Change Detection Analysis of Catchment Area of Tighra Reservoir, Gwalior, Madhya Pradesh, India Using IRS P6 LISS III Satellite Images

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Abstract—The present study analyzed the land use/land cover changes of catchments' area of Tighra reservoir using IRS P6 LISS III of 2006, 2007 and 2008 with digital image processing and GIS techniques. The landuse/ landcover were broadly classified into 7 classes as water bodies, deciduous forest, open scrub, agricultural plantation, mixed barren land, Built-up and fallow land. Change analysis of landuse/landcover of the catchment area shows that from 2006-2008, agricultural land and built-up were observed to increase to about 3.35% and 5.19% approximately. Fallow land and mixed barren were also observed to increase by about 2.86% and 2.7% respectively. However, deciduous forest, water bodies and open scrub were noticed to decrease in area to about 10.83%, 2.14% and 1.23% respectively. The vast changes are due to unplanned urbanization and encroachment of land for agriculture, besides sedimentation of the reservoir. Therefore it is suggested here that local people should be properly educated and frequent monitoring should be conducted.

I. Introduction

Land use and land cover change has become a central component in current strategies for managing natural resources and monitoring environmental changes (Saxena et al. 2008). Due to increasing population growth rates, there have been increasing rates of conversions of forest and woodlands in developing economies all over the world, mainly for the slash and- burn farming practice. The degradation of forest or woodland have impact on catchment areas and biochemical cycles (Helmer et al. 2000) and leads to soil erosion and water shortage not only in the regions immediately affected by deforestation, but also in reasonably distant areas. An accurate knowledge of land use and land cover features represents the foundation for land classification and management. Remote Sensing has been used for many years and has great potential in mapping and assessing natural resources over a larger area (Lillesand et al. 2004). Remote sensing contributes in documenting the actual change in land use/land cover on regional and global scales from the mid-1970s (Lambin et al. 2003). GIS and remote sensing data provide a general extensive synoptic coverage of large areas. Thus these technologies provide a system for regularly monitoring the changes occurring in the area with a view to better planning (Saxena et al. 2008). Change detection is the temporal effects as variation in spectral response involves situations where the spectral characteristics of the vegetation or other type in a given location changes over time (Adia et al. 2009). Singh (1989) described change detection as a process that observes the differences of an object or phenomenon at different times. The Tighra reservoir provides water to the Gwalior city. Sustainable utilization of the reservoir will ensure the ecosystem stability and lower risk of degradation. Therefore the present study was conducted on Tighra catchment area to create a baseline data of landuse and landcover and also identify the changing pattern of vegetation cover using remote sensing and GIS techniques.

II. Study Area

Tighra reservoir was formed due to construction of a dam on Sank River during 1910 to 1917. The reservoir is located at about 18 km west of Gwalior city in North Madhya Pradesh, India (Figure 1). It is situated at a latitude of 26˚12'00"N and a longitude of 78˚30'00"E. The height of the dam is about 24.08 ft and the maximum depth of the reservoir is approximately 72ft. The catchment area of the reservoir is approximately 414.24sq km. The reservoir is fed with water mainly through precipitation in the months from July to September. The reservoir was mainly constructed for irrigation, pisciculture and for supplying drinking water to the Gwalior city. However, due to increase in population, the demand of water increases and as a result the reservoir is now used only for supplying drinking water to the Gwalior city. The reservoir also provides a scenic view for its beautiful fauna and flora and hence serves as a tourist spot.

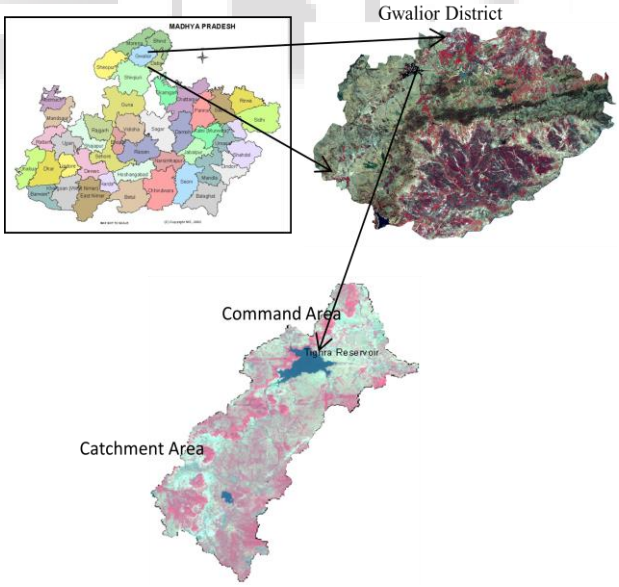


Fig. 1: Tighra Reservoir, Gwalior District, Madhya Pradesh.

