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Regional Analysis and Assessment of Urbanisation Pattern of Bihar Using Open Data from Indian Geoportal- Bhuvan

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Abstract

This paper investigates the pattern of land utilisation in Bihar, India using land use and land cover (LULC) data from India's geo-portal 'Bhuvan' which provides semi-classified satellite imagery from Indian earth observation satellites. Bihar shows poor performance in several development indices. Major part of the state's geographic area is under 'Agriculture' LULC class and about 7% area is covered with 'Built-up' class. Analysis of LULC map presents the status and trend of coverage as well as utilisation of geographical area. Thematic maps prepared using Geographic Information Systems (GIS) identify the spatial pattern of distribution of LULC data. Per capita area of 'Built-up' and 'Urban Built-up' land cover classes relates to the urbanisation rate of the whole state, i.e. 11.3% for year 2011.

Keywords: Land use and land cover, LULC, Bhuvan, ISRO, GIS, Bihar, Urbanisation

Introduction

Land ecosystem comprising of soil, water and biodiversity fulfils the community's demand for energy, food, water and other requirements. At present rate, human consumption requires 1/3 of land more to fulfil its needs (United Nations, 1992). There is need to assess the availability of resources and growing demand of the same. Rapid population growth usually induces changes across several dimensions of human as well as nature's existence- most of these changes, as Billie Turner opines are likely to be disadvantageous for human beings (National Research Council, 1993). Land is used under different land use patterns like agricultural land, forest, fallow land etc. Richard Bilsborrow highlights a correlation between a nation's population density and arable land percentage (Bilsborrow, 1992). Nearly half of world's habitable land is under agricultural use (Ritchie & Roser, 2013).

Land use and land Cover (LULC) maps display the features and activities over a geographical area, usually as seen from satellite and other Remote Sensing (RS) systems. These

maps provide information about the state of landscape at a particular time as well as during an interval, enabling monitoring of temporal changes (Roy & others, 2015). Planners and policy makers employ these data in Geographic Information System (GIS)- a digital technology to analyse, store and map spatial data (Teixeira, 2018). Using GIS and RS imaging as well as interpretation of images of large geographical areas can be done quickly and repetitively, consuming less time and money (Sivakumar, 2010). By 2030, urbanization in developing world will be 56% (Brockherhoff, 2000). Per capita area under built-up land use can be used as a parameter to assess the land-use efficiency of a region (Masini, 2019). Knowledge of LULC and its temporal changes is crucial to understand land usage patterns in the long-term and facilitate planning, monitoring and evaluation of sustainable development (Roy & others, 2015)

Indian Space Research Organisation (ISRO), National Remote Sensing Centre (NRSC) and several other agencies have collaborated and made available the thematic maps on LULC for the policy makers and general public. These datasets have been used here to present the current status of land cover pattern in the state of Bihar in India. NRSC used temporal data from Linear Imaging Selfscanning Sensors LISS-III of Resourcesat-1 & 2 satellites to prepare geospatial database on 'Land Use/ Land Cover' (LULC) under National Resources Census project covering whole of India (NRSC, 2014). The satellite images were classified under Level-I, Level-II and Level-III classes after elaborate discussions with various state and central agencies. The final classified thematic maps were made available to the public through Bhuvan, the Geoportal of Indian Space Research Organisation (ISRO) whose web link is https://bhuvan-app1.nrsc.gov.in/thematic/thematic/index.php. 'Bhuvan' in Sanskrit means 'World' or 'Earth'. The present dataset was prepared and released by ISRO under National Resources Census Project in the form of an atlas as well as in the form of geoportal Bhuvan, using multitemporal Resourcesat-2 terrain-corrected data on 1:50,000 scale (NRSC, 2014) for years 2005-06, 2011-12 and 2015-16.

Study area

Bihar is one of 28 Indian states, located in the eastern region, having a total geographical area of 94,169 Sq.Km. It's the 3rd largest state by population and 13th largest by area in the country (Census of India, 2011). By urbanization, Bihar is ranked at last but one place with 11.29% population living in urban areas according to 2011 Census, the same was 10.46% as per 2001 Census (Census of India, 2011). The state is predominantly a rural region. There is a need to explore how the geographical area in state is being utilised and to relate it with the low urbanisation rate as a whole. Present study traces a pattern with respect to distribution of various LULC classes over the geographical area of Bihar.

