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Authors: Sandeep Agrawal, Debadutta Parida, & Nilusha Welegedara

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Spatiotemporal Changes in Land Use in High-growth And High-density Remote Rural India: A Case of Bihar

Sandeep Agrawal
University of Alberta
Edmonton, Alberta, Canada
sagrawal@ualberta.ca

Debadutta Parida
University of Alberta
Edmonton, Alberta, Canada
dparida@ualberta.ca

Nilusha Welegedara
University of Alberta
Edmonton, Alberta, Canada
yalingas@ualberta.ca

Abstract

This study quantifies the spatiotemporal changes in high-population growth and high-density rural regions of India, areas that are also referred to as “urural.” The urural areas are remote, high-density rural areas far from zones of urban influence, experiencing growing population pressures. Using satellite-borne remote sensing data and its analysis of select districts in the State of Bihar, the study confirms the hypothesis that land use changes are underway in these remote rural regions while drawing attention to the alarming degree of these changes. High population density, population pressure, and economic changes in remote rural regions are the leading causes of significant land use transformations. The transformations are so substantial that these areas can no longer be characterized as rural by definition. Dramatic changes in all types of land use are evident, but most notable are decreases in land dedicated to agricultural use, receding water bodies, and rampant deforestation, with significant increases in built-up areas and bare land. Further, more land is being used for brick manufacturing to satisfy rampant building construction, degrading prime agricultural land to become bare and barren. The situation calls for an urgent and multi-pronged intervention from all levels of the government. As a start, the urural areas urgently need urban amenities, especially water, drainage, sanitation, and healthcare.

Keywords: high-growth, high-density, rural, India, *urural*, remote-sensed

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Changements spatio-temporels dans l'utilisation des terres dans l'Inde rurale reculée à forte croissance et à haute densité : un cas du Bihar

Résumé

Cette étude quantifie les changements spatio-temporels dans les régions rurales à forte croissance démographique et à haute densité de l'Inde, des zones également appelées « ururales ». Les zones ururales sont des zones rurales reculées, à forte densité, éloignées des zones d'influence urbaine, subissant des pressions démographiques croissantes. À l'aide de données de télédétection satellitaires et de son analyse de certains districts de l'État du Bihar, l'étude confirme l'hypothèse que des changements d'utilisation des terres sont en cours dans ces régions rurales reculées tout en attirant l'attention sur le degré alarmant de ces changements. La forte densité de population, la pression démographique et les changements économiques dans les régions rurales éloignées sont les principales causes des transformations importantes de l'utilisation des terres. Les transformations sont si importantes que ces zones ne peuvent plus être qualifiées de rurales par définition. Des changements spectaculaires dans tous les types d'utilisation des terres sont évidents, mais les plus notables sont la diminution des terres consacrées à l'agriculture, le recul des plans d'eau et la déforestation galopante, avec une augmentation significative des zones bâties et des terres nues. En outre, de plus en plus de terres sont utilisées pour la fabrication de briques afin de satisfaire la construction de bâtiments effrénée, dégradant les terres agricoles de qualité pour devenir nues et stériles. La situation appelle une intervention urgente et sur plusieurs fronts de tous les niveaux du gouvernement. Dans un premier temps, les zones ururales ont un besoin urgent d'équipements urbains, notamment d'eau, de drainage, d'assainissement et de soins de santé.

Mots-clés: forte croissance, forte densité, rural, Inde, *urural*, télédétection

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1.0 Introduction

High population density is seen as a crucial attribute of urbanity (Castells, 1977; Harvey, 1985; Qadeer, 2000, 2004; Rex & Moore 1967; Wirth, 1938). Thus, one might expect that high density and population pressure would transform the spatial organization, land market, and housing and community needs of a rural area, endowing it with urban characteristics. Vast regions that are economically and socially rural but whose population densities qualify them as urban—what Qadeer (2004) identifies as *ruralopolitan* densities (described in detail later in this paper)—have emerged in India, neighbouring countries in South Asia, and many parts of the Third World. As Qadeer (2000) points out:

> Among such areas are parts of rural Java, most of Bangladesh, central Punjab and the Peshawar valley in Pakistan, the South Yangtze River valley in China, the Mekong Delta in Vietnam, the lower Nile valley in Egypt, the

> islands of Barbados, Jamaica and Cape Verde, north-east Nigeria, Burundi, and Rwanda. (p. 1583)

India loosely follows the United Nations (UN) guidelines on rural-urban designations defining a rural area as having a maximum density of 400 persons per square kilometer (Qadeer, 2000; UN, 2005). Based on this, along the Ganges River in India, on the route from Delhi to Kolkata, in Kerala, and along the coasts of the states of West Bengal and Odisha, rural population densities are way past the density threshold (Perez, et al., 2019; Government of India, 2011a). This density criterion, along with two other requirements (a population of less than 5,000 and at least one-quarter of the adult male population employed in the agriculture sector) forms the definition of a rural area in the Census of India (Government of India, 2011b).

Several scholars such as Qadeer (2000, 2004) and Vidyarthi et al. (2017) argue that areas of rural India where population density is high show signs of changing land use, deteriorating economic situations, and poor or absent physical and social infrastructure. In this study, using remote sensing and GIS datasets, we intend to document the nature and extent of land use changes occurring in the select rural areas of India. We limit our exploration to 'urural' areas, i.e., the rural areas that are remote, far from zones of urban influence, but are experiencing increased population pressures and density to determine if these two factors contribute to land use changes. To do this, we tracked changes between 2001 and 2018 to decipher the spatiotemporal trends in land use changes.

The rest of the paper begins by explaining the phenomenon of increasing population and density in rural areas. We then elaborate on the method used and the subsequent findings, which expound on land use changes leading to reduced agricultural land, receding water bodies, and deforestation, thereby making way for more built-up, urban areas or barren lands. The conclusion brings the concept of urural, land use changes, and the drivers of the change together. It confirms our hypothesis that urural areas of India, characterized by high population growth and high density, are experiencing reduced agricultural land, water bodies, and forest land at the expense of increasing built-up areas and barren land. It calls for urgent attention to these regions' needs such as water, drainage, sanitation, and healthcare.

2.0 Literature review

2.1 Blurring Urban-rural Distinction

High-density rural regions are both a little-understood phenomenon and a distinct type of human settlement. High-density settlements in the rural Indian context specifically are largely unexplored. In contrast, in the Western world, the urbanization of the countryside has been more thoroughly investigated within the context of suburbanization and urban sprawl. However, a few scholars have examined the mixing of urban and rural areas in regional contexts, particularly in Asia, generating insights on changing land and density patterns in such locations. They have described this phenomenon through various terminology with some conceptual variations among them: dispersed metropolis (Ginsburg et al., 1991), desakota (McGee, 1991), peri-urban interface (Rakodi, 1998), rural-urban fringe (Adell, 1999; Carter, 1981), urban rural interface or UR-I (López-Goyburu & García-Montero, 2018), meta-agglomerations (Perez et al., 2019), spread region (Mookherjee, 2020), in-situ urbanization (Zhu, 2004; Zhu et al., 2013), rurban (Afshar, 1994), ruralopolis (Qadeer, 2000, 2004) or urural (Vidyarthi et al., 2017).

