Research Article

Spatio-temporal Variation in Landuse/cover Dynamics in Shahzad River Basin Uttar Pradesh, India: A Geospatial Approach

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Abstract Landuse/cover is an important component that reflects the interaction between environment and human activities. Landuse/cover pattern is an outcome of natural and socio-economic factors and their utilization by man in space and time. The present study makes an attempt to monitor landcover dynamics in Shahzad river basin, a rainfed basin in Lalitpur district of Uttar Pradesh (India) using remote sensing and GIS technique. Digital Elevation Model (DEM) was prepared using Shuttle Radar Topography Mission (SRTM) data, the lowest and highest elevations encountered in the basin are 280 m and 495 m above MSL respectively. The higher elevations are encountered in southern most parts of the basin whereas lower elevations are found in the north. The general slope is from south to north, as defined by the course of the Shahzad river. Two data set viz. IRS-P6 LISS III data of 2005 and IRS-P6 LISS III of 2015 have been analyzed through visual interpretation technique. Visual interpretation technique was used to identify the various landuse/cover categories. Landuse/cover maps of 2005 and 2015 derived from satellite data were digitized in Arc GIS environment. Editing and topology building was carried out using Arc GIS 10 and area under each category of landuse/cover was computed in km2 as well as in percentage. An attempt was made to estimate and quantify the overall change as well as transitional change in landuse/cover classes over a decade. A comparison of 2005 and 2015 data analysis suggests that the area of water body has significantly increased from 19.53 km^2 in 2005 to 34.85 km^2 in 2015, i.e. 15.32 km^2 (1.39%), the area of uncultivated land has decreased from 352.81 km^2 (32.61%) in 2005 to 337.80 km^2 (30.7%) in 2015, showing 15.01 km^2 (1.91%) decrease. The area of cultivated land has increased from 464.78 km^2 (42.76%) to 473.06 km^2 (43%), i.e. 8.28 km^2 (0.24%). However, vegetation in the watershed has reduced, i.e. under open forest and dense forest has reduced by 11.37 km^2 (1.04%) and 13.27 km^2 (1.21%) respectively during 2005-2015. Open scrub, stone quarry, built-up land, exposed rock and wasteland have also reported change in their respective areas. Open scrub has slightly increased from 73.63 km^2 (6.69%) to 76.23 km^2 (6.93%), whereas stone quarry has increased from 1.78 km^2 (0.16%) to 3.53 km^2 (0.32%), which suggests expansion in quarrying activity. Change matrix analysis indicates that cultivated land, uncultivated land, open scrub and wasteland are the most unstable categories which have interchanged into different landuse/cover during 2005-2015. Moreover it also indicates, cultivated land (38.42 ha), uncultivated land (51 ha) and open scrub (59.64 ha) has been converted into settlement area.

Keywords Landuse/land cover; Change matrix; Accuracy assessment

1. Introduction

Land use and land cover (LULC) are terminologically different terms but are often used interchangeably. Land cover refers to the physical characteristics of the earth including area captured under vegetation, water, soil, landforms, topography etc. whereas landuse refers to the pattern in which land resources have been utilized by the humans. Different driving forces acting upon the surface of earth lead to the formation or modification of land use/cover categories. The land use/cover pattern of a region is an outcome of natural and socio-economic factors and their utilization by man in time and space (Rawat and Kumar, 2015). Hence, assessing the land use/ cover and their dynamic nature is not only important for estimating the area of a land used under different categories but in turn helps in evaluating the potential of natural resources, watershed management, socio-economic planning and other development sectors.

Since land use/cover are paired complementary to each other thus change in land use affects the land cover and vice versa. Change in land cover does not primarily indicate deterioration of land but it may be driven by the anthropogenic activities and can also be triggered by natural processes there by affecting the biospheric and climatic cycle. Since natural resources are dynamic in nature, thus land use/cover changes are important elements for monitoring, evaluating, protecting and planning for earth resources (Rawat et al., 2013). LULC classification and change detection is one of the most reliable methods to monitor the land dynamics. Change detection of LULC is generally carried out using multi-temporal data sets to assess changes in the landscape witnessed in the country, especially at watershed or basin level to provide more accurate information about landuse/cover dynamics for proper management and conservation of natural resources (Gibson and Power, 2000).

Remote sensing and GIS have emerged as one of the most powerful tools for classifying, mapping, monitoring, evaluating and assessing the natural resources in less time, with low cost and better accuracy. Satellite image pixcels can be classified in LULC categories either by automatic extraction or by visual interpretation method (Meinel and Neubert, 2000). Automatic classification is based on extrapolating the celebrated patches of homogeneous color and texture on the satellite image, thereby providing a meaningful categorization of LULC (Dronova et al., 2011; Chen et al., 2012). Further the pixel-based analysis may lead to the 'salt-and-pepper' effect in mapping heterogeneous landscapes (Zhang et al., 2014). It is difficult to determine the accuracy of the result produced by the automatic classification, even sometimes it fails to recognize difference in "use" of given surface land (Fallati et al., 2017). On the other hand, visual interpretation is a slow and tiresome method as compared to the automatic supervised classification but can be rationally used when analyst is familiar with the field and research area is comparatively small. Visual interpretation has advantage over automatic classification since the former can identify dynamic changes more accurately and hence represents the process of landuse/cover change more effectively. Therefore this interpretation technique is frequently used in practical approach like in rural development, smart city project, flood mapping etc. (Zhang et al., 2014). Vector layer in form of polygons are used to divide the image into the parcels, these parcels are classified into desired classes, thus avoids inter-class spectral variation (Apline et al., 1999; Apline and Smith, 2008).