Need for study

The paper examines the suitability of LULC data on Bhuvan portal of NRSC for the purpose of decision making for study area. Bihar state has Human Development Index of 0.574, least in the country (Global Data Lab, 2018) and 32% of its population lives under poverty (NITI Aayog, 2020). Of the total GDP, contribution of agriculture sector, industries and service sector is 20%,

19% and 61% respectively (Bihar Budget Analysis, 2020). Satellites and Department of Space are matters of the Central Government which provides unbiased uniform data for all of its states. Some states like the study area however show poor performance in several development indices (NITI Aayog, 2020). The paper establishes the practicality of utilising NRSC data, openly available on public media and platforms like Bhuvan portal for enabling the decision makers to better understand the ground realities and hence evolve suitable development plans.

Materials and methods

Primary source of data or this paper is the geo-portal of ISRO- Bhuvan. LULC data is openly available on this portal in the form of semi-classified satellite imagery for each district along with relevant metadata which includes area statement of polygons representing the districts. Tabulating and sorting of this data was done after compilation along with respective population data sourced from Census of India reports and relevant projections from UN report (UNFPA, 2009). The methodology for this paper is outlined in the flow diagram in Figure 1.

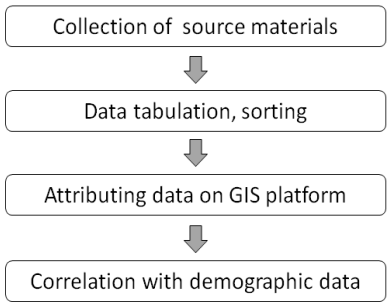


Figure 1: Methodology of Study

Source of data

LULC maps for the years 2005-06, 2011-12 and 2015-16 obtained from *Bhuvan* portal in two phases- firstly state level data for Bihar state and secondly the district-wise data for thirty-seven[1] districts of Bihar. Land use and land cover data were tabulated for six macro classes – Built up, Agriculture, Forest, Barren land, Grazing fields and Wetlands, as in Table 1 . The paper mainly focuses on assessing the built-up pattern all across the state, hence the macro class 'built-up' has been further parted under subclasses – urban built up, rural built up and mining. Subclasses urban and rural built-up have been emphasised upon since mining constitutes of small percentage of land – about 0.013% of whole state.

[1]Presently however there are 38 districts, one district 'Arwal' having been carved out from another district 'Jehanabad' in year 2001 which has not been updated in the dataset of Bhuvan. For the purpose of this paper, both districts have been combined as 'Jehanabad', hence total number of districts is taken as 37 only.

LULC Classification methodology

A GIS vector layer created for the study area was overlaid on the terrain corrected Resourcesat-2 LISS III imagery procured during three seasons of referred years viz. 2005-06, 2011-12 and 2015-16 subsequently. Seasons are – Monsoon, Pre-monsoon and Post-Monsoon during August-October, December-March and April-May months respectively. The satellite imagery was classified by NRSC in consultation with various state agencies.

Physical features observed on the surface of Earth are defined as Land Cover. It gets to be known as Land Use when an economic identity and function is attributed to it (Gregorio & Jansen, 2005). The NRSC has adopted nine Level-I classes, twenty nine Level-II classes and seventy nine Level-III classes for year 2005-06, whereas this was further adjusted to eight, thirty one and fifty one classes of respective Levels for years 2011-12 (NRSC, 2012) and 2015-16 (NRSC, 2014). For the purpose of this study Level-I classes are referred to, which are further elaborated in respective Level-II and Level-III classes, as shown in the Table 1.

Geographical distribution of Land cover

Geographical Information System (GIS) along with Remote Sensing (RS) techniques offers a tool to assess and detect the pattern of distribution and change for land cover over an area (Hegazy & Kaloop, 2015). The LULC data were mapped on the district map of Bihar state. QGIS, open source GIS software was used to attribute the area of each LULC classes in terms of percentage of total district area. Percentage of geographical area of each district under various LULC classes presents the pattern of distribution of land cover. Thematic maps showing this percentage were prepared for each LULC class corresponding to years 2005-06, 2011-12 and 2015-16. Change is detected through making observations at different times (Singh, 1989).