McGee (1991) has explored the phenomenon of non-agricultural activities infiltrating rural areas through his concept of “desakota” (derived from the Bahasa Indonesian language, in which *desa* means village and *kota* means city). He deploys this term to describe corridors of mixed agricultural and non-agricultural activities connecting large cities of Southeast Asia. Rural villages are situated within these linear corridors that connect the urban centres. Agrarian and urban land uses have transformed these villages, which have grown substantially in size due to this mixed-use. In the Indian context, Perez et al.’s (2019) conceptualization of the transformation of urban and rural areas is in line with McGee’s desakota concept. They contend that the force behind the current change is the urban centres as ‘meta-agglomerations’ acting as a larger organizing framework in the regional space. Mookherjee (2020) also acknowledges the rapid development of hybrid urban-rural spaces under the influence of large megacities, but terms it as ‘spread-region.’

In the context of the United Kingdom and United States, the terms peri-urban interface and rural-urban fringe are used conceptually. In general, peri-urban interface refers to transitional areas between the city and surrounding rural areas showing significant hybridity and flexibility. Rakodi, (1998, p. 3) describes peri-urban interface as:

> The peri-urban interface is a dynamic zone both spatially and structurally. Spatially it is the transition zone between fully urbanised land in cities and areas in predominantly agricultural use. It is characterised by mixed land uses and indeterminate inner and outer boundaries, and typically is split between a number of administrative area. It is also a zone of rapid economic and social structural change, pressures on natural resources, and changing labour market opportunities and patterns of land use.

On similar lines, in the United States, the concept of rural-urban fringe evolved in the 1940s and 1950s, to describe rural areas surrounding the city space that showcased urban characteristics in terms of densities, land use patterns, and social behavior of residents. Carter (1981) defined the rural-urban fringe as:

> The space into which the town extends as the process of dispersion operates, an area with distinctive characteristics which is only partly assimilated into the growing urban complex, which is still partly rural and where many of the residents live in the country but are not socially and economically of it.

López-Goyburu & García-Montero (2018) attribute the blurring urban-rural boundaries to growing regional mobility, and conceptualize the hybrid or diffused spaces as an ‘urban-rural interface (UR-I)’. They argue that the UR-I spaces must be understood as a separate and independent system in planning.

Ginsburg et al. (1991) favour “dispersed metropolis” to describe the extended metropolis between the rural and urban corridors, which are socio-economic zones organized by neither urban nor rural strategies in particular; rather, they preserve the essential ingredients of each form. In his words, “This is a complex and compound regional system that consists of central cities, fringe areas, exurbs, satellite towns and extensive intervening areas of dense population and intensive traditional agricultural land uses” (1991, p. xiii). Most people live in villages and almost all of the land is cultivated, with the landscape and topography remaining unchanged for the most part. However, most people’s incomes in these extended metropolitan zones come from non-agricultural sources: village-based work, small-town industries, city work entailing daily commutes from the village, and remittances from family members who have relocated to central cities. Ginsburg attributes these income streams to the ongoing improvements in the transportation system.

The concept of “in situ urbanization,” coined by Zhu (2004), addresses the dramatic growth in rural villages as a direct result of government intervention. He examined urbanization in the rural areas of the Quanzhou municipality in China and across Fujian Province, the region in which Quanzhou is located, exploring beyond just the coastal areas of the province as the government claims (Zhu et al., 2013). Government schemes aimed at developing township and village enterprises in the rural areas were intended to stop the flow of rural-to-urban migration, but have led instead to increased rural industries in China. These changes, in turn, have undermined the distinction between rural and urban areas (Zhu, 2004). Importantly, rural regions of both China and India have undergone in situ urbanization. However, the Indian experience is mostly a natural one, with little or no government involvement—unlike the Chinese instances, fueled by government intervention.

Qadeer (2000) has identified the urban potential of high population density in rural areas, calling such regions “ruralopolises.” These hybrid settlement systems are spatially urban but economically, institutionally, and socially agrarian and rural. A ruralopolis is an area with:

- high population density;
- an agricultural economic base;
- small landholdings and pressure on land; and
- extended corridors or bands of homesteads and villages sprawled amidst farms and woods.

Qadeer (2004) explains a ruralopolis as a form of urbanization that emerges with large institutional deficits or lags between needs and provisions for facilities, services, and resources as well as administrative organizations on the one hand, and spatial-environmental structures and community institutions on the other.

These rural communities are situated away from large centres, having grown exclusively through “urbanization by implosion” (Qadeer, 2004). Notably, while ruralopolises experience intensive population growth from within by increased births, they lack parallel increases in infrastructure, institutional capacity, or public services.

While rural segments of urban areas have long been called “rurban” (Afshar, 1994), Qadeer (2000) was more interested in the transformation that occurs in such regions, rather than considering them as simply a settlement type or zone.

For him, preexisting urban patterns and lifestyles alter rural forms that exist at the periphery of large metropolitan areas and cities, thereby generating new rurban forms. Examples include rooftop or backyard chicken farms; the keeping of large animals like cows, goats, sheep, or pigs in cities; and rural industries making gunny bags, shopping bags, handicrafts, carpets, and many more other items for urban dwellers. Conversely, computer and internet cafés in the countryside would also qualify.

Vidyarthi et al.’s (2017) chapter on high-density rural areas in India mentioned above extends Qadeer's (2004) concept. This work, however, proposes the term “urural” for remote, high-density rural areas far from zones of urban influence—unlike McGee’s (1991) desakota, Ginsberg’ et al’ s (1991) extended metropolis, and even Afshar’s (1994) rurban. The increasing population *and* density, mainly due to natural growth of these urural areas, as well as their economy (a criterion not considered in Qadeer’s ruralopolis), have evolved past the current definition of rural, due to in-situ transformation that occurred *without* government intervention or support (different from Zhu’s [2004] examples from China). Specifically, what makes them urural is that urban elements have been introduced in remote rural areas changing their physical, social, and economic character. The urural classification draws attention to the blurring of rural-urban distinctions in areas not proximal to cities or within metropolitan areas.

Significantly, rising unemployment, poverty, and the shift away from traditional agricultural work towards the non-agricultural sector are contributing to increased rates of out-migration from the area to metropolitan cities or even nearby towns. These concerns intertwine with increasing pressures on land and public resources in these areas, producing evermore conflicts linked to drainage routes, land ownership, and access to water (Poonia & Punia, 2018; Vidyarthi et al., 2017). The increase in land values prompts many rural residents to sell their holdings, which are then converted to non-agricultural uses. Recent studies from India indicate that residents in the rural-urban continuum in India use migration as an adaptation strategy, to reduce risks associated with monsoon rain-dependent agricultural practices as well as other effects of climate change (Singh & Basu, 2019).

Urural regions are also complex because they are difficult to classify within the current binary system of rural and urban. A clear divide between rural and urban does not exist anymore, given the emergence of new urban forms and evolving patterns of physical development. In the 2011 Census of India[1], the areas we identify as urural areas in this study are categorized simply as rural—and not even census towns (CTs), which are settlements that are administered as rural areas, but which have crossed the thresholds of urban characteristics with respect to size, density, and nature of the workforce. We hypothesize that urural zones are more rural in their physical characteristics and further away from any urban influence. Moreover, when compared to CTs, these areas have fewer or no institutions such as banks and schools or infrastructures such as sewerage, drainage, and water supply systems. In this paper, we intend to examine if the urural areas in India are indeed undergoing land conversion from agricultural to non-agricultural uses.

