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Using Remote Sensing Data to Study Wetland Dynamics – A Case Study of Harike Wetland

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ABSTRACT

In the context of environment, wetlands play a very important role. They protect and improve the quality of water and keep the local weather moderate. They are one of the most productive areas of our ecological system. Disappearance of such wetlands has caused changes in weather conditions and reduction of sub-soil water level. The Harike wetland ecosystem in the Punjab state of India was created in 1953 by the construction of a barrage at the confluence of the Satluj and Beas rivers. Considered a wetland of international importance, it was included in the list of Ramsar sites in 1990. It is a breeding ground and habitat for a large variety of migratory as well as domiciled birds. Like many wetlands in India, Harike is also beset with problems and its area is reducing. Therefore, in the present study, the wetland area mapping has been carried out using multidate IRS satellite data and the wetland area has been classified into aquatic vegetation, water spread area and water logged area for the years 1990, 1999 and 2003. These water related features have been delineated using normalized difference water index (NDWI). It has been found that the wetland area has reduced by more than 30% over a period of 13 years.

Keywords: Wetland, runoff, ground water, remote sensing, aquatic, waterlogged

INTRODUCTION

Remote sensing is used extensively to monitor wetland acreage changes. Color infrared photography and other imagery taken at different dates are compared and changes are recorded and subject to statistical analyses. Wetlands form a major category of aquatic ecosystems. Generally, they are not only physically sandwiched between the terrestrial and open water systems (lakes and rivers) but are also transitional in nature between the two (Gopal, 1994). Wetlands are characterized by soils that remain waterlogged or under shallow water permanently or for periods long enough to cause certain changes in their physico-chemical and biological characteristics and to allow the growth and development of plant and animal communities specifically adapted to the particular hydrological regimes (Mitsch and Gosselink, 2000). Peatlands, marshes, swamps, mangroves, shallow lakes (less than 3 m deep), floodplains and the littoral zones of lakes are all wetlands. Wetlands occur in all places starting from tropical to temperate regions including high altitudes. At global level these ecosystems occupy about 6% of the total land mass. Total area of India so far designated under wetland ecosystems is 40,50,536 ha. (14,61 ha natural and 25,89, 265 ha. man-made) out of which 22,476ha area has been reported under important wetlands in Punjab (Anonymous, 1990).

Most wetlands are highly productive, support disproportionately high biodiversity, and perform valuable functions. Their availability and distribution at the global level not only determines the successful human settlement but also is responsible for climate controls and ecosystems productivities. Some of the important functions of wetlands useful in the maintenance of overall balance of nature are: flood control, water storage and purification, protection of shorelines and hinterlands, floral and faunal habitats, gene pools, recreational besides providing outputs of commercial value and economic sustenance to the people (Jerath, 1992). However, these functions and values depend largely upon their hydrological attributes.

Wetland systems directly and indirectly support millions of people, providing goods and services to them. They contribute to important processes, which include the movement of water through the wetland into streams or the ocean; decay of organic matter; release of nitrogen, sulfur, and carbon into the atmosphere; removal of nutrients, sediment, and organic matter from water moving into the wetland; and the growth and development of all organisms that require wetlands for living. The direct benefits of wetlands are the components/products such as fish, timber, recreation, and water supply, and the indirect benefits arise from the functions occurring within the ecosystem such as flood control, ground water recharge, and storm protection. Wetlands may be of a great significance to indigenous people as part of their cultural heritage. Wetlands have the capacity to retain excess floodwater during heavy rainfall that would otherwise cause flooding. Wetland vegetation plays a major role in erosion control, which in turn contributes to shoreline stabilization and storm protection. Wetlands retain nutrients by storing eutrophic parameters like nitrogen and phosphorus, flooding waters in vegetation, or accumulating them in the sub-soil, thus decreasing the potential for eutrophication and excess plant growth in receiving waters. They also help in absorbing sewage and in purifying water supplies (Ramchandra, 2001). Apart from this, the socio-economic values, through water supply, fisheries, fuel wood, medicinal plants, livestock grazing, agriculture, energy resource, wildlife resource, transport, recreation and tourism, and so forth, are significant. The functional properties of a wetland ecosystem clearly demonstrate its role in maintaining the ecological balance.

