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Geospatial Technique for Land use/Land cover Mapping using Multi-Temporal Satellite Images: A case study of Samastipur District (India)

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Abstract

The present study attempts to generate land-use/land-cover (LULC) map using standard (FCC) satellite imagery of IRS P6 LISS III for Samastipur District (India). Multi temporal IRS satellite images acquired during three crop growing seasons viz., Kharif (July-November), Rabi (December-March) and Zaid (April-July) were used to map the spatial and temporal variability in cropping pattern and other land use and land cover classes using visual interpretation technique. Among the various classes of landuse/ land cover, agricultural land is the predominant category occupying 2276.58 sq km (85.02 %) of the area. Among agricultural land, agricultural land-two crop area comprising (32.13%) and agricultural land-rabi crop (29.88%) constitute the dominant categories. It is estimated that built up constitutes 219.65 sq km comprising 8.20% of the total area. Based on selective field checks, the overall classification accuracy of the LULC map derived from the satellite image was 90% with the Kappa coefficient of 0.83. Therefore, integrated geospatial approach, incorporating remote sensing and GIS techniques, is a powerful technique for mapping and evaluating the LULC categories.

Introduction

The intensification of agricultural practices under the auspices of the “Green Revolution” that includes better seeds, extensive fertilizer use, and irrigation has dramatically altered the relationship between humans and environmental systems across the world (Ozdogan *et al*., 2010, Pandey *et al*., 2015, Pandey *et al*., 2012). Since independence the population has increased by 284 percent (363 to 1033 M) and food grain production by 386 percent (51 to 196 MT) whereas 260 M population still lives below poverty line (National Remote Sensing Agency, 2004). The country has 150 M hectares of agricultural area and about 24% GDP is met from the agricultural production. The highly dependent crop production systems are sensitive to monsoon climate, drought and cyclones etc. and as well suffers from unscientific irrigation/fertilization practices as well as pest attacks (National Remote Sensing Agency, 2006, Singh *et al*., 2011). Apart from this, trend of switching to commercial non-food crops is cause of concern. While food grain production increased only by 1.7 times over the last two decades, non-food grain production quadrupled during the same period (Sreenivas *et al*., 2015).

Land use and land cover (LULC) attributes in a watershed directly influence water driven erosion, knowledge of these parameters plays an important role in ranking erosion potential and in prioritizing and developing sustainable watershed and agricultural management practices (Renard *et al*., 1997). Accurate LULC maps can be effective tools in aiding soil erosion control efforts, as such maps can play an important role in watershed management as a whole and help in deciding what sort of lands are capable of sustaining agriculture and which are not (Cihlar, 2000, Renschler and Harbor, 2002). Remotely sensed data and the potential to distinguish between different characteristics of land features from this data provides great potential for rapidly creating accurate LULC maps (Homer *et al*., 2004, Yadav *et al*., 2015, Singh *et al*., 2014a, Singh *et al*., 2014b).

Land use and land cover (LULC) classes characterize important information of natural landscape and human activities on the Earth's surface (Gong *et al*., 2011, Kanga *et al*., 2013). In recent decades, remotely sensed data have been widely used to provide the land use and land cover information such as degradation level of forests and wetlands, rate of urbanization, intensity of agricultural activities and other human-induced changes (Kanga *et al*., 2015, Kanga *et al*., 2014, Singh *et al*., 2014c, Singh *et al*., 2014d).

Land cover describes the physical appearance of the earth’s surface, while land use is a land right related category of economically using the land (Kanga *et al*., 2011, Nagarajan and Poongothai, 2011). Thus, a knowledge of both land use and land cover is important for land planning and land management activities. The USGS devised a land use and land cover classification based on aerial photography of 1970-1980 on 1: 250,000 using hierarchical classification system (Anderson *et al*., 1976). In India, National Remote Sensing Centre, Indian Space Research Organisation (ISRO) developed a 22 fold classification system for nationwide LULC mapping using multi-temporal satellite images of IRS- LISS-I data of kharif (July-october) 1988 and Rabi (November-March) 1989 were used to generate details of cropland in kahrif and rabi seasons, the area under double crop, fallow lands, wasteland, waterbodies etc (National Remote Sensing Agency, 1989).

