Mapping, monitoring and conservation of Harike wetland ecosystem, Punjab, India, through remote sensing

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Abstract. The Ramsar Convention of IUCN held in 1971 in Iran raised global awareness of the conservation and management of wetlands. Wetlands, the transitional zones that occupy an intermediate position between dryland and open water, regulate the flow of water and nutrients, thereby facilitating optimum functioning of the physical and biological cycles of nature. Harike wetland in the Indian State of Punjab has been declared a wetland of international importance. Thus it is felt necessary to reclaim and develop Harike wetland for its optimum potential use, but a reliable and accurate wetland database is not available. This study aimed at the generation of a database in terms of landuse/landcover, extent of waterspread and its seasonal variation, aquatic vegetation status and turbidity levels of lake water, using multidate satellite data. The threats of the Harike wetland have been identified and adequate measures for its conservation and management suggested.

1. Introduction

India, by virtue of its geographical extent, varied terrain and climatic conditions, supports a rich diversity of inland and coastal wetland ecosystems. The wetland in India are distributed in various ecological regions. Although the significance of wetlands has been known for a long time, their role in maintaining ecological balance is less understood. The Ramsar Convention of IUCN held during 1971 in Iran raised global awareness of the conservation and management of wetlands.

Remote sensing techniques, together with ground truth, are widely used to collect information on the qualitative and quantitative status of natural resources in protracted areas. Parihar *et al.* (1986) used high-resolution space photographs to derive information on vegetative cover in order to study the wildlife habit. Wetland mapping in West Bengal, India, using remotely sensed data was done by Sharafat Ali *et al.* (1991). Several investigators have also used remotely sensed data for water quality monitoring of lakes and reservoirs. Carpenter and Carpenter (1983) used Landsat data for modelling inland water quality. Khorram and Cheshire (1985) applied remote sensing techniques to ascertain the water quality in the Neuse river estuary in North Carolina. Lindell *et al.* (1985) used Landsat imagery to map coastal water turbidity, whereas Ritchie and Cooper (1988) estimated the concentration of suspended sediments through Landsat MSS data. Manu and Robertson (1990) estimated suspended sediment concentration from spectral reflectance data. Wani *et al.* (1996) effectively used IRS LISS-II data to quantify suspended sediment concentration in

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the Dal lake (Srinagar, India) surface water. The study showed the existence of a positive functional correlation between the concentration of suspended solids and visible wavelength.

The Harike wetland has assumed international importance, as it is a breeding ground and habitat for a large variety of migratory as well as domiciled birds. In recent years, anthropogenic pressure has created an extensive ecological imbalance. Therefore, it is felt necessary to conserve this wetland ecosystem for its optimum potential use, but a reliable and accurate wetland database is not available. In the present study, an attempt was made to map landuse/landcover and to generate baseline information about spatial distribution and the variation in the waterspread, turbidity and aquatic vegetation in different seasons for the Harike wetland for its conservation and management.

2. Study area

The Harike wetland ecosystem, rich in aquatic flora and fauna has an area of 285.1 square kilometres and spreads into the four districts of Amritsar, Firozpur, Kapurthala and Jalandhar in the Indian State of Punjab. The area under study forms a part of the Indo-Gangetic alluvial plain of Holocene age (Chopra and Sharma 1993) and is located between latitudes 31°05′15″ and 31°14′15″ N and longitudes 74°55′30″ and 75°07′30″ E. The area is drained by the Satluj and Beas rivers and their tributaries. Both these perennial rivers rise in the high Himalayas and traverse a long distance before entering the State of Punjab and coalescing at Harike (figure 1), where an irrigation barrage was built in the 1950s. This manmade lake not only recharges ground water but also provides irrigation to parts of Punjab and the neighbouring State of Rajasthan through the Sirhind feeder and Rajasthan canal.

3. Climate

The climate of the study area, influenced by the Himalayas in the north, has a direct bearing on the ecosystem. It experiences an annual rainfall of 668 mm. The southwestern monsoon, constituting about 70% of the annual rainfall, begins in the first week of July and extends into September. It experiences extreme heat during the months of April, May and June. The mean daily maximum temperature rises up to 43°C in June, and the mean daily minimum temperature can be as low as 0.6°C in January.