India is blessed with numerous rivers and streams. By virtue of its geography, varied terrain, and climate, it supports a rich diversity of inland and coastal wetland habitats. There are a number of man-made wetlands for various multipurpose projects. Examples are Harike Barrage at the confluence of the Beas and the Sutlej in Punjab, Bhakra Nagal Dam in Punjab and Himachal Pradesh, and the Cosi Barrage in Bihar-Nepal Border. India's climate ranges from the cold, arid Ladakh to the warm, arid Rajasthan, and India has over 7,500 km of coastline, major river systems, and mountains. There are 67,429 wetlands in India, covering about 4.1 million hectares. Of the estimated 4.1 million hectares (excluding irrigated agricultural lands, rivers, and streams) of wetlands, 1.5 million hectares are natural and 2.6 are man-made, while the coastal wetlands occupy an estimated 6,750 sq km, largely dominated by mangroves (Ramchandra, T.V., 2001)

Traditional wetland ground surveys are too time consuming and expensive though, and remote sensing imagery can provide time and cost-effective solutions. Remote sensing has provided a great mean to study various ecosystems of the earth including wetlands by providing cost and time effective data. Over the years, remote sensing has been used as a tool to map large areas of wetlands. Moreover, remote sensing in the form of aerial photography served the purpose of identification, delineation and measurement of spatial extent of wetland successfully (e.g., National Wetland Inventory (NWI)).With regular passages of remote sensing vehicles (aircraft and/or satellites) over a location, land information in the form of multi-date, multi-spectral images can be obtained within a constant period of time. Changes in surface environmental conditions can therefore be monitored using space-borne digital imageries. With launch of remote sensing satellites like the Landsat series with Multispectral Scanner (MSS) and later Thematic Mapper (TM), it has become cost effective and convenient to acquire multi-date digital images over a greater array of spatial and temporal scales than was possible with aerial photography. Landsat-MSS has been used successfully for the study of relatively larger wetlands. Yet, its use is very limited for studies of different aspects (e.g., vegetation species identification, discrimination, etc.) of all types of wetlands, specifically, inland wetlands which usually have smaller areal extent and complex mixture of vegetation species. Basic constraints of using Landsat-MSS data for wetland mapping inventory in early studies were geometric inaccuracy and the poor spatial, spectral, and radiometric resolutions of data. Availability of Landsat-TM data solved this problem of coarse resolutions to some extent. With a spatial resolution of 30 meters, it becomes possible to study relatively smaller areas. Several investigators have used remotely sensed data for ascertaining water quality and mapping of lakes and reservoirs (Chopra et al. 2001). Landsat MSS, Landsat TM, and SPOT satellite systems have been used to study wetlands (Lunetta & Balogh, 1999; Shaikh et al., 2001; Shepherd et al., 2000; Töyrä et al., 2000). Other studies have included AVHRR, IRS, JERS-1, ERS-1, SIR-C and RADARSAT (Alsdorf et al., 2001; Bourgeau-Chavez et al., 2001; Chopra et al., 2001). There has been some research done on wetlands using radar data (Bourgeau-Chavez et al., 2001; Alsdorf et al., 2001; Rio & Lozano-García, 2000) as well as LIDAR (MacKinnon, 2001) but the majority has been concentrated on Landsat TM, MSS, SPOT, and airborne CIR photos.

This study aimed at measuring the extent of water spread area and its variation, aquatic vegetation status of Harike wetland in different years, using satellite data.

