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Monitoring & analysis of wastelands and its dynamics using multi-resolution and temporal satellite data in part of Indian state of Bihar

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ABSTRACT

Voluminous increase in population has created an excessive demand for productive land. At the same time land degradation because of desertification, soil salinity, waterlogging, floods/droughts, excessive soil erosion and unscientific agricultural practices has resulted in the creation of vast stretches of wastelands. This has necessitated adoption of scientific measures for increasing land productivity and bringing more areas under cultivation/forests. In the present study, the multi-temporal satellite images of IRS P6 LISS-III were used to map wastelands dynamics over different seasons. An attempt has also been made to evaluate the potential of high spatial resolution LISS IV (*5.8* m) data over moderate spatial resolution LISS-III data (23.5 m) from the Indian Remote Sensing Satellite for delineation of wastelands in a portion of the Indo-Gangetic plains of northern India. Visual interpretation based on image characteristics and a prior knowledge of the study area was used to delineate wasteland classes. Using LISS III data, 1372.92 and 605.90 hectares of land areas are identified as affected by seasonal and permanent waterlogged respectively, and using LISS IV, 1113.33 and 105.84 hectares of land areas are identified as affected by seasonal and permanent waterlogged respectively. Wasteland classes such as seasonal and permanent waterlogged could be further separated into wasteland classes such as land with dense scrub, land with open scrub, degraded pastures/grazing lands and degraded land under plantation using higher resolution satellite data.

Keywords: Wasteland dynamics, Satellite data, GIS, Eastern-Gangetic plains, Waterlogging

1. Introduction

Increasing pressure of population has created an excessive demand for food, fodder, fuel and fibre. This has necessitated adoption of scientific measures for increasing land productivity and bringing more areas under cultivation/forests. At the same time land degradation due to desertification, soil salinity, waterlogging, floods/droughts, excessive soil erosion and unscientific agricultural practices has resulted in the creation of vast stretches of wastelands. About 16 per cent of the country's geographical area is under wastelands (Jaga et al., 1993). Wasteland means degraded land which can be brought

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under vegetative cover with reasonable efforts, and which is currently under-utilized, or land which is deteriorating due to lack of appropriate water and soil management or on account of natural causes (Saha et al., 1990). Information on geographical location, aerial extent and spatial distribution of wastelands is essential for their effective management and sustainable development (Gautam and Narayan, 1988).

The Indo-Gangetic Plains are drained by some of the largest river systems in the world. These plains are also severely affected by frequently occurring disastrous floods, and are presently regarded as the worst flood affected region in the world (Agarwal and Narain, 1996). Almost every year, monsoon floods in the Indo-Gangetic Plains cause countless misery to the inhabitants living on the floodplains. The plains of north Bihar in eastern India have recorded the highest number of floods in India in the last 30 years (Kale, 1997). In India, an estimated 2.46 Mha of land is reported to have suffered from waterlogging (Anonymous, 1991). Water logging, closely associated with salinization and/alkalinization, continues to be a threat to sustained irrigated agriculture, affecting an estimated 6 million ha of fertile land in India (Anonymous, 1976).

India is estimated to have about 58.2 million hectares of wetlands (Prasad et al., 2002) many of which are distributed around the Indo-Gangetic plains. Generally regarded as ‘‘a water-surplus area’’ (Ghosh et al., 2004) the entire region is characterized by palaeo levees, swamps or flood basins locally called ‘‘Chaurs’’ relict palaeo channels aggraded to different extents, meander belts, ox-bow lakes, and cut-off loops (Ahmad, 1971). Waterlogging in the low lying areas is created due to seepage from irrigated uplands and seepage from canal water with inadequate water management practices (Brahmabhatt et al., 2000). Pandey et al., (2010a) examined the impact of natural and anthropogenic features on flood induced waterlogging in parts of Bihar plains, and revealed that canals and railway line induced highest waterlogging conditions.

Spaceborne multispectral data, by virtue of providing synoptic views of fairly large areas at regular intervals, have been found to be very effective in providing the necessary information on salt-affected soils and waterlogged areas in a timely and cost-effective manner (Bouwer et al., 1990, Dwivedi et al., 2001). In visual interpretation of satellite data, high soil moisture and surface waterlogged areas are identified as deep dark grey to light black in color (Mandal and Sharma, 2001). Pandey et al., (2010b) described that areas with high waterlogging risk in northern Bihar plains corresponds to high flood hazards and vulnerability due to poor socio-economic conditions in these areas.