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[1] The census of 2011 is the most recent census available for India. The Census of India uses a binary classification of areas as urban or rural

2.2 Factors Leading to Land Conversion

Scholars posit that multiple factors contribute to land use conversion, but very few made connections between density and land use changes in areas classified as rural in the Census of India. Yet, even these few explorations are limited to rural regions in the vicinity of an urban centre, while our focus is on remote rural areas. Fazal (2000) is one such scholar, having looked at urban expansion surrounding a mid-size city in northern India with a method similar to ours. He evaluated the trade-offs linked to the rapid conversion of agricultural areas to non-agricultural uses that accommodates the growing urban population, observing that this unfolds at the expense of surrounding fertile agricultural land and a loss of food production. Fox et al. (2017) focused on Kerala, a state with a high population density, employing mixed methods (including remote sensing) to show that land use change is gradually decreasing agricultural land. This shift is dependent on several intertwined factors, including declining profitability of agriculture, rural urbanization, unreliable weather, housing demands, remittances from the Gulf countries, and government policies such as MNREGA[2].

2.3 Measuring Land Use Conversion

Various research tools can uncover changes in land use over time, but remote sensing and geospatial technology systems provide high accuracy at a lower cost than other methods (Rawat & Kumar, 2015). Various satellite sensors provide several image types (i.e., spatial and temporal resolution) that detect specific land types to meet diverse research needs. As well, scholars use numerous techniques to classify land use in both urban and rural settings: for example, supervised classification (Huang et al., 2015; Mallupattu & Reddy, 2013); unsupervised classification (Mishra et al., 2014); calculation of normalized difference in vegetation index; and a normalized difference built-up index (Rawat et al., 2013). However, most of these methods depend heavily on the spatial and temporal resolution of satellite images, and the known information of prior ground-based land use maps (Al-doski et al., 2013).

Since reliable spatial land use data for the study area were unavailable in the public domain, for this study, we used an ISODATA (iterative self-organized data) clustering technique in Erdas Imagine 10.1 version to understand detailed information about existing major land use classes. Section 3.2, Data Analysis, goes into detail about this approach. We applied this technique on the Landsat[3] satellite imageries, which were available for our study area during the study time frame.

3.0 General Description of the Study Area

In 2011, for the first time since India's independence in 1947, the absolute increase in population in India was higher in urban areas than in rural areas. While this trend varies from state to state and from region to region, India remains a predominantly rural country, with 69% of the population in 2011 living in rural areas (Government of India, 2011a). At the national level, India's population density has increased from

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[2] MNREGA refers to the Mahatma Gandhi National Rural Employment Guarantee Act of 2005, which guarantees 100 days of wage employment in a financial year to unemployed rural households.

[3] The Landsat program is the longest-running enterprise for acquisition of satellite imagery of Earth. The most recent, Landsat 8, was launched on February 11, 2013.

325 persons per square kilometre in 2001 to 382 persons per square kilometre in 2011. Thus, given the proportion of the population still living in rural areas, it is a safe assumption that this increased density is due to growth not only in urban centres but also in rural regions.

Bihar is the second-most densely populated state in the country (surpassed only by West Bengal), and the second most rural state with about 89% of the total rural population (behind Himachal Pradesh). While the urban population in Bihar has grown steadily at a rate of 35.4% between 2001 and 2011, the rural population has also kept pace, growing at about 24% between 2001 and 2011 (see Table 1). Despite higher urban growth, urban areas accounted for only about 11% of Bihar's population in 2011. Agriculture contributes only about 20% of the state's total GDP, while it employs more than 62% of the total workers in the state (Institute for Human Development, 2012).

We selected three districts in the state—Madhubani, Gopalganj, and Rohtas—as case studies (see Figure 1). The population densities of the districts of Madhubani and Gopalganj in 2011 were 1,279 and 1,258 persons per square kilometre, respectively. The decanal population growths in the two districts are 25.2% and 18.8%, respectively. The district of Rohtas was chosen as a 'control' case study as it has a population density of 763 persons per square kilometre—in other words, markedly less. It is noteworthy that in Bihar, all districts exceed India's urban density threshold of 400 persons per square kilometre, but employment in the non-agricultural sector falls below the urban threshold.

Madhubani and Gopalganj are among the top six densest rural districts in the state. Rohtas, conversely, is one of the least dense but is also slightly more urban (14.4%) than the other two. In keeping with the national and state trends, the urban population growth in all three districts is higher than the rural population growth. Still, Madhubani is one of the most rural districts (96.4%), closely followed by Gopalganj at 93.6%. Madhubani and Gopalganj neatly fit the definition of urural areas in terms of their population growth, density, location, and rurality. Rohtas as a control area markedly differs from the other two districts in terms of density, helping us isolate the effect of density.

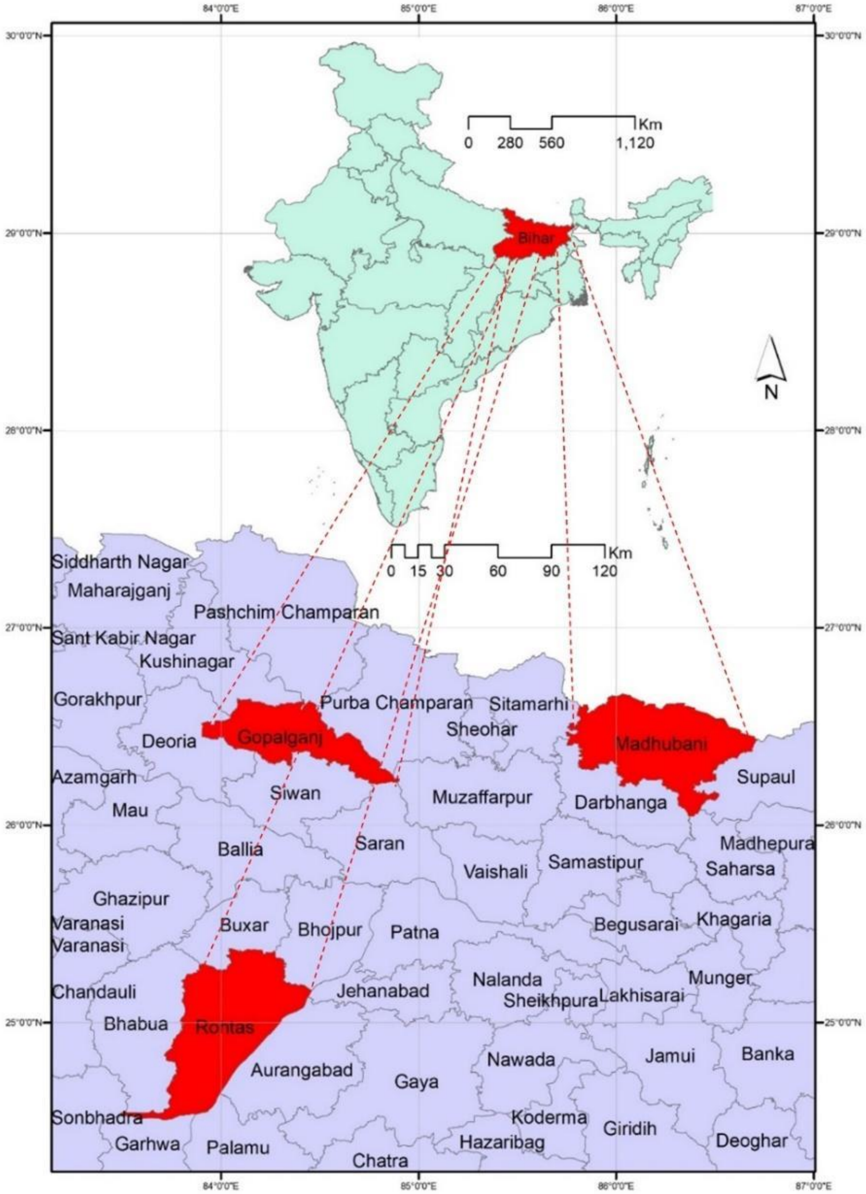
Many districts in Bihar—such as Vaishali, Siwan, Sheohar, and Samastipur—have a higher population (see Table 1). We have not included them in our case studies for several reasons. Vaishali and Siwan showed a higher rural growth between 2001 and 2011, but had a higher urbanization rate, thus subjected to more influence from urban areas. We also found limited available data on these areas beyond the census. Sheohar was carved out of Sitamarhi District in 1994, making it challenging to compare and contrast the data temporally, therefore not appropriate for a longitudinal study such as presented here. Although Samastipur exhibits similar characteristics to those of Madhubani, the latter was chosen to ensure that the study areas were geographically far apart from each other, to avoid any 'interactive influences' among the case studies. This was also a factor in the choice of our control region.