Table 1 LULC Classification of NRSC

Sr. No.	Level-I Classes	Level-II Classes	Level-III Classes
1	Built up	Urban	Residential, Mixed built up, Public / Semi Public, Communication, Public utilities / facility, Commercial, Transportation, Reclaimed land, Vegetated Area, Recreational, Industrial, Industrial / Mine dump, Ash / Cooling pond
		Rural	Rural
		Mining	Mine / Quarry, Abandoned Mine Pit, Land fill area
2	Agriculture	Crop Land	Kharif, Rabi, Zaid, Two cropped, More than two cropped
		Plantation	Plantation - Agricultural, Horticultural, Agro Horticultural
		Fallow	Current and Long Fallow
		Current Shifting cultivation	Current Shifting cultivation
3	Forest	Evergreen / Semi evergreen	Dense / Closed and Open category of Evergreen / Semi evergreen

		Deciduous	Dense / Closed and Open category of Deciduous and Tree Clad Area
		Forest Plantation	Forest Plantation
		Scrub Forest	Scrub Forest, Forest Blank, Current & Abandoned Shifting Cultivation
		Swamp / Mangroves	Dense / Closed & Open Mangrove
4	Grass/ Grazing	Grass/ Grazing	Grassland: Alpine / Sub-Alpine, Temperate / Sub Tropical, Tropical / Desertic
5	Wastelands	Salt Affected Land	Slight, Moderate & Strong Salt Affected Land
		Gullied/Ravenous Land	Gullied, Shallow ravine & Deep ravine area
		Scrub land	Dense / Closed and Open category of scrub land
		Sandy area	Desertic, Coastal, Riverine sandy area
		Barren rocky	Barren rocky
		Rann	Rann
6	Wetlands/ Water Bodies	Inland Wetland	Inland Natural and Inland Manmade wetland
		Coastal Wetland	Coastal Natural and Coastal Manmade wetland
		River/ Stream/ Canals	Perennial & Dry River/stream and line & unlined canal/drain
		Water Bodies	Perennial, Dry, Kharif, Rabi & Zaid extent of lake/pond and reservoir and tanks
7	Snow and Glacier	Snow and Glacier	Seasonal and Permanent snow

Source: (NRSC, 2014)

K-means clustering

Clustering helps group the districts with certain similar characteristic. K-means clustering is a popular technique, widely used in various fields to achieve clustering results (Liu, Zhao, & Zhao, 2016). It involves mainly two steps- finding the centre of clusters and assigning members to those clusters. The steps involved are sequentially as follows (Jain, Murty, & Flynn, 1999):-

- Finding random cluster centres
- Calculating the distance of each member from clustering centres

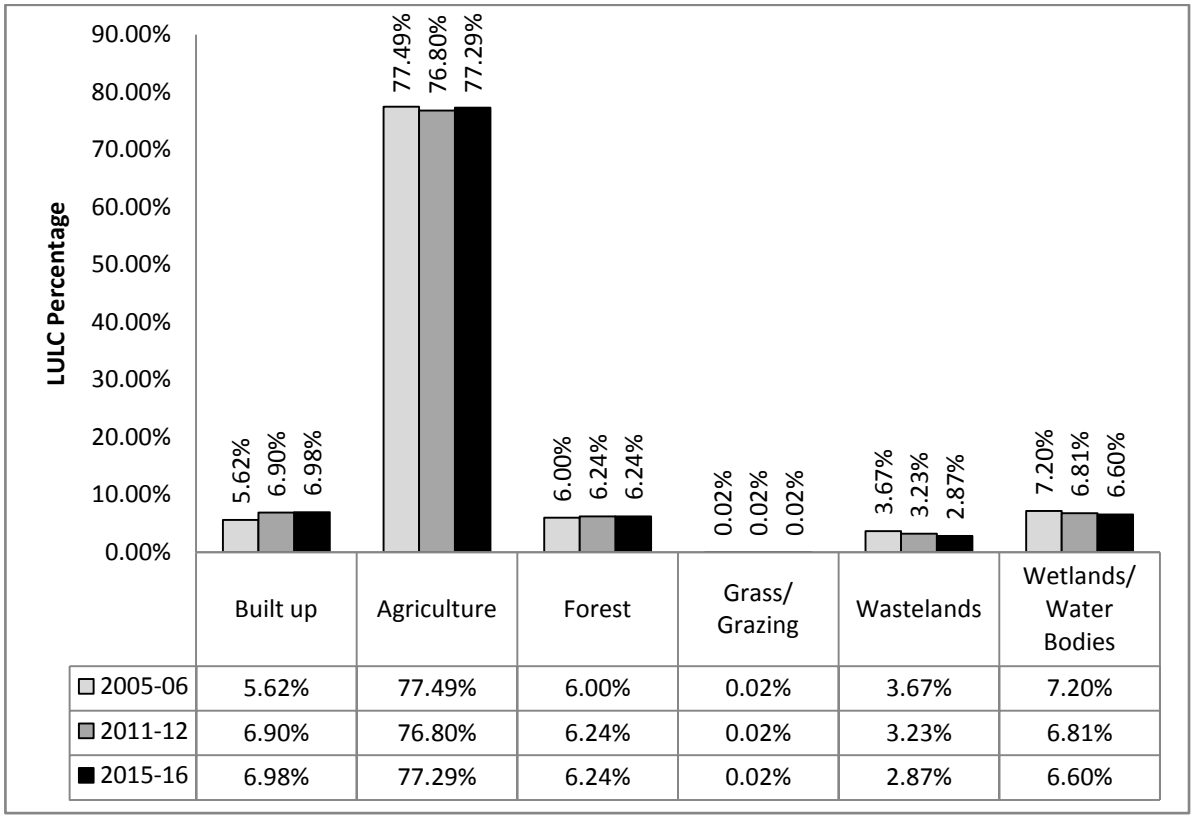
The authors have used SPSS software to run this clustering, wherein it was possible to observe the ANOVA test as well, using which the significance value of the variables were obtained. The LULC class data were taken as variables and the districts of study area were taken as individual cases of study. The clustering exercise helped us group the districts according to their similarity or nearness with each other with respect to 'significant' variables.