In the present study, multi temporal satellite data (IRS-P6 LISS-III) of the years 2005-06 were used to evaluate the area statistics and dynamics of wastelands of Bhagwanpur Block, District-Vaishali (Bihar). This study also highlights the utility of high resolution satellite data (IRS-P6 LISS-IV) in mapping of wastelands.

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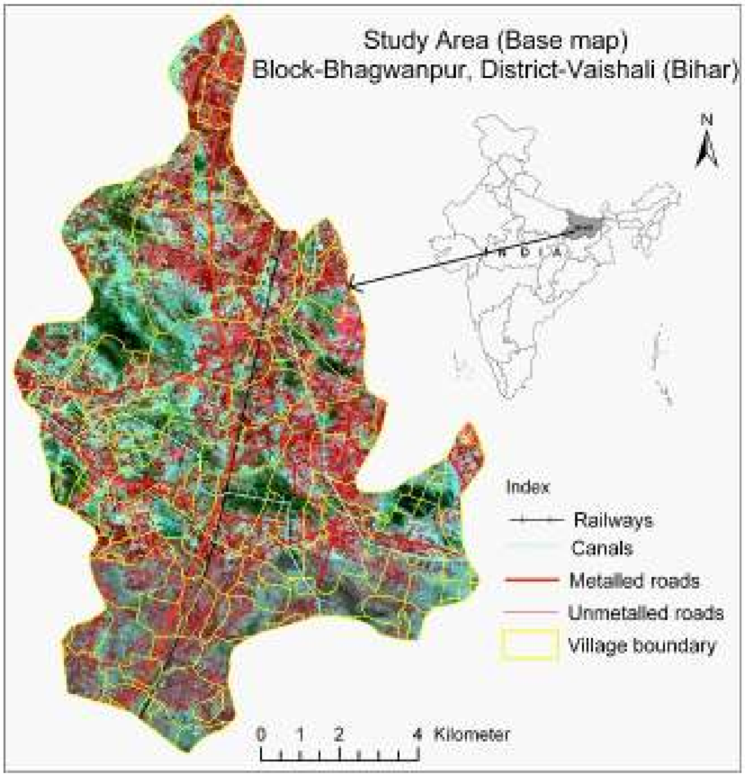

Figure 1: Location map of the study area

2. Study Area

The study area is a part of the Eastern Gangetic Plain (Figure 1). The area under investigation is located between 85°14'00" to 85°22'00" E longitudes and 25°45'00" to 25°56'00" N latitudes, covering a total area of 110 sq km. The climate of the study area is tropical to sub-humid tropical. The average annual rainfall in the study area is around 1200mm, and 85% of the rainfall occurs during 4 months, spanning from June to October. The mean relative humidity varies from a minimum of 40% in April to a maximum of 85% in the month of July. The temperature varies from 5°–25°C in winter to 20°- > 40°C during summer. The major cropping pattern in the study area is cereal based, and rice, maize and wheat are the dominant crops. Besides this, some cash crops such as sugarcane and tobacco are also grown in the area.

3. Materials and Method

To study the spatial dynamics of wastelands, and to evaluate the utility of high resolution satellite data for wasteland mapping, the IRS P6 satellite data and topographical maps were used (Table 1 and 2).

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Table 1: Details of satellite data used in the study

Sensor	Date of Acquisition	Spatial Resolution
(IRS-P6 LISS-III)	31- October -2005	23.5m
(IRS-P6 LISS-III)	09-February-2006	23.5m
(IRS-P6 LISS-III)	22-April-2006	23.5m
(IRS-P6 LISS-IV)	13- December-2006	5.8m
(IRS-P6 LISS-IV)	08-April-2007	5.8m

Table 2: Details of topographical maps

Source of publication / year	Toposheets number	scale
Survey of India (SOI) / 1973	72 G1,G5	1:50 000

