Wetland Information System Using Geo-informatics in Himachal Pradesh, India

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ABSTRACT: An updated geo-spatial database of wetlands is prerequisite for management and conservation planning. A project was carried out to generate inventory of wetlands for the state of Himachal Pradesh using remote sensing data and organize database in GIS format. The wetlands categorized under 19 classes have been mapped using remote sensing data from Indian Remote Sensing Satellite P6 Linear Imaging Self Scanner (IRSP6 LISS3). In this project, eight wetland theme layers were prepared ie wetland extent/ wetland boundary, water spread (These are two layers representing post-monsoon and pre-monsoon water spread during the year of data acquisition), aquatic vegetation spread (These are two layers representing presence of vegetation (floating and emergent) as manifested on the pre-monsoon and post-monsoon imageries), Turbidity ratings (These are two layers representing qualitative turbidity of the open water in the wetlands rated as low, medium and high for the pre- and post-monsoon seasons). Small wetlands (< 0.0225 Sq. Km) are mapped as point features. The results are organized at 1: 50,000 scale at district, state and topographic sheet (Survey of India reference) level using Geographic Information System (GIS). The extent of wetlands in the state has been estimated to be 984.96 Sq. Km. The river/stream (555.58 Sq. Km) is the most dominant wetland type in the state of Himachal Pradesh followed by reservoirs and high altitude wetlands. In addition, 471 small wetlands (< 0.0225 Sq. Km) have also been identified. Significant change in the water spread, turbidity of open water, and spread of aquatic vegetation in the wetlands was observed during pre- and post-monsoon seasons.

Key words: wetlands; Indian Remote Sensing; LISS3; pre-monsoon; post-monsoon

1. INTRODUCTION

The wetlands in Himachal Pradesh are facing various challenges in the form of inherent problems both natural and manmade. Increased human activity has influenced hydro biological regime of wetlands. The lakes are deteriorating, even drying up at some places and facing unprecedented threat from weed growth, algal bloom, pollution and siltation. An updated and accurate inventory of wetlands is prerequisite for management and conservation planning of wetlands. Keeping in view, a project aimed at generating inventory of wetlands in the State of Himachal Pradesh on 1:50,000 scale using Indian Remote Sensing Satellite P6 Linear Imaging Self Scanner (IRSP6 LISS3) and organizing the digital database in GIS was executed.

1.1 Physical basis

The reflectance of clear water is generally low. However, the reflectance is maximum at the blue end of the spectrum and decreases as wavelength increases The best wavelength region for discriminating land from water is the near-IR and mid-IR (0.74 - 2.50 μm). In the near- and middle-infrared regions, water bodies appear very dark, even black, because they absorb almost all of the incident radiant flux, especially when the water is deep and pure and contains little suspended sediment or organic matter (Bhavsar, 1984; Harrington, 1992; Ritchie et al., 1976; Schiebe, 1992).

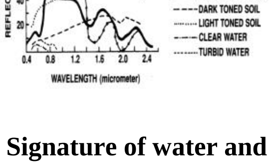

Figure 1 Spectral Signature of water and other targets

2. METHODOLOGY

2.1 Study area

The state of Himachal Pradesh has an area of 55,673 sqkm. Himachal Pradesh has the distinction of being the home of five rivers Sutlej, Ravi, Chenab, Jhelum, and Yamuna. The state is mountainous in nature and the perennial white snowline on the Himalayas is a prominent physiographic feature of the state. The state may be divided into four major physiographic divisions (from south to north) Outer Himalaya, Lower or Lesser Himalaya, Main or Central Himalaya and Trans-Himalaya. There is general increase in elevation from west to east and from south to north. The elevation ranges from 400 m in the southern tract to over 6400 m in the main Himalaya. Himachal Pradesh has diverse climatic conditions due to altitudinal variations (Negi, 1990). The climatic conditions vary from hot, sub-humid and tropical in the southern low tracts to temperate, cold alpine and glacial in the northern and eastern high mountains. The state of Himachal Pradesh is divided into the following 12 administrative districts Bilaspur, Chamba, Hamirpur, Kangra, Kinnaur, Kullu, Lahaul & Spiti, Mandi, Shimla, Sirmaur, Solan and Una **(Figure 2**).