Result

The total geographical area of Bihar state as per NRSC maps is taken as 94,169 sq.km. in year 2015-16, adjusted from 94,171 sq.km. in previous years. Percentage change in geographical area under six LULC classes- Built-up, Agriculture, Forest, Grass, Wastelands & Wetlands is shown year-wise in the Figure 2. First part of study takes into account the overall state data. Over the duration from year 2005 to 2015, minor decrease in net area is observed in Agriculture, Forest, Wastelands and Wetlands-0.20%, 0.23%, 0.80% and 0.60% respectively. Built up area observes a slight increase of 1.36%. Level-II data of built up area class shows that Urban built up which was 15% of total built up area in year 2005-06 came down to 13.0% in 2011-12 and saw a small increase to 13.6% in 2015-16. Rural built up area which consisted of 84.1% of total built up in 2005-06 also decreased to 83.9% in 2011-12 and further to 82.7% in 2015-16. Second part of the study analyses district-wise data on LULC.

For the purpose of comparing respective data among the districts, the per capita values are derived using the demographic data from Census of India 2011 report along with projected values for years 2005 and 2015 from UN report on district population projection (UNFPA, 2009). Maximum, minimum and average per capita geographical area under various LULC class among 28 districts of Bihar state is given in

Table 2.



	Built up	Agriculture	Forest	Grass/ Grazing	Wastelands	Wetlands/ Water Bodies
2005-06	5.62%	77.49%	6.00%	0.02%	3.67%	7.20%
2011-12	6.90%	76.80%	6.24%	0.02%	3.23%	6.81%
2015-16	6.98%	77.29%	6.24%	0.02%	2.87%	6.60%

Source: Author's inference from National Remote Sensing Centre(NRSC, 2014)
Figure 2: Land use Change in Bihar State from 2005 to 2016

Built up and urbanisation

The LULC area has been correlated with population and total geographical area of the respective districts to make it comparable among all districts. The range of data for all districts under the considered LULC is divided in five equal intervals and the districts falling under these interval categories have been represented in different colours as in the Figure 4. Summary of 'Built up' and 'Urban Built up' LULC classes have been given in

Table 3 and

Table 4.

The pattern of urbanisation rate across all districts has been compared in terms of per capita urban built-up area, refer Figure 3. Patna is the capital of Bihar state and shows highest per capita Urban Built-up among all districts. Figure 3 lists the districts in alphabetical order and assigns serial number to each. Thematic maps were prepared, while denoting each district with these serial numbers on the georeferenced GIS map of Bihar for three years viz. 2005-06, 2011-12 & 2015-16 on following themes, refer Figure 4.