Satellite images available in raster format need to be geo-referenced in a coordinate system, so as to generate spatial information to be handled subsequently in a GIS environment. The processes of geo-referencing involve assigning a coordinate system and transforming the raster image to input coordinates system. This facilitates viewing, querying and analyzing the geographic data. The dynamic nature of wasteland categories warrants the uses of multi-season satellite data for their accurate delineation. Hence, such images need to be geo-referenced in a common coordinate and projection system. The satellite data (IRS-P6 LISS-III and IRS-P6 LISS-IV) were geo-referenced using an image-to-map registration technique taking LANDSAT ETM^+ image as base layer. Field verification is an important component in mapping, and its validation exercise. Field checks were carried out to acquire field characteristics of wasteland areas, and to relate them with corresponding image characteristics. The sample areas to be verified in the field were initially identified and located precisely on the topographical sheets of Survey of India. The field study enabled to establish the relationship between image interpretation elements (colour, texture, pattern, shape, size, association, etc.) and wasteland classes. This facilitated the on-screen visual interpretation for delineation of wasteland classes and was carried out on IRS-P6 LISS-III imagery of 2005-06. This provided the spatial extent, distribution and dynamics of wastelands. Then IRS P6 LISS-IV satellite image was used to redefine the wasteland boundaries and classes. In order to evaluate the utility of higher resolution satellite data over moderate resolution satellite data.

5. Results and Discussion

Visual interpretation based on image characteristics, and a prior knowledge of the study area was carried out to delineate wasteland areas (Figure 2). Since the area receives rainfall during early June to late October, intermixing of different wasteland classes occur for this period due to the growth of hydrophytic grasses and weeds. To overcome this, the Rabi season (February) image was considered as base image for delineation of different wasteland classes, where separation among land use /land cover classes is more. This helped in better identification and mapping of wastelands. An area is said to be

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waterlogged when the water table rises to an extent that the soil pores in the root zone of a crop become saturated, resulting in restriction of the normal circulation of air, decline in the level of oxygen and increase in the level of CO_2 (Anonymous, 1976). Surface waterlogged areas and water bodies exhibit similar reflectance characteristics, which can be discriminated from other associated land covers like salt affected soils, forest, fallow land and crop lands by virtue of the very low spectral response in all the spectral bands, especially in the near infrared (0.77- 0.86μm) (Dwivedi et al., 1998). To ascertain the waterlogging dynamics, the water logged areas have been categorized into seasonal water and permanent water logged areas. An area, which remains waterlogged throughout the entire year, is termed as permanent waterlogged area, and remaining of the waterlogged area, which generally dried up before the end of Rabi cropping season ending by mid April, is termed as seasonal waterlogged area. Seasonally waterlogged areas appear very clear in different shades of blue and cyan in standard false colour composite (FCC) image generated from space borne multispectral data, and acquired during the months November and December (Dwivedi et al., 1999).

The multi-temporal satellite images of IRS P6 LISS-III were used to map waterlogging dynamics over different seasons. It is estimated that 1372.92 and 605.90 hectares of area are affected by seasonal and permanent waterlogging respectively (Table 3). A fairly large area is occupied under water during monsoon season (October). With the passage of time, the outer boundaries of such waterlogged areas get dried up (Seasonal waterlogged), and only central portion (core area) remains waterlogged (Permanent waterlogged) till the end of Zaid season (April).

Then IRS P6 LISS-IV satellite images of December and April were used to map the wastelands. It was estimated that 1113.33 and 105.84 hectares of area are affected by seasonal and permanent waterlogging respectively using LISS IV (Table 3). A total of 1978.82 hectares of land area is categorized as permanent and seasonal waterlogged using moderate resolution satellite data (LISS III), whereas 1219.17 hectares of land area is categorized as permanent and seasonal waterlogged using high resolution data (LISS IV). The permanent and seasonal waterlogged classes could be further categorized into land with dense scrub and land with open scrub using high resolution satellite data (Figure 3). Examples of wasteland classes interpreted on LISS III and LISS IV are given at figure 4-6. A reduction of 759.65 hectares wasteland area especially in classes like permanent and seasonal waterlogged is observed. This is because of further categorization of these classes into land with dense scrub and land with open scrub by using high resolution satellite data. Few new wasteland classes such as degraded pastures/grazing lands and degraded land under plantation could also be identified on higher resolution satellite images (LISS IV). These wasteland classes could not be mapped using moderate spatial resolution satellite images (LISS-III).

