Journal of Soil and Water Conservation, Vol. 8, No. 4, pp 25–30 (2009)
Received: 5 June 2009; Accepted: 1 August 2009

Wetland management for sustainable development

SOMEN ACHARYA[1] and TARUN ADAK[2]

ABSTRACT

Wetlands ecosystems are a natural resource of local, regional and global significance. Historically, their high level of plant and animal (especially bird) diversity is perhaps the major reason why wetland protection has become a high priority worldwide, supported by international agreements, such as Ramsar Convention and the International Convention of Biological Diversity. More recently, a number of goods and services provided specially by wetland ecosystems have been identified that may even outweigh biodiversity in terms of their importance for human welfare and sustainable natural resource management. Wetlands, as transitional zones between land and water, provide a natural protection against extreme floods and storm surges. They may also store freshwater to be used for drinking water preparation or for irrigation. Wetlands bordering streams, rivers and lakes have a water quality enhancement function that is increasingly recognized. As natural habitats for fish, riverside wetlands, shallow lakes and coastal wetlands have the potential to produce large fish stocks, which are exploited commercially in some regions, but could be enhanced by restoring wetlands in degraded areas. Because wetlands often provide spawning habitats, their importance as a source of juvenile fish for large aquatic lakes and river channels should not be underestimated. In addition to these local and regional benefits, wetlands as a global resource provide a net sink of carbon dioxide. However, in recent years wetlands are a threatened part of our natural ecosystem. Centuries of draining have ensured the destruction of many of our wetlands. Declining area and quality of wetlands in recent times have had serious consequences for wildlife. Remaining areas of wetland habitats are increasingly small and isolated and their decline continues. Having clear goals along with a site specific plan is the key to successful wetland management. Construction, grading, fertilization and other changes to the land surrounding wetlands may increase the flow of water and pollutants to wetlands, overwhelming their ability to function and remain healthy. Therefore, immediate steps are to be undertaken as a part of policy matter for conserving, restoring and sustaining the existing wetlands ecosystems.

Key words: Biodiversity, Importance, Legislations, Management plans, Mitigation options, Wetland ecosystem

Wetlands are those areas inundated or saturated by surface or ground water at a frequency and duration sufficient to support and that, under normal circumstances, do support a prevalence of vegetation typically adopted for life in saturated soil conditions. Wetland generally includes swamps, marshes, bogs and similar areas. Internationally accepted definition of wetland is, "areas of marsh, fen, peat land, 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 6 meter." Globally, wetlands are estimated to occupy nearly 6.4% of the earth surface, out of which man-made bogs 30%, fens 26%, swamps 20%, flood plain 15% and others 9%. Tropical wetlands cover about 2.64 million km^2 worldwide whereas wetlands in temperate and boreal regions occupy about 5.72 million km^2. Indian wetlands are mostly associated with river systems distributed from the cold, arid zone of Ladakh, and the warm, arid zone of Gujarat-

Division of Environmental Sciences and Division of Agricultural Physics, Indian Agricultural Research Institute, Pusa Campus, New Delhi-110 012. ([1]Present address: Scientist, Defence Institute of High Altitude Research, C/o 56 APO, Leh; someniari@gmail.com). [2]Present address: Scientist, Division of Crop Production, CISH, Rehmankhera, Lucknow; tarunadak@gmail.com).

Rajasthan to the tropical monsoon of central India and the wet, humid zone of the southern peninsula. Of an estimated 4.1 million hectares of wetlands (excluding irrigated agricultural lands, rivers, and streams), 1.5 million hectares are natural and 2.6 are man-made, while the coastal wetlands occupy an estimated 6,750 km^2, largely dominated by mangroves.

