Land Use and Land Cover Changes in the Rapidly Urbanizing National Capital Region in India

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Introduction

The hitherto unseen fast-paced urban growth in the Global South (Datta & Shaban 2017) transforms peri-urban spaces, making their sustainable management extremely difficult. Such rapid city expansion adversely affects the natural environment in myriad ways (Thebo et al. 2014), thereby abetting natural landscape fragmentation (Fahey 2017). For mitigating such impacts and in order to manage urban growth more sustainably, an in-depth understanding of land use and land cover (LULC) dynamics within and around urban entities is needed (Kantakumar et al. 2016).

Indian cities are likely to add an additional 416 million new urban residents by 2050 (UN Habitat 2020). The National Capital Region (NCR) of India, which comprises the National Capital Territory (NCT) of Delhi and its adjacent districts in the states of Rajasthan, Uttar Pradesh and Haryana (covering a total of 54,984 km²), is home to around 46 million people (NCRPB 2013). As one of the largest urban agglomerations worldwide, urban expansion in the NCR has adversely impacted social-ecological systems, particularly waterbodies (Paul & Nagendra 2015). Additionally, such rapid urban growth has outstripped the provision of urban infrastructure (Schindler & Kishore 2015, Bhan 2013), especially where urban growth has transgressed into former rural hinterlands.

While population growth in the entire NCR has been examined using Census data (Jain & Korzhenevych 2020, Jain et al. 2019a), existing studies investigating its overall urban growth-related LULC changes need to be updated (Jain & Pallagst 2015, Jain & Siedentop 2014). Additionally, till date, almost all urban analyses regarding such aspects have either focused solely on the NCT of Delhi (Jain et al. 2019b, Ahmad et al. 2016) or merely examined any one of its satellite towns (Horo & Punia 2019, Follmann et al. 2018). Additionally, the administrative structure of the NCR with its 721 settlement units, and a mix of urban and rural governance set-ups is complex (see Fig. 1). Managing urban growth in the NCR, therefore, requires a better understanding of the spatio-temporal changes on the scale of the different settlement units.

In this context, our analysis addresses LULC changes of the entire NCR in a detailed manner, using up-to-date remote sensing datasets, along with discerning the same for each of its constituent settlement units, in a phase-wise manner from 2000 to 2018.

Our analysis highlights the dynamic built-up growth and the alterations of six LULC classes for the different administrative settlement units. Pertinently, this helps to discern where urban growth has been spatially concentrated over the last two decades within the NCR, and how it is related to the existing administrative set-ups and government policies. In particular, we highlight that the recent dynamic growth of built-up areas in the NCR has happened especially in areas under rural administration, which have limited capacity to govern such fast-paced urban growth and landscape transformation in a sustainable manner.

Settlement characterization in India – the rural/urban dissonance

India's settlement divisions, as outlined by the Census of India, are quite complex when distinguishing between urban and rural settlements, from legal and statistical viewpoints. Thus, it is important here to highlight the differences between *legally* and *statistically* urban/rural entities. Firstly, as per the Indian Constitution, urban and rural areas are *legally* different. Urban areas are governed by urban local bodies (defined under the 74th Amendment Act of 1992), including Municipal Corporations (MCs) and Nagar Panchayats (Notified Area Council or City Council, NPs), while rural areas (defined under the 73rd Amendment Act of 1992) are governed by a three-tier rural governance system (districts, blocks, villages) with Gram Panchayats (GPs) at the local village level. Secondly, the Indian Census distinguishes between urban and rural forms. Statutory Town (STs), Census Towns (CTs), Outgrowths (OG) and Urban Agglomerations (UA) are statistically urban, while all other areas (i.e. villages) are considered rural (Chakraborty et al. 2017). However, the above CTs, while being denoted as *urban* based on their socio-spatial characteristics, i.e. having a total population of above 5,000 people, with at least 75% of their main male workers employed outside the agricultural sector and a minimum population density of 400 persons/km² (Census of India, 2011), continue to remain governed by *rural*

institutions (Table 1). As per the 2011 Indian Census, 23.77 million people lived within the study area (average population density 6,063 persons/km^2), of which 22.04 million were urbanites (16.02 million resided in STs and NPs and 6.02 million in CTs) and only 1.66 million were ruralists. In particular, population growth is quite rapid in the CTs located in the peripheral areas of the major STs in the NCR (Jain 2018).

