Journal of Environmental Management 148 (2015) 112–123

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Wetland assessment, monitoring and management in India using geospatial techniques

J.K. Garg*,[1]

Guru Gobind Singh Indraprastha University, Sector 16C, Dwarka, New Delhi 110078, India

ARTICLE INFO

Article history:
Received 31 May 2013
Received in revised form
16 December 2013
Accepted 16 December 2013
Available online 30 January 2014

Keywords:
Wetlands
Remote sensing
GIS
Geospatial techniques
Ramsar convention
Biodiversity
Information system

ABSTRACT

Satellite remote sensing and GIS have emerged as the most powerful tools for inventorying, monitoring and management of natural resources and environment. In the special context of wetland ecosystems, remotely sensed data from orbital platforms have been extensively used in India for the inventory, monitoring and preparation of action plans for conservation and management. First scientific inventory of wetlands in India was carried out in 1998 by Space Applications Centre (ISRO), Ahmedabad using indigenous IRS (Indian Remote Sensing Satellite) data of 1992–93 timeframe, which stimulated extensive use of geospatial techniques for wetland conservation and management. Subsequently, with advances in GIS, studies were carried out for development of Wetland Information System for a state (West Bengal) and for Loktak lake wetland (a Ramsar site) as a prelude to National Wetland Information System. Research has also been carried out for preparation of action plans especially for Ramsar sites in the country. In a novel research, use of the geospatial technology has also been demonstrated for biodiversity conservation using landscape ecological metrics. A country-wide estimate of emission of methane, a Green House Gas, from wetlands has also been made using MODIS data. Present article critically reviews the work carried out in India for wetland conservation and management using geospatial techniques.

1. Introduction

Wetlands, the cradles of biodiversity and key constituent of our environment, are among the most productive ecosystems housing more or less all floral and faunal taxonomic units. They are not only important for the survival of fishes, birds, turtles and crocodiles and other aquatic life but also are habitats of many rare and endangered species, as for example, the Brown Antlered Deer (Ruc*ervus eldi)* in the swamps of Loktak Lake in India. Due to reckless filling and improper use of wetlands a large number of them have either been lost or are incapable of fulfilling their designated functions/services. Wetlands, the kidneys of our landscape, are under the constant threat resultant from encroachment, siltation, aquaculture development, pollution and taming of rivers. The cumulative strain on wetlands is increasingly becoming evident in the form of decrease in biological diversity, deterioration of water quality, sedimentation, shrinkage in areas under wetlands, reduction in migratory bird population, and the productivity of fish and other fauna.

India has a long history and tradition of conservation of natural resources. As part of religious ritual, people revere and worship many rivers and wetlands throughout the country. For providing protection to representative wetlands in India, Ministry of Environment and Forests, Govt. of India has undertaken a National Plan for Conservation of Aquatic Ecosystems (NPCA) in the country and brought National Wetland Conservation Programme (NWCP) and National Lake Conservation Plan (NLCP) under its umbrella. A large number of wetlands including Ramsar sites, national parks, bird sanctuaries, notified wetlands and lakes get funding for their conservation and action plan preparation under this programme. Ministry has also enacted several legislations for their protection and management of wetlands including mangroves and coral reefs.

Ramsar convention (1971) on wetlands, the first intergovernmental convention for conservation and 'wise use' of any ecosystem, entered into force in 1975 and has 168 contracting parties from all over the world. So far the convention has 2169 wetland sites under its aegis covering 206.64 million ha area (Ramsar Convention, 2013). India signed the Convention on February 1, 1982 and has identified 26 wetlands (Chilka, Keoladev National Park, Harike, Loktak, Chilka, Wular, Sambhar, Ashtamudi, Bhitarkanika, Bhoj, Deepor Beel, East Calcutta Wetlands, Kolleru, Point Calimere wildlife and bird sanctuary, Pong dam lake, Chandratal, Renuka, Sasthamkotta, Tso Moriri, Hokera, Surinsar-Mansar, Vembanad-Kol, Kanjali, Ropar, Rudrasagar, Upper Ganga River –

* Tel.: +91 11 25302371; +91 9313583845.
E-mail address: gargjk@gmail.com.
[1] Formerly with Space Applications Centre (ISRO), Ahmedabad 380015, India.

0301-4797/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jenvman.2013.12.018

Brijghat to Narora, Bhoj and Nal Sarovar) for affording priority conservation in the country.