III. Methodology

IRS LISS III of different acquisition periods were used in this study. The satellite images were purchased from NRSC, Hyderabad India shown in Table 1. Besides SOI toposheets of 54F/16, 54J/4 at 1:50,000 scale of the study area were used as reference map.

Tab. 1: List of sensors with its acquisition date.

S.N.	Sensor	Path/ Row	Date of acquisition	Spatial resolution (m)
1	IRS LISS III	98/53	11th April 2006	23.5
2	IRS LISS III	97/53	08th March 2007	23.5
3	IRS P6 LISS III	98/53	07th March 2008	23.5

The raw satellite images were geo-referenced with the already referenced topographic maps using image to image GCP methods i.e. map coordinates were assigned to the image data using UTM WGS84 ZONE 44 projection system. A second order polynomial was applied keeping the RMS error to 0.2 pixels. The images were then resample using nearest neighbor resampling method to obtain the geo-rectified images. Unsupervised classification was used as preliminary steps for knowing the different landscape feature of the study area with reference to SOI toposheets. About 30 clusters were generated and each cluster were assigned a new color class feature. Extensive field survey was done to obtain ground truth of the landscape feature of the catchment area. GPS and photographic camera were used to verify and confirm the information gathered through remote sensing. Supervised classification was then applied to the images using ground truth information. The similar clusters were recoded to 10 classes and the re-recoded signatures were again used as an input file to generate 07 classes of landuse and landcover. Stratified random sampling methods along with ground truth data was adopted for assessing the overall accuracy assessment. Change detection was analyzed using image differencing algorithms as this was the standard and most verified techniques for vegetation analysis. The area statistics for each of the landuse/ landcover classes was derived separately from the classification of the images for each year of the data used. Then, the area derived by each landuse/ landcover for the various periods were compared and the changes were determined.

IV. Results And Disscusion

A. Landuse/ Landcover:

For any management and conservation planning of the Reservoir, landuse/ landcover pattern in the catchment is an important factor to be assessed. The landuse/ landcover of the catchment area of Tighra Reservoir was categorized according to the changes in the spectral radiance values during different temporal periods along with secondary information such as toposheets map, old literature and limited ground survey. The landuse/ landcover is broadly classified into 7 classes as water bodies, deciduous forest, open scrub, agricultural plantation, mixed barren land, Built-up and fallow land as shown in Table 2.

Table. 2: Landuse/landcover classification used for the catchment area of Tighra Reservoir, Gwalior.

Landuse/landcover types	Description
Water bodies	Includes all the water bodies, rivers, well, tanks, etc. containing clear open water.
Deciduous forest	The catchment area is mainly covered by deciduous trees all around the seasons. These trees can be classified as dry and green deciduous according to the seasons.
Open scrub	Open scrub mainly consists of Acacia species were very much dominant over the area. This class is also included in the forest types.
Agriculture area	Includes area with crop plantation and arable land.
Mixed barren land	Includes area of barren land and rocky cliffs.
Built-up	Includes area of villages, roads, government buildings construction, etc.
Fallow Land	Includes area of agricultural field where the crop has been harvested and is preparing for another plantation.

Table. 3: Land use/ Land cover of Catchment area of Tighra Reservoir in terms of Area Square miles and percentages.

Sr. No.	Landuse/ landcover	Apr-06		Mar-07		Mar-08	
		Area sq miles	Area %	Area sq miles	Area %	Area sq miles	Area %
1	Water bodies	5.5	3.4	3.3	2	2	1.26
2	Deciduous forest	31.8	19.6	19	11.8	14.2	8.771
3	Built-up	9	5.6	10.3	6.4	17.5	10.79
4	Open Scrub	38.3	23.7	30.4	18.8	36.4	22.47
5	Agriculture area	16	9.9	30.1	18.6	21.4	13.25
6	Fallow	39.4	24.4	41.4	25.6	44.1	27.26
7	Mixed barren	21.8	13.5	27.2	16.8	26.2	16.2
		161.8	**100**	**161.8**	**100**	**161.8**	**100**