The accuracy of spatial data has been defined by the United States Geological Survey USGS, 1990 as: "Accuracy assessment or validation is an important step in the processing of remote sensing data. It determines the information value of the resulting data to a user. During the last two decades, numerous studies have been published concerning accuracy assessment of (LULC) classifications (Congalton, 1996, Rosenfield *et al*., 1986, Foody, 1992, Pandey *et al*., 2013). In the present study, multi temporal satellite data from IRS-P6 LISS-III sensor were used to monitor the spatial extent and distribution of LULC during the three seasons viz., Kharif, rabi and Zaid in the year 2005-2006. IRS-LISS III data with multi-spectral bands provide reflectance over green, red, near infrared and shortwave infrared region and this spectral information over different seasons enables the discrimination of crop and other vegetation more reliably using various techniques (Nathawat *et al*., 2010).

Study area

Samastipur district is one of the districts of North Bihar. The district area falls in Survey of India toposheet no 72G, 72 F and 72 K. The district lies between 25º 27’ to 26º 05' north latitudes and 85º 31’ to 86º 23' east longitudes. The district is bounded on the north by the Baghmati river which separates it from Darbhanga district, on the west by Vaishali and some part of Muzaffarpur districts, on the south by the Ganges, and on the east by Begusarai and some part of Khagaria districts. The district covers a total area of 2677.42 sq km (figure.1). The climate of this district is on the whole dry, hot in summer and mild cold in winter. Agriculture is the main economic occupation of the district and about 83 per cent of the total working population depends on it. Rabi is dominant crop and wheat, pulses and edible oil seeds are also grown here. The soil is sandy loam with moderately high organic matter, which is suitable for vegetables and spices cultivation. In 2011, Samastipur had population of 4,261,566 whereas in 2001 census it was 3,394,793. There was change of 25.53 percent in the population compared to population as per 2001. In the previous census of India 2001, Samastipur district recorded increase of 25.63 percent to its population compared to 1991. (http://www.census2011.co.in/census/district/73-samastipur.html).

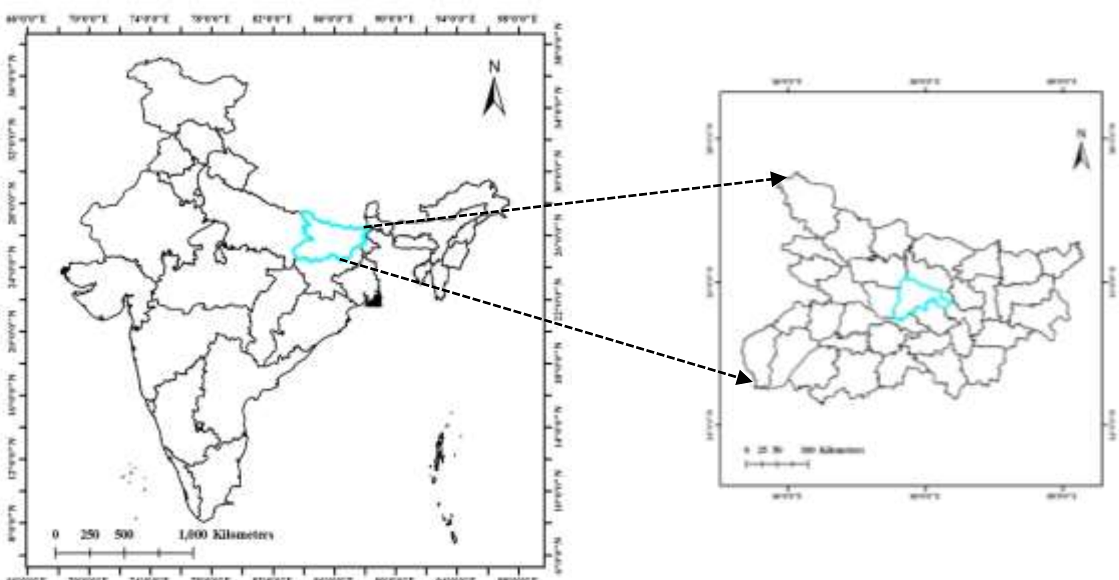

Figure 1: Location map of the study area

Data used and methodology

Multi temporal IRS satellite images acquired during three crop growing seasons viz., Kharif (July-November), Rabi (December-March) and Zaid (April-July) were used to map the spatial and temporal variability in cropping pattern and other land use and land cover classes (Table 1).