Remote sensing, especially from orbital platforms, has proven to be a very useful technique for inventorying, monitoring and management of wetland ecosystems. Use of remote sensing for 1st scientific inventory of wetlands in the country (Garg et al., 1998) encouraged many organisations and researchers to take a plunge for using the technology for wetland inventory at regional level and also for their conservation and management. This was a landmark study involving 22 organisations, mainly State Remote Sensing Centres, and played a pivotal role in capacity building. Further impetus in the use of technology for wetland studies came when Wetland Information Systems were developed for the state of W. Bengal, and Loktak Lake (a Ramsar site in the state of Manipur in NE India) by Space Applications Centre (ISRO), Ahmedabad using GIS (Geographical Information System). Subsequently, studies using remote sensing and GIS were carried out in different parts of India primarily for important wetlands. Main emphasis in these studies has been to monitor water spread, turbidity/siltation, aquatic vegetation infestation, and trophic status of various fresh water wetland ecosystems. Salim Ali Centre for Ornithology and Natural History (SACON) has also carried out inventory of 72 prioritised districts in the country (Prasad et al., 2002).

2. Wetland definitions and classification system

Wetlands are broadly defined as a 'variety of shallow water bodies and high groundwater environments that are characterized by permanent or temporary inundation, soils with hydric properties, and plants and animals that have adapted to life in saturated conditions' (Lewis, 1995). Generally, two types of wetland definitions are in vogue, one which looks wetlands as ecotones, i.e. transition zone between terrestrial and aquatic ecosystems and the other which treats whole water body as a wetland keeping in view management perspectives. Two of the most commonly used definitions are as under:

Table 1
Indian wetland classification system.

Level I	Level II	Level III (1st inventory)		Modified level III (3rd inventory)	
Inland wetlands				1000	
	Natural			1100	
		1.1	Lakes/ponds	1101	Lakes
		1.2	Ox-bow lakes/ cut-off meanders	1102	Ox-bow lakes/ cut-off meanders
		1.3	Waterlogged	1103	High altitude wetlands
		1.4	Playas	1104	Riverine wetlands – marshes/swamps
		1.5	Swamp/marsh	1105	Waterlogged
				1106	River/stream
	Man-made			1200	
		2.2	Reservoirs	1201	Reservoirs/barrages
		2.2	Tanks	1202	Tanks/ponds
		2.3	Waterlogged	1203	Waterlogged
		2.4	Abandoned quarries	1204	Salt pans
		2.5	Ash pond/ cooling pond		
Coastal wetlands				2000	
	Natural			2100	
		3.1	Estuary		
		3.2	Lagoon	2101	Lagoons
		3.3	Creek	2102	Creeks
		3.4	Back water (Kayal)	2103	Sand/beach
		3.5	Bay	2104	Intertidal mud flats
		3.6	Tidal flat/mud flat	2105	Salt marsh
		3.7	Sand/beach/spit/bar	2106	Mangroves
		3.8	Coral reefs	2107	Coral reefs
		3.9	Rocky coast		
		3.10	Mangroves		
		3.11	Salt marsh/ vegetation		
		3.12	Other vegetation		
	Man-made			2200	
		4.1		2201	Salt pans
		4.2		2202	Aquaculture ponds

Source: Garg et al. (1998); Garg and Patel (2007).

Table 2
Wetland ecosystems – needs and RS/GIS compliance.

Variable	Information needs	Status
Water quality	Pollution sources/waste outfalls	Large point waste outfalls possible to map
	Thermal pollution	Possible to detect
	Phytoplankton/algal blooms	Feasible
	Turbidity/sediment load	Possible in conjunction with field data
	Oil pollution	Possible in coastal waters
	Pollutant species	Ground based studies
Spatial information	Inventory and monitoring	Operational at all scales
	Structural components/ habitat types	Operationally possible on 1:50 000/ 1:25 000 or larger scales
	Aquatic vegetation/ weeds extent	Emergent, floating weeds possible to delineate on 1: 50 000/25 000 or larger scales
	Aquatic vegetation type	Large patches can be discerned
Biodiversity	Habitat diversity	Possible at 1: 50 000/25 000 or larger scales
	Fragmentation	
	Edge to area ratio	
	Habitat-biotic assemblages etc.	
Catchment characteristics	Land cover, landforms, drainage, slope, hydrogeomorphology, etc.	Possible at 1: 50 000/25 000 and larger scales
Action plan for conservation & management	Integration and criteria based action plan generation	Possible at 1:25 000 and larger scales in GIS environment

i) US Fish and Wildlife Service (Cowardin et al., 1979)

"Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water level. For purposes of this classification, wetlands must have one or more of the following three attributes: 1) at least periodically, the land supports predominantly hydrophytes; 2) the substrate is predominantly undrained hydric soil; and 3) the substrate is nonsoil and is saturated with water or covered by shallow water level at some time during the growing season of each year".

ii) Ramsar Convention (1971, 2013)

"Submerged or water saturated lands, both natural and man made, 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 meters". (www.ramsar.org).

Article 2.1 further 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'.

2.1. Indian wetland classification system

No suitable wetland classification existed for a comprehensive inventory of wetlands in the country prior to the implementation of