The most extensive landcover in April 2006 is fallow land of about 39.4 sq miles (24.4%) followed by open scrub of about 38.3 sq miles (23.7%) respectively (Figure 2). Deciduous forest covered an area of about 31.8 sq miles (19.6%) and mixed barren occupies about 21.8 sq miles (13.5%) of the catchment. Agricultural land cover an area of about 16 sq miles (9.9%) while built-up covers about 9.0 sq miles (5.6%) of the catchment. Water bodies cover about 5.5 sq miles (3.4%) of the catchment area. Similarly, in March 2007 the landuse/landcover was extensively covered by fallow land of about 41.4 sq miles (25.6%) of the catchment area. Open scrub covers about 30.4 sq miles (18.8%) followed by agricultural land about 30.1 sq miles (18.6%) respectively. Mixed barren comprises an area of about 27.2 sq miles (16.8%) of the catchment followed by deciduous forest which cover an area of about 19.0 sq miles (11.8%). Built-up covered an area of about 10.3 sq miles (6.4%) while water bodies covered about 3.3 sq miles (2.0%) of the catchment area. In March 2008, the spectral radiance of fallow land was estimated to be about 44.1 sq miles covering about 27.26% of the catchment. This is followed by open scrub which occupies about 36.4 sq miles (22.47%), mixed barren land of about 26.2 sq miles (16.2%), agriculture area of about 21.4 sq miles (13.25%), built-up of about 17.5 sq miles (10.79%) and deciduous

forest of about 14.2 sq miles (8.77%) of the catchment area. Water bodies were estimated to be very low during this period which covers an area of about 2 sq miles i.e., 1.26% of the catchment area.

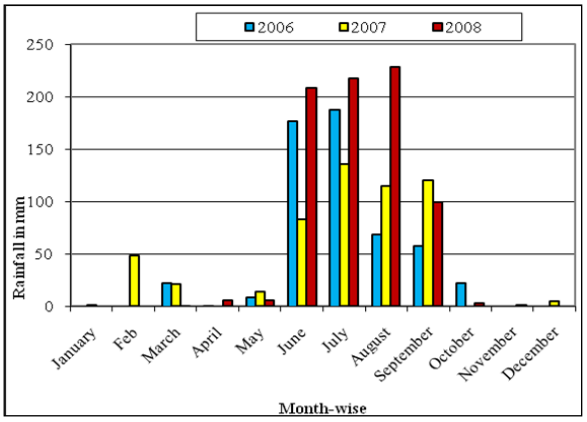
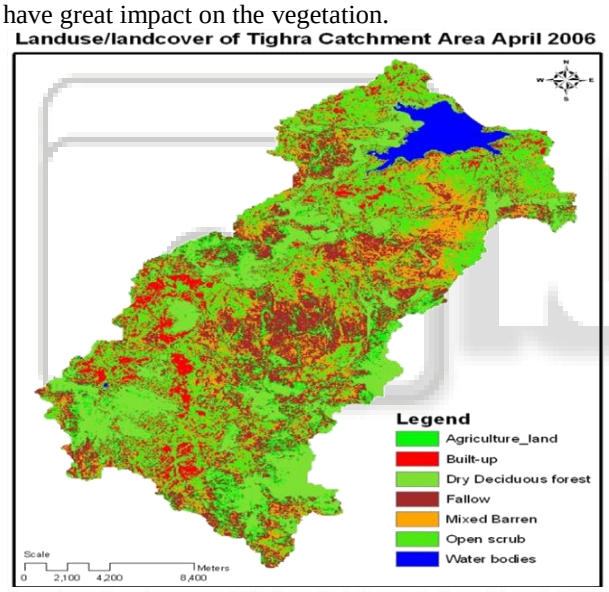
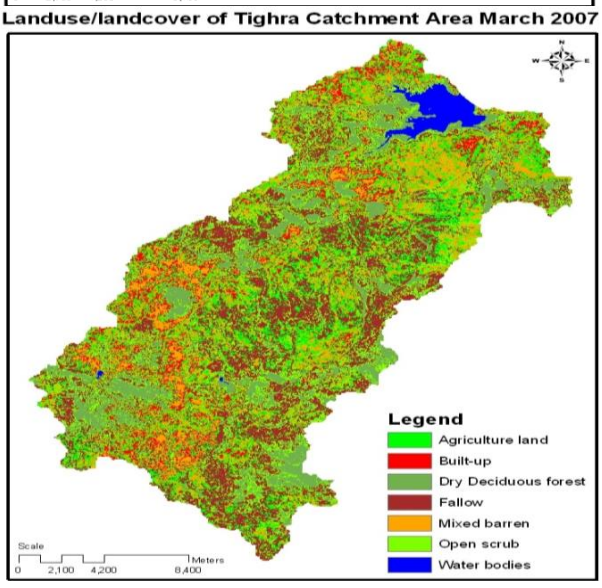


Fig. 2: Monthly rainfall in mm from 2006-2008

Figure 2 shows monthly rainfall data from 2006 to 2008. From 2006-2008, maximum rainfall was observed during monsoon periods (June-September) in 2008 to about 230mm while minimum rainfall was observed in 2007 to about 140mm during monsoon periods. Rainfall data also have great impact on the vegetation.