Table 1. *Summary of Demographic Data of a Few Districts in Bihar*

District	**Population (2011)**	**Population Density (sq. km.)**	**Decal Growth Rate (2001-2011)**	**Rural Population (2011)**	**Rural Population (2001)**	**% Urban (2011)**	**% Rural (2011)**	**Rural Growth Rate (2001-2011)**	**Urban Growth Rate (2001-2011)**	**Literacy Rate 2011**
Madhubani	4,487,379	1279	25.2	4,325,884 (urban: 161,495)	3,450,736 (urban: 124,545)	3.6	96.4	25.4	29.7	69.9
Gopalganj	2,562,012	1258	18.8	2,399,207 (162,805)	2,022,048 (130,590)	6.4	93.6	18.7	24.7	67.0
Rohtas	2,959,918	763	20.8	25,32,153 (4,27,765)	2,103,116 (3,47,632)	14.4	85.6	20.4	23.5	73.4
Samastipur	4,261,566	1465	25.3	4,113,769 (147,797)	3,271,338 (123,455)	3.5	96.5	25.8	19.7	63.8
Sheohar	656,246	1882	29.0	628,130 (28,116)	494,699 (21,262)	4.3	95.7	27.0	32.2	56.0
Vaishali	3,495,021	1717	28.6	3,261,942 (233,079)	2,531,766 (186,655)	6.7	93.3	28.8	24.9	68.6
Siwan	3,330,464	1495	22.2	3,147,551 (182,913)	2,564,860 (149,489)	5.5	94.5	22.7	22.4	71.6

Sources: Government of India, 2011c; Vidyarthi et al., 2017.

Figure 1. Map of the study area.



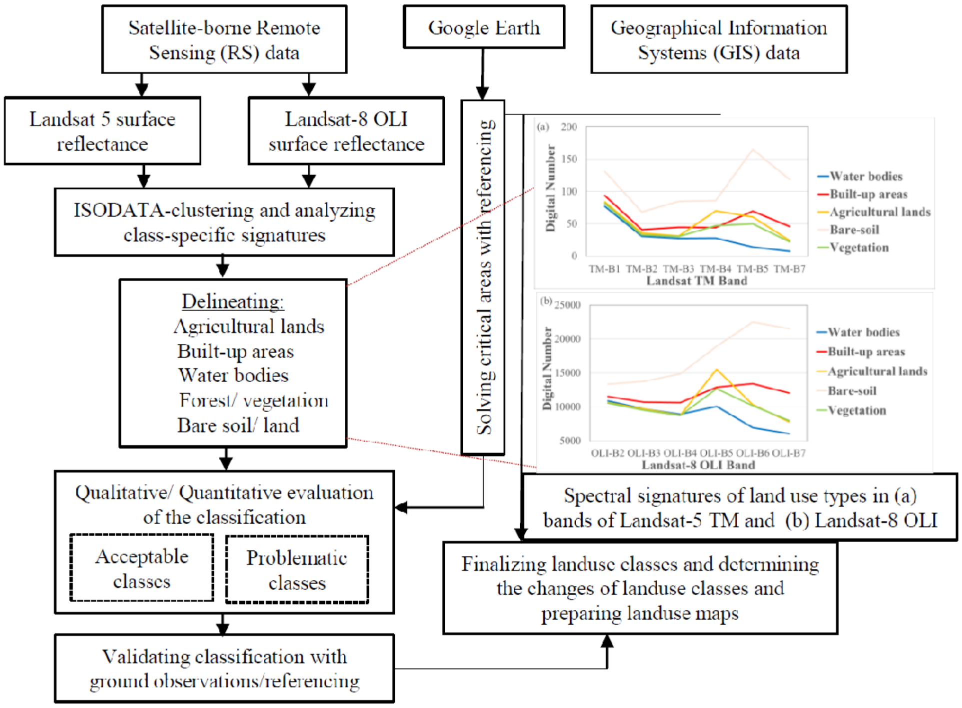
Source: Authors (ArcGIS® software by Esri).

4.0 Methods

The method comprised three major components (see Figure 2):

1. Selecting satellite-borne remote sensing data
2. Collecting GIS datasets representing study areas
3. Navigating Google Earth datasets during and after classification procedures, for referencing when required.

Figure 2. Schematic diagram of the method adopted to conduct this study.



Data collection and spatial analysis were carried out in March-April 2019. We updated the database with more cloud-free data in June 2021 and conducted further analysis to update the study. We selected the Landsat-derived satellite images to study land use changes in 2001, 2010, and 2018. After downloading images, we preprocessed and classified the data to delineate five different land use classes (see Figure 2). Previous studies have adopted various versions of land use classifications while analyzing rural areas based on their study objectives, such as agricultural lands, built-up areas, industrial activities (e.g., food industries), forested lands (e.g., dense and sparse), water bodies (e.g., river, ponds, reservoirs, and seasonal canals), swamp, bare soil, sands, and others (Mallupattu & Reddy, 2013; Mishra et al., 2016; Thakur et al., 2011; Tiwari, 2008). For this study, we chose five dominant land use classes to satisfy our study objectives: agricultural, built-up, water bodies, forest/vegetated areas, and bare soil (see Table 2).

Table 2. *Major Five Categories of Land Use Types*

Land Use Types	**Description**
Agriculture	Land typically devoted to agricultural practices like farmland and cropland
Built-up area	Buildings and paved surfaces like roads and airstrips
Bare soil	Dry river beds, land use for brick manufacturing

Table 2 continued

Vegetation/forests	Areas dominated by trees, shrubs, grazing areas, and grasslands
Water bodies	Rivers, ponds, reservoirs, lakes, canals, and irrigation channels

4.1 Data Requirements

We obtained cloud-free satellite data for 2001 and 2010 from Landsat 5 and the 2018 data from Landsat 8 OLI. Additionally, we identified several other datasets, such as GIS data, Google Earth data, and ground truth data for validation purposes. We re-projected satellite images and GIS data into Universal Transverse Mercator (UTM) Zone 45 N with World Geodetic System 1984 (WGS84) datum. A brief explanation of the datasets we employed are as follows:

4.1.1 Remote Sensing Data. We downloaded the Landsat 8 OLI and Landsat 5 Thematic Mapper (TM) images (30 m spatial resolution) from the United States Geological Survey (USGS) website for the study areas (USGS, 2019). We also purchased panchromatic satellite images from the Indian Space Research Organization (ISRO) at 5.6 m spatial resolution. However, we had to reject many of them because of substantial cloud contamination and wide variations in the dates when the images were captured. Such wide variations lead to inconsistencies due to changing crop patterns and the onset of monsoon season, which could result in varying sizes of water bodies.