4. Methodology

The landuse/landcover map of the Harike wetland ecosystem was prepared through visual interpretation of Indian Remote Sensing Satellite (IRS) 1A LISS-II multidate data of post-monsoon (October 1991), Spring (February 1992) and pre-monsoon (May 1992) in the form of paper prints of false colour composite (FCC) generated from bands 2, 3 and 4 on a 1:50 000 scale (figures 2 and 3). To monitor the change in landuse/landcover and vegetation status, multi-season data for the year 1996 in the form of diapositives of IRS satellite data were also used; however, no apparent change was observed. Standard image interpretation characteristics such as tone, texture, shape size, pattern and association, along with sufficient ground truth and local knowledge, were followed to delineate different landuse categories. Procom 2 was used to enlarge the film diapositives for proper identification and delination of various landuse categories and to transfer the details on the base map prepared from Survey of India (SOI) topographical maps on a 1:50 000 scale. As

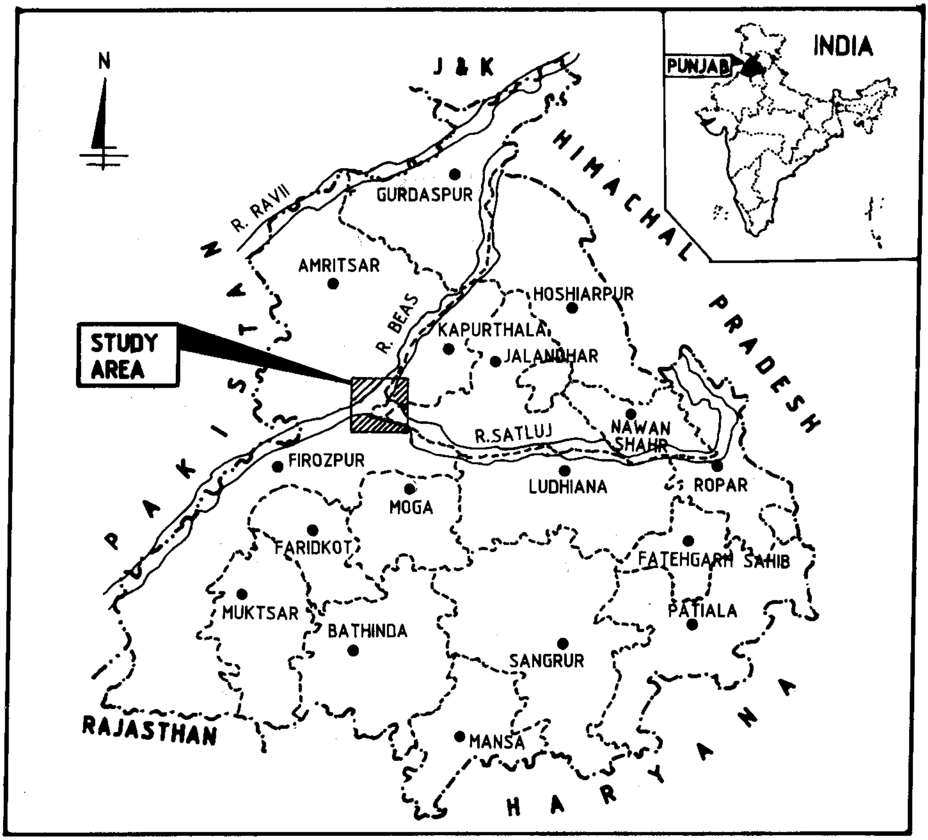


Figure 1. Location map of the study area.

the area in the middle of ecological zone was inaccessible, here the different units were identified on the basis of similar characteristics of the units lying at the fringe area of the ecological zone. Since the mapping scale was 1:50 000, it was possible to delineate with ease units (plantation) as small as 0.08 km, supported by ground truth. Simultaneously, the wetlands zone demarcated and supplied by the Punjab State Council for Science & Technology (nodal agency) was also registered and digitally classified. Multidate IRS-1A LISS-I digital data in the form of computer compatible tapes (CCTs) were used to generate the landuse/landcover map of the wetland zone (figure 4). Pre-monsoon and post-monsoon variations in water spread and turbidity of the water in the lake were also recorded (figure 5). The quantitative turbidity ratings (low, moderate and high) were assigned based on the hue manifested on the FCCs. The details of the data products used in this study are given in table 1.