Wetlands in India

Origin and distribution of wetlands in India is diverse in nature; mostly associated with the major river or lakes systems. The major river systems in the northern parts of country are Ganga, Yamuna, and Brahmaputra and in the southern India, Krishna, Godavari, and Cauvery. The central part of India has the Narmada and the Tapti. The Indo-Gangetic floodplain is the largest wetland regime of India. Most of the natural wetlands of India are connected with the river systems of the North and the South. The lofty Himalayan mountain ranges in northern India accommodate several well-known lakes, especially the palaearctic lakes of Ladakh and the Vale of Kashmir, which are sources of major rivers. In the north-eastern and eastern parts of the country, the massive floodplains of Ganga and Brahmaputra along with the productive system of swamps, marshes, and oxbow lakes are located. Apart from natural sources, a number of man-made wetlands are created for various multipurpose projects. Some of the finest examples are Harike Barrage at the confluence of the Beas and the Sutlej in Punjab, Bhakra Nagal Dam in Punjab and Himachal Pradesh, Keoladio National Park of Bharatpur and the Coshi Barrage in Bihar-Nepal Border. Generally two types of wetlands exist; with natural source and man-made creation. They are briefly described in Table 1a and 1b.

Importance of wetlands

Flood control: Wetlands have the capacity to retain excess floodwater during heavy rainfall that would otherwise cause flooding. By retaining flood flows, they maintain a constant flow regime downstream, preserving water quality and increasing biological productivity for both aquatic life as well as human communities of the region.

Ground water recharge: Periodically inundated wetlands are very effective in storing rainwater and are the primary source for recharging ground water supplies. The extent of groundwater recharge depends on the types of soil and its permeability, vegetation, sediment accumulation in the lakebed, surface area to volume ratio, and water table gradient.

Erosion control/shoreline stabilization: Wetland vegetation plays a major role in erosion control, which in turn contributes to shoreline stabilization and storm protection. Coastal wetlands, in particular mangrove forests, play an important role in shoreline stabilization and storm protection by

Table 1a: Natural wetlands

Wetland type	General description
Marsh	Herb dominated, standing water through all or most of the year, often with muck soil.
Swamp	Dominated by woody veg. & usually wet for extended periods during growing season
Mangrove	Tidal swamp dominated by mangrove sp
Peat land	Peat dominated wetland
Bog	Nutrient poor peatland, typically characterized by shrubs, other woody sp & peat moss
Fen	Nutrient rich peat land, represented by sedge
Wet meadow	Herb dominated, may be seasonally flooded or saturated for extended period
Bottomland	Riverside or streamside wetland, usually on floodplain
Flatwoods	Forest wetland
Lagoon	Brackish or saline, with one or more relatively narrow connections with sea

Table 1b: Man-made wetlands

Aquaculture	Aquaculture ponds, including fish ponds and shrimp ponds
Agriculture	Ponds including farm ponds, stock ponds, small tanks
Salt exploitation	Salt pans and salines
Industrial	Mining pools, waste water treatments plant, sewage plant, settling ponds
Water storage areas	reservoirs

reducing the damage caused by wind and wave action.

Retention of nutrients: Wetlands retain nutrients by accumulating eutrophic parameters like nitrogen and phosphorus in the sub-soil thereby decreasing the potential for eutrophication in receiving water. They also help in absorbing sewage and in purifying water supplies.

Supply of water: The wetland waters are used for irrigation, industry, thermal power plant, potable supply and fish production under natural eco-system. Livelihoods of people are secured for example around 30,000 people is dependant on Pulicat lake for their survival. At Chilka lake 9000 fishing vessels are active throughout the day and night.

Wetland and biodiversity

In general, wetland communities are highly dynamic as they are located at the interphase of terrestrial and aquatic ecosystem. The species richness and oxodiversity in such areas are so high, that it offers a specialized habitat for many macrophytes, plankton, invertebrates, and vertebrates. Apart from richness and diversity of flora, the presence of large number of wild relatives of cultivated plants for desirable characters makes the wetland unique (Tiner, 2002; Acharya, 2000).

Wetland and carbon sequestration

Wetland ecosystem receives and releases organic carbon through hydrologically driven mass flow. Bottomland hardwood forest store C in tree biomass for much longer time (Productivity ranges between 200 and 2000 g dry matter per year). Peat lands acts as sink for Carbon between 20–300 g C/m^2/ year. The finest example is the Canadian wetland which store about 154 Gt C than what is stored in forests (95 Gt C in biomass and soil). So the creations of new wetlands certainly contribute to sequestration of Carbon. This is one way to mitigate green house gas emission.

Products from the wetlands

A variety of valuable products may be generated from the wetlands, like (*i*) forest resources, (*ii*) wildlife resources (*iii*) fisheries (*iv*) forage resources, (*v*) agricultural resources and (*vi*) drinking water supply. Henceforth, sustainability as well as livelihood security of coastal peoples is secured through dynamics opportunity existed in wetlands.