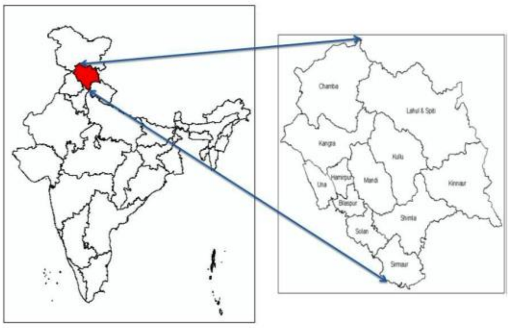

Figure 2 Location Map of the study area

2.2 Data Used

2.2.1 Remote sensing data

IRS P6 LISS 3 data was used to map the wetlands. IRS P6 LISS 3 provides data in 4 spectral bands: green, red, Near Infra Red (NIR) and Short Wave Infra Red (SWIR), with 23.5 m spatial resolution and 24 day repeat cycle. Two date data (April-May and Oct-Dec) were acquired to capture the pre-monsoon and post-monsoon hydrological variability of the wetlands. **Figure 3** shows the overview of the part of Himachal Pradesh as seen in the IRS P6 LISS 3 satellite data of post-monsoon and pre-monsoon season.

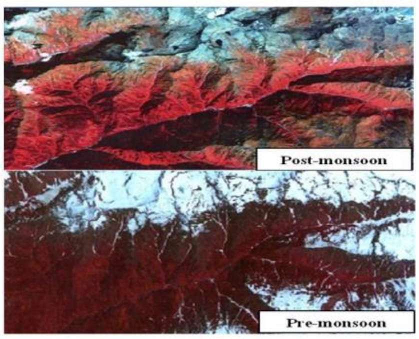

Figure 3 High Altitude Wetlands of Kullu region of Himachal Pradesh are identifiable on IRS P6 LISS 3 image of post monsoon and pre monsoon season

3.2.2 Ground Truth Data

Ground truth data or field investigation forms integral part of the interpretation methodology of remote sensing data. Field survey involved visiting a number of test sites representing different wetland categories. The information and location were recorded with the help of maps, image print outs and Global Positioning System (GPS). The field photographs were also taken to record the water quality (subjective), status of aquatic vegetation and water spread. **Figure 4** shows field survey of natural lakes in Mandi District. All field verification work was done during months of October and November.

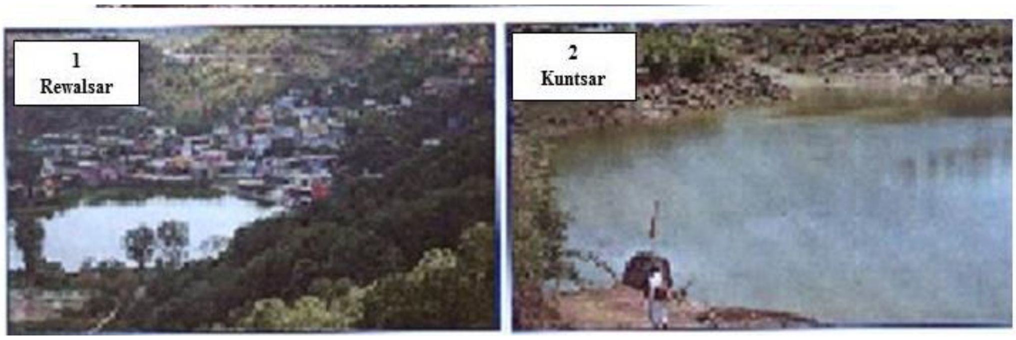

Figure 4 Field survey of natural lakes in Mandi District

3.2.3 Other data

Surveys of India topographical maps (SOI) were used for reference purpose. Lineage data of National Wetland Maps at 1:250,000 scale was used for reference.

3.3. Creation of spatial framework

To create wetland database of the state, which forms a part of national framework and is covered in multiple map sheets, National Natural Resource Management System (NNRMS) standards were followed and four corners of 1: 50,000 (15'X 15' grid) is taken as tics or registration points to create each map taking master grid as the reference (Anon. NNRMS Standards, 2005; Dasgupta et al, 2000; Garg and Patel, 2007).

3.4 Geo-referencing of satellite data

The raw satellite images were converted to specific map projection using geometric correction. Ortho-rectified and geo-referenced master LISS III data of 2004-05 was used to geo-reference the 2006-07 data by image to image registration with less than 0.5 pixel RMSE.

3.5 Mapping of wetlands

The two date satellite images were analyzed using standard image processing software to delineate different wetland classes. The wetland layers generated for each inland wetland are wetland boundary (wetland extent would encompass open water, mud flats and aquatic vegetation), water spread, aquatic vegetation (floating and emergent) and turbidity status in pre-monsoon and post monsoon season.