5. Results and discussion

5.1. *Landuse/landcover of Harike wetland ecosystem*

The landuse/landcover map of the study area (figure 3) was prepared following the visual interpretation technique and adopting the classification system proposed by the Space Applications Centre (SAC), Ahmedabad, India. The study area has been classified into five major units: built-up land, agricultural land (crop land, plantation, etc.), forest, wasteland and wetland. These are further subdivided, and

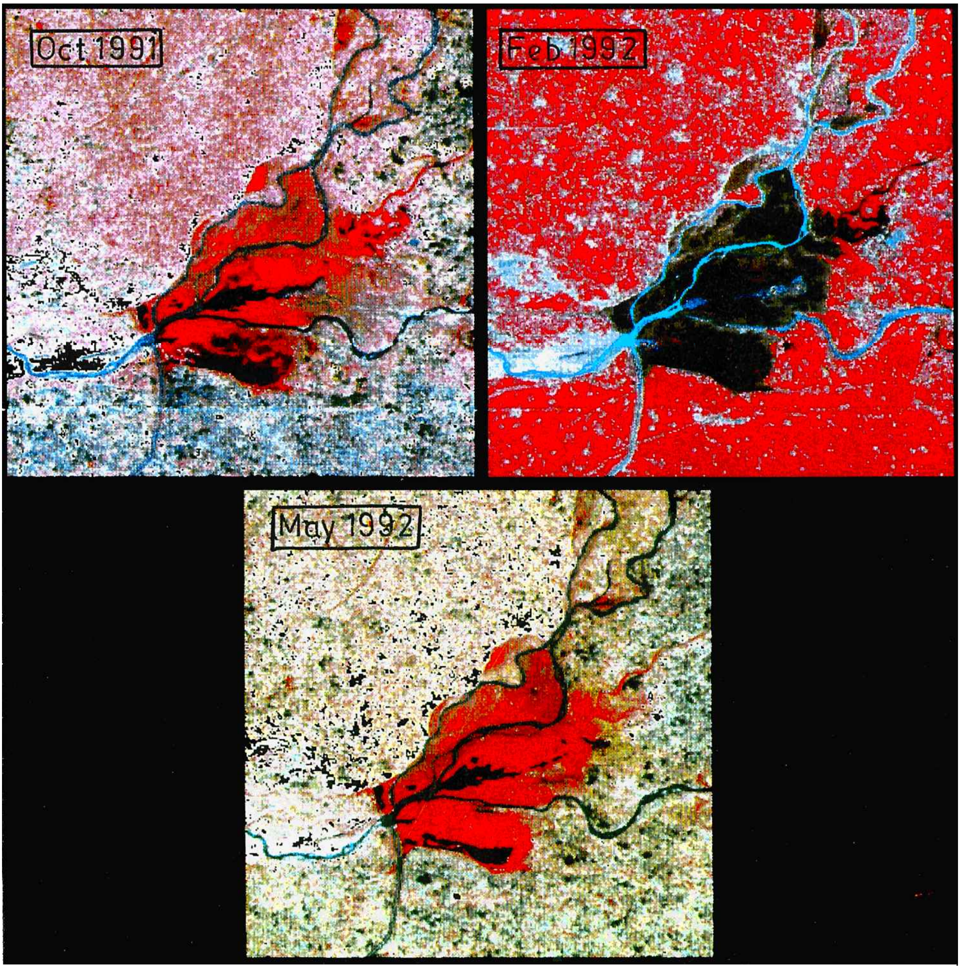


Figure 2. Multidate FCC of the Harike wetland system.

their areas were computed and are given in table 2. Perusal of the data indicates that, out of a total wetland area of 285.1 sq. km, an area of 10.8 sq. km is waterlogged. The lake/ponds cover 3.6 sq. km, whereas 0.5 sq. km is covered by oxbow lakes and cut-off meanders. The area under wasteland (land with or without scrub) comes out at 3.6 sq. km, whereas the sandy area occupies 24.2 sq. km. The area under swamps or marsh comes out at 43.1 sq. km. Plantations and built-up land cover 0.08 and 0.66 sq. km, respectively. A substantial area (198.6 sq. km) of the wetland is being used for agriculture. A digitally classified map of Harike wetland ecological zone is shown in figure 4. The area under various landuse categories within the notified wetland is given in table 3.