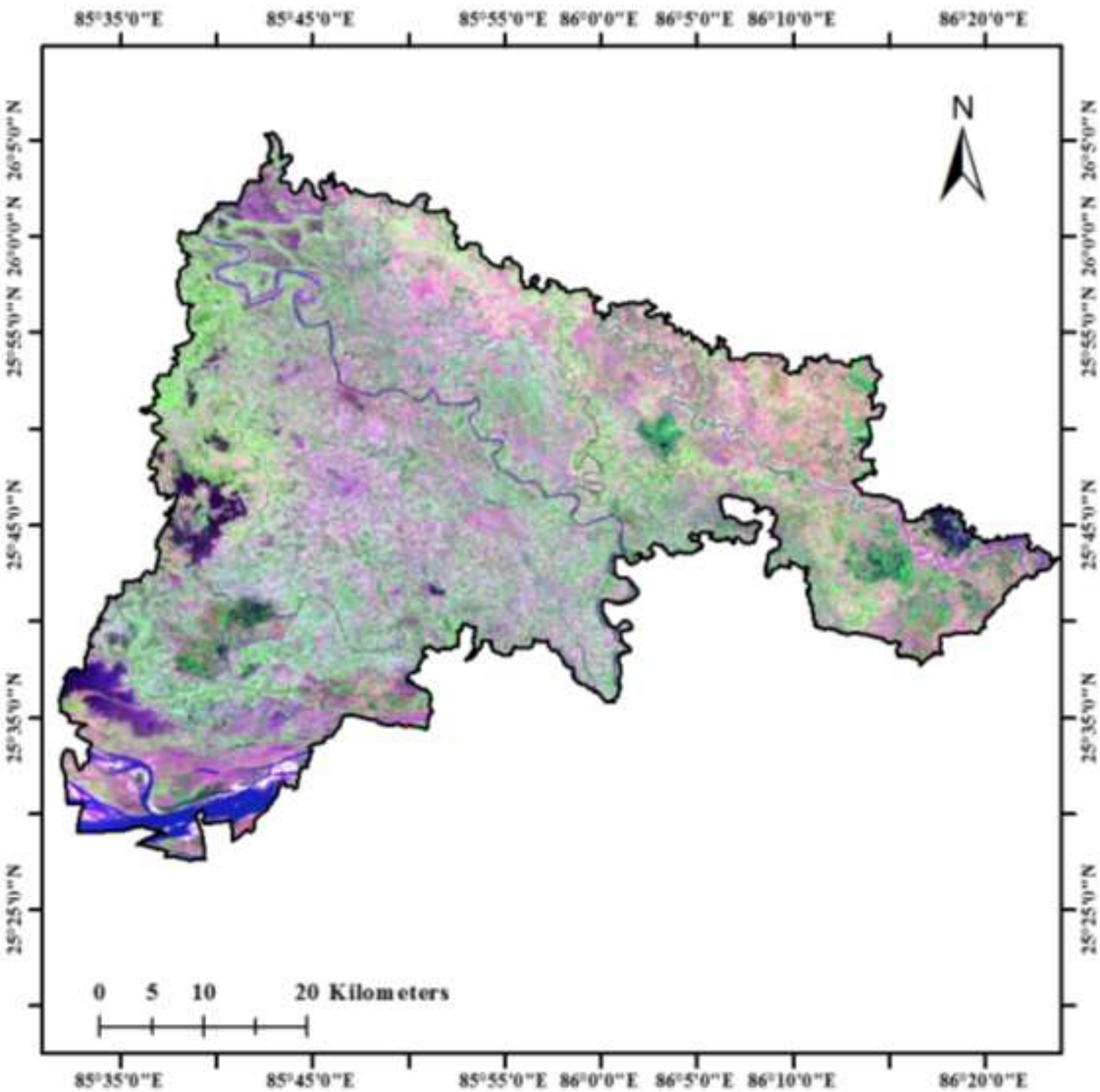

Figure 2: Satellite image of study area.