The Study Area

For this study, Hairke wetland has been selected which is meeting point of the Beas and Satluj rivers falling in Punjab state of India. The Harike wetland ecosystem, which acquires rich flora and fauna, spreads in four districts of Amritsar, Ferozpur, Kapurthala and Jalandhar in Punjab, India. The shallow reservoir situated 55 km south of the city of Amritsar, was built in 1953 by the construction of a barrage at the confluence of the Satluj and Beas rivers. Harike lake was declared a 41 sq. km. wildlife sanctuary in 1982. Considered a wetland of international importance, it was included in the list of Ramsar sites in 1990. The sanctuary area was enlarged in 1992 to 86 sq. km. It is a breeding ground and habitat for a large variety of migratory as well as domiciled birds. Like many wetlands in India, Harike is beset with problems. These include silting and shrinking of the water body, water hyacinth infestation, encroachment, fishing, plantations, water pollution and grazing.

This man made lake not only recharges groundwater but also provides irrigation to southern parts of Punjab and neighbouring state of Rajasthan through Sirhind feeder and Rajasthan canal. For rainfall and runoff studies, the catchment of river Satluj is considered from Nangal to Harike and that of Beas from Pong to Harike. Beas river originates from the greater Himalayas near Rohtang Pass. The Beas enters Hoshiarpur district in Punjab at Talwara. The Beas and the Satluj practically form the Northern and Southern boundaries of Hoshiarpur district. The Beas joins the Satluj at Harike in Patti Tehsil of Amritsar district (WAPCOS, 1996). A field visit to the wetland area has been made in the month of April 2005. The author observed that the growth of hyacinth was very high and it was about 2-3 meter high during that period. With the abundance of water hyacinth, the Harike wetland had turned into a marsh.

The satellite data used in this study were Indian Remote Sensing (IRS) LISSII for the year 1990 and IRS LISS III data and for the years 1999 and 2003. The LISSII data was available for November while LISSIII data was available for the Month of April.

METHODOLOGY

Creation of Data Base

The catchment boundary of the two rivers meeting at Harike was taken from Survey of India toposheets at a scale of 1:250,000. The study area is covered in four toposheets numbered 53A, 53B, 44M and 44N. The analog maps were converted to digital form through scanning. These digital data were then digitized and converted to vector form using R2V software. The drainage map and boundary maps were then imported to Integrated Land and Water Information System (ILWIS) GIS Software. The map of the study area showing drainage network is shown in Figure 1.

Processing of Remote Sensing data

As the wetland comprises of mainly three major classes viz. wetland (aquatic vegetation), water and marshy land (waterlogged), these are the classes, which have been mapped using remote sensing data. Although spectral signatures of water are quite distinct from other land uses like vegetation, built-up area and soil surface, yet identification of water pixels at the water/soil interface is difficult and depends upon the interpretive ability of the analyst. Deep-water bodies have quite distinct and clear representation in the imagery. However, shallow water can be mistaken for soil while saturated soil can be mistaken for water pixels, especially along the periphery of the lake. Secondly, it is also possible that a pixel at the soil/water interface will represent mixed conditions. McFeeters (1996) developed a band ratioing index, which is called the Normalized Difference Water Index (NDWI). The NDWI is calculated as follows:

$$NDWI = \frac{(GREEN - NIR)}{(GREEN + NIR)}$$

where GREEN is a band that encompasses reflected green light and NIR represents reflected near-infrared radiation. When equation (3) is used to process a multi spectral satellite image that contains a reflected visible green band and NIR band, water features have positive values of NDWI; while soil and terrestrial vegetation features have zero or negative values, owing to their typically higher reflectance of NIR than green light.

RESULTS

The landcover maps of study area have been prepared using NDWI approach. The study area has been classified in three major classes viz. wetland (aquatic vegetation), water and marshy land (waterlogged). The aquatic vegetation consists of hyacinth and grass etc., but in this study vegetation has been taken as one class. The land cover for the three dates has been shown in Figure 2. The spatial extent falling under three categories of wetland, water and waterlogged area have been computed and given in Table 1. Classifications derived from remotely sensed images are subject to error. For this an accuracy assessment has been made to check the error in classification. A field visit has been made to have the ground truth data. It was found from accuracy assessment that the classification made is quite good.