- Sr. no. (i) to (iii)- District-wise per capita geographical area (in Sq.M.) under 'Built up' LULC
- Sr. no. (iv) to (vi)- District-wise Per capita geographical area (in Sq.M.) under 'Urban Built up' LULC
- Sr. no. (vii) to (ix)- District-wise Percent geographical area under 'Built up' LULC
- Sr. no. (x) to (xii)- District-wise Percent geographical area under 'Urban Built up' LULC

Table 2 : District-wise per capita area (sq.m.) of LULC classes

		Built up	Agriculture	Forest	Grass/ Grazing	Wastelands	Wetlands/ Water Bodies
2005-06	Max. Value	78.85; Jamui	1412.51; Kaimur	787.06; Kaimur	14.24; Aurangabad	524.86; Jamui	193.80; Supaul
	Min. Value	10.23; Gopalganj	519.16; Patna	NIL; 23 districts	NIL; 26 districts	0.44; Nalanda	7.53; Sheikhpura
	Average Value	44.25	859.76	79.04	0.65	53.01	75.27
2011-12	Max. Value	96.27; Araria	1296.63; Kaimur	754.37; Kaimur	2.15; Vaishali	351.54; Jamui	8.89; Sheikhpura

	Min. Value	38.52; Saran	456.61; Patna	NIL; 12 districts	NIL; 28 districts	0.86; Nalanda	158.80; Supaul
	Average Value	68.18	785.24	75.84	0.16	37.99	66.88
2015-16	Max. Value	89.83; Araria	1209.28; Kaimur	700.01; Kaimur	2.04; Vaishali	0.87; Nalanda	128.63; Supaul
	Min. Value	36.75; Saran	424.61; Patna	NIL; 11 districts	NIL; 29 districts	297.62; Jamui	8.52; Sheikhpura
	Average Value	64.94	746.45	71.42	0.14	30.98	60.71

Source: Author's derivation from (NRSC, 2014), (Census of India, 2011), (UNFPA, 2009)

Table 3: Per capita geographic area under 'Built up' LULC

Range (Sq.M./ Person)	Percentage of Bihar area		
	2005-06	2011-12	2015-16
10.2 - 27.4	17.03% (6 districts)	0.00% (0 districts)	0.00% (0 districts)
27.4 - 44.6	34.59% (13 districts)	6.47% (2 districts)	9.68% (3 districts)
44.6 - 61.9	33.49% (13 districts)	34.94% (12 districts)	36.55% (13 districts)
61.9 - 79.1	14.89% (5 districts)	34.82% (13 districts)	38.26% (15 districts)
79.1 - 96.3	0.00% (0 districts)	23.77% 10 districts	15.51% 6 districts

Source: Author, (NRSC, 2014)

Table 4 : Per capita Geographic area under 'Urban Built up' LULC

Range (Sq.M./Person)	Percentage of Bihar area under range		
	2005-06	2011-12	2015-16
0.0 - 5.4	68.75% (25 districts*)	44.66% (15 districts)	46.23% (16 districts)
5.4 - 10.9	16.36% (13 districts)	36.45% (14 districts)	31.80% (12 districts)
10.9 - 16.3	7.18% (13 districts)	6.18% (4 districts)	9.27% (5 districts)
16.3 - 21.8	2.16% (5 districts)	4.99% (2 districts)	4.99% (2 districts)
21.8 - 27.2	5.55% (0 districts)	7.71% (2 districts)	7.71% (2 districts)

*Three districts have zero 'Urban Built up' area

k-means clustering

A total of 37 districts were grouped in clusters using the k-means of the variables, as presented in

the Table 5. Three sets of variables were used and k-means were calculated for each. Variables relate to 'Built-up', 'Forest' and 'Wasteland' showed more significance than other variables in each set in clustering the districts. In Table 5 column (D) refers to the specific serial number of the variables listed in column (B) for each row respectively.

