



Mapping environmental impacts of rapid urbanization in the National Capital Region of India using remote sensing inputs



Richa Sharma ^{a,b,d}, P.K. Joshi ^{b,c,*}

^a National Institute of Urban Affairs (NIUA), New Delhi 110 003, India

^b Department of Natural Resources, TERI University, New Delhi 110 070, India

^c School of Environmental Sciences, Jawaharlal Nehru University (JNU), New Delhi India

^d Vlaamse Instelling Voor Technologisch Onderzoek (VITO), Boeretang 200, 2400 Mol, Belgium

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ABSTRACT

The study investigates the features and process of a decade and a half long urbanization in National Capital Region (NCR) of India, focusing upon the relationship of urbanizing land use land cover (LULC) and the consequent changes in environment. The satellite derived parameters of greenness (NDVI), imperviousness (NDBI), bareness (NDBal), moisture (NDWI) and land surface temperature (LST) were used as indicators of environmental dynamism. All except NDBal, showed high correlations (0.71–0.99) among each other and were found to be significant for measuring environmental conditions. Three annual LULC maps (1998, 2002/03 and 2011) were prepared by merging three season (kharif, rabi and zaid) LULC maps. Change detection results show that built-up areas increased by 82 km² (1998–2002/03) and 157 km² (2002/03–2011) and sparse built-up increased by 96 km² (1998–2002/03) and 281 km² (2002/03–2011) in the study period. Urbanization in the region has been marked with conversion of agricultural land to built-up (both sparse and dense, or exposed land for further construction activities). With increasing area and density of built-up, LST and NDBI was found to increase in same proportion while a respective fall in NDVI and NDWI was observed. This highlights the process of urbanization impacts on environment of NCR, India.

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1. Introduction

Urbanization is often seen as a process associated with demographic and economic dynamics in a society; however, at the same time it is a phenomenon that transforms ecological environment at local as well as global scales (Huang et al., 2010). Global rapid urbanization has resulted in extensive environmental changes including green-house gas emissions (Hoorneweg et al., 2011), deforestation (Biamonte et al., 2011; Paudel and Yuan, 2012), desertification (Qi et al., 2011), biodiversity losses (Delgado and French, 2012; McKinney, 2006), decreased soil fertility (Chen, 2007), water quality (Kaushal et al., 2008; Nilsson et al., 2003; Paul and Meyer, 2001), ecosystem services (Alberti, 2005; Bolund and Hunhammar, 1999), fragmentation of natural landscapes (Su et al., 2010), changing ecology and biodiversity of the region (Blair, 2004; Hasse and Lathrop, 2003), depletion of natural resources and degradation of air quality (Zhang et al., 2004) and many others. Urban areas are centres of high population that demand large disproportionate fractions of environmental resources making cities the major drivers of environmental degradation (Grimmond, 2007). Cities serving as hubs of economic activities exploit resources in a manner that threatens their own biophysical health destroying environmental quality irreversibly (Li et al., 2012). The

* Corresponding author at: Department of Natural Resources, TERI University, New Delhi 110 070, India.

E-mail addresses: richa.sharma85@gmail.com (R. Sharma), pkjoshi27@hotmail.com (P.K. Joshi).

complexity of dynamics and irreversible nature of urban land transformations make it highly crucial topic of research (Miller and Small, 2003).

Urbanization is creating massive alterations in land cover which in turn modify the sensible and latent heat fluxes of the surface. Impervious areas have higher sensible heat as compared to vegetated areas, resulting in higher temperatures of urban constructed surfaces in contrast to lower vegetation covered lands (Liu et al., 2012; Rahman et al., 2011). Along with this phenomenon of urban heat island (UHI), other human activities such as increased pollutant emissions (Mirzaei and Haghghat, 2010), anthropogenic heat emissions (Ichinose et al., 1999) and others alter the environment at local regional and global scales (Grimm et al., 2008). This paper primarily aims at understanding the process of impacts of urbanization on environment at regional scale.