To generate thematic information for subsequent use in GIS platform, satellite images need to be georeferenced in a suitable coordinate system. The processes of georeferencing involve assigning a coordinate system and transforming the raster image to input coordinates system. Therefore all the images need to be georeferenced to a common coordinate and projection system to facilitate viewing, querying and analyzing the geographic data. Field verification is an important component during mapping, for accuracy assessment of mapped categories. Therefore field checks were carried out to acquire field characteristics of LULC of an area, and to relate them with corresponding image characteristics. The sample area to be verified in the field were initially identified and located precisely on the topographical maps of Survey of India (SOI). The field study established the relationship between image interpretation elements like colour, texture, pattern, shape, size, association, etc. and the LULC categories. On-screen visual interpretation of satellite images was carried out for delineation of various LULC categories which was subsequently used to examine the spatial extent, distribution and dynamics of LULC classes (figure 2). LULC classification scheme given by NRSC (2004) was adopted in classifying various categories of LULC categories in the area (figure 3).

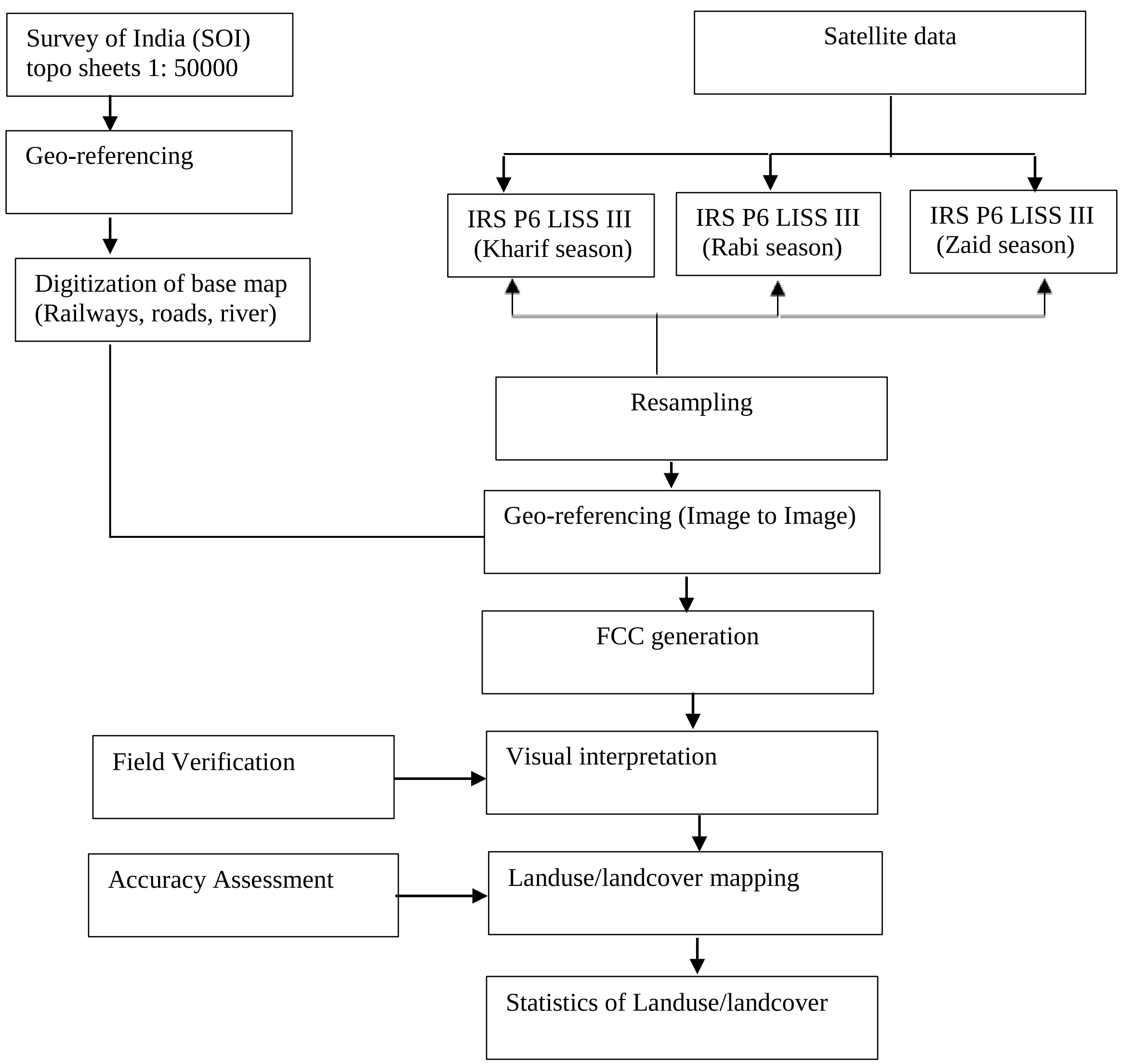

Figure 3: Flow chart of the methodology for LU/LC mapping.