Landsat 8 OLI began operating in 2013. Hence, we relied on the Landsat 5 data for 2001 and 2010 and Landsat 8 OLI data for 2018. These images were acquired with a combination of path-row[4] 140-42,141–42, 141-43, 142-42, and 142-43 to cover the three districts of the study area. The details of the band specifications of Landsat 5 and Landsat 8 OLI satellites are summarized on the USGS website (USGS, n. d.). We have selected the January-April period for the analysis as it is the normal crop growing season of the area[5]. Depending on the availability of cloud-free images, satellite images were downloaded for the following days for the three districts:

(i) January 10, 2001, February 20, 2010, and March 3, 2018, for the district of Madhubani;

(ii) March 06, 2001, February 18, 2010, and March 21, 2018, for the district of Gopalganj; and

(iii) April 7, 2001, March 31, 2010, and April 6, 2018, for the district of Rohtas.

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[4] The path-row is a part of the Worldwide Reference System, which enables a user to inquire about satellite imagery over any portion of the world by specifying a nominal scene center, designated by Path and Row numbers.

[5] In Bihar, the entire agricultural operation is roughly divided into two crop seasons—Kharif and Rabi. The Rabi season starts from about the third week of May and lasts until the end of October, followed by the Rabi season (Government of Bihar, 2014). Our data comprises cloud-free images from January until April encompassing the Rabi season.

4.1.2 GIS Data. In addition to satellite imageries, we collected geographic information system (GIS) datasets for the national boundary of India, district boundaries, road and railway networks, and major rivers. These datasets were obtained from the MapCruzin.com data portal in early 2019, which is a reliable repository frequently used for different research studies.

4.1.3 Google Earth Data. We used Google Earth's historical data through the Google Earth Pro desktop version software. This particular dataset provided high-resolution images for identifying different historical land use data over the study areas. It also enabled us to verify and compare already classified images to check validity. Also, Google Earth Pro provided the necessary support to check specific land use patterns when confusion appeared upon generating different land use classes using satellite imagery. In these cases, we verified the classified land use information against specific points (i.e., latitude and longitude) in Google Earth, which we compared with the historical data.

4.2 Data Analysis

Once we preprocessed the data, we employed the following three-step analysis:

1. We combined the acquired satellite band layers into a single image (except for Band-6 of Landsat 5 TM, which is normally used for thermal mapping and soil moisture estimation). These images were subset into the focused view of the three study districts to obtain the area needed to represent each district (see Figure 1). GIS datasets were used to generate the Area of Interests (AOI) images in ERDAS Imagine and thereby to subset the study area from the satellite imageries.

   We applied an unsupervised classification using the Iterative Self-Organized Data Analysis Technique (ISODATA) clustering algorithm to develop land use maps for each district (see Figure 2). The ISODATA clustering algorithm provides the ability to statistically assign a value to every single pixel of an image (Melesse et al., 2006). Additionally, the clustering algorithm helps to generate different classes of land use based on spectral similarities (see Figure 2 to see the spectral signatures of the five land use types).

2. Considering the size of the districts and major land use classes, we used the ISODATA clustering algorithm to generate 40 classes (see Figure 2). Then, we evaluated and classified the class-specific spectral signatures of 40 classes into the five broad categories of land use (detailed in Table 2). To confirm the five broad land use classes, we consulted several other sources, such as (i) Google Earth images; (ii) surface reflectance-based multi-spectral Landsat 5 and Landsat 8 bands with various combinations; and (iii) historical Google maps.

3. We calculated the areas that underwent changes during the past 17 years and prepared the maps depicting the changes in land use in the study districts. The land use changes that occurred between 2001- 2010 and 2010- 2018 were analyzed to understand the trend of changes. We then validated these generated maps using a stratified random sampling method to assess how

well a classification worked. The kappa statistic is widely used to compare the accuracy of generated land use classifications (Ismail & Jusoff, 2008; Kitada & Fukuyama, 2012). We calculated the kappa statistics (K) using the following equation:

$$K = \frac{(Observed\ value - Expected\ value)}{(1 - Expected\ value)} \text{------------------------------(ii)}$$

Accuracy assessments indicated that the land classifications were performed with fairly high accuracy. The overall accuracy of land classification was 90.97%, 90.60%, and 91.00% for 2001, 2010, and 2018, respectively. The kappa value was 0.78 for all three years. The rating of Kappa statistics is considered substantially accurate when the value sits somewhere between 0.61 – 0.80 (Rwanga & Ndambuki, 2017). A Kappa value of 1 is considered almost perfect.

5.0 Results and Discussion

Our analysis shows some interesting findings related to land use changes in the three selected districts in Bihar. We noticed a substantial reduction in agricultural land and an increase in built-up areas in high-density districts, namely Madhubani and Gopalganj, that are most likely being used for residential and other associated land uses (see Table 3). Also noticeable were increases in bare land and depletion of forest and vegetative cover in these districts. Although all three districts experienced a reduction in water body area, the two districts—with higher density experienced higher losses.

5.1 Reduced Agricultural Land

Agricultural land has been decreasing since 2001 in all three study districts (see Table 3). In the case of Madhubani, our analysis shows that the agricultural land area shrank by about 3.80% in the last 17 years. In Gopalganj, the shrinkage was about 3.55% during the same time frame, whereas very little change is spotted in Rohtas, which was 1% (see Table 3 for details). In percentages, the number might look small. However, from 2001 to 2018, Madhubani and Gopalganj districts lost around 10990.40 ha and 5273.30 ha of agricultural land, respectively. Madhubani, however, experienced much larger losses of agricultural land between 2010 and 2018.

Much of the agricultural lands were converted into built-up areas because of the population pressure and the need for people to house themselves. In our case studies, we noticed 4.22% of agricultural land turned into built-up areas in Madhubani, while in Gopalganj, 5.09% of agricultural land experienced this conversion (see Table 4). Further losses in agricultural land might have been compensated for by clearing out forests for agriculture purposes (Reddy et al., 2016) or changing rainfall patterns linked with climate change (Meer & Mishra, 2020), a phenomenon often witnessed in similar conditions in different geographical contexts in India.

Agricultural land is also turning into bare land. These are most likely because of an increase in brick kiln industries that manufacture bricks to meet the demands for building construction in the nearby towns or cities or within the rural area itself. 2.2% and 1.2% of agricultural land in Madhubani and Gopalganj respectively became bare. Although the proportions may not seem big, the areas are substantial. Some bare land was used for agricultural purposes, but the area is fairly small relative to what turned bare (see Table 4). As of 2019, the Madhubani and Gopalganj districts had 228 and 201 registered brick kilns, respectively, that are spread over more than 2000 ha of land in each district (Government of Bihar, 2019). In addition to brick kilns, other local industries have grown, especially in Madhubani, such as livestock and poultry, agro-based industries, wood furniture, and repairing and servicing shops (Government of India, 2016).

Sinha et al. (2017) present similar findings confirming the loss of agricultural lands in Bihar and raising shrinkage in the agricultural area as a critical concern for sustaining food security for the ever-increasing population. Singh & Asgher (2005) affirm the growing demand for bricks and the use of good fertile alluvium soil from the river floodplains of the study areas for brick manufacturing. Brick manufacturing provides more cash to the landowner as well as employment for the landless farmers but at the expense of turning productive agricultural land sterile for growing crops.

The transformation of agricultural lands into other land uses can have important long-term implications on the sustainable livelihood and food security of rural communities, further exacerbated by existing economic and social barriers (Gaur & Squires, 2020; Vidyarthi et al., 2017). Some critical implications of rural agricultural land depletion that arise from these changes are reduced cultivable land, exacerbated land values, increased non-farm activities, changing cropping patterns and farming practices, and imposed food insecurity challenges.