The various steps included in mapping of wetlands are as follows:

1. A model was created in Erdas imagine software to generate NDVI, NDWI, MNDWI, NDPI and NDTI images by applying band algebra and finally two stacks of indices were created for pre-monsoon and post- monsoon seasons.
2. The wetland boundary for pre-monsoon and post- monsoon seasons was interpreted visually in arc GIS environment using MNDWI, NDPI and NDTI combination from stack of indices. The union of vector layers of both seasons was done to get final extent of all wetlands.
3. The Open water spread was interpreted using MNDWI, NDPI and NDVI combinations.
4. The vegetation extent was interpreted using NDWI, NDPI and NDVI combinations.

5. Normalized Difference Turbidity Index (NDTI) and Modified Normalized Difference Water Index (MNDWI) image were used to generate qualitative turbidity levels based on signature statistics and standard deviations (Townshend and Justice, 1986; Tucker and Sellers, 1986). Based on the analysis of sensor data covering the Indian sub-continent, the variation in the turbidity levels of different water bodies has been recorded and it has been found that the NDTI varies from -0.2 to 0.0 in the case of clear water and from 0.0 to 0.2 for the moderately turbid water bodies. In the case of highly turbid water bodies, the NDTI values are found to be greater than +0.25. Therefore Three qualitative turbidity ratings (low, medium and high) is followed for pre-and post-monsoon turbidity of lakes, Reservoirs, barrages and other large wetlands. In False Colour Composite (FCC), these generally appear in different hues as given in **Table 1.**

Sr. No.	Qualitative Turbidity	Conditional Criteria	Hue on False Colour Composite(FCC)
1	Low	$> +1\sigma$	Dark Blue/Blackish
2	Moderate	$> -1\sigma$ to $<= +1\sigma$	Medium Blue
3	High/Bottom Reflectance	$<= \mu - 1\sigma$	Light Blue/Whitish Blue

Table 1: Qualitative turbidity rating

6. The information on wetland extent, open water extent, vegetation extent and turbidity information was converted into vector layers using region growing properties or on-screen digitization
7. The wetlands smaller than 0.0225 Sq Km are mapped as point features.
8. SRTM DEM was used to generate the elevation layer and all wetlands above 3000m amsl were assigned as high altitude wetlands.

3.6 Wetland Classification System/ Coding and attribute system

The Modified National Wetland Classification System is used for wetland Delineation and mapping comprising 19 wetland classes which are organized under a Level III hierarchical system. Feature codification scheme for every input element has been worked out keeping in view the nationwide administrative as well as natural hierarchy (State-District) within feature class for each of the theme. All data elements are given unique name **(Table-3).**

3.7 Generation of Reference Layers

Base layers like major road network, settlements, drainage are interpreted from the current image or taken from other project data base. The administrative boundaries (district, state) are taken from the known reference data.

3.8 Map composition and output

Map composition for atlas has been done at district and state level. A standard color scheme has been used for the wetland classes and other layers. The digital files are made at 1:50,000 scale. The hard copy outputs are taken in A3 size.

3.9 Accuracy Assessment

A comprehensive accuracy assessment protocol has been followed for determining the quality of information derived from remotely sensed data. Accuracy assessment involves determination of thematic (classification) as well as location accuracy. In addition, GIS database(s) contents have been also evaluated for accuracy. Quality assurance and quality control measures have been taken for data collection, analysis, verification and reporting.

Wettcode*	Level I	Level II	Level III
1000	Inland Wetlands		
1100		Natural	
1101			Lakes
1102			Ox-Bow Lakes/Cut-Off Meanders
1103			High altitude Wetlands
1104			Riverine Wetlands
1105			Waterlogged
1106			River/Stream
1200		Man-made	
1201			Reservoirs/Barrages
1202			Tanks/Ponds
1203			Waterlogged
1204			Salt pans
2000	Coastal Wetlands		
2100		Natural	
2101			Lagoons
2102			Creeks
2103			Sand/Beach
2104			Intertidal mud flats
2105			Salt Marsh
2106			Mangroves

Table 2 Wetland Classification System and Coding

3. RESULTS AND DISCUSSION

A total of 170 wetlands have been mapped at 1:50,000 scale in the state (**Table 3 and Figure 5**). In addition, 471 small wetlands (< 0.0225 Sq. Km)) have also been identified. Total wetland area estimated is 984.96 Sq. Km that is around 1.77 per cent of the geographic area of the state. The study revealed that river/stream (555.58 Sq. Km) is the most dominant wetland type in the state of Himachal Pradesh followed by reservoirs and high altitude wetlands. There are 13 Reservoirs/Barrages with 418.17 Sq. Km area. A total 42 high altitude lakes are mapped with 3.87 Sq. Km area. The other wetlands are Tanks/ponds, Waterlogged and Lakes/ponds. Aquatic vegetation is observed in Reservoirs/Barrages and Tanks/Ponds. The aquatic vegetation in wetlands was observed only during pre-monsoon season (52.94 Sq. Km). The open water spread area is significantly lower during pre-monsoon (492.45 Sq. Km) compared to post-monsoon (691.07 Sq. Km). The qualitative turbidity of water is mainly low to moderate in both the seasons. **Table 4** shows wetland area under different turbidity levels and supporting aquatic vegetation.