In the recent past the advancement of research has led to more emphasis on development at watershed level, as the traits and allocation of natural resources depends upon the natural boundary. Many workers consider watershed as a basic unit for the identification, estimation, development and prioritization of natural resources. Adinarayana et al. (1995) used integrated approach to prioritize watershed on the basis of sediment yield index in Western Ghats, Rahaman et al. (2015) prioritized sub watershed on morphometric basis using Fuzzy Analytical Hierarchy Process in Kallar watershed, Welde (2016) conducted the study on prioritization of watershed for land and water management in Tekeze dam, Ethiopia. Watershed, besides being a naturally occurring hydrological unit also carries a unique socio-ecological aspect which plays an important role in determining the ecological, food and social security and provision of life support services to local communities. Several attempts have been

made in the recent past to quantify the change detection by applying remote sensing and GIS techniques. Kibret et al. (2016) carried out a study in South Central Ethiopia, to assess the LULC changes during four decades using multi temporal satellite data. Fallati et al. (2017) have carried out LULC analysis in the Republic of Maldives using remote-sensing data through visual interpretation technique in conjunction with socioeconomic data.

The present study makes an attempt to assess the LULC changes and probable causes leading to the changes in the Shahzad watershed, Lalitpur district, Bundelkhand, India from 2005 to 2015. The region of Bundelkhand have complex geological and physiographical landscape varying from Bundelkhand Plains, Bundelkhand upland and vindhyan Plateaus. The study area has remained socio-economically backward with moderate drought frequency but high intensity, and faces the metrological drought. Hence, monitoring the resources and assessing the cause of changes become a prime focus especially in the agricultural dominant watershed. The major objectives of the study are to (i) identify and delineate different LULC categories under the area for 2005 and 2015 (ii) Verify the accuracy of the data in order to get more reliable and accurate results (iii) quantify the amount of overall change in LULC categories both in area and percentage as well as to monitor the LULC transformation from one category to another and (iv) ascertain the possible causes of change. Several studies have been carried out throughout the globe on the change detection analysis by using remote sensing data (Palaniyandi and Nagarathinam, 1997; Rogan and Chen, 2004; Güler et al., 2007; Chunxiao et al., 2008; Song et al., 2009; Prakasam, 2010; Nagarajan and Poongothai, 2011; Liu et al., 2012 and Garai and Narayana, 2018).
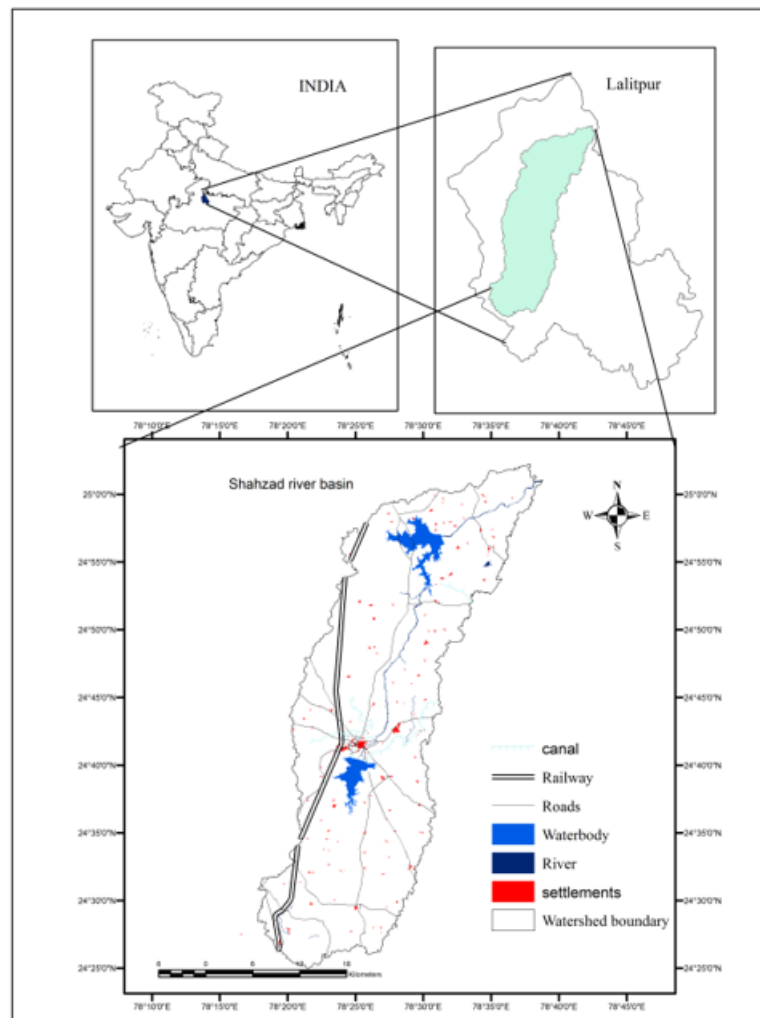