Remotely sensed satellite data provide relatively robust measures of environmental indicators unlike the conventional surveying techniques which are extensively utilized to study urban sprawl and their impacts. Researchers have used geospatial techniques to analyze interactions between land use, green cover and surface temperatures (Gillies et al., 1997; Miller and Small, 2003; Owen et al., 1998; Sandholt et al., 2002; Voogt and Oke, 2003; Weng et al., 2004; Xiao and Weng, 2007; Xiao et al., 2007). This research analyses the importance of various biophysical variables as indicators for environmental health in Delhi, the rapidly urbanizing capital city of India. The changing LULC is analyzed to study the increasing area of built-up. It further investigates how increase in built-up areas and densities influences the various environmental parameters.

2. Study area

While delineating study area, a special consideration was given to city with coercively urbanizing satellite cities. Thus the metropolitan city of Delhi along with its neighboring satellite cities appeared to be the most viable choice, as it is the capital city of India exhibiting soaring rates of urbanization and at the same time is also surrounded with a number of smaller satellite cities that form part of now National Capital Region (NCR). Inclusion of satellite cities in the study area helped in assessing the impacts of urbanizing metropolis on associated smaller cities that are increasingly becoming a characteristic of urbanization in the developing nations like India.

2.1. National Capital Region (NCR)

National Capital Region (NCR) of India is a conurbation comprising of country's capital Delhi and parts of other neighboring states (Haryana, Uttar Pradesh and Rajasthan). The region spans across an area of 33,578 km² (NCR Planning Board, 2011). The concept of NCR came through the first master plan of Delhi in 1962, with an aim of redistributing the population pressure from NCT (National Capital Territory) Delhi. Of other states, UP contributes major portion to NCR, providing its Gautam Buddha Nagar and Baghpat districts.

Study area comprising of DMA (Delhi Metropolitan Area), extends from 28.3°N to 28.88°N and 76.84°E to 77.51°E covering an area of approximately 5000 km² consisting of urban area of Delhi and adjoining satellite cities of Gurgaon, Faridabad, NOIDA and Ghaziabad (Fig. 1). The region is located along the Aravalli Range and experiences typical semi-arid climate that makes it more prone to UHI (Buyantuyev and Wu, 2010; Huang et al., 2009; Schwarz et al., 2012). There is a wide range of temperature variations with scanty and irregular rainfall. Temperature varies from 40.3 °C (mean maximum) in summers to 6 °C (mean minimum) in winters (IMD, 2012). Hottest months are May and June, and August is the month with maximum precipitation (251.1 mm). Average annual rainfall for the region is 845 mm, with maximum rains occurring in July–September, the monsoonal months. Based on weather patterns of the region, three seasonal crops are practiced in study area; Kharif, Rabi, and Zaid. Areas where two or more crops are practiced fall under the category of Double crop (Table 2).

2.2. Gurgaon

Gurgaon is second largest city in state of Haryana. Unbridled urbanization in city over past decade has resulted in 73.9% increase in population (Census of India, 2011). The city referred as the information technology (IT) hub, is expanding far and wide since 1990s by acquiring agricultural lands from neighboring villages, transforming these to urban built-up. Gurgaon thus exhibits archetypical heterogeneous landscape with mosaics of high-rise building and typical rural settlements. It is situated in south west of Delhi at a distance of 32 km. Proximity to Delhi and international airport (12 km) is a major driving factor in its growth. Another important driving force is the surging real estate because of high migration rates from Delhi due to availability of cheaper land as compared to the national capital.

2.3. Faridabad

Faridabad, the largest city of Haryana is 25 km from Delhi. It is the only city in Haryana to have a functional municipal corporation (created in 1993), governing its 35 wards. In an endeavour to reduce congestion in Delhi, central government made several policies to promote industrialization in Faridabad, which eventually resulted in rampant urbanization of the city, supported by the fact that it inhabited 1.05 million people in 2001 and was the only city in Haryana to have a million

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