SNo.	**Wett code**	**Wetland Category**	**Number of Wetlands**	**Total Wetland area (Sq km)**	**Open Water**	
					Post monsoon Area (Sq km)	**Pre monsoon Area (Sq km)**
	1100	**Inland Wetland - Natural**				
1	1101	Lakes/pond	8	0.52	0.49	0.26
2	1102	Ox-bow lakes	-	-	-	-
3	1103	High altitude wetlands	42	3.87	2.85	1.28
4	1104	Riverine wetlands	-	-	-	-
5	1105	Waterlogged	10	0.47	0.39	0.19
6	1106	River/Stream	67	555.58	271.53	170.63
	1200	**Inand Wetland - Man-made**				
7	1201	Reservoirs/Barrages	13	418.17	414.45	319.66
8	1202	Tanks/Ponds	27	1.34	1.06	0.29
9	1203	Waterlogged	3	0.30	0.30	0.14
10	1204	Salt Pans	-	-	-	-
		Total	**641**	**984.96**	**691.07**	**492.45**

Table-3: Area estimates of wetlands in Himachal Pradesh

Sr. No.	Turbidity Level	Open Water Area Under Turbidity (Sq km)	
		Post-Monsoon	Pre-Monsoon
1	Low	468.70	339.49
2	Moderate	222.36	152.96
3	High	---	---
Sr. No.	**Aquatic Vegetation**	**Open Water Area Under Aquatic Vegetation**	
		Post-Monsoon	**Pre-Monsoon**
1		---	52.94

Table-4: Wetland area under different turbidity levels and aquatic vegetation in Himachal Pradesh

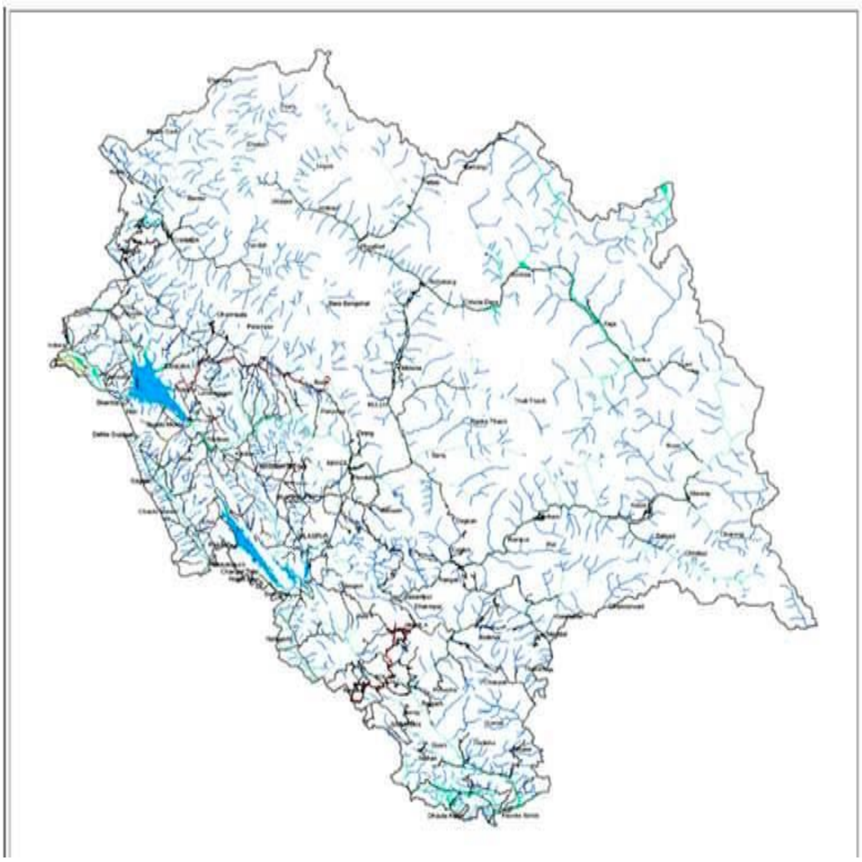

Figure 5 Wetland map of Himachal Pradesh

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