5.2. *Water spread and aquatic vegetation*

The seasonal variation in water spread of Harike lake was recorded using multi-seasonal (post-monsoon, spring and pre-monsoon) data. It was revealed that the post-monsoon extent of the Harike wetland was 82.8 sq. km and that of the spring season was 75.7 sq. km, whereas the pre-monsoon spread was 76.9 sq. km (figure 5).

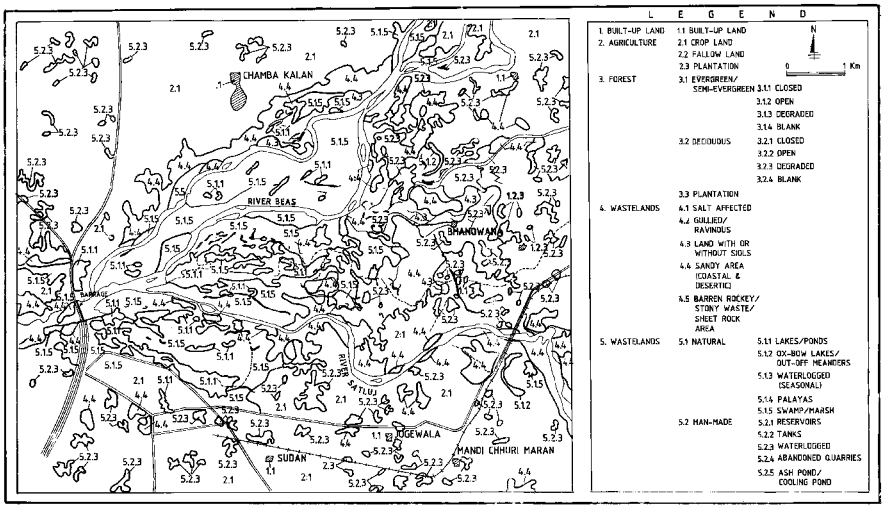


Figure 3. Landuse/landcover map of the Harike wetland and environs.