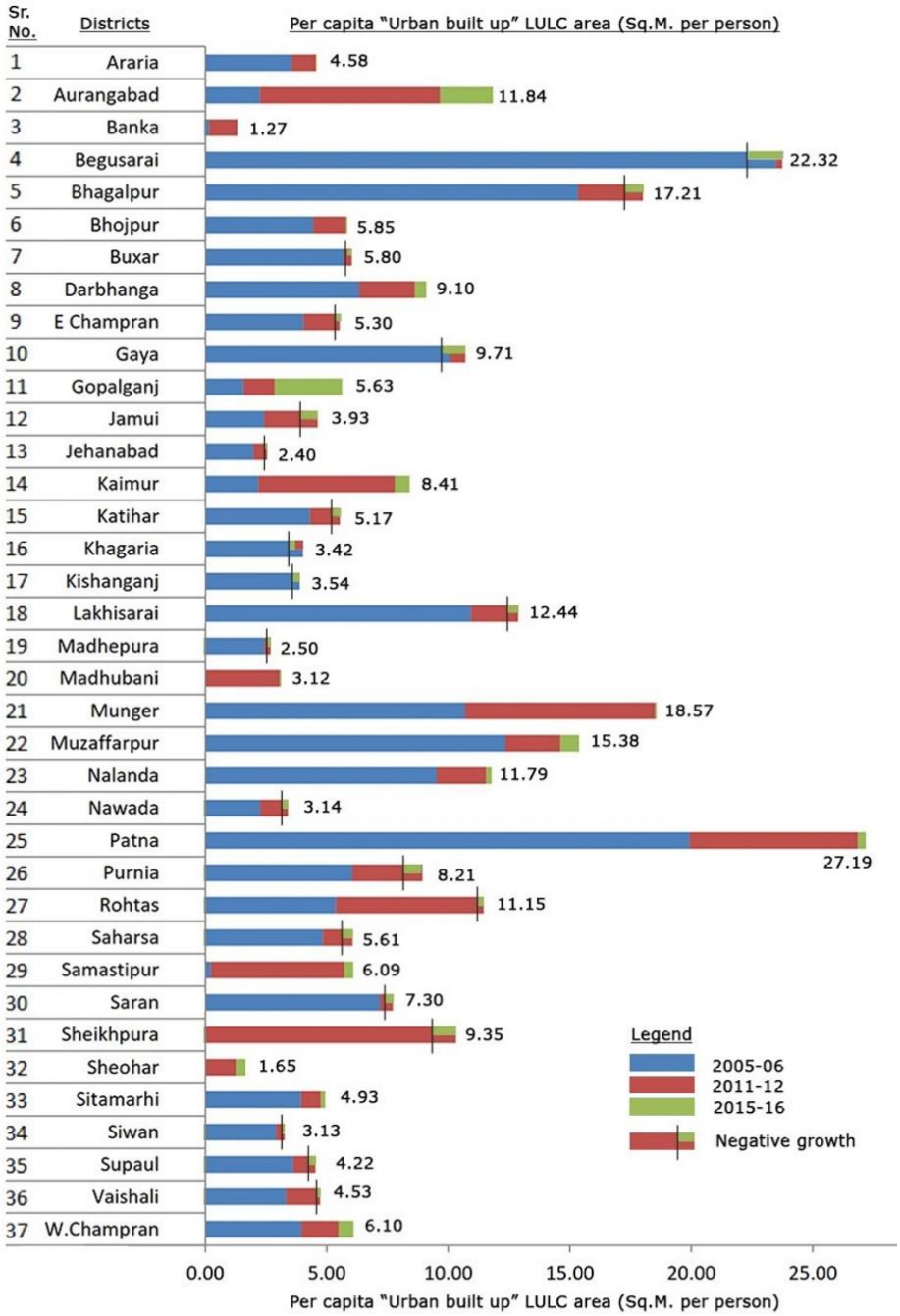
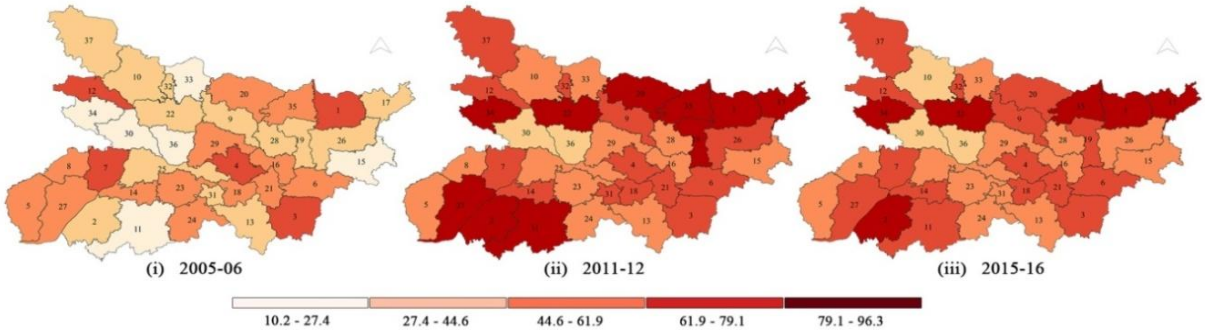