Management of waste water treatment from constructed wetlands

Waste water can be treated for safe disposal and use, by using several plant species, viz. *Sagittoria* sp, *Typha* sp, *Lemna* sp, *Colocasia esculenta*, *Nelambo lutia*, *Scirpus* sp, *Najas* sp, *Spirodela* sp etc. Plant species which can be suitable for hyperaccumulation are *Azolla pinnata*, *Eichhornia crassipes*, *Lemna minor*, etc. Moreover, the constructed wetland may also be used as a tool for pollution removal. The major advantages being its simplicity and having low maintenance cost; solves the problem of pollution at the source level; socio-economically acceptable, ensure community participation; eco-friendly way of pollutants removals and finally allows maximum use of waste water for agriculture purpose.

Application of nanotechnology in treating wetland water for drinking water

Nano particles may be used for treating waste water of wetlands for the purpose of portable drinking water. However, applicability of this latest technology entirely depends on the cost effectiveness. This may be possible for commercial production wherein large volume of water samples may effectively be treated with small amount of nano particles. In Australia, USA and other parts of the world, already large farm production of drinking water from treated waste water plant is actually going on using nano particles.

Management of wetlands through remote sensing and Geographical Information Systems (GIS)

One of the finest tools of modern day science is the use of remote sensing and GIS in delineating the area, discharge arte, water volume, ground water recharge, soil loss calculation as well as deposition in reservoir, pollution distribution etc. Furthermore, spatial and temporal variations of soil-water interactions can be successfully evaluated using these modern tools. Fish farming, migratory bird movement and water transport or tourism can also be managed in an effective and efficient way using GPS systems. Marshy land and other swampy forest land area, tree coverage, timber volume, forest fire, etc and other important spatio-temporal variability in the wetland forest can be successfully delineated using remote sensing and GIS

(Seshamani *et al.* 1994; Ramsey III, 1995; Mohan and Shrestha, 2000; Srivastava *et al.* 2001).

Wetland threats

Most of our wetlands are facing serious threat for their existence. These threats to the sustainability of wetlands are mainly due to human actions. Human actions responsible for wetland threats are through drainage water from wetlands for agriculture, forestry; discharge of pesticide, herbicides, nutrients from domestic sewage etc. The filling of wetlands for solid waste disposal, roads, commercial and residential purposes further adds to this threat. Sometimes there is a great need for conversion of wetlands for aquaculture and mining of wetlands for peat, coal, gravel, phosphate and other mineral, aggravated the situation. Moreover, groundwater abstraction; hydrological alteration by cannels, roads and other structure; washing activities in the lakes and streams; flow of sewage and siltation from adjoining colonies are also responsible for rapid deterioration of wetland sustainability. Vigorous weed (*Eichornia crassipes*) growth in lake causing shrinkage of lake area and less water availability; bathing activities in the lake at the idol immersion bank and population growth etc adds the degradation processes (Buchsbaum, 1994; Castelle *et al.* 1994; Chapman, 1996).

Wetland losses

Although there was significant reduction in loosing estuarine wetlands, like tidal marshes from 547 acre/year during 1950's–1970 to 5 acre/year during 1990's; the freshwater wetlands, like forested swamps were lost at an increasing rate from 2,373 acre/year during 1950's–1970 to 2807 acres/year during 1990's.

Restoration and mitigation activities for sustainable development of wetlands

Several mitigation options are to be evolved for the sustainability of wetlands like constructing gabion structure to control flow of solid waste, construction of special bank to reduce soil loss and soil deposition (Fig. 1), construction of road adjacent to lake to act as buffer zone to check encroachment, removal of weeds (*Eichornia crassipes and Ipomea aquatica*) from the wetlands, collection of city's solid waste and dispose at proper place and afforestation activities to check encroachment, siltation and flow of sewage and agricultural residues. Furthermore, adoption of multidisciplinary approach is necessary to co-ordinate among various agencies and specialists belonging to agriculture, forestry, environment, hydrology, ecology, geography etc. so that they can contribute/develop meaningful appropriate alternatives. Training and Awareness campaign are essentially required for rising the level of awareness of environmental issues and their impact assessment amongst the people for the purpose of effective resource conversion. Therefore in a nutshell, management action plan should be designed in such a way that it develops catchments area scientifically to control siltation, pollution, biodiversity conservation, sustainable resource utilization and finally monitoring and evaluation of the wetland resource inventory soundly (Gibbs, 2000; Prasad *et al.* 2002).