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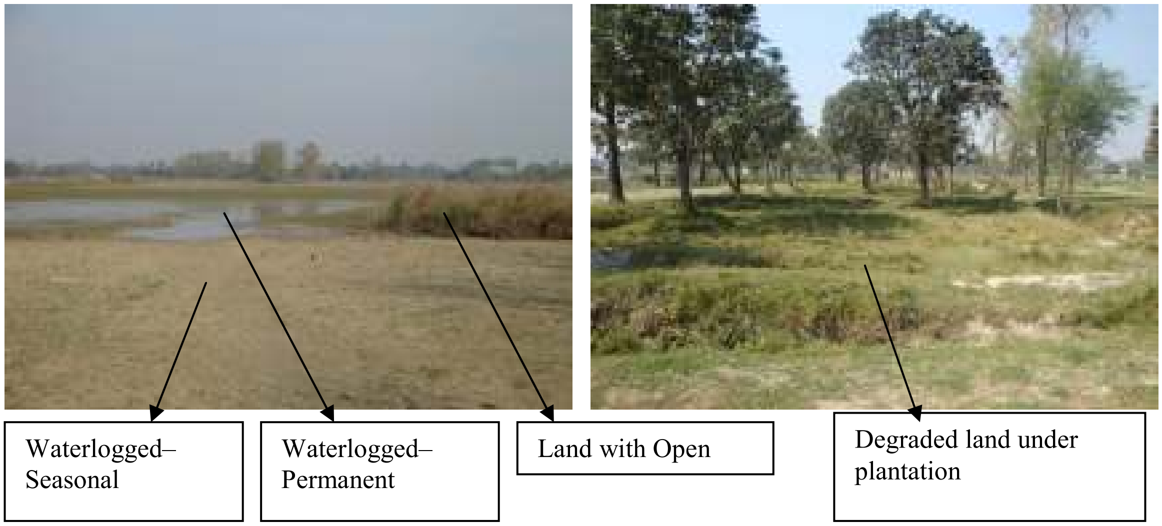

Figure 2: Photograph showing various wastelands classes identified in the study area during field verification.

Table 3: Wasteland statistics generated from LISS-III and LISS-IV sensors

Wasteland Categories	Area in hectares (LISS III)	Area in hectares (LISS IV)	Remarks
Land with dense scrub		64.79	Identified in LISS IV image
Land with open scrub		107.80	Identified in LISS IV image
Waterlogged-seasonal	1372.92	1113.33	Further classified as Land with Dense scrub and Land with Open scrub in LISS IV image
Waterlogged-permanent	605.90	105.84	Further classified as Waterlogged-Permanent in LISS IV image
Degraded pastures/grazing lands		29.89	Identified in LISS IV image
Degraded land under plantation		4.97	Identified in LISS IV image

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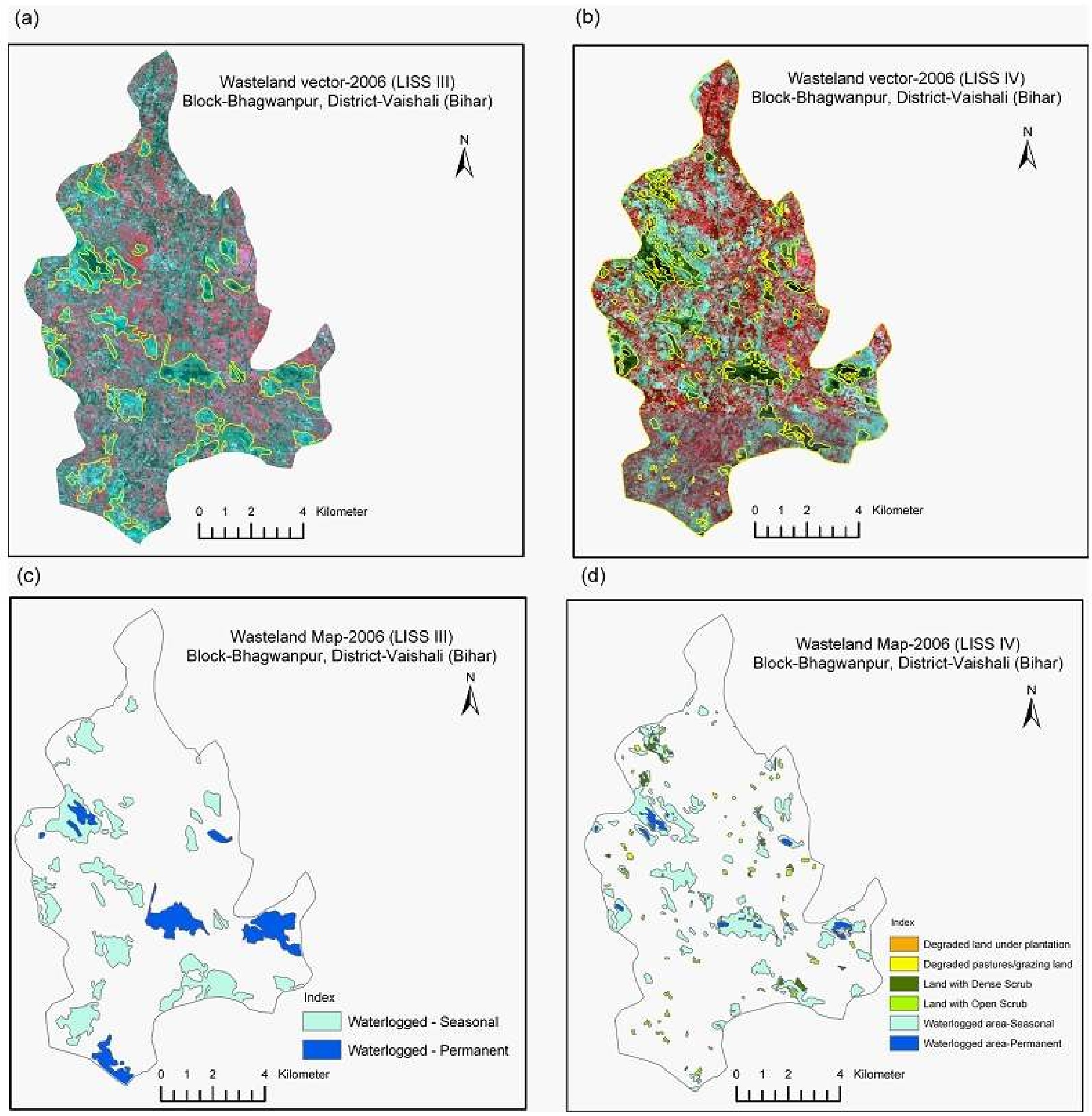