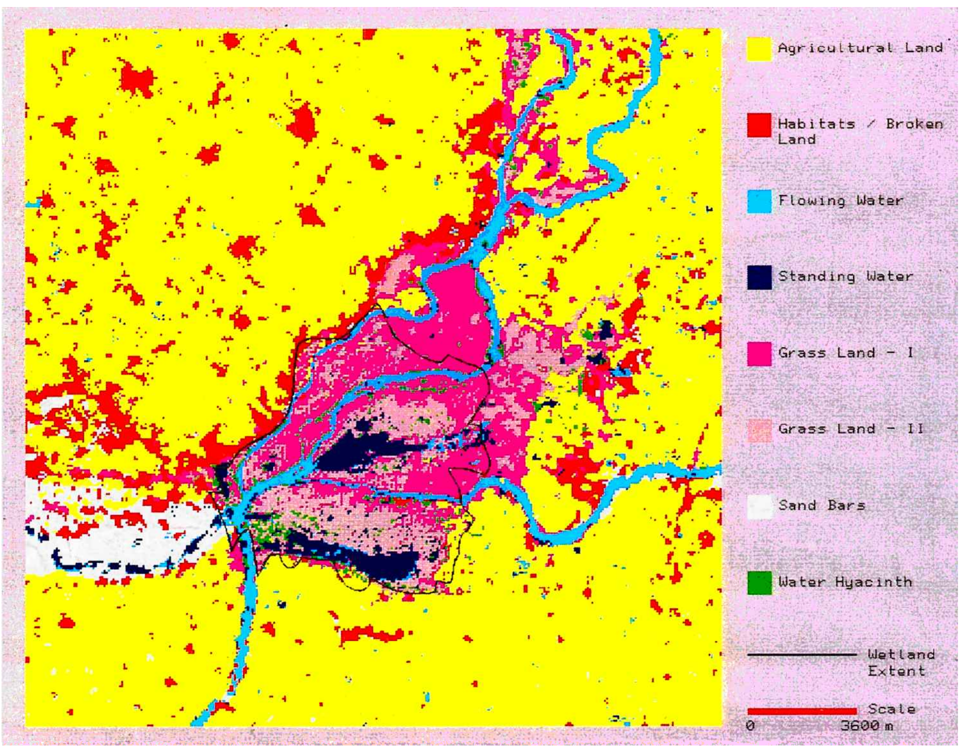
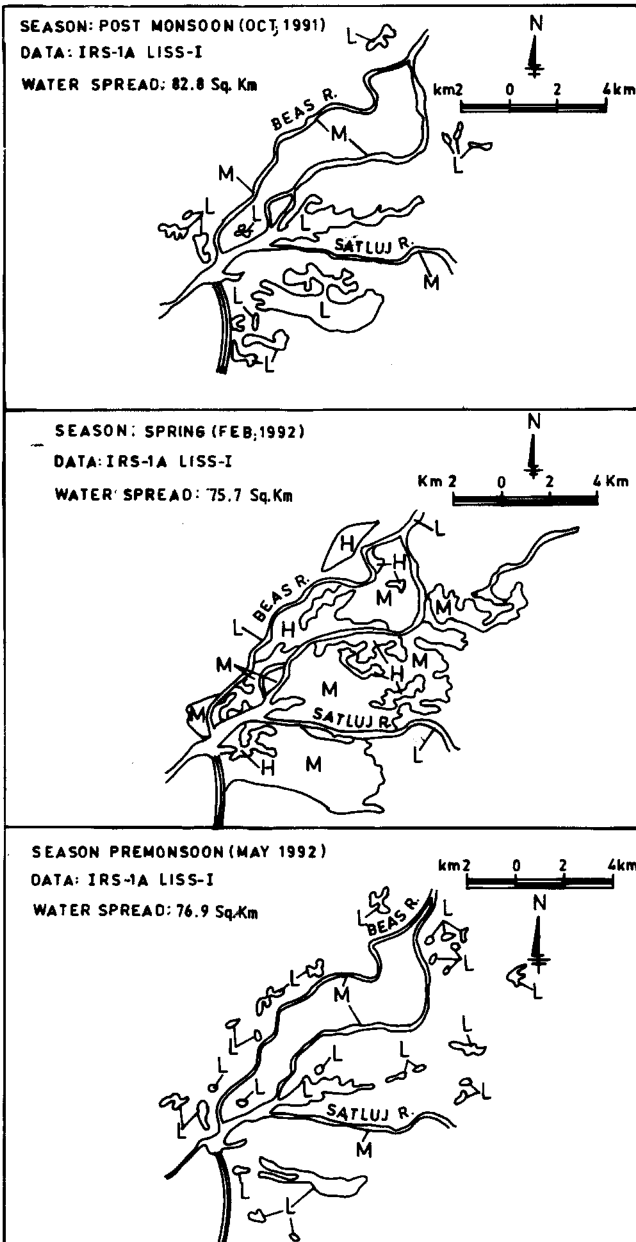


Figure 4. The Harike wetland ecological zone.

The water spread post-monsoon is greater because of the release of more water from the Pong and Bhakra dams and rainwater from the area below the dams through feeding rivers (Beas and Sutlej).

Visually, three types of aquatic vegetation could be recognized (figure 6). A large



L E G E N D

TURBIDITY CLASSES OF HARIKE WETLAND

SYMBOL	TURBIDITY	HUE ON COLOUR COMPOSITE
L	LOW	DARK BLUE
M	MODERATE	MEDIUM BLUE
H	HIGH	LIGHT BLUE / WHITISH BLUE

Figure 5. Monitoring of water spread and turbidity of the Harike wetland.

Table 1. Satellite data used in the study.

Data type	Path	Row	Date of pass
IRS 1A LISS-I	31	46	29.10.91
IRS 1A LISS-I	31	46	16.02.92
IRS 1A LISS-I	31	46	25.05.92
IRS 1A LISS-II	31	46	04.10.92
IRS 1A LISS-II	31	46	12.05.93
IRS 1B LISS-II	31	46	24.04.96
IRS 1B LISS-II	31	46	03.10.96

Table 2. Area* under various landuse categories in the Harike wetland ecosystem.