Table 1 Details of IRS P6 LISS III satellite images used in the study

S.No.	**Path no.**	**Row no.**	**Date of acquisition (Kharif season)**	**Date of acquisition (Rabi season)**	**Date of acquisition (Zaid season)**
1	105	53	17/10/2004	05/03/2006	03/04/2005
2	105	54	05/11/2005	14/02/2005	22/04/2006

Results and Discussion

Land Cover is defined as observed physical features on the Earth's Surface. When an economic function is added to it, it becomes Land Use. (FAO, 2005). The study uses multi-temporal geometrically co-registered IRS P6–LISS III data for three seasons, viz. winter (January to March); pre-monsoon (April to May) and post-monsoon (mid-October to December) for LULC mapping. We used first order polynomial equation with allowable Root Mean Square (RMS) error of less than one pixel (default) for geometric rectification. The RMS error was found to be 0.4 pixels (less than 9.2 m) in case of LISS-III data, with minimum of 15 Ground Control Points GCPs in each scene having a range of 0.35 to 0.60 pixels (i.e., 8 to 15 m). The classes, namely, built up, wasteland, cropland, water bodies, wetland, grass land and scrubland were mapped using visual interpretation technique. Ground truth data was collected and the errors and discrepancies in the LULC map were corrected using the ground truth data and ancillary information supplemented by existing maps to produce the final map (figure 4a-4d). The on-screen image interpretation technique was used to prepare the LULC maps with the minimum mapping unit of 2.5 hectares.

The geographic area of Samastipur district is 2677.42 sq km in which agricultural land occupy 2276.58 sq km (85.02 %) area. Area statistics of various categories of LULC mapped in area is given in Table 2. Among the various categories of agricultural land present in the area (figure. 5), five categories of agricultural land viz., agricultural land-two crop area (32.13 %), agricultural land-Rabi crop (29.88%), agricultural land-more than two crop (10.67%), agricultural land-Kharif crop (5.37%) and agricultural land-current fallow (6.98%) constitute the dominant categories. The people of the northern Bihar plain are primarily dependent on agriculture and are of low-income group (Pandey *et al*., 2010). The figure clearly indicates that district has 85% of main workers as agricultural labourers and cultivators and are directly dependent on agriculture. Therefore, in the events of flooding, a huge area of agricultural fields are inundated under flood water during monsoon period. When the flood water retreated, portion of a large agricultural field comes under waterlogging because of poor external drainage and drainage congestion. Therefore, flood-waterlogging hazards which occur synchronously severely affect the socio-economic conditions of the people of Samastipur District than any other natural hazard (Pandey *et al*., 2010). The other categories of wastelands have an areal extent of 4.7% of the district geographic area. It is apparent that riverine sand comprises a dominant wasteland type as they cover an area of 83.94 sq km comprising 3.14% of the state area. Among the various categories of wastelands mapped in the district, four categories of wastelands viz., land with open scrub (0.88%), land with dense scrub (0.02%), wetlands (0.61%) and Grazing land (0.06%) constitute the dominant categories (figure 6). It is estimated that built up constitutes 219.65 sq km comprising 8.20% of the total area.

4a) Grazing land

4b) Wetlands

4c) Agricultural Land

4d) Scrubland

Figure 4: Ground truth data and ancillary information supplemented by existing maps to produce the final map

Accuracy assessment

Accuracy assessment was carried out to compare the classified image with reference data, wherein error matrix was used to compute overall accuracy, producer's accuracy (error of omission), and user's accuracy (error of commission) (Story and Congalton 1986), and the Kappa coefficient was derived. Kappa coefficient is a measure of agreement between interpretation and verification which not only accounts for the number of correctly classified units but also the commission and omissions. The kappa coefficient (^K) was computed as (Bishop *et al*. 1975):

$$k = N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+})(x_{+i}) \Big/ N^2 - \sum_{i=1}^{r}(x_{i+})(x_{+i})$$

where r is the number of rows in the matrix, x_{ii} is the number of observations in row and column i (the i^{th} diagonal elements), x+i and xi+ are the marginal totals of row r and column i, respectively; and N is the number of observations.