Table 1: Rural and urban categories within the NCR

Census Area Classification		Legal Status under the Constitution of India	
Urban	Statutory Towns (STs)	Urban	Municipal Corporation (elected)
			Municipal Council (non-elected)
			Nagar Panchayats* (NPs, town council, non-elected)
	Census Towns (CTs)	Rural	Gram Panchayats (villages)
Rural	Villages		

Note: As per the 74th Constitution Amendment Act (part IXA) of 1992, a Nagar Panchayat governs areas in transition from a rural to an urban area. It does not embrace Census Towns governed by rural administration as mentioned and provided in 73th Constitution Amendment Act (part IXA) of 1992.

Analyzed image datasets and methods

Supervised classification via the maximum likelihood method was done on Landsat TM 4/5 images (30×30 m pixel resolution) of 2000 and 2010 and Landsat 8 OLI images of 2018 (see Table 2 for the image details and achieved classification accuracy). Seven LULC classes (built-up area, barren land, forest/vegetation, water bodies, open land, agricultural fallow and crop land) were extracted for each time period. Google Earth images were used for validation and the computed Kappa statistics, based on the confusion matrix, helped ascertain the classification accuracy (Chakraborty et al. 2021). From the above prepared three LULC datasets, two LULC change maps and transition matrices (Phase I: 2000-2010 and Phase II: 2010-2018) were generated. Through them, the LULC changes that had occurred were enumerated for the whole NCR and its different settlement units, with attention to changes in built-up extents and the specific LULC components these have encroached upon.

Discerned LULC changes in the NCR and its constituent units

Across the three time periods examined, marked LULC alterations were noticed over the entire NCR.

Built-up area initially covered 10.6% of the NCT in 2000, but this had substantially expanded to 31.1% by 2018. Concomitantly, the areal coverage of croplands had declined markedly from 12.1% in Phase-I (2000 to 2010) to 4.6% in Phase-II (2010 to 2018). The change trends for the forest/vegetation and waterbodies classes were mixed, with a decline during Phase-I and a rise during Phase-II. This contrasted the trends shown by the open lands and agricultural fallow classes; whose areal coverage rose during Phase-I but fell in Phase-II. Barren lands stayed more or less constant during Phase-I, before reducing partially in Phase-II.

Table 2: Satellite image details and classification accuracy

Year	Path and row	Acquisition date
2000	146, 40 & 147, 40	19.02.2000 and 29.03.2000
2010	146, 40 & 147, 40	14.02.2010 and 21.02.2010
2018	146, 40 & 147, 40	24.03.2018 and 31.03.2018

Accuracy assessment of classified images (based on 500 random sample points)			
	2000	**2010**	**2018**
Overall Accuracy	82.6	84.40	81.80
Kappa coefficient	70.82	76.34	73.01

The above LULC changes were also analyzed individually for the different settlements across administrative units. In 2000, a substantial portion of the built-up class was concentrated within the STs and CTs of the Delhi NCT, being markedly less in the other settlement units (Fig. 2). The only exceptions were the STs of Ballabgarh, Ghaziabad, Gurgaon and the CTs of Dardi. During Phase-I, a considerable growth in the built-up category occurred in the CTs (76.95%) and rural areas (209.36%), with this being particularly marked in the CTs of Dadri, Gautam Buddh Nagar, Delhi NCT and in the rural areas of Dadri, Delhi NCT and Ghaziabad. In Gautam Buddh Nagar, industrial development (formation of the Noida Special Economic Zone) was behind this notable increase. During the same time, the built-up area increased from 38.6 km^2 to 68.5 km^2 in the STs of Ghaziabad. Previous studies have also reported a similar trend of built-up growth in this region (Tripathy & Kumar 2019, Ahmad et al. 2016). Our results substantiate them and further reveal that not just the NCT of Delhi but every settlement unit within the NCR underwent rapid built-up growth in Phase-II.