Figure 1: *Location map of Shahzad basin*

Study Area

The Shahzad river basin is located in Lalitpur district of Bundelkhand region in Uttar Pradesh (India) and bounded by 24° 25' N to 25° 03'N latitudes and 78° 17' E to 78° 39' E longitudes with a geographical area of about 1100 km^2. Shahzad river (a tributary of Jamini river) flows from south to north through the center of the watershed bifurcating it into East and West. The basin experiences sub-humid climate with average annual rainfall of 806 mm. Topography is represented by plains, pleateau, hills and ridges where elevation values range from 280m to 495m above mean sea level. Geologically, the area is dominated by Bundelkhand Granatoid Complex (BGC) comprising of gneisses, schist and granites which are underlained by arechean formation. North East-South West (NE-SW) trending quartz reefs and basic dykes traverse the BGC. Thick pile of quaternary sediments of older alluvium comprising of Banda alluvium overlies on the BGC formation. Sandstone of Kaimur group (Upper Vindhyan) is exposed in the south (GSI, 2008). The basin is mainly drained by Shahzad river and its tributaries. The dendritic to sub-dendritic drainage pattern dominates the watershed, however there are variation in drainage pattern at local level, where main river divides the entire watershed into eastern and western halves. Two reservoirs namely Shahzad reservoir and Govindsagar reservoir are the characteristics feature in the north and south respectively.

The watershed is mainly defined agricultural land where the main landuse is cultivation which is by and large rainfed, however irrigation from ground water at places is through tube wells. Major crops grown in the area are Sorghum, Pigeon pea, Black gram, Green gram, Barley, Mustard etc. Over exploitation of ground water has not only resulted in lowering of water level but has also caused failure of wells.

2. Materials and Methods

Data Base Preparation

IRS P6 LISS III false color composite (FCC) of 2005 and 2015 February, with band combination 2,3,4 and spatial resolution of 23.5m were used for landuse/cover mapping and classification (Figure 2). The data for same month has been used to reduce the reflectance conflict and seasonal variation for the classification of landuse/cover. The satellite data pertaining to study area was obtained from National Remote Sensing Centre (NRSC), Hyderabad. The data set were imported to ERDAS imagine version 14 to extract the desired form of image used for classification purpose. The layer stack option in raster tool box was used to generate standard false color composite (FCC). Image was geo-referenced and was projected in Universal Transverse Mercator (UTM) projection, taking World Geodetic System (WGS84) as the datum. The study area lies in UTM Zone 44 N. The georeferenced boundary of Shahzad watershed as Area of Interest (AOI) was superimposed on satellite image to subset the image and to extract the study area.

Landuse/Cover Delineation and Analysis

Visual interpretation technique was followed for change detection of land use/cover using ArcGIS 10 software, since the authors are familiar with the area being classified. Interpretation keys were developed on the basis of field knowledge and literature. To enable storage of data associated with each LULC, a data base structure was created prior to visual interpretation of IRS FCC images. Based on spectral characteristics of landuse/cover classes, the interpretation keys were developed (Table 1) and on-screen digitization for various landuse/cover classes was created in form of polygons with unique ids. Ground truthing was carried in key areas to verify the spectral signature. Twelve landuse/cover classes were identified in the study area viz. (i) cultivated land (ii) uncultivated land (iii) dense forest (iv) open forest (v) open scrub (vi) waterbody (vii) dry waterbody (viii) exposed rock (ix) stone quarry (x) industrial land (xi) built up land and (xii) wasteland.
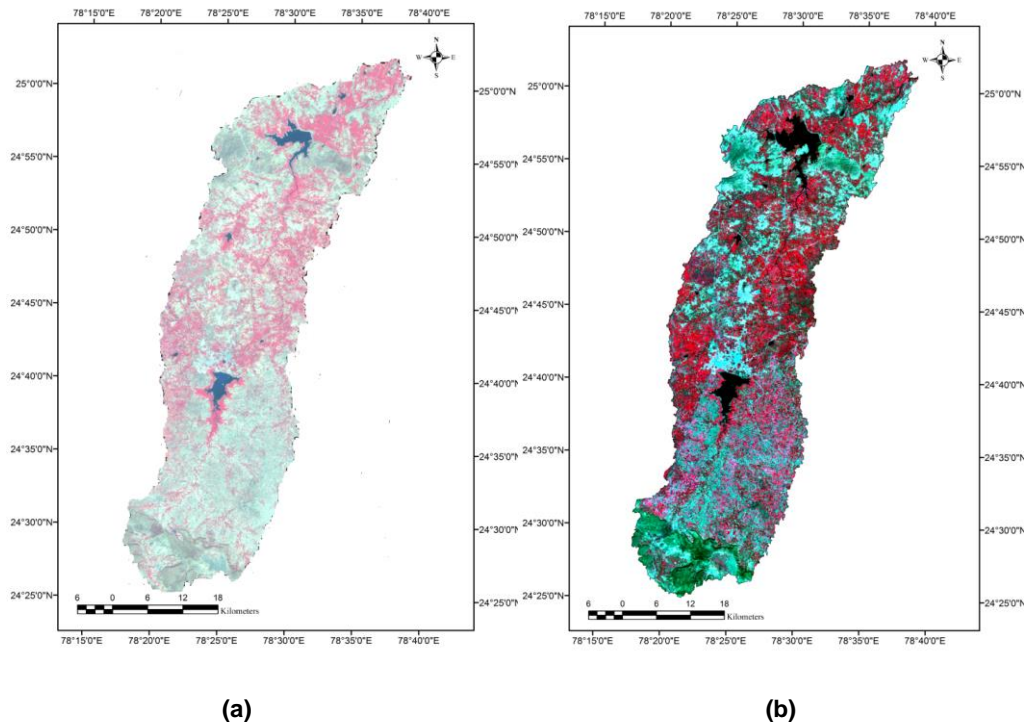
(a) **(b)**