Table 3. *Land Use Change in Madhubani, Gopalganj, and Rohtas Districts*

Madhubani

Land Use	2001 Area (in ha.)	2010 area (in ha.)	2018 Area (in ha.)	Difference within class 2001-2010 (in ha.)	Difference within class 2010-2018 (in ha.)	Difference within class 2001-2018 (in ha.)	Difference within class 2001-2018 (%)	% Change across land uses
Agriculture	289489.99	287408.08	278499.57	-2081.91	-8908.51	-10990.4	-3.80	-3.19
Built-up area	20792.16	23291.10	34877.68	2498.94	11586.58	14085.52	67.74	4.09
Bare soil	5724.43	7018.29	7994.43	1293.86	976.14	2270	39.65	0.66
Vegetation/ Forest	23195.22	22270.03	19553.08	-925.19	-2716.95	-3642.14	-15.70	-1.06
Water bodies	5307.93	4522.23	3584.97	-785.7	-937.26	-1722.96	-32.46	-0.50
Total	344509.73	344509.73	344509.73					

Gopalganj

Land Use	2001 Area (in ha.)	2010 area (in ha)	2018 Area (in ha.)	Difference within class 2001-2010 (in ha.)	Difference within class 2010-2018 (in ha)	Difference within class 2001-2018 (in ha.)	Difference within class 2001-2018 (%)	% Change across land uses
Agriculture	148519.34	143683.30	143246.01	-4836.04	-437.29	-5273.3	-3.55	-2.58
Built-up area	25633.52	32903.37	39102.97	7269.85	6199.60	13469.5	52.55	6.58
Bare soil	2594.18	2405.32	4293.38	-188.86	1888.06	1699.2	65.50	0.83
Vegetation/ Forest	23664.30	21550.87	15817.26	-2113.43	-5733.61	-7847.0	-33.16	-3.83
Water bodies	4314.09	4182.57	2265.81	-131.52	-1916.76	-2048.3	-47.48	-1.00
Total	204725.43	204725.43	204725.43					

Rohtas

Land Use	2001 Area (in ha.)	2010 area (in ha)	2018 Area (in ha.)	Difference within class 2001-2010 (in ha.)	Difference within class 2010-2018 (in ha)	Difference within class 2001-2018 (in ha)	Difference within class 2001-2018 (%)	% Change across land uses
Agriculture	277666.66	276455.22	274902.38	-1211.44	-1552.84	-2764.3	-1.00	-0.71
Built-up area	29412.45	32392.02	34037.13	2979.57	1645.11	4624.7	15.72	1.19
Bare soil	16424.66	16585.71	17331.45	161.05	745.74	906.8	5.52	0.23
Vegetation/ Forest	59599.21	59390.06	57851.43	-209.15	-1538.63	-1747.8	-2.93	-0.45
Water bodies	4798.26	3078.18	3778.84	-1720.08	700.66	-1019.4	-21.25	-0.26
Total	387901.2	387901.2	387901.2					

Table 4. *Transition Matrix of Land Use Area (ha) from 2001 to 2018 in Madhubani, Gopalganj, and Rohtas Districts*

Madhubani—2018							
Land use class		Agriculture	Built-up area	Bare soil	Vegetation/ Forest	Water bodies	**Total 2001**
2001	Agriculture	269108.67 (92.96%)	12208.23 (4.22%)	6359.04 (2.20%)	901 (0.31%)	913.05 (0.32%)	**289489.99**
	Built-up area	1518.39* (7.30%)	18926.19 (91.03%)	137.7 (0.66%)	157.96 (0.76%)	51.92 (0.25%)	**20792.16**
	Bare soil	3943.18 (68.88%)	496.06 (8.67%)	1084.68 (18.95%)	175.4 (3.06%)	25.11 (0.44%)	**5724.43**
	Vegetation/ Forest	2142.11 (9.20%)	2943.32 (12.63%)	201.69 (0.87%)	17697.91 (75.97%)	310.19 (1.33%)	**23195.22**
	Water bodies	1787.22 (33.67%)	303.88 (5.73%)	211.32 (3.98%)	720.81 (13.58%)	2284.7 (43.04%)	**5307.93**
Total 2018		**278499.57**	**34877.68**	**7994.43**	**19553.08**	**3584.97**	**344509.73**
Gopalganj—2018							
Land use class		Agriculture	Built-up area	Bare soil	Vegetation/ Forest	Water bodies	**Total 2001**
2001	Agriculture	136862.23 (92.15%)	7567.02 (5.09%)	1828.62 (1.23%)	1561.9 (1.05%)	699.57 (0.47%)	**148519.34**
	Built-up area	1791.05* (6.99%)	23465.8 (91.54%)	41.4 (0.16%)	287.96 (1.12%)	47.31 (0.18%)	**25633.52**
	Bare soil	854.37 (32.93%)	701.01 (27.02%)	601.49 (23.19%)	268.2 (10.34%)	169.11 (6.52%)	**2594.18**
	Vegetation/ Forest	2186.31 (9.24%)	6605.28 (27.91%)	1182.24 (4.99%)	13258.74 (56.03%)	431.73 (1.82%)	**23664.3**
	Water bodies	1552.05 (35.98%)	763.86 (17.71%)	639.63 (14.83%)	440.46 (10.21%)	918.09 (21.28%)	**4314.09**
Total 2018		**143246.01**	**39102.97**	**4293.38**	**15817.26**	**2265.81**	**204725.43**
Rohtas—2018							
Land use class		Agriculture	Built-up area	Bare soil	Vegetation/ Forest	Water bodies	**Total 2001**
2001	Agriculture	265884.94 (95.76%)	3745.91 (1.35%)	1921.23 (0.69%)	5400 (1.94%)	714.58 (0.26%)	**277666.66**
	Built-up area	1357.28* (4.61%)	27674.89 (94.09%)	167.49 (0.57%)	181.21 (0.62%)	31.58 (0.11%)	**29412.45**
	Bare soil	3616.92 (22.02%)	459.24 (2.80%)	9318.84 (56.74%)	2172.23 (13.23%)	857.43 (5.22%)	**16424.66**
	Vegetation/ Forest	2907.9 (4.88%)	2115.9 (3.55%)	5147.28 (8.64%)	49065.87 (82.33%)	362.26 (0.61%)	**59599.21**
	Water bodies	1135.35 (23.66%)	41.19 (0.86%)	776.61 (16.19%)	1032.12 (21.51%)	1812.99 (37.78%)	**4798.26**
Total 2018		**274902.38**	**34037.13**	**17331.45**	**57851.43**	**3778.84**	**387901.2**

Note: * This misclassification was mainly due to the similar spectral reflectance in dry agricultural areas and built-up areas. Numbers within the brackets represent the percentage of land-use types that remain unchanged and changed according to the area of each land use in 2001.

5.2 Increased Built-up Areas

Of the three districts, Madhubani and Gopalganj, which have the highest population density, are experiencing a rapid rise in built-up areas. Between 2001 and 2018, the built-up areas have increased by 14085.52 ha and 13469.50 ha in Madhubani and Gopalganj districts, respectively. In the same period, however, Rohtas experienced only a 4624.70 ha increase in built-up area. Both Madhubani and Gopalganj witnessed a higher conversion to built-up areas between 2010 and 2018.

These changes are likely a response to the needs of the growing population and their associated demands, leading to the consumption of other land uses (especially agricultural land, forested areas, and depleting wetlands), as these demands are wide-ranging: home construction and related physical infrastructures (e.g., roads, bridges, and railroads); amenities and healthcare systems (e.g., schools and hospitals); service sectors; and businesses. As a result, built-up areas have been increasing rapidly, so much so that by 2018 Madhubani had 67.74% more such areas (based on the 2001 figure) and Gopalganj, 52.55% more (see Table 3). In the case of Rohtas, the built-up areas have not expanded as much, recording a 15.72% increase in the past 17 years.