Among the rural areas, Dadri experienced a boom in its built-up growth rate (352.6%), followed by Ballabgarh (270.4%) and the NCT of Delhi (237.0%).
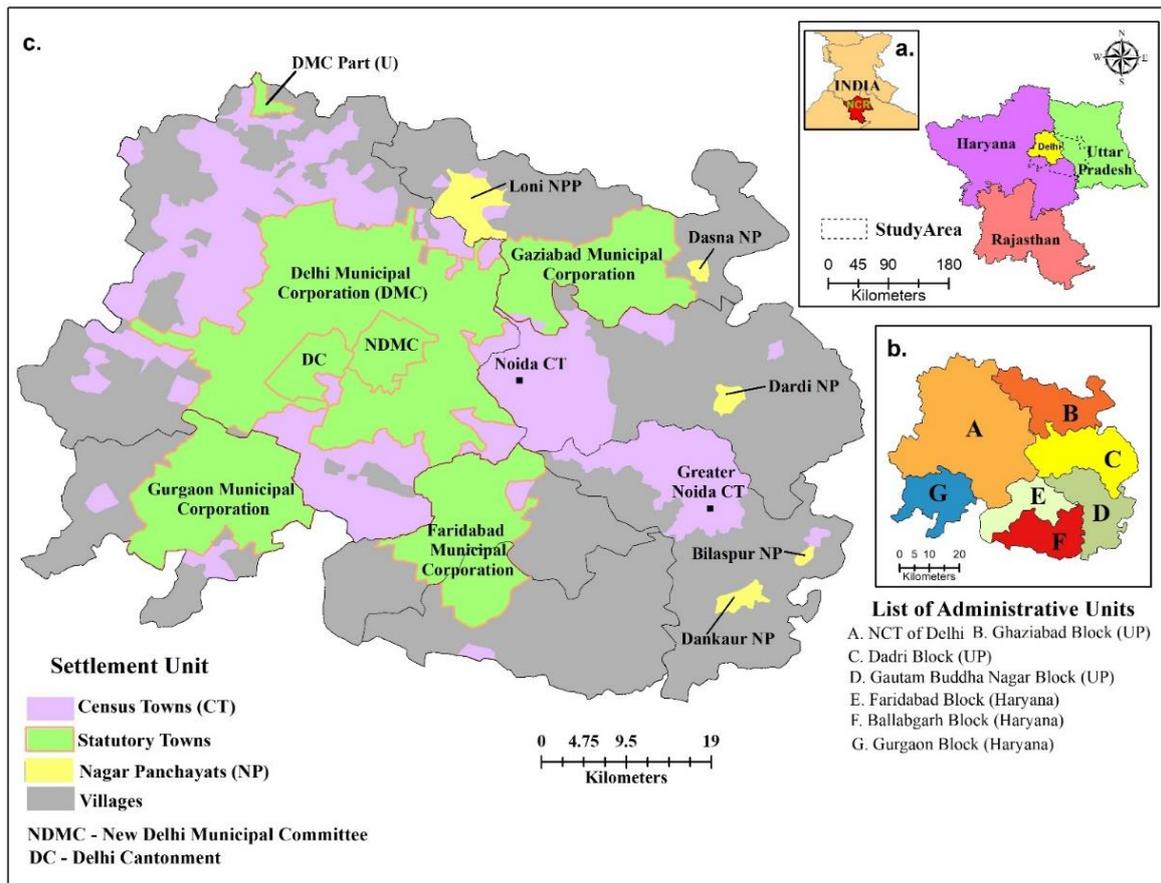
Fig. 1: The Study Area, with a. National Capital Region; b. Different administrative units; c. Various settlement units (prepared by authors using Administrative Atlas, Census of India 2011)
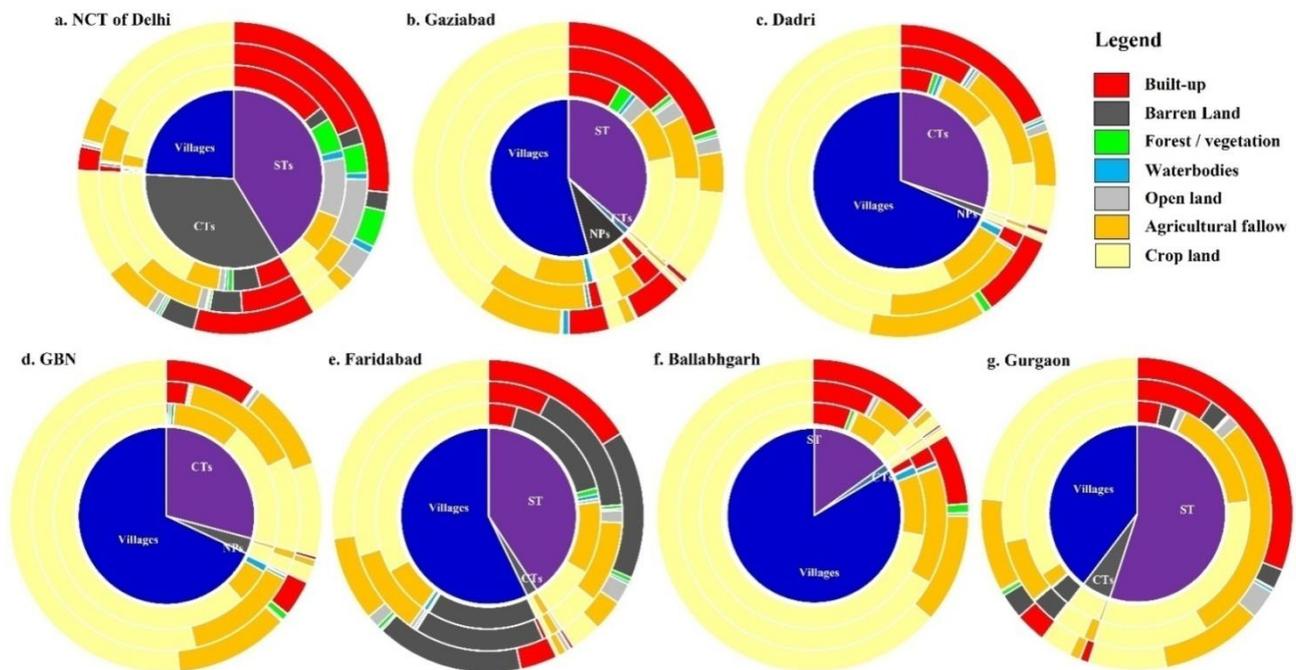

