorb and accumulate ions and the leaves become quite fleshy.

9. Conclusion

Wetlands also have been called "biological supermarkets" because of extensive food chain and rich biodiversity that they support. They play major roles in the landscape by providing unique habitats for a wide variety of flora and fauna**.** The quality and quantity of wetlands are declining continuously in an alarming rate. As a result, it will affect the biodiversity, reduction of ecosystem services with adverse outcomes for human, livelihoods. So, the need of the hour is to make continuous research and conservation strategies for protecting the world's wetlands.

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