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Analysing urban sprawl and land consumption patterns in major capital cities in the Himalayan region using geoinformatics

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ABSTRACT

In the present study, spatio-temporal urban sprawl and land consumption patterns were analysed in seven capital cities located in the Himalayan region during 1972, 1991 and 2015 using multi-temporal satellite images. The study exhibits that capital Himalayan cities experienced rapid growth (830.92%) with high population increase (333.45%) during the observation period (1972–2015). The significant urban growth was observed in the cities of western and middle Himalayan region *viz.,* Srinagar (9.36 km^2–142.19 km^2), Kathmandu (11.38 km^2–92.58 km^2) and Dehradun (4.1 km^2–50.09 km^2) in the higher altitudes due to remarkable increase in the population (0.5–1 million persons) during 1972–2015. On the contrary, Itanagar (7.19 km^2), Gangtok (7.09 km^2), Shimla (3.04 km^2) and Thimphu (2.93 km^2) observed less urban growth with moderate to low population growth (i.e., 0.05 to 0.15 million persons). The Shannon entropy based study exhibits that the cities *viz.,* Kathmandu, Gangtok and Itanagar observed comparatively more dispersed urban growth during later period (1991–2015) as compared to the previous period (1972–1991) whereas, the remaining cities observed comparatively less dispersed urban growth during later period. The temporal land consumption pattern exhibits low density urban growth in Srinagar, Dehradun and Kathmandu, as observed with decrease in population density and increasing land consumption during 1972–2015 as compared to other cities, wherein urban densification was evident with increase in population density and decrease in land consumption. The cities in central and western Himalayan region observed high urban growth as compared to cities in eastern Himalayan region. The result shows that the capital cities contributes insignificant proportion (0.5%; 314 km^2) of urban area in Himalayan region and accommodating large (*ca.* 4 million) population during 2015. The study indicates unplanned and haphazard growth in all capital Himalayan cities, leading towards urban densification as well as dispersion in the periphery with varied pattern and intensity. The specific trends and patterns of urban and population growth are governed by geographical as well as socio-economic-political factors at local to regional scale. The high population pressure induced higher risk to the urban residents as well as constrained urban growth over higher vulnerable zones. The study necessitates implementation of suitable urban planning methods considering socio-economic and physico-cultural characteristics of the region.

1. Introduction

Urban areas are the engines of economic growth and development because of its varied opportunities, infrastructure, facilities, the standard of living, and economic development (Duranton, 2008). These factors act as a centripetal force and influence high population increase leading to the horizontal and vertical growth of urban areas (Pandey, Kumar, & Jeyaseelan, 2013). It is noteworthy that 3% of the earth landmass is now urbanized (United Nations, 2011) accommodating *ca.* 54% of the total global population (McMilchael, 2000). Although, rapid urbanization is one of the indicators of high human development index and globalization, it still has various negative impacts especially in developing countries like India, where the population growth and built-up growth are not simultaneous and well-planned. According to The World Bank (2014), annual urban population growth in India was 2.38% in 2014. Due to the lack of proper urban planning strategies, and their effective implementation, the haphazard urban growth tends to induce and increase various complex urban problems (Dickson, Baker, Hooranweg, & Tiwari, 2012). The deterioration of groundwater quality and quantity (Kumar & Pandey, 2016; Nas & Berktay, 2010), air pollution (Marshall, Pielke, Steyaert, & Willard, 2004), noise pollution (Kumar & Pandey, 2013; Silvia, Ricardo, & Luis, 2003), excessive slum formation (Kohli, Sliuzas, & Stein, 2016) traffic congestion, sprawl, loss of wetland, biodiversity, and green cover are the major examples

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predominantly evident in the rapidly urbanizing city in the developing world (Alberti, 1999; Bhattarai & Conway, 2010; Goyal & Sidhartha, 2003). These changes may have an adverse impact on ecology, water resources within the urban landscape with the largest impacts being on human health (Alberti, 1999; Goyal & Sidhartha, 2003; Paul & Meyer, 2001). The extensive urbanization induces contentious of high land consumption process, which is the ratio of population and urban area at a given time (Antrop, 2004). Land consumption provides an insight of population growth trend in growing urban region. In the major cities of developing countries, urban sprawl threatens the natural resources through large-scale land consumption (Terzi & Bolen, 2009). Urban sprawl, as implied by its name, is an inherently dynamic spatial phenomenon. It has been loosely defined as dispersed and inefficient urban growth (Hasse & Lathrop, 2003) which has many negative economic, social and ecosystem impacts (Ogle, Delparte, & Sanger, 2017). As an indicator of urban sprawl, many scholars have characterised the urban growth patterns using Shannon Entropy method, which means the compactness or dispersion of urban growth (Kumar, Pathan, & Bhanderi, 2007; Sudhira, Ramachandra, & Jagdish, 2004; Yeh & Li, 2001). These land surface change processes efficiently capture by spatio-temporal mapping and monitoring through remote sensing methods (Yeh & Li, 1996, 1997, 1999; Harris & Ventura, 1995; Meaille & Wald, 1990; Qian, Zhou, & Hou, 2010; Weng, 2001; Westmoreland & Stow, 1992). Remote sensing of urban environments together with Geographical Information System (GIS) techniques are predominantly being used as an effective procedures for mapping land use/land cover, building density, climatic conditions, socio-economic characteristics and their inter-relationship (Lo, 1997) as well as managing urban environment (Banzhaf, Grescho, & Kindler, 2009).