The vectors derived from the digitization of LULC areas mapped from satellite images were checked for accuracy assessment of visual classification. For this purpose, the LULC vectors were converted to raster data, and the Kappa coefficient was used to make an accuracy assessment. Based on selective field checks, the overall classification accuracy of the LULC map derived from the satellite image was 90% with the Kappa coefficient of 0.83. Any wrong identification of pixels was corrected and the revised classified maps of LULC units were used for the area calculation.

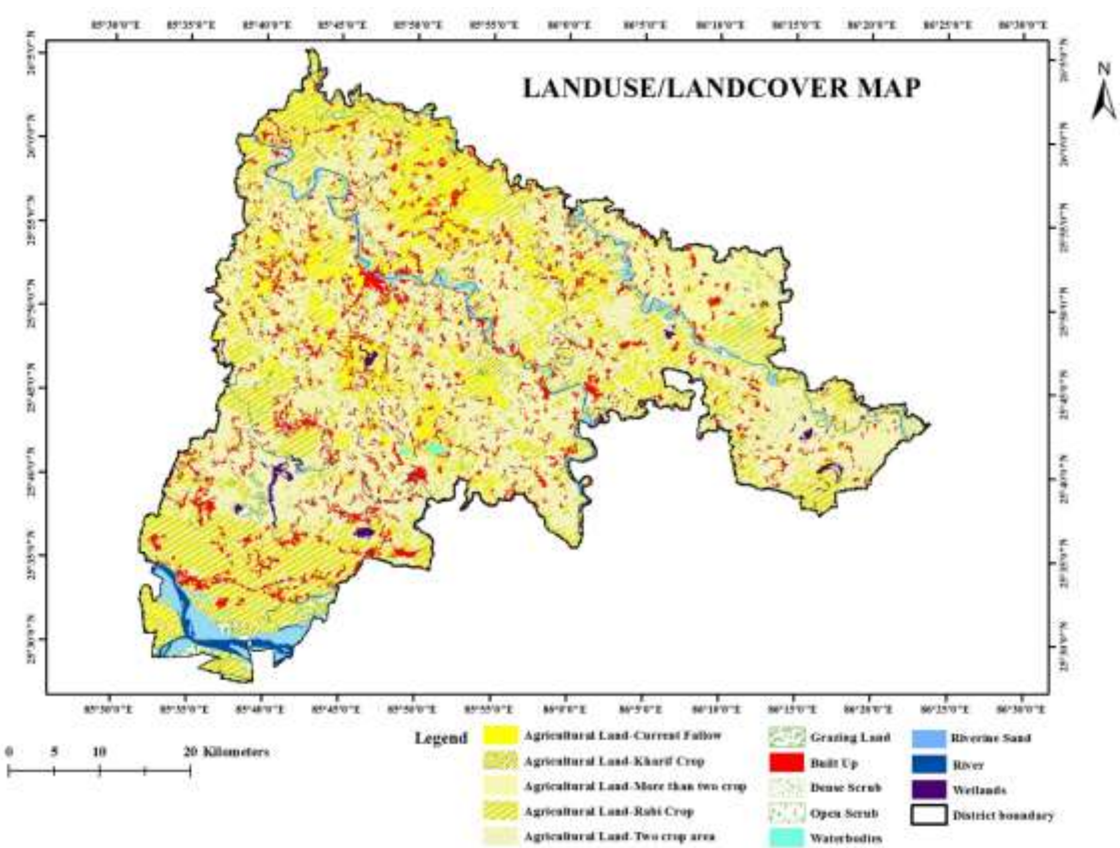

Figure 5: Landuse/landcover map of the study area

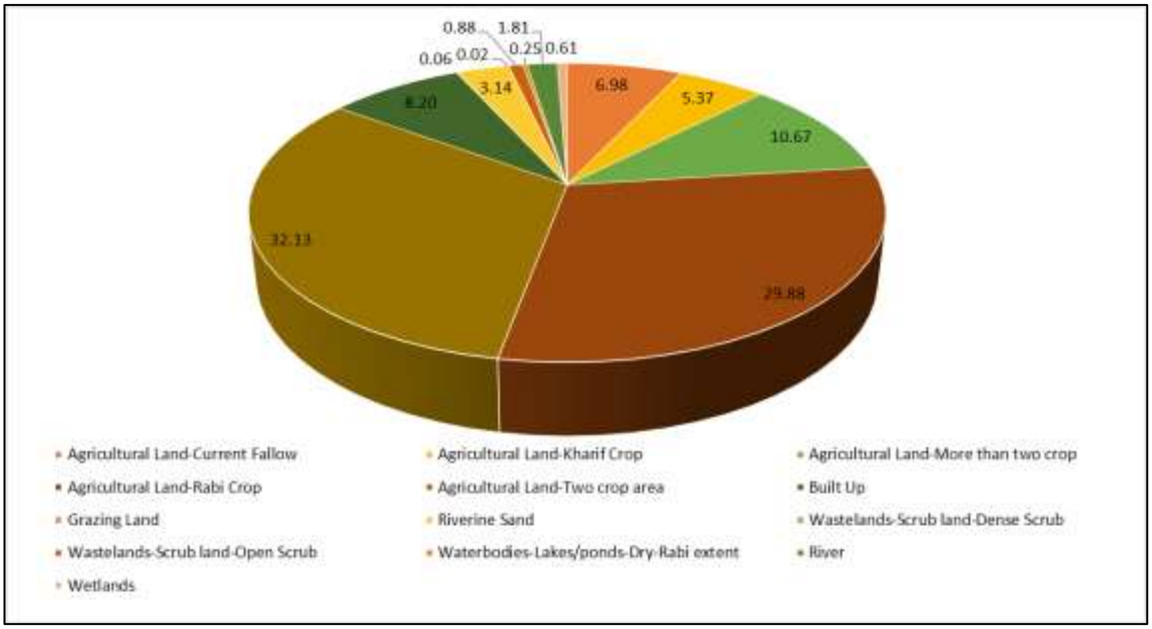

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Figure 6: Distribution of Landuse/landcover in the study area.

Table 2: Area statistics of various categories of LULC mapped in area

S.No.	Landuse/landcover Classes	AREA (SQ KM)	Area (in %age)
1.	Agricultural Land-Current Fallow	186.86	6.98
2.	Agricultural Land-Kharif Crop	143.76	5.37
3.	Agricultural Land-More than two crop	285.64	10.67
4.	Agricultural Land-Rabi Crop	800.06	29.88
5.	Agricultural Land-Two crop area	860.26	32.13
6.	Built Up	219.65	8.20
7.	Grazing Land	1.50	0.06
8.	Riverine Sand	83.94	3.14
9.	Wastelands-Scrub land-Dense Scrub	0.62	0.02
10.	Wastelands-Scrub land-Open Scrub	23.54	0.88
11.	Waterbodies-Lakes/ponds-Dry-Rabi extent	6.79	0.25
12.	River	48.57	1.81
13.	Wetlands	16.24	0.61

Conclusion

Mapping of LULC using remote sensing and GIS techniques is a cost effective method of obtaining a clear understanding of the land cover alteration processes due to land use change and their consequences. The study uses multi-temporal geometrically co-registered IRS P6–LISS III data for three seasons, viz. winter (January to March); pre-monsoon (April to May) and post-monsoon (mid-October to December) for LULC mapping. In the present study cropland is the most dominant LULC category comprising (85.02 %) of the area. North Bihar is undoubtedly the most backward region, as reflected through its lowest urbanization level, the lowest literacy rate and the highest decadal growth rate of population. Waterlogging and flood constitutes the main hazards in the northern Bihar plains resulting due to surplus water availability in the region. The severity of these hazards turns into a disaster due to existence of high population density with low socio-economic status. In this context, careful observation and mapping of LULC using satellite data of high to medium spatial resolution is crucial for understanding the long-term usage patterns of natural resources and facilitating sustainable management to plan, monitor and evaluate development.

Authors' contributions: *Dr. S.K. Singh (Asistant Profesor) has done interpretated the data and manuscript writing and also corresponding author of menuscript.*

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