Figure 3: Wasteland vectors (a) LISS III (b) LISS IV with corresponding satellite images and delineated wasteland classes (c) LISS III (d) LISS IV.

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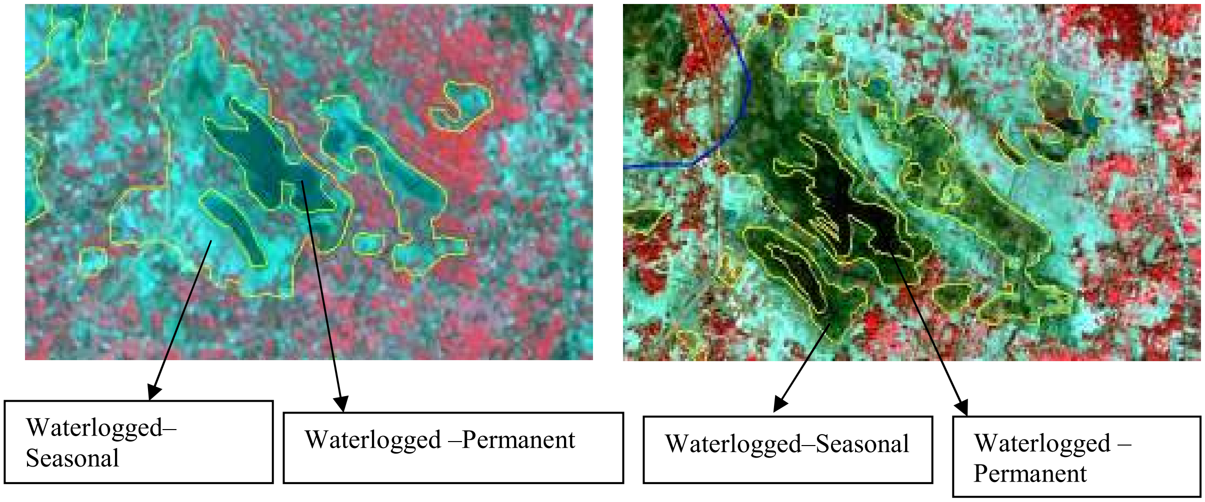

Figure 4: (a) IRS P6 LISS-III (b) IRS P6 LISS-IV (2005-2006)