Figure 3: Growth in Per capita Urban built up LULC from year 2005 to year 2015

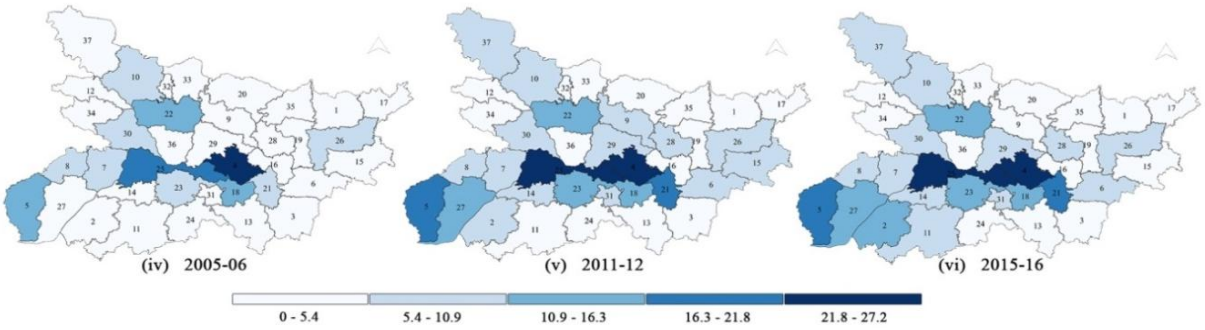
Discussion and Conclusions

Applicability of Bhuvan data

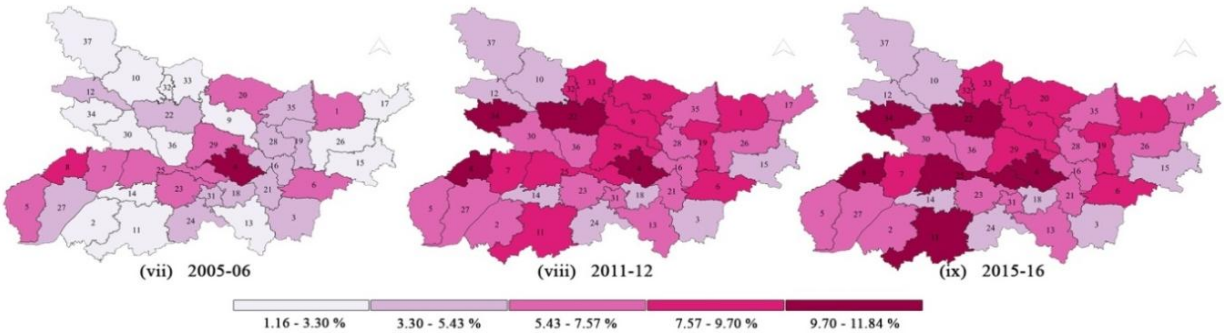
Per capita GDP of Bihar is 50,735 about 31% of national average, and stands at the least position among all states. Bihar has a majority of its landuse under agricultural or wasteland category- more than 80% since year 2005, refer Figure 2.



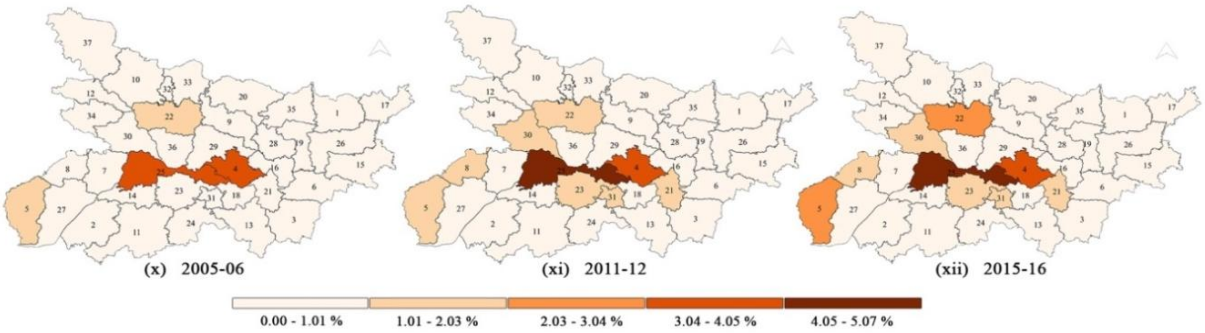
District-wise Per Capita Geographical Area (in Sq.M.) under "Built Up" LULC