Map symbol	Landuse category	Area (sq. km)
1.1	Built-up land	0.66
2.1	Crop land	198.6
2.3	Plantation	0.08
4.3	Land with or without scrub	3.6
4.4	Sandy area	24.2
5.1.1	Lakes/ponds	3.6
5.1.2	Oxbow lakes and cut-off meanders	0.5
5.1.5	Swamp/marsh	43.1
5.2.3	Waterlogged	10.8
	Total	285.1

* Based on the visual interpretation of the ecosystem.

Table 3. Area* of different landuse categories in the Harike wetland zone.

S. No.	Landuse category	Area (sq. km)
1.	Agricultural land	1.9
2.	Habitat and broken land	1.1
3.	River channel with flowing water	4.5
4.	Ponded area stagnant water	7.6
5.	Wetland with water hyacinth	7.0
6.	Grassland I	19.0
7.	Grassland II	12.7
8.	Sand bars	0.12
	Total	53.9

* Based on the digital classification of the zone.

portion of the wetland is covered by water hyacinth (vegetation type I), which grows in standing water. Nearly 43.1 sq. km under marsh and swamps can be put into this class. A large portion of wetland is covered by grasses. The grasslands have been classified into two categories based on the variation in spectral signatures on the FCC, i.e. vegetation type II and III. The area mapped as vegetation III (grassland II) is characterized by high reflectance in the infrared region (band 4 of IRS-I), whereas the area classified as vegetation II (grassland I) has high reflectance in the blue, green and red spectral regions (bands 1, 2 and 3 of IRS-I) in the pre-monsoon and post-monsoon data. There is a possibility of miscalculation of water hyacinth

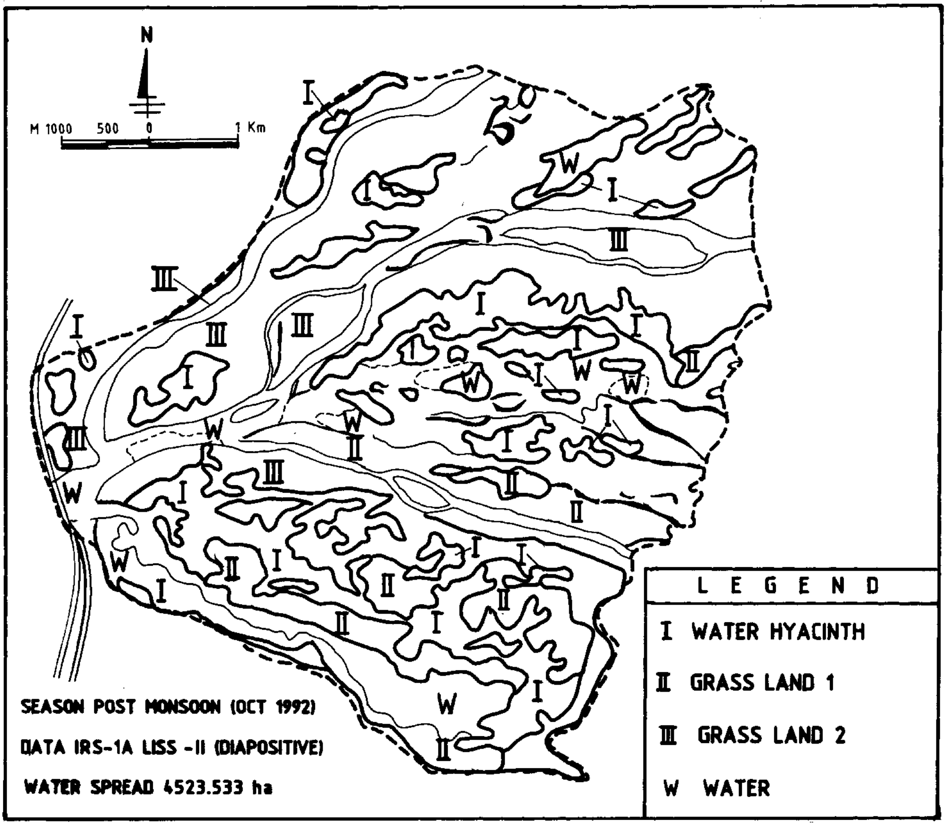


Figure 6. Aquatic vegetation status of the Harike wetland.