Figure 2: *Satellite images (a) IRS P6 LISS III (2010), (b) IRS R2 LISS III (2015)*

Table 1: *Spectral characteristic of landuse/cover classes*

Landuse/cover class	Image characteristics	Topography	Relief/slope
Cultivated land	Pinkish to bright red color, Coarse texture, irregular pattern and regular to sub-regular shape	Plain	Very low to gentle
Uncultivated land	Bluish green to brownish green tone, smooth texture, contiguous pattern and irregular in shape	Plain	Very low to gentle
Dense forest	Dark greenish tone, woolly texture, contiguous to non-contiguous pattern and irregular shape	High relief/ plateau slope	Moderate to steep
Open forest	Greenish tone, medium texture, contiguous to non-contiguous generally found within the protected or reserved forest	High relief/ rugged	Gentle to moderate
Open scrub	Light greenish tone with medium to smooth texture, scattered and irregular in shape	Rugged/plain	Gentle to moderate
Waterbody	dark blue to black in color, smooth texture, irregular shape with defined boundary	Depressed to plain	Low to very gentle slope
Dry waterbody	Light cyan color, smooth texture irregular shape associated along the boundaries of waterbody	Depressed to plain	Low to very gentle slope
Exposed rock	Bright tone, rough texture, bold topography, isolated hillocks and plateau generally devoid of vegetation	Rugged	Moderate to steep slope
Industrial land	Bright tone, smooth texture, regular to sub-regular shape	Plain	Very gentle slope
Stone quarry	Milky to light cyan tone, rough texture, depressed pit filled with water, scattered and irregular in shape	Rugged/ subdued	Moderate to gentle
Settlement	Bright cyan tone, coarse texture, semi-circular pattern and irregular shape	Plain	Low to very gentle slope
Wasteland	Bright cyan tone, smooth texture, non-contiguous, scattered pattern and irregular shape	Plain/rugged	Low to very gentle slope

Accuracy Assessment

An accuracy assessment was carried out after the LULC mapping was accomplished. Landuse/cover result of 2015 was validated by ground observation and recorded GPS values, transect walk, group discussion and interview, as well as Google earth imagery. Validation and training data set for 2005 landuse/cover result were Google image, topographic map and group discussion and interview conducted during field visits in 2014 and 2015. 500 sample points for each year were selected throughout the study area. Sample were randomly selected based on areal extend of each category. To further increase the accuracy, some sample points were taken at transitional boundary of two different LULC classes, dam boundary and intersection of cultural classes like road, river, railways etc. Confusion matrix (contingency table) for 2005 and 2015 was created using the observed and the classified landuse/cover map of each class for accuracy assessment. Accuracy parameter viz. producer's accuracy (a measure of omission error), user's accuracy (a measure of commission error), overall accuracy and kappa statistics were estimated (Thakkar et al., 2017). Producer's accuracy is a ratio of number of correctly classified pixels to the number of training pixels (the column total) used in particular category whereas User's accuracy is obtained by dividing the number of correctly classified pixel by total number of pixel in that category (the row total). The overall accuracy is computed by dividing the number of correctly classified pixel by total number of reference pixel. Kappa analysis is a discrete multivariate technique used in accuracy assessments (Jensen 1996). Kappa analysis yields a Khat statistic (an estimate of Kappa) that is a measure of agreement or accuracy (Congalton 1991).

$$\hat{k} = \frac{N \sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+}.x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+}.x_{+1})}$$

Where,

r = number of rows in the error matrix
x_{ii} = number of observation in row i and column i (on the major diagonal)
x_{i+} = total of observations in row i (shown as marginal total to right of the matrix)
x_{+1} = total of observation in column i (shows as marginal total at bottom of the matrix)
N = total number of observation included in matrix

**Landuse/Cover Change Detection and Analysis**

Post classification technique was applied to the generated temporal landuse/cover maps to perform the landuse/cover change detection. Vector layer of 2005 and 2015 were overlaid to produce change information inform of "from" to "to" classes. Cross tabulation of two different decadal data of classified image were compared to determine the qualitative and quantitative aspect of the change for the period 2005-2015. Change matrix was produced in GIS environment. Quantitative areal data of the overall landuse/cover changes as well as gains and losses in each category between 2005 and 2015 were then compiled.