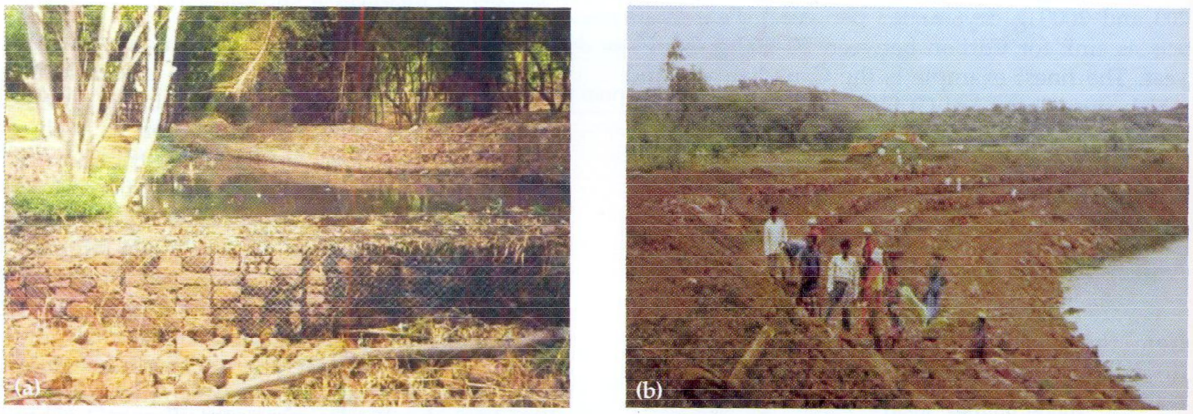

Fig. 1: Restoration and Mitigation activities for sustainable development of wetlands (*a*) Gabian structure to control flow of solid waste (*b*) Construction of Special Bank

Policy matters

With rapid realization of wetland values, the national wetland policy was formulated with the major goals as follows.

1. Management of national wetland networks
2. Integration with other policies such as water, soil, forests
3. Stop conversion of wetlands for any other land use purpose
4. Public awareness and education
5. Scientific monitoring, assessment and research
6. Managing special sites
7. Enforcement, regulation and legislation
8. financial mechanism
9. Restoration of degraded site
10. Sustainable use and conservation

However the already existing policies state the following:

(*a*) Article 48A and 51A (g) - To protect and improve the natural environment including the rivers, lakes and wildlife.

(*b*) National conservation strategy and policy statement on environment and development (1992) highlights conservation of wetlands, coastal areas, rivers and island ecosystems.

(*c*) National forest policy amended in 1948 and national Wildlife Action Plan (1983) emphasizes long term conservation of wildlife.

Legislation

Over 200 state and central laws exists for regulating wetland resources of the world with respect to protection of water, fish, birds and lands (Shine and de Klemm, 1999). In addition there are international laws and conventions for the said purpose.

The Ramsar convention: The convention of wetlands of international importance, especially as waterfowl habitat, often known as Ramsar convention from its place of adaptation in Iran in 1971 is an intergovernmental treaty which provides the framework for international cooperation for the conservation of wetlands. The Ramsar list of wetlands of international importance now includes 1,801 sites (known as Ramsar Sites) covering around 1,630,000 km², up from 1,021 sites in 2000. Presently, there are 158 contracting parties, thereby agreeing to accept a number of obligations, including the following:

1. To designate wetlands of international importance for inclusion in a list of 'Ramsar sites'.
2. To maintain the ecological character of listed Ramsar sites.
3. To recognize planning so as to achieve the wide use of all the wetlands on their territory.
4. To designate wetlands as nature reserves.

Relevant laws in India: In India, a number of laws relevance to wetland habited regulation are being designed such as:

- The Environment (protection) Act, 1986
- The Environment Impact Assessment Notification 1994
- The Wildlife (protection) Act, 1972
- The Tamil Nadu Aquaculture (regulation) Act
- The West Bengal Fishery Act

However, some lacunae in the present policy make it difficult for improved sustainable management in an effective and efficient manner. These include lack of co-ordination and integration of policies, conflicts in land use planning/ development, intersectional or interdepartmental conflicts/claims including boundary disputes across states and nations.