Fig. 2: Area (in km²) under different settlement units and LULC classes in different administrative units in the study area. Note: Innermost circles represent total area under different settlement units. Second, third and fourth circles show area under LULC classes in 2000, 2010 and 2018, respectively. Abbreviations – ST: Statutory Town, CT: Census Town, NP: Nagar Panchayat, GBN: Gautam Buddh Nagar (prepared by the authors)

The built-up coverage in the NPs doubled during Phase-II, particularly in Ghaziabad (from 12.7 km² in 2010 to 24.4 km² in 2018). Forest/vegetation cover increased during Phase-II, mainly in the STs of the Delhi NCT and Faridabad and in the CTs of Dadri and Faridabad, particularly due to government greening initiatives (Sharma & Joshi 2016), but decreased in the villages and NPs.

In Phase-I, the open land extents increased in the CTs and villages while in Phase-II, only the STs of the Delhi NCT showed an overall loss of 72.4 km² in this category. Agricultural fallow lands increased by nearly 200 km² in rural locales during Phase-I, mostly in Dadri (44.1 km²) and the Delhi NCT (41.3 km²). In Phase-II, the sharpest decline in this component occurred in the STs of Gurgaon and Delhi NCT and in the CTs of Delhi NCT and Dadri. In Phase-I, the maximum cropland loss (200.1 km²) occurred in the rural areas, again mostly in Dadri (46.8 km²). For the CTs and STs, this decline was 158.6 km² and 106.5 km², respectively, mostly in the CTs of Delhi NCT, Dadri and in the ST of Gurgaon (63.8 km²). Crop land reduction was less marked during Phase-II.