3. Results and Discussion

Landuse/Cover Status

Landuse/cover derived through 2005 IRS data suggests that, the basin occupies an area of about 464.78 km^2 (42.10%) under cultivated land and 352.81 km^2 (31.92%) area under uncultivated land. Open scrub occupies an area of 73.63 km^2 (6.69%), which is wide spread throughout the whole basin. Open forest though present as patches throughout the basin has an area of 24.99 km^2 (2.27%), whereas dense forest occupies an area of 65.07 km^2 (5.91%) and is confined to southern and north-western parts of the basin. The exposed rock terrain is largely confined to the southern part of the basin and occupies an area of 0.56 km^2 (0.05%). Although the settlements/built-up land are present throughout the basin, but are largely confined to the central part of the basin in and around Lalitpur

town and occupies an area of about 15.06 km^2 (1.36%). Wasteland occupies an area of 77.64 km^2 (7.05%) and is found in the northern and western parts, and is associated with the open scrub, cultivated and uncultivated lands. The other land use/land cover category viz; industrial land and stone quarry occupy areas of about 3.87 km^2 (0.31%) and 1.78 km^2 (0.16%) respectively. The quarrying activity is reported from southern part of the Shahzad watershed, where sandstone is being mined for use as a building stone. Figure 3 (a) presents land use/land cover map derived from LISS III FCC data of 2005.
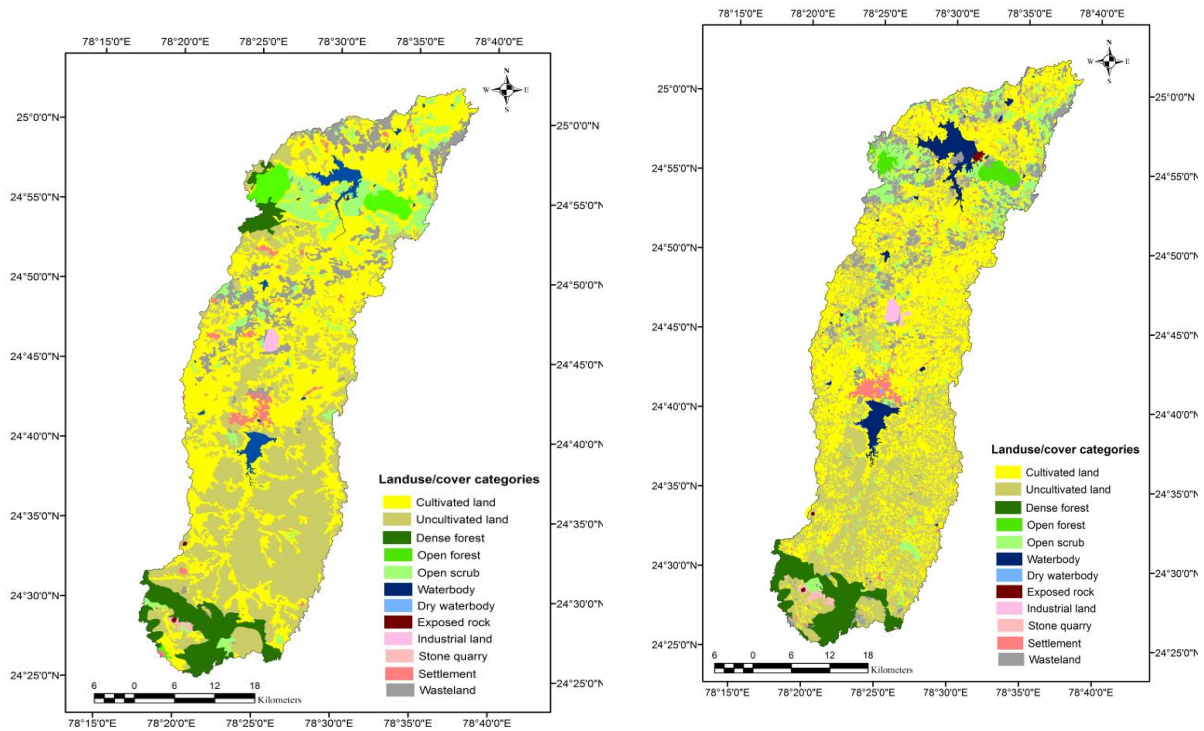
Figure 3: *Landuse/cover of Shazad watershed (a) 2005 (b) 2015*

Landuse/cover analysis of 2015 IRS data suggests that in Shahzad basin cultivated land covers an area of 473.65 km^2 (43.00%), whereas 337.80 km^2 (30.70%) area is occupied by uncultivated land. The other dominant LULC categories are wasteland and open scrub with areas of 83.53 km^2 (7.59%) and 76.23 km^2 (6.93%) respectively. Natural vegetative cover i.e. dense forest covers 51.80 km^2 (4.70%) area whereas open forest occupies 13.62 km^2 (1.23%) area. Though the area under waterbody has increased to 34.85 km^2 (3.16%) but an increase in area of about 2.07 km^2 (0.18%) is also observed in dry waterbody, compared to 2005. The other land use/land cover categories viz; industrial land and stone quarry, occupy areas of about 4.69 km^2 and 3.53 km^2 respectively. Table 2 presents details of area and extent of change under each category of LULC in the Shahzad watershed during 2005-2015. Figure 3 (b) presents LULC map derived from 2015 IRS FCC data.

Table 2: *Landuse/cover statistics (2005-2015) of Shahzad watershed*

Landuse/cover category	2005		2015		Change 2005-2015	
	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)
Cultivated land	464.78	42.10	473.06	43.00	8.25	0.9
Uncultivated land	352.81	31.07	337.80	30.70	-15.01	-1.37
Dense forest	65.07	5.91	51.80	4.70	-13.27	-1.21
Open forest	24.99	2.27	13.62	1.23	-11.37	-1.04
Open scrub	73.63	6.69	76.23	6.93	2.6	0.24
Wasteland	77.64	7.05	83.53	7.59	5.89	0.54
Waterbody	19.53	1.77	34.85	3.16	15.32	1.39
Dry waterbody	0.32	0.02	2.07	0.18	1.75	0.16
Exposed rock	0.56	0.05	1.52	0.13	0.96	0.08
Industrial land	3.87	0.31	4.69	0.47	0.82	0.16
Stone quarry	1.78	0.16	3.53	0.32	1.75	0.16
Settlement	15.06	1.36	16.71	1.51	1.65	0.15
Total	1100	100	1100	100	75.67	7.4

Accuracy Assessment

Accuracy assessment is an important factor in classification. One of the most commonly followed method is the preparation of a classification error matrix (confusion matrix/contingency table). Error matrices compare, on a category-by-category basis, the relationship between known reference data (ground truth) and the corresponding result of a classification (Lillesand et al., 2004).