with grassland II because of the spectral overlap between these classes. Verification of different types of grasslands was not possible due to the inaccessibility of the area and non-availability of other collateral data. Since these classes were separable, they are mapped as distinct units. The dominant species of grasses growing in the area are *Saccharum munja*, *Saccharum spontaneum*, *Typha elephantia*, *Cynodon dactylion*, *Desmostachiya bipinnata* (Dabb) and *Vetiveria zizanioides*.

5.3. *Turbidity*

Qualititatve turbidity of Harike lake was recorded based on hue as manifested on the FCC. The turbidity classification is based on the system proposed by SAC (table 4). The turbidity of water in the Harike lake is variable. The variation and distribution of turbidity during the spring, pre-monsoon and post-monsoon seasons is shown in figure 5.

Table 4. Classification of water bodies based on turbidity.

Turbidity level	Map symbol	Hue on FCC
Low	L	Dark blue
Moderate	M	Medium blue
High	H	Light-blue/whitish-blue

5.4. *Water quality of lake*

Analysis of the water of the Sutlej and Beas rivers upstream of Harike indicated that the water of these rivers is polluted, especially in areas where industrial and municipal effluent are drained into the rivers. Another source of pollution is run-off from the fields. The portion of the Harike lake fed by the Sutlej river is excessively eutrophic and the portion fed by Beas water is mildly eutrophic, but eutrophication has not yet been seen in the middle portion of the reservoir and the downstream areas (Parwana and Bansal 1991).

6. Threats to the Harike wetland

The coverage of wetland in the ambit of environment is something different. The Harike wetland, falling under manmade freshwater riverine system, is a multifaceted habitat for a wide variety of organisms. The wetland, although recognized as an area of international importance for waterfowl conservation, faces many serious problems. Keeping in view the present landuse, waterspread, turbidity and aquatic vegetation, the threats to the Harike wetland were identified as being due to the factors discussed below.

6.1. *Weed infestation*

Water hyacinth (*Eichhornia crassipes*) is the main weed that has invaded the Harike wetland. The area under the plant doubles every 6–15 days, depending on the nutrient status of water.

6.2. *Siltation*

In the Harike lake, silt had started depositing near the barrage at the beginning of 1985. Siltation has reduced the erstwhile lake to shallow wetland now. A major amount of silt is deposited in the monsoon season when heavy rains wash down the soil from hill slopes and fields in the catchment area of the two rivers.

6.3. *Pollution*

The pollution is the result of the nutrient input from sewage and effluents and washdown of fertilizers and pesticides from agricultural fields into the two rivers.

6.4. *Water fluctuation*

The depth of wetland is only a few metres when full. The depth reduces further in the lean periods when the inflow of water is less during summer. In fact, the irrigation is most desired at this stage, so more water has to be released into the canals from the wetland, leaving it with little water. This practice makes portions of the wetland bare at the bottom, enabling the development of weeds. Illegal fishing and poaching are the other threats to the Harike wetland. These threats have resulted not only in a shrinkage of the lake area but also deteriorated the natural environment for the survival of birds. These unfavourable conditions have forced the migratory birds to drift away from the Harike lake, which was once considered to be a safe dwelling place for them.

7. Conservation and management

The growth of weeds in the water inflow of industrial effluents and the addition of agricultural waste products and fertilizers in the ponded area has resulted not only in shrinkage in lake area but also deteriorated the ecosystem for the survival of birds (Jerath 1992). A number of conservation measures have been suggested to conserve the Harike wetland. These measures include eradication of water hyacinth by biological, chemical and mechanical means, monitoring of water quality of the lake, regulation of fishing between October and February every year during the bird migration period, fencing some of the selected portions from encroachment and afforestation of the catchment area. To control further the siltation in the lake, the sluice gates should be kept fully open, so that there is no retardation in the velocity of water and the silt being carried into the lake is carried away with it.

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