Table 4 sheds more nuanced light on this change. Between 2001 and 2018, in Madhubani, 4.2% of agricultural land and 12.6% of forest land were converted into built-up areas, while these figures in Gopalganj were 5.1% and 27.9%, respectively. In Rohtas, these numbers are almost negligible, constituting only 1.3% agricultural land and 3.5% of forest land. The differences here illustrate how unique the concern is in high-growth and high-density rural areas.

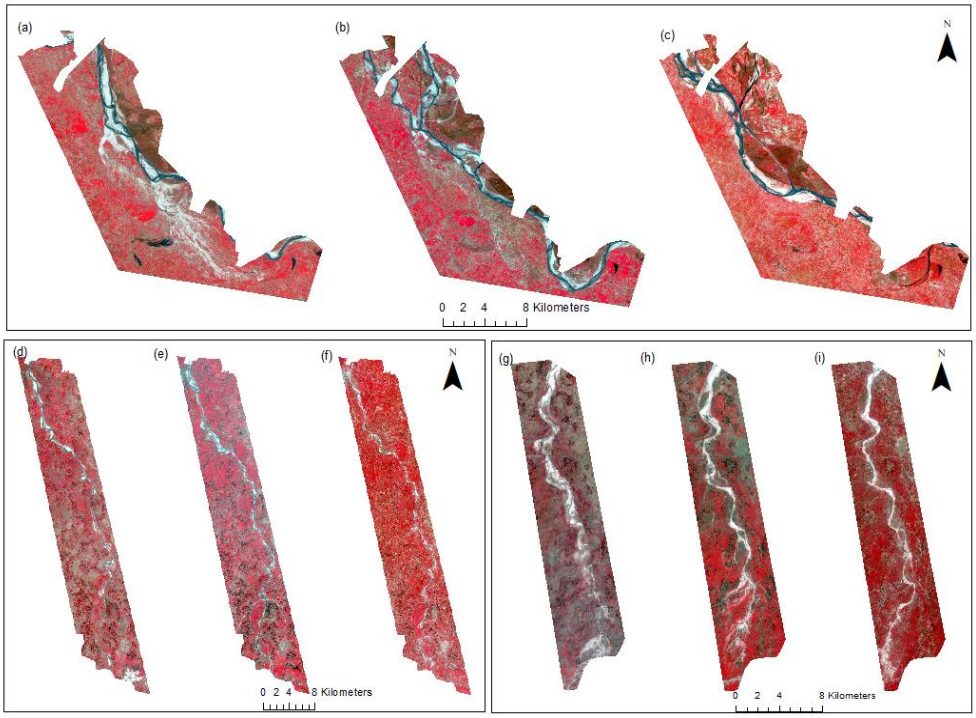
Salghuna et al. (2018), in their study in the Krishna district of Andhra Pradesh, attributed the increase in built-up land use there to necessary accommodations to population growth, largely due to the construction of the new capital city of Telangana – Amravati. They also pointed to excessive mining and logging of the forests as additional contributing factors. Scholars also highlight that the phenomenon of increasing built-up areas contributes to the destruction of the forest areas, as demonstrated by Rahaman et al. (2020), in their study of land use and land cover changes in the Barddhaman district in West Bengal, India. Rapid increases in built-up areas, often at the cost of forest and vegetation areas, result in increased ecological disturbances, micro-climatic conditions, and long-term threats to the ecosystem (Prasad & Ramesh, 2019; Salghuna et al., 2018). Although the growth dynamics of the predominantly rural character of our study areas may be different, these areas all reflect the intense trade-offs between economic growth and ecological conservation.

5.3 Increasing Bare Lands

The proportion of bare soil has increased in all three districts between the years 2001 and 2018. Gopalganj registered the most increase, with an increase in bare lands of 65.5% (1699.20 ha; see Table 3). Madhubani follows this, at 39.65% (2270 ha; see Table 3). Increases in bare lands occurred in Madhubani during the 2001–2010 period, whereas Gopalganj saw this phenomenon during the 2010–2018 period. 6359 ha (2.2%) of agricultural land in Madhubani has become barren since 2001 while 1828 ha (1.2%) of farmland in Gopalganj turned barren over the same period. While as a proportion of agricultural land area, these may not seem large figures, they are significant when we look at the land areas involved.

Some of the changes in bare and agricultural lands could be attributed to the seasonal floods and massive shifts in the course of rivers in both Madhubani and Gopalganj (see Figure 3; Vidyarthi et al. 2017). The bare land left by the river is possibly used by farmers to grow crops.

Figure 3: False color composite (FCC) Landsat satellite images (NIR, red and green bands as RGB).



Note: Images show massive shifts of the Gandak River in Gopalganj from (a) 2001, (b) 2010 to (c) 2018; Kamla River in Madhubani from (d) 2001, (e) 2010 to (f) 2018; and Bhuthi Balan River in Madhubani from (g) 2001, (h) 2010 to (i) 2018. Vegetation appears red, rivers appear blue and the bare lands appear white in images.

Furthermore, during the months of January until March, some water bodies might have dried up due to lack of rainfall, variations in the monsoon season in the previous year, changes in the course of a river, or extended periods of very high temperature, which is a common phenomenon in this region. Also, major rivers often do not carry enough water in this season, leaving the riverbeds bare. This lack of water in the riverbeds, along with the presence of numerous brick kiln industries, contributes to the increasing percentages of bare lands.

On the other hand, Rohtas experienced an increase of a mere 5.52% (906.80 ha). Its southwestern part consists of a plateau, hills, and deep gorges, accounting for a major part of the bare lands in the district, which remained largely the same between 2001 and 2010 and between 2010 and 2018.

An increase in the proportion of bare soil can lead to serious environmental and economic consequences: decreased agricultural productivity because of the removal of topsoil, disruption of biodiversity and ecosystem, and degradation of surface water quality.

5.4 Increasing Deforestation and Depletion of Vegetative Cover

In India, deforestation is generally linked to population growth as it requires more land for people and also brings changing socio-economic conditions, environmental factors, and forest (mis)management (Reddy et al., 2016; Roy, 2014). Population growth and the subsequent agricultural expansion are the top driving forces behind deforestation (Geist & Lambin, 2002). As Table 3 shows, vegetation or forested areas have decreased significantly in the Gopalganj district by 33.16% (7847 ha) between 2001 and 2018. In the same period, Madhubani experienced a comparatively lesser reduction of 15.70% (3642.14 ha) and Rohtas had the least reduction of 2.93% (1747.80 ha). However, the decline in vegetation cover was noticeable during 2010–2018 (see Table 3) in all three districts. Table 4 shows that in Madhubani, 12.6% of vegetation and forest land turned into built-up areas, and a further 9.2% were cleared to make way for farmlands.

In Gopalganj, the population increase is likely one of the dominant factors for decreasing forest land use, as percentages of built-up areas have increased to accommodate more people. Of note is that the population growth rate between 2001 and 2011 in the Gopalganj district was 19.02% (Government of India, 2011d). Table 4 shows that 27.9% of vegetation and forest land turned into built-up area while 9.2% of vegetation and forest were removed for farming. In contrast, Rohtas, with a relatively lower population density, experienced very little increase in built-up areas and deforestation over the same time period. However, detailed ground truthing information may be required to confirm the large-scale deforestation we have detected with the Landsat imagery.