The error matrix shows the overall accuracy of 83.2% and 84.6% followed by Kappa coefficient of 0.80 and 0.82 in classified images of 2005 and 2015 respectively. Both producer and user accuracy of individual classes ranges from 65.21% to 96.11% and 71.42% to 100% in 2005 (Table 3) whereas for 2015, producer and user accuracies turned out to be 71.42% to 100% and 73.33% to 96.07%, respectively (Table 4).

Table 3: *Error matrix for LULC map derived using FCC data of 2005*

Reference data 2005														
Lulc classes	Cl	Ucl	Df	Of	Os	Wb	Dwb	Er	Il	Sq	Stlmnt	Wl	Total	PA (%)	UA (%)
Cl	99		7	4	2								112	96.11	88.39
Ucl		69				1		2			5	7	84	93.24	82.14
Df	2		15	4	2								23	65.21	65.21
Of			1	32	4							1	38	76.19	84.21
Os			2	58					1		2	6	69	77.33	84.05
Wb	2				16								18	94.11	88.88
Dwb				1	3								4	75	75
Er								6				1	7	75	85.71
Il									6				6	75	100
Sq		1								5		1	7	83.33	71.42
Stlmnt		2			3						51	4	60	79.68	85
Wl		2			6	2					6	56	72	73.68	77.77
Total	103	74	23	42	75	17	4	8	8	6	64	76	500		
	overall accuracy		83.2%						kappa coefficient			0.80			

PA - Producers accuracy; UA - User accuracy.

Table 4: *Error matrix for LULC map derived using FCC data of 2015*

Lulc classes	CI	Ucl	Df	Of	Os	Wb	Dwb	Er	Il	Sq	Stlmnt	WI	Total	PA (%)	UA (%)
					Reference data 2015										
CI	88	1	7	4							2		102	96.70	86.27
Ucl	1	75			12						7	3	98	88.23	76.53
Df			33	5									38	80.48	86.84
Of				42	3								45	79.24	93.33
Os		6	1	2	50								62	72.46	80.64
Wb	2					11	2				3		15	91.66	73.33
Dwb						1	5						6	71.42	83.33
Er								4				1	5	66.66	80
Il									6			2	8	100	75
Sq										3		1	4	100	75
Stlmnt		3									47	2	52	79.66	90.38
WI				4			2					59	65	86.76	90.76
Total	91	85	41	53	69	12	7	6	6	3	59	68	500		
Overall accuracy			84.6%								kappa coefficient				0.82

PA - Producers accuracy; UA - User accuracy.
CI - Cultivated land; Ucl - Uncultivated land; Df - Dense forest; Of - Open forest; Os - Open scrub; Wb - Water body; Dwb - Dry water body; Er - Exposed rock; Il - Industrial land; Sq - Stone quarry; Stlmnt -Settlement; WI - Waste land.

Landuse/Cover Change

A comparative analysis of the 2005 and 2015 land use/land cover suggests significant changes in the Shahzad basin. Amongst the notable changes are, a substantial decrease in uncultivated land from 352.81 km^2 in 2005 to 337.80 km^2 in 2015, showing 15.01 km^2 (1.37%) reduction in area with respect to 2005. The area under dense forest has reduced from 65.07 km^2 in 2005 to 51.80 km^2 in 2015, i.e. 13.27 km^2 (1.21%) fall in its aerial extent with respect to 2005. The area under open forest has also decreased from 24.99 km^2 in 2005 to 13.62 km^2 in 2015, which is 11.37 km^2 (1.04%). The area under cultivated land has increased from 464.78 km^2 in 2005 to 473.06 km^2 in 2015, an increase of 8.25 km^2 (0.9%). Area under wasteland has marginally, increased from 77.64 km^2 in 2005 to 83.53 km^2 in 2015, showing 5.89 km^2 (0.54%) in its areal extent. The area under open scrub has gone up from 73.63 km^2 (6.69%) in 2005 to 76.23 km^2 in 2015, showing a small increase of 2.6 km^2 in its extent. The area under dry waterbody has increased from 0.32 km^2 to 2.07 km^2. However, the area under water body has increased from 19.53 km^2 (1.77%) in 2005 to 34.85 km^2 in 2015, which is 15.32 km^2 (1.39%). The area under settlement/built-up land has increased from 15.06 km^2 (1.36%) in 2005 to 16.71 km^2 (1.51%) in 2015. The area under stone quarry has expanded from 2.29 km^2 in 2005 to 3.53 km^2 in 2015. Area under Industrial land area has increased from 3.87 km^2 in 2005 to 4.69 km^2 in 2015 suggesting some development and industrial expansion. Exposed rock has increased from 0.56 km^2 in 2005 to 1.52 km^2 in 2015 due to the fact that vegetative cover over it has been removed/ degraded and the underlying rock is exposed. Figures 4 and 5 show the changes in major LULC categories during 2005-2015.