District-wise Per Capita Geographical Area (in Sq.M.) under "Urban Built Up" LULC



District-wise Percent Geographical Area under "Built Up" LULC



District-wise Percent Geographical Area under "Urban Built Up" LULC

Figure 4 : District-wise Built up and Urban Built up LULC of Bihar

Development indices of study area show poor performance in several sectors- esp. human development, poverty, industrialisation, GDP, etc. indicating the need for development interventions to drive growth in these sectors including urbanization. Wasteland and less productive agricultural areas can be shifted to other nature of activities towards achieving development goals. Land which is underutilised at present can be managed strategically to serve as catalyst. Policy makers and planners can correlate Bhuvan data with demographic and socio-economic data to draft appropriate development plans.

Table 5 : K-means clustering of districts

Sr. No. (A)	Variables (B)	Year (C)	Significant Variables (D)	K (E)	Clusters' size (F)
I	LULC area under Built-up LULC area under Agriculture LULC area under Forest LULC area under Grass LULC area under Wasteland LULC area under Wetland LULC area under all classes	2005-06	#1 and #3	3	13+4+20
		2011-12	#1 and #3	3	15+4+18
		2015-16	#6	3	14+18+5
II.	Per capita LULC area under Built-up Per capita LULC area under Agriculture Per capita LULC area under Forest Per capita LULC area under Grass Per capita LULC area under Wasteland Per capita LULC area under Wetland Per capita LULC area under all classes	2005-06	#1 and #4	2	30+7
		2011-12	#5	4	20+1+6+10
		2015-16	#2, #3, #5 and #7	4	14+1+7+16
III.	Percentage LULC area under Built-up Percentage LULC area under Agriculture Percentage LULC area under Forest Percentage LULC area under Grass Percentage LULC area under Wasteland Percentage LULC area under Wetland	2005-06	#5	2	29+8
		2011-12	#1, #2, #3 and #5	2	29+8
		2015-16	#1, #2, #3 and #5	3	28+5+4

Limitations of Bhuvan data

The available data, used in this study has interval of 5 years; shorter intervals enable better understanding of temporal change and seasonal fluctuations. Also, district level data fails to elucidate grass root scenario. Though perspective plan are prepared using district level data, it's difficult to address local level issues in executable schemes or projects without local level data; for which settlement level data also needs to be procured and made available by concerned agencies to the planners and decision makers. As regards the study area, the number of local agencies involved in the ISRO's programme (NRSC, 2014) is negligible. More local agencies ensure better ground

trothing and hence better representation of actual scenario.

Conclusion

The random pattern observed in LULC distribution places districts in varying positions in each LULC class. Built up LULC class plays relatively higher significant role in clustering districts with respect to Bhuvan data, as is evident in k-clustering analysis. Patna district shows lesser per capita urban built up than Begusarai district, although Patna is host to the largest urban agglomeration in the state and has the administrative as well financial capital of the state.

A little less than 80% of the state area is covered under 'Agriculture' LULC class- 77.3% in 2015-16. About three-quarter area of Bihar state - 74.81% in 2015-16 & 79.76% in 2011-12 has 'Built-up' LULC class ranging from 44.6 to 79.1 Sq.M. per person. This includes urban as well rural areas covered by 'Built up' class. As regards the 'Urban Built-up' LULC class, about 80% of state – ie. 78.03% in 2015-16, 81.11% in 2011-12 & 85.11% in 2005-06 is ranging from zero to 10.9% - which resonates with the 11.29% urbanisation rate given by Census of India in year 2011 (Census of India, 2011). Central Bihar and few districts of South-Western part of state don't fall in this range. Further studies can address local level LULC data to analyse the dynamics of land use in the state.

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