Action plan

Since there is no specific legislation on wise use of wetlands, following actions may be considered as the most urgent need of the hours at present (a current plan of acton is depicted in Fig. 2)

- Comprehensive unified wetland conservation legislation.
- Legislation relating to wetlands to include regulation of activities in the catchments area impacting water body.

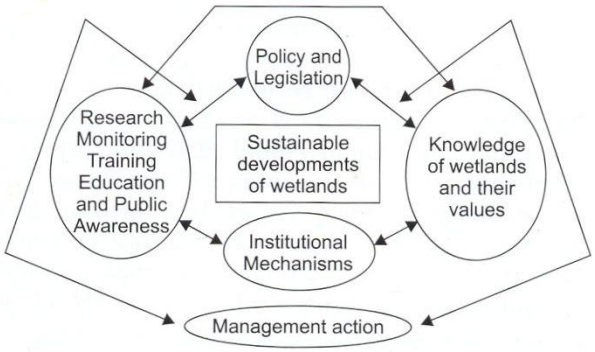

Fig. 2: Current action plan required for wetland protection

- Zone based regulation of activities to ensure sustainable use of wetland resources

CONCLUSION

Wetlands are among our most valuable natural resources. They are among the most biologically diverse and productive landscape types and important repositories of aquatic biodiversity. The diverse ecoclimatic regimes extant in the country resulted in a variety of wetland systems ranging from high altitude cold desert wetlands to hot and humid wetlands in coastal zones with its diverse flora and fauna. These are very complex systems that offer a variety of benefits to both people and wildlife which can influence, and are influenced by, what goes on around them. The type and amount of vegetation around a wetland can greatly affect its value for wildlife and how the wetland performs other functions. A wide range of local, state, federal and private programs are needed to support the national policies of wetlands in India and around the world so as to conserve, maintain and efficient utilizations of natural resources. Recent technologies like use of Remote Sensing and Geographic Information System (GIS) in flood zonation mapping, in monitoring irrigation and cropping patterns, ground water modeling, change analyses and in mapping of surface water bodies to generate attribute information on biodiversity and socioeconomic themes are essentially required in evolving a conservation network of wetlands for the entire country.

REFERENCES

Acharya G V. 2000. The hidden hydrological services of wetland ecosystem. *Ecological Economics*, **35**, 63–74.

Buchsbaum R. 1994. Management of coastal marshes. In D. M. Kent (Ed.), *Applied wetlands science and technology*, pp. 331. Boca Raton, FL.: CRC Press.

Castelle A J, Johnson A W and Conolly C. 1994. Wetland and stream buffer size requirements: A review. *Journal of Environmental Quality* **23**: 878–82.

Chapman D V. 1996. Water quality assessments: A guide to the use of biota, sediments, and water in environmental monitoring (2nd edn.). London: E & FN Spon.

Gibbs J J. 2000. Wetland loss and biodiversity conservation. *Conser. Biol.* **14**: 314–17.

Mohan S and Shrestha M N. 2000. A GIS based integrated model for assessment of hydrological changes due to land-use modifications. pp. 27–29. *In:* T.V. Ramchandra (edn.) *Symposium on Restoration of Lakes and Wetlands*, November 2000, Indian Institute of Sciences, Bangalore.

Prasad S N, Ramachandra T V, Ahalya N, Sengupta T, Kumar Alok, Tiwari A K, Vijayan V S and Vijayan L. 2002. Conservation of wetlands of India-a review. *Tropical Ecology* **43**: 173–86.

Ramsey III, E W. 1995. Monitoring flooding in coastal wetlands by using radar imagery and ground-based measurements. *International Journal of Remote Sensing* **16**: 2495–2502.

Seshamani R, Alex T K and Jain Y K. 1994. An airborne sensor for primary productivity and related parameters of coastal waters and large water bodies. *International Journal of Remote Sensing* **15**: 1101–1108.

Tiner R W. 2002. *Wetlands*-Encyclopedia of soil science pp. 1437–41.