Change Detection

Change detection matrix (Table 5) was prepared to understand the land cover dynamics under various categories. Major LULC changes occurred during the decade (2005-2015) are listed below:

(i) An area of about 8.41 km^2 of dense forest has been converted into open scrub, 5.01 km^2 area under wasteland, 2.24 km^2, 1.64 km^2, 0.67 km^2 and 0.32 km^2 area into uncultivated land, stone quarry, cultivated land and open forest respectively whereas 46.63 km^2 is still under dense forest.
(ii) An area about 18.90 km^2 under open scrub has been converted into cultivated land, 13.33 km^2 area into uncultivated land, 18.06 km^2 into waste land, 1.97 km^2 under dense forest, 1.27 km^2 into industrial

land, 1.21 km^2 under waterbody, 1.10 km^2 under exposed rock and 0.59 under settlement whereas 17.98 km^2 area of open scrub has remained unchanged.

(iii) An area of about 27.79 km^2 under wasteland has been converted into agricultural land (15.71 km^2 area into cultivated land and 12.08 km^2 area into uncultivated land), 15.08 km^2 area into open scrub whereas 34.16 km^2 area still remain under wasteland.

(iv) An area of about 6.78 km^2 open forest has been converted into open scrub, 4.02 km^2 area into wasteland whereas 12.93 km^2 remained under open forest category.

(v) An area of about 205.14 km^2 uncultivated land remained in same category during 2005-2015 whereas 118.68 km^2 has been converted into cultivated land, 10.47 km^2 into open scrub and 15.13 km^2 into wasteland.

(vi) An area of about 104.01 km^2 cultivated land has been converted into uncultivated land, 14.03 km^2 area into waterbody, 17.29 km^2 into open scrub, 7.10 km^2 into wasteland, 1.72 km^2 into dry waterbody, 1.06 km^2 into dense forest, and 0.38 km^2 into settlement.

**Table 5:** *Landuse/cover matrix showing land encroachment (in hectare) of Shahzad basin during 2005-2015*

2005/2015	Cl	Ucl	Df	Of	Os	Wb	Dwb	Er	Il	Sq	Stlmnt	Wl	2005
Cl	**31873.23**	10401.34	106.77	5.48	1729.51	1403.91	172.14	4.81	26.19	6.11	38.42	710.04	46478
Ucl	11868.53	**20514.61**	180.26	22.30	1047.98	49.43	0.39	0.83		32.09	51	1513.53	35281
Df	67.81	224.67	**4663.09**	32.21	841.77		1.05	0.09		164.83	10.29	501.87	6507.71
Of	52.44	33.27	35.09	**1293.32**	678.23						4.49	402.13	2499
Os	1890.67	1333.17	197.99	8.67	**1798.86**	121.94		110.23	1.27	34.08	59.64	1806.44	7363
Wb	31.93	2.49	0.26		8.37	**1871.72**	34.11	0.16		1.66	1.14	1.88	1953.74
Dwb						32.05							32.05
Er	7.09	4.19			4.19	1.90		**34.43**		4.47			56.29
Il									387				387
Sq	2.23	57.73			5.76			2.24		**109.98**		0.34	178.30
Stlmnt											**1506**		1506
Wl	1571.03	1208.50	1.31		1508.29	4.43	0.01		53.65			**3416.74**	7764
	47365	33780	5184.80	1362	7623	3485.40	207.71	152.81	468.12	353.25	1671	8353	110006.11