Findings from similar studies in other districts in India by Roy (2014) and Reddy et al. (2016) suggest that forest land depletion is likely due not only to population growth but also to the lack of district-level policy tools for monitoring and conserving forest lands. Salghuna et al.'s (2018) Andhra Pradesh study shows that government policies regarding forest conservation are inconsistent. While the forest department adopts various conservation strategies, it is silent on people encroaching on forest lands. Bihar government policies and practices need to be analyzed to further investigate the situation in Gopalganj.

5.5 Depleting Water Bodies

The plains of north Bihar get water from the numerous rivers originating in the Himalayas, along with reasonably high rainfall during the monsoon season (Sinha et al., 2018). In our research, we noticed that in all three study districts, water bodies constitute between 1% to 2% of the total land area, and this proportion has decreased only slightly. Nonetheless, overall, the amount of water bodies in all three districts has consistently been decreasing since 2001.

In the cases of Madhubani and Gopalganj, we found that the water bodies in the districts were reduced by 32.46% (1722.96 ha) and 47.48% (2048.30 ha) between 2001 and 2018 (see Table 3). Most of these water bodies were in decline during both periods in both of these two districts. This depletion may have been the result of the water needs of the growing population, irrigation purposes, and expanding built-up areas that could be encroaching on some water bodies. Some water bodies were also being used for agricultural purposes when the water receded (33.67% in Madhubani and 35.98% in Gopalganj, but the areas in proportion to the farmland are fairly small; see Table 4 for further details). Additionally, some of the wetlands, such as swamps and small retention ponds, may have been depleting due to reductions in the inflow of water and drainage re-organization, to suit the needs of the growing population (Singh & Sinha, 2019). During the monsoon season (June to August), the three areas—but particularly Madhubani and Gopalganj—experience severe floods due to heavy rainfall and overspill from the rivers. However, because we collected our data during the relatively dry season of January to April, the water bodies we discovered were mostly seasonal and were probably leftovers of those generally present in the monsoon season.

Loss of water bodies often has a detrimental effect on local communities, which are entirely dependent on the rain. During the monsoon months, these water bodies replenish groundwater and collect rainwater for the rest of the season. Increased salinity and drinking water shortage are becoming common occurrences, which have been linked with threats to water security (Upadhyaya, 2013), increased soil pollution (Kumari et al., 2019), and more water-based disputes and conflicts among communities as documented by Vidyarthi et al. (2017).

6.0 Conclusion

Our study objective was to track spatiotemporal changes in urural areas of India using three rural districts in the State of Bihar as case studies. We used satellite-borne remote sensing data to confirm our hypothesis that water bodies, vegetation, and agricultural land use have decreased while the built-up areas and barren lands are continuously increasing due to high population growth and density in rural districts. The study findings demonstrate significant changes in land use patterns observed over the last 17 years, particularly in the last decade in the two urural areas, i.e. high-growth and high-density study districts—Madhubani and Gopalganj—in Bihar, but not in the relatively low-density rural district of Rohtas (which we considered our control comparison). Almost all changes such as an increase in built-up areas and bare lands, a reduction in agricultural lands, and depletion in vegetative cover and water bodies were significant in Madhubani and Gopalganj when compared with Rohtas. What this means is that high population density, population pressure, and economic changes in remote rural regions are leading to significant land use transformations, essentially, turning them into areas with urban characteristics.

Built-up areas are marked as one of the major expansions in the rural areas. Agricultural land areas and vegetation cover have decreased significantly to accommodate housing and the affiliated needs of the growing population. The type of land use under pressure for urban development may vary. For instance, deforestation is much higher in Gopalganj, while the loss of agricultural land is much higher in Madhubani, but each type is being ‘paved’ for creating new built-up areas.

Increases in bare lands and decreases in water bodies were also noticeable. Interestingly, these various changes occurred in the two high-density rural districts (Madhubani and Gopalganj). However, all three districts showed evidence of growing bare lands. We attribute increasing bare lands in the two high-density districts to urban expansion and more agricultural land being dedicated to manufacturing a massive amount of bricks for construction purposes. In the case of Rohtas, the low-density district, the presence of hilly terrain and deep gorges and ravines in a portion of the district lends itself to more bare lands.

Clearly, these are alarming trends in the high-growth and high-density rural districts as they portend the possibility of a looming crisis in food supplies, insufficient availability of potable water, and decreasing forest cover. The scarcity of such basic necessities of life is already leading to abject poverty, high unemployment, and social conflicts; it is also forcing people to migrate out of the area (Vidyarthi et al., 2017). These changes should be of major concern to the state and national level policy-makers and government officials. The situation warrants a stricter implementation of agricultural land conversion laws, coupled with strategic management of natural resources, that will place a check on expanding built-up areas and brick-manufacturing activities, as well as establish better employment and incentives for farmers (such as PM-Kisan scheme[6], expanded MNREGA, and/or other forms of subsidies) to remain in farming activities, and thus reduce rural to urban migration.

Such urural areas are the new frontier in rural and regional planning in India. Barring some progress in educational facilities and improvements in road connectivity, other forms of physical and social infrastructure and services are not commensurate with the urban characteristics of these villages—especially their population, density, and land use changes (Vidyarthi et al., 2017). The spatial and socio-economic characteristics of these areas are close to those described in Ginsburg's (1991) extended metropolis or even McGee's (1991) desakota concept, especially with respect to these features: the rural nature of these landscapes, which also reveal shifting land uses; the non-agricultural economy; the improving connectivity; and the dense, but also migratory, population. However, as noted earlier, urural areas are remote and far from any metropolitan zone of influence.

Two possible explanations would account for similarities in the spatial and socio-economic characters of urural areas and those of either extended metropolises or desakota regions. Either the metropolitan influence transcends far beyond what we have traditionally understood, or these characteristics appear despite the absence of a metropolitan area in the vicinity. Such appearances perhaps arise also because of rapidly diversifying and interconnected rural-urban economies and an ever-improving transportation system beyond a metropolitan area, one that allows people to traverse much longer distances in short amounts of time.

The findings of this study further suggest that urural areas need urban amenities (water, drainage, sanitation, and healthcare) in view of the fact that they face unprecedented population density and economic pressures. An increase in disputes and public encroachments might be a result of population density pressures on land and lack of public resources. The government needs to recognize the reality of these zones of intense rural-urban interaction and direct investment in these underserved areas.

This study could help the Government of India's National Rurban Mission, which has two specific goals: to stimulate local economic development and to enhance basic urban services in rurban clusters. Interestingly, land use changes are not a factor that was invoked to identify rurban clusters. The study methods used here could, therefore, be applied to the hundred or so identified clusters, along with other factors, to prioritize those in dire straits and thus most in need of urgent attention.

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[6] PM-Kisan is the abbreviation of Pradhan Mantri Kisan Samman Nidhi, which pays out Rs. 6,000 (Indian Rupees) annually as minimum income support to farmers, who have small land holdings.

Employing remote sensing data to ascertain land use changes is useful. However, a larger and significantly more in-depth study is needed to better understand the dynamics affecting the change of land use and other characteristics in remote rural areas across India and in other countries where they are characterized by high-growth and high-density populations, such as in Bangladesh, China, and Pakistan. Future research can investigate relationships among rural population density, built-up density, and agricultural changes. Further investigation is also necessary to identify other major factors affecting the loss of fertile agricultural land in such countries. Higher-resolution satellite imagery could lead to more nuanced land use classifications, which will help to determine a more accurate calculation of areas under different land uses. This should be coupled with more detailed ground-truthing in the form of field checks, as well as qualitative interviews with the locals to ascertain the minutiae of changes and the factors affecting them.

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