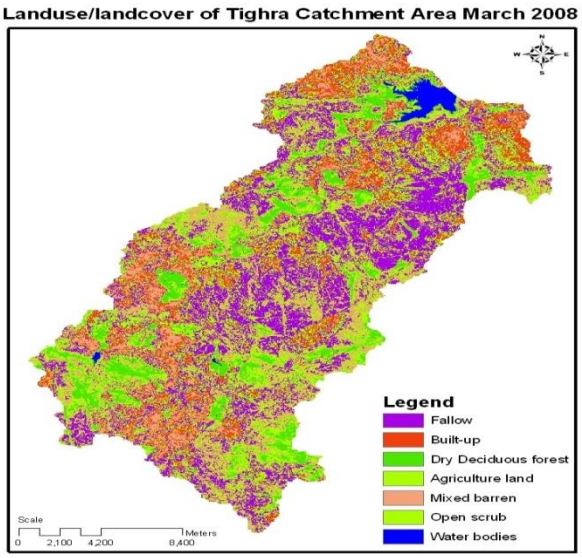


Fig. 3: Landuse/Landcover of catchment area of Tighra Reservoir during April 2006, March 2007 and March 2008.

B. Accuracy Assessment:

The overall accuracy of the landuse/landcover classification is estimated as 94.69% and the Kappa statistics as 0.9391 indicating high accuracy of the assessment. The confusion was created between the mixed barren and the built-up type during classification as the spectral radiance is almost similar. However, this was overcome by using band ratio and indices. The overall Kappa statistics indicates 0.91 to 0.93 implying the high relation between the classified maps.

C. Change Detection Analysis

The most prominent changes from 2006 to 2007 in catchments of Tighra Reservoir is the increased in agricultural land by about 8.7% followed by mixed barren and fallow land of about 3.3% and 1.2% (Table 4). Built-up is also observed to increase in area by about 0.8% respectively. Deciduous forest and open scrub both shows decreased in vegetation covered to about 7.8% and 4.9% respectively. Water bodies are also observed to decrease to about 1.4% by 2007. Similarly, from 2007 to 2008, agricultural land is observed to decrease by about 5.35% which is followed by deciduous forest to about 3.03% respectively. Water bodies and mixed barren land are also shown to decrease in area to about 0.74% and 0.6% approximately. However, built-up areas were calculated to increase in area in 2008 by about 4.39% approximately. Open scrub and fallow land were also observed to increase to about 3.67% and 1.66%

Table. 4: Changes in landuse/landcover in catchment area of Tighra Reservoir from 2006-2008.

Sl No.	Landuse/ landcover	Area (%)		
		April 2006-March 2007	March 2007-March 2008	April 2006-March 2008
1	Water bodies	-1.4	-0.74	-2.14
2	Deciduous forest	-7.8	-3.03	-10.83
3	Built-up	0.8	4.39	5.19
4	Open Scrub	-4.9	3.67	-1.23
5	Agriculture area	8.7	-5.35	3.35
6	Fallow	1.2	1.66	2.86
7	Mixed barren	3.3	-0.6	2.7

(-) indicates decrease, (+) indicates increase respectively. Similarly, from 2006-2008, agricultural land and built-up were calculated to increase to about 3.35% and 5.19% respectively. Fallow land and mixed barren were also observed to increase by about 2.86% and 2.7% approximately. However, deciduous forest, water bodies and open scrub were noticed to decrease in area to about 10.83%, 2.14% and 1.23% respectively.

V. CONCLUSION

From this study, the landuse/landcover in the catchment area of Tighra Reservoir has changed over the years. Through GIS and Remote Sensing technologies, seven (07) broad classes of landuse/landcover were analyzed and mapped from 2006 to 2008 using IRS P6 LISS III. These were water bodies, deciduous forest, built-up, open scrub, agriculture, fallow land and mixed barren. The result shows that from 2006 to 2008, there were decrease in water bodies (-2.14%), deciduous forest (-10.83), open scrub (-1.23%) and increase in built-up (5.19%), agricultural land (3.35%), fallow (2.86%), mixed barren (2.7%). The landuse/landcover changes in the catchment area were due to unplanned urbanization and encroachment of land for agriculture, besides sedimentation in the reservoir. Therefore, it is concluded here that unplanned urbanization and encroachment of land for agriculture should be checked. It is also suggested that local people should be educated about the importance of the catchment area and the impact that will affect the reservoir from any unplanned activities within the catchment.

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