The substantial rise in built-up areas attests to the ongoing rapid urban growth in the region (Fig. 3). In Phase-I, nearly 101 km² of agricultural fallow lands transformed into built-up spaces, with 36.5 km² of this alteration occurring just within the STs and CTs of the NCT of Delhi. In Phase-II, nearly 348 km² agricultural fallow lands were altered into built-up areas across the entire region, with the greatest change occurring in the ST of Gurgaon (62.1 km²), followed by that in the CTs of Delhi NCT (50.8 km²) and Dadri (38.4 km²).
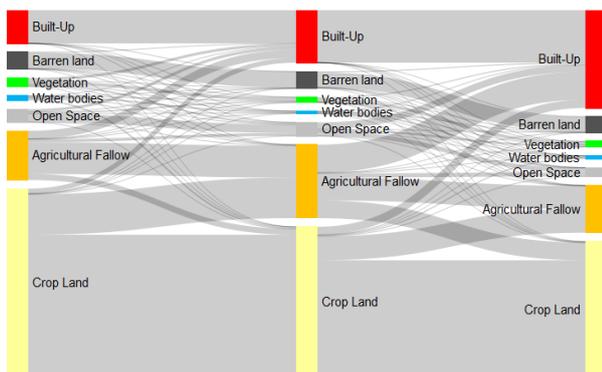

Fig. 3: LULC alterations in the study area from 2000 to 2018 (Left panel- 2000; Middle panel- 2010 and Right panel- 2018; prepared by the authors)

In rural areas, such transformations were significantly higher during Phase-II, most of which occurred in Dadri (24.8 km²), the NCT of Delhi (17.5 km²) and Ballabgarh (12.2 km²). While the satellite towns of Gurgaon and Faridabad underwent such marked land transformation due to the Haryana State Government's multiple acquisitions of agricultural land for planned urban development, particularly in Gurgaon (Goel 2011), the role of

unplanned development (which is often either undocumented or unregulated) in abetting such marked urban growth is also important (Follmann et al. 2018). This creates difficulties for the local administration in suitably governing and providing services for these spaces, as noted before, especially if it is outside their ambit.

Among the other LULC classes, significant changes were noticed in the open space category, which experienced overall changes of about 35 km² during Phase-I and 84.2 km² during Phase-II in its extents. This change was most striking in the STs of the NCT of Delhi (alterations of 24.8 km² in Phase-I and 64.0 km² in Phase-II). Barren lands, forest/vegetation cover and water bodies had also morphed into built-up areas (especially in the STs of the Delhi NCT), but showed a lower intensity of change during Phase-II.

Concluding discussion

The findings of this remote sensing-based analysis support and extend the existing knowledge regarding the contemporary processes of urban growth in Delhi's urban periphery. Especially, the rapid growth of built-up areas in legally rural places (CTs and villages) has outpaced that occurring within the legally defined urban areas (STs and NPs). In particular, CTs and villages have only limited administrative capacity to govern this urban growth with regard to spatial planning and infrastructure provision (Jain & Korzhenevych 2020). This results in a fragmented local and regional governance and mismatch between the rural/urban administered spaces – a typical phenomenon of the Indian peri-urban landscape (Krishnankutty 2018, Mitra 2018).

Existing planning approaches in the NCR – including master planning (e.g. Master Plan for Delhi, currently revised for 2041) and regional planning (NCR Regional Plan-2021, notified in 2005) have largely failed – if not widely ignored – to account for and integrate the occurring urban growth beyond legally-defined urban boundaries within their guidelines. By discerning these LULC changes for both the administratively rural and urban areas, this research highlights the need for an integrated regional planning approach.

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