Cl - Cultivated land; Ucl - Uncultivated land; Df - Dense forest; Of - Open forest; Os - Open scrub; Wb - Water body; Dwb - Dry water body; Er - Exposed rock; Il - Industrial land; Sq - Stone quarry; Stlmnt -Settlement; Wl - Waste land. No change transition types = bold.
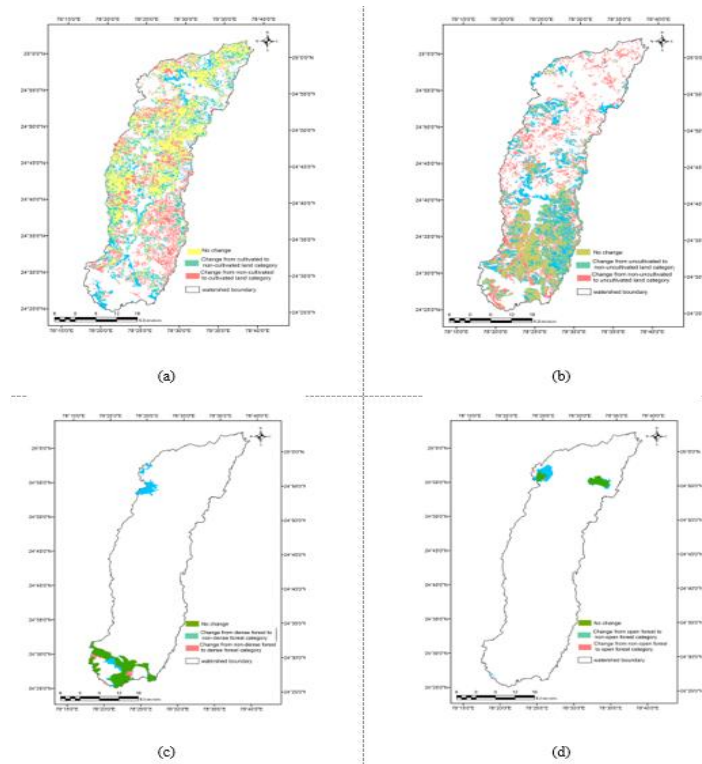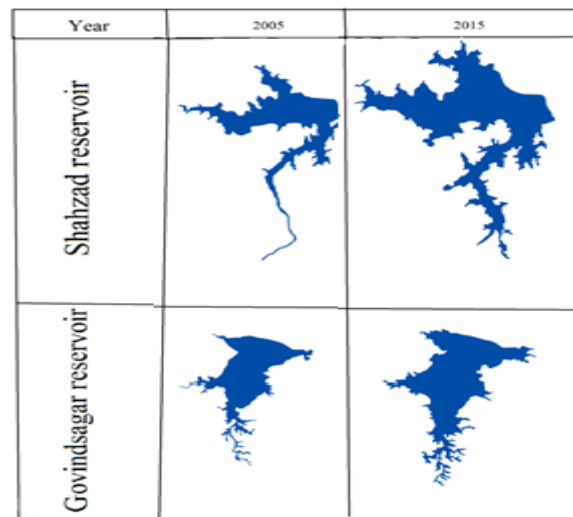
Figure 4: *Landse/cover change in different categories during last decade (2005-2015) in Shahzad basin (a) Cultivated land (b) uncultivated land (c) Dense forest and (d) Open forest*
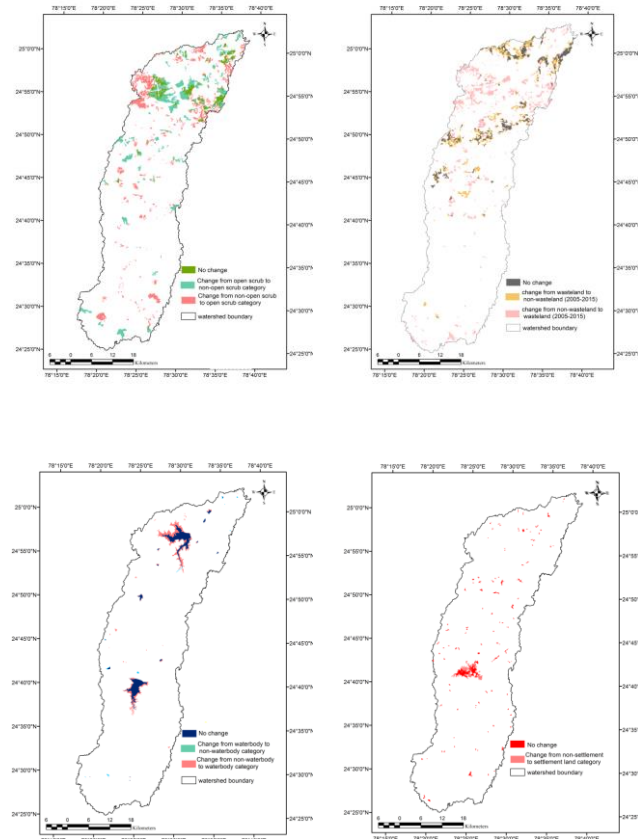
Figure 5: *Landse/cover change in different categories during last decade (2005-2015) in Shahzad basin (a) Open scrub (b) Wasteland (c) waterbody and (d) Built-up land*

Figure 6: *Water spread in major reservoir during 2005 and 2015*

Surface Water and Landuse Pattern

Agriculture in Shahzad basin is rainfed and depends upon the rainfall but it has been observed that area around the surface water body especially environ dams have shown positive change over the decade. Figure 6 shows the water spread in the reservoir during 2005 and 2015 which has resulted into conversion of uncultivated lands into cultivated land thereby indicating good irrigation facilities and water availability.

4. Conclusion

Multi temporal satellite imagery and GIS application have proved to be cost effective and accurate method to quantify the spatial and temporal phenomenon of LULC dynamics which would have not been possible with the conventional mapping. From the study it is concluded that LULC is dynamic in nature, thus interconversion of one LULC class to another at different part of the watershed in same time period is frequent depending upon the local variation like water availability, geology, livestock stress etc. e.g. in some part of the study area, 15.08 km^2 wasteland has converted into open scrub whereas in other part 18.06 km^2 open scrub has converted to wasteland. Study area is primarily agriculture dominated watershed thus, both cultivated and uncultivated land are of paramount importance. Cultivated land has increased by 8.25 km^2 due to conversion of uncultivated land and open scrub into cropland due to increase in irrigation facility over the decade. The Dense forest has reduce in its areal decreased by 13.27 km^2 due to conversion and degradation in open forest, whereas open forest has been converted into open scrub and waste land due to natural and anthropogenic factors. Other dominated category is open scrub which has increased by 2.6 km^2 since wasteland, open forest and dense forest has been converted into open scrub. Areal extent of dry waterbody has increased due to decline rainfall and utilization of surface water but overall extent of waterbody has also increased as water from Rajghat reservoir (built on the Betwa river) fed to Govindsagar reservoir for irrigation purpose. Settlement has increased due to expansion of Lalitpur town over a decade. The present study highlights the capacity of remote sensing coupled with GIS in analyzing the change dynamics of LULC. A study like this will open a new spectrum for planning, managing and utilizing the available natural and land resource at watershed level.

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