From the Table 1 it was observed that the total wetland area has reduced from 100.31 sq. km. in 1990 to 71.08 sq. km. in 2003, which means approximately 30%, area has been reduced, over a period of 13 years. It is also observed that the area under aquatic vegetation was quite high in 1990 as compared for 1999 and 2003. This is because the satellite data for the year 1990 was of post monsoon month (November), while the satellite data for the years 1999 and 2003 was of pre-monsoon month (April). Therefore it can be seen from Table 1 that due to high aquatic vegetation in 1990, the area under water and waterlogged for 1990 was less in comparison to other years. However, the area under water reduced from 20 to 16.07 sq. km from 1999 to 2003 and similarly area under waterlogged has also been reduced from 26.34 to 20.15 sq.km. in the two years.

Table 1: Areal extent of the wetlands in different years

Year	Total wetland Area (sq. km)	Aquatic vegetation (sq. km)	Water (sq. km)	Waterlogged (sq. km)
1990	100.31	74.62	9.216	16.47
1999	92.33	45.99	20.00	26.34
2003	71.08	34.86	16.07	20.15

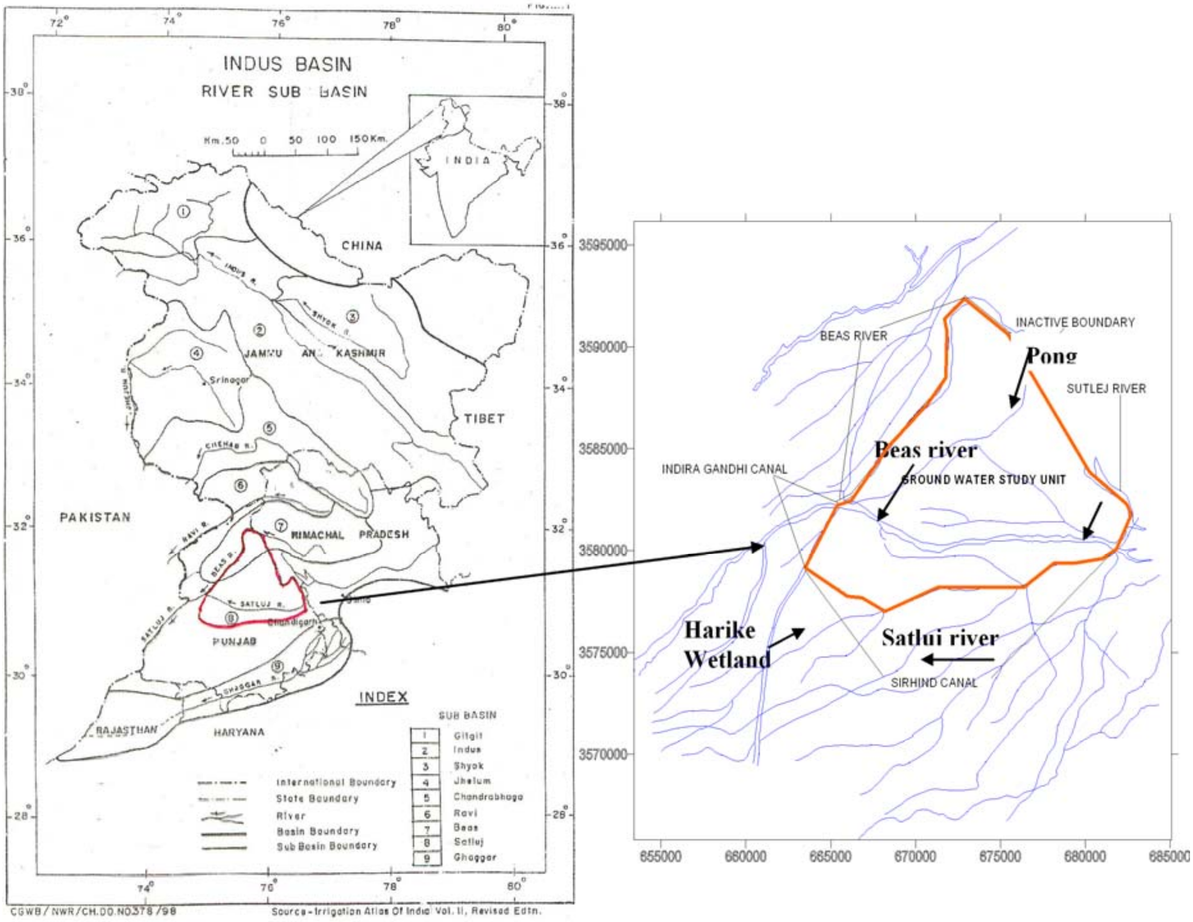

Figure 1: Location map of the study area

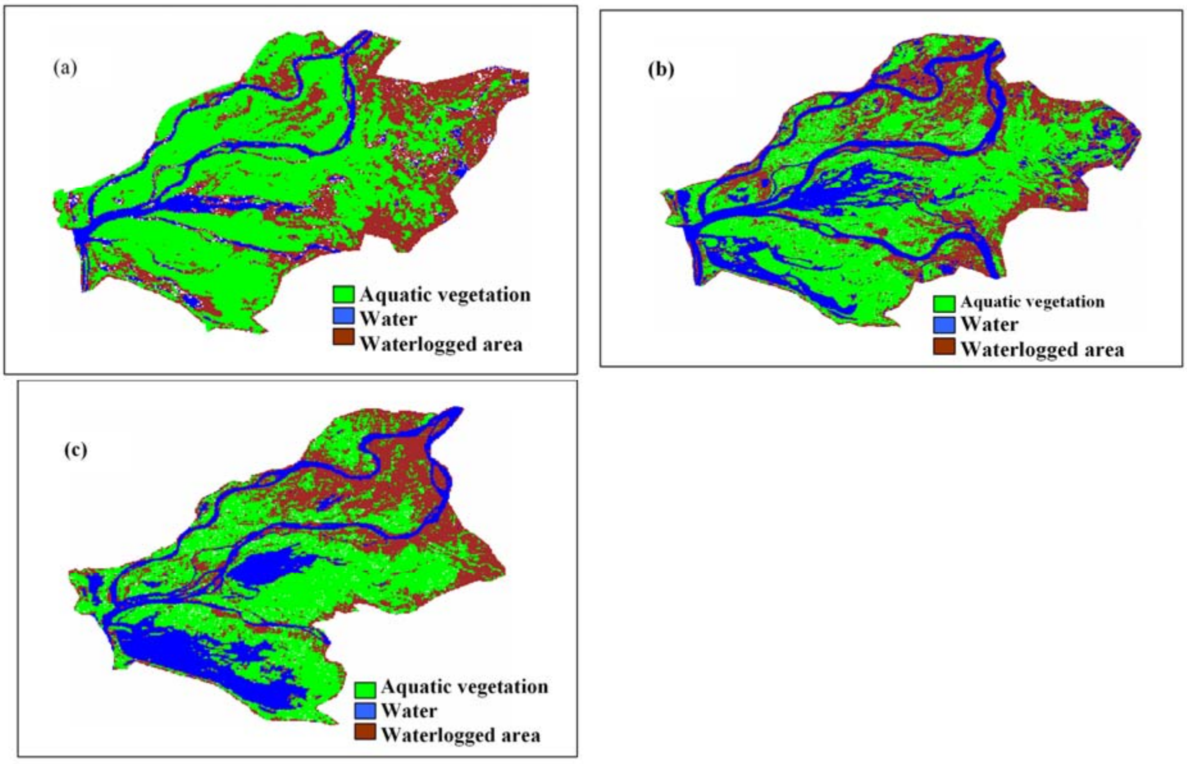

Figure 2: Wetland area in (a) 1990 and (C) 2003

CONCLUSIONS

The wetland area of Harike is reducing due to various reasons such as silting and decreasing trend of flow in upstream catchment etc. The reasons for reduction in runoff at wetland is the over exploitation of ground water in the catchment area. The wetland area mapping has been carried out using remote sensing data for a period of 1990 to 2003 and wetland area in these years have been computed. It was observed that about 30% total wetland area has reduced in these years. The Harike wetland is a source of water through canal irrigation and plays an important role in the economy of the state.

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