The urban growth studies are being done at local (city centric) (Banzhaf et al., 2009; Thapa & Murayama, 2010), regional (Kumar, Pandey, Hoda, & Jeyaseelan, 2011; Yi, Zeng, & Wu, 2016) to global scales (Sutton, 1997; Schneider & Woodcock, 2008; Seto, Fragkias, Gunerlap, & Reilly, 2011). The local and regional level urban studies are primarily directed by political constraints, whereas urban studies at global scale providing concisely the urban growth characteristics. As urban growth processes are primarily directed by surface landform and topography, physiographic homogeneity for urban studies is more appropriate. The Himalayas are one of the grandest areas in the world (Karan & Iijima, 1985), having unique topography and regulating mountain ecosystem, which is very fragile in nature. It is also prone to human-made as well as various natural disasters events with varied intensity *viz.,* earthquake, landslide, cloud bursts, flood, road and dam constructions (Dickson et al., 2012; Rawat, Tiwari, & Pant, 2011). The Himalayan region is characterised by insignificant proportion of urban area (0.5%) and sparse population due to topographic and climatic constraints, accommodating *ca.* 4 million population (UNPD, 2014), together indicating increasing pressure on the existing urban region and posing high risk to the environment (Karan & Iijima, 1985; Tiwari, 2007). Therefore, in the present study, the spatio-temporal urban growth patterns in major capital cities in Himalayan region were mapped and analysed in conjugation with population growth to deduce urban sprawl patterns and land consumption patterns in changing climatic conditions.

2. Study area

In the present study, all the major capital regions in Himalayan region *viz.,* Srinagar, Shimla, Dehradun, Kathmandu, Gangtok, Thimphu and Itanagar were taken into consideration. These are the capital cities, which plays an important role in the socio-economic development of the Himalayan region. The study area was delineated using 2 km of an outer buffer of municipal boundaries of the cities (Fig. 1). The Great Himalayas is the youngest fold mountain system, which stretches uninterruptedly for about 2500 km from west to east between Nanga Parbat (elevation 8126 m) and Namcha Barwa Peak (elevation 7756 m), covering Pakistan (west), India, Nepal, Bhutan and China (east). The Himalayas, as a great climatic divide affecting large systems of air and water circulation, help in determining meteorological conditions in the Indian subcontinent to the south and in the Central Asian highlands to the north. Tropical, subtropical, temperate, and alpine vegetation are present in Himalayan region, which is determined mainly by elevation and precipitation.

2.1. Srinagar

Srinagar, the largest among all the Himalayan urban centres is located in the centre of Kashmir valley and is the capital of Jammu & Kashmir state, India. It is situated between 34°12′ - 33°58′N latitude and 74°38′- 75°59′E longitude at an average elevation of 1600 m above mean sea level (asl) covering an area of around 300 km^2 (Fig. 1a). The city is encircled by the natural wall of mountains (the sub-mountain branches of the Pir-Panjal range) having a height ranging from 1800 to 4300 m above MSL. The Jhelum River flows from South-East to North-West direction (Zahoor, 2011). The total population of the city is 14, 29,000 persons in 2015 (United Nation Population Division, 2014).

2.2. Shimla

Shimla, the capital city of Himachal Pradesh state, is one of the oldest municipalities of India. It lies in the north-western ranges of the Himalayas (Kumar & Biswas, 2013). It is situated between 31°12′ - 30°58′N latitude and 76°59′ - 77°27′E longitude at an average elevation of 2397 m asl covering an area of 32.40 km^2 (Fig. 1b). The highest point is the Jakhu hill located at 2454 m elevation. The city is located on a ridge and stretches nearly 9.2 km from east to west direction. The closest river is Sutlej River, which is about 21 km away (Kanga, Thakur, Kumar, & Gupta, 2014). The total population of the city is 188, 539 persons in 2015 (India Population, 2017).

2.3. Dehradun

Dehradun, the capital city of Uttarakhand state, India, is a part of the Doon valley and lies between 30°24′- 30°15′N latitudes and 77°57′ E - 78°8′E longitudes at an altitude of 640 m asl covering an area of 58.24 km^2 (Fig. 1c). Two intermittent streams *viz.,* Rispana River and Bindal River, on the east and west respectively mark the physical limits of Dehradun municipality (Roy, 2007). The total population of the city in 2015 is 812, 000 persons (UNPD, 2014).

2.4. Kathmandu

Kathmandu Metropolitan City is the capital of country Nepal and lies between 27°46′ - 27°39′N latitudes and 85°15′ - 85°23′E longitudes at an elevation of around 1400 m above msl covering an area of 51.66 km^2. It lies in a valley region near the confluence of the Baghmati and Vishnumati Rivers (Fig. 1d). Due to rapid change in urban landscape, Kathmandu is now expanding as a mega city (Chhetri & Kayastha, 2015). The total population of the city in 2015 is 1,183,000 persons (UNPD, 2014).

2.5. Gangtok

Gangtok, the capital of Sikkim state, India lies between 27°23′ - 27°16′N latitude and 88° 34′ - 88° 40′E longitudes (Fig. 1e). The topography of the region is highly undulating with hills of 900–2400 m asl covering an area of 24.87 km^2. Gangtok is situated in the key part of the leaf shaped Rongni Chu River catchment, surrounded by Rani Khola River in the West and the Rora Chu River in the East. The population of Gangtok city in 2015 is 115, 000 persons (UNPD, 2014).