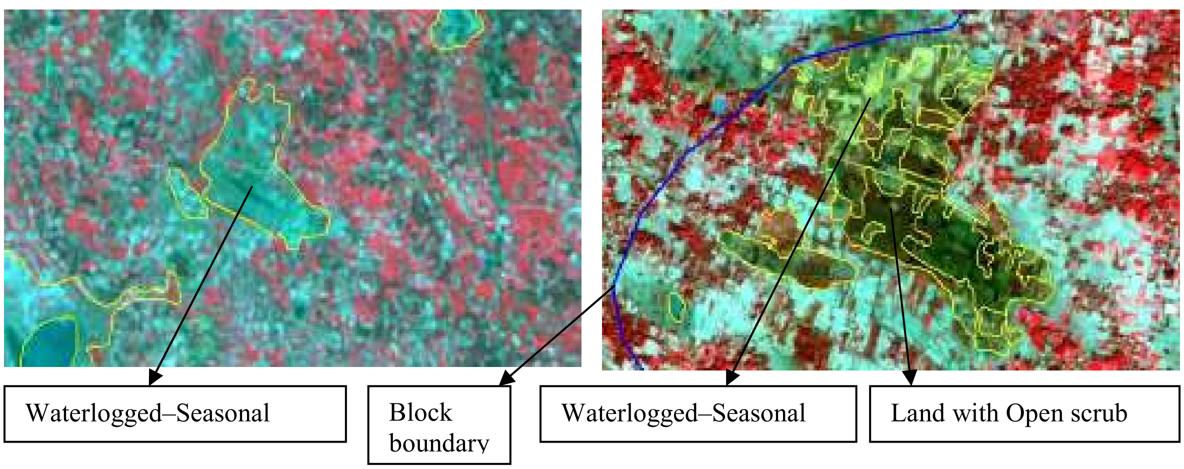

Figure 5: (a) IRS P6 LISS-III (b) IRS P6 LISS-IV (2005-2006)

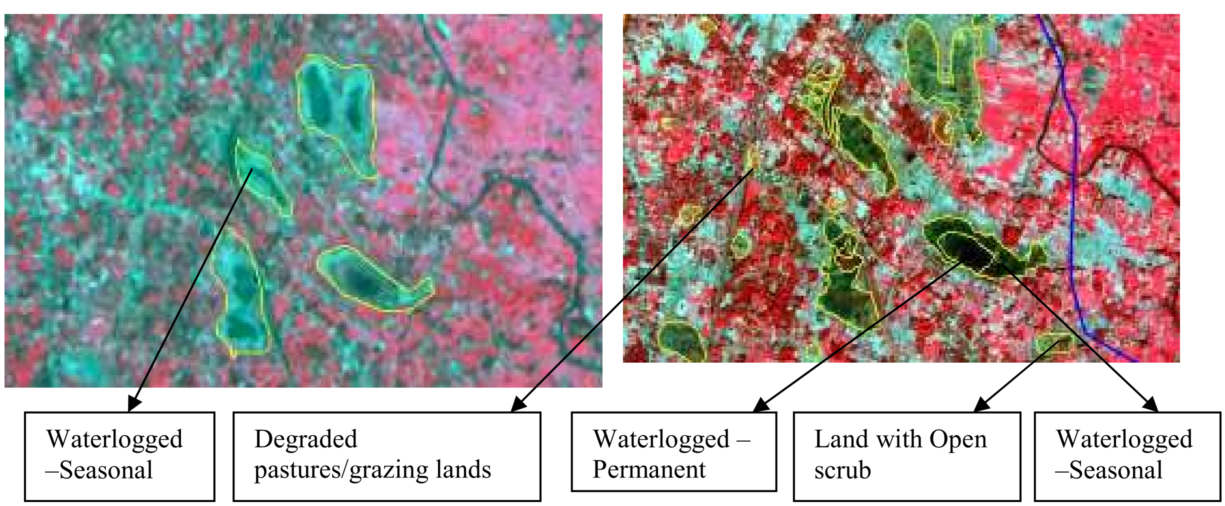

Figure 6: (a) IRS P6 LISS-III (b) IRS P6 LISS-IV (2005-2006)

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6. Conclusion

Using higher spatial resolution satellite data (IRS-P6 LISS-IV) 1426.62 hectares of land area is classified as wasteland in the study area, which is 552.2 hectares less than the area mapped from moderate spatial resolution satellite data (IRS-P6 LISS-III). Wasteland classes such seasonal and permanent waterlogged could be further separated into wasteland classes such as land with dense scrub, land with open scrub. Few more wasteland classes also could be identified like degraded pastures/grazing lands and degraded land under plantation using higher resolution satellite data (IRS-P6 LISS-IV). It can be stated that LISS IV data facilitates interpretation to further differentiate a wasteland class delineated on moderate spatial resolution satellite data. Moreover, these data are found to be useful in achieving high mapping accuracy in delineation of wasteland classes. This signifies the advantages of higher spatial resolution satellite data over moderate spatial resolution satellite data for wastelands study.

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