Spatial Analyses of the Guwahati Metropolitan Region: Documenting the Expansion of The City Using Remotely Sensed Satellite Data.

Aarav Varshney, Vanshika Drolia, Satvik Agarwal, Argha Chakrabarty.
Environmental Studies Program, Ashoka University, India.

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1. INTRODUCTION

In this study, We will be documenting the spatial and characteristic features of the region around the city of Guwahati, India. We used remotely sensed satellite data to qualitatively analyze the expansion of the city. Broadly speaking, Remote sensing is the process of detecting and monitoring the physical characteristics of an area by measuring it' reflected and emitted radiation at a distance (typically from satellite or aircraft)[1]. Remotely sensed satellite data is especially useful in recognizing large scale spatial features including different land use and land cover features, natural and geologic features, and urban features amongst others. Comparative analysis of the region at different times allows one to document changes in land use patterns including the expansion of urban areas in cities such as Mumbai, over time.

Currently, urban areas occupy around 3% of the earth's land surface[2] . Whereas about 47 % of the world's population lived in urban areas in the year 2000, 60 % of the world population is expected to be urban by the year 2030[3] . The global population is growing at around 70 million per year and many of the most populous urban areas are expected to be in the Asian continent, including India. To best accommodate the rapid growth of the population in these urban centers, it is important to understand the spatial characteristics of the region. In this study, We will be documenting the spatial features and characteristics of the region around Guwahati including land-use patterns, expansion of the city, and other changes in land-use patterns over a period of approximately 20 years. We are using remotely sensed satellite data from 1989 and 2011 as well as an intermediate year, i.e. 1999 to document urban expansion and changes in land-use patterns.

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[1] (https://www.usgs.gov/faqs/?qt-news_science_products=0#qt-news_science_products)
[2] (UNEP, WRI, Population Reference Bureau, 2006; UN/ESA, 2005)
[3] (One Planet Many People, UNEP; WRI, Population Reference Bureau, 2006; UN/ESA, 2005)

2. STUDY REGION

The city of Guwahati is located in the state of Assam, India between latitudes 28°18N and 24°N and longitudes 89°46E and 97°4E.
Guwahati is built on the banks of the Brahmaputra River that flows through North- East India to converge with the Bay Of Bengal. It is surrounded by Nilachal, Chitranchal and Narakasur Hills. The population of the city (in the Guwahati metropolitan area) has grown from 97,389 in 1951 to 4,35,280 in 1981 to 9,68,549 in 2011[4]. The population has doubled between the years 1981-2011. Which is just in the last 30 years.

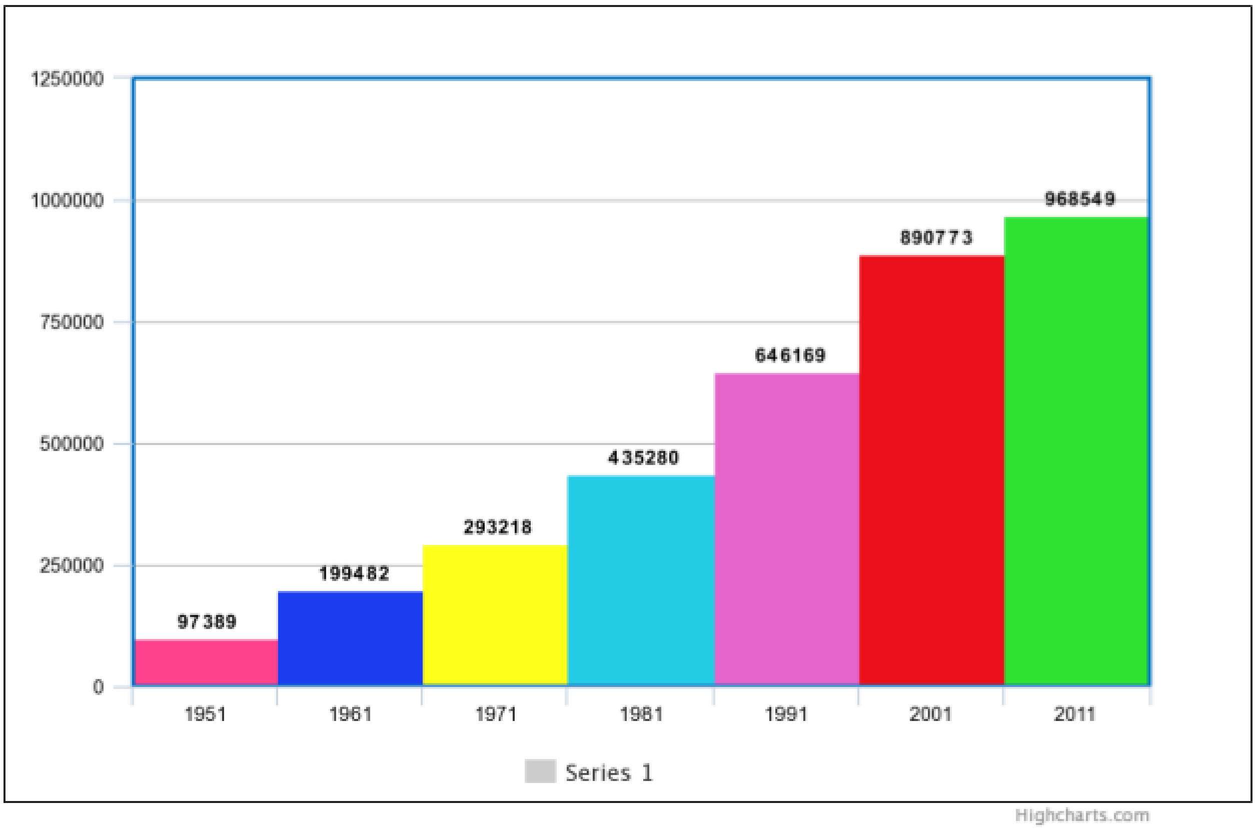

Figure 1. Population growth of Guwahati over the past 70 years. The figure shows that the most pronounced increase in the number of residents was between 1991-2001.

[4] "Guwahati City Census 2011 Data." *Guwahati City Population Census 2011-2020 | Assam*, www.census2011.co.in/census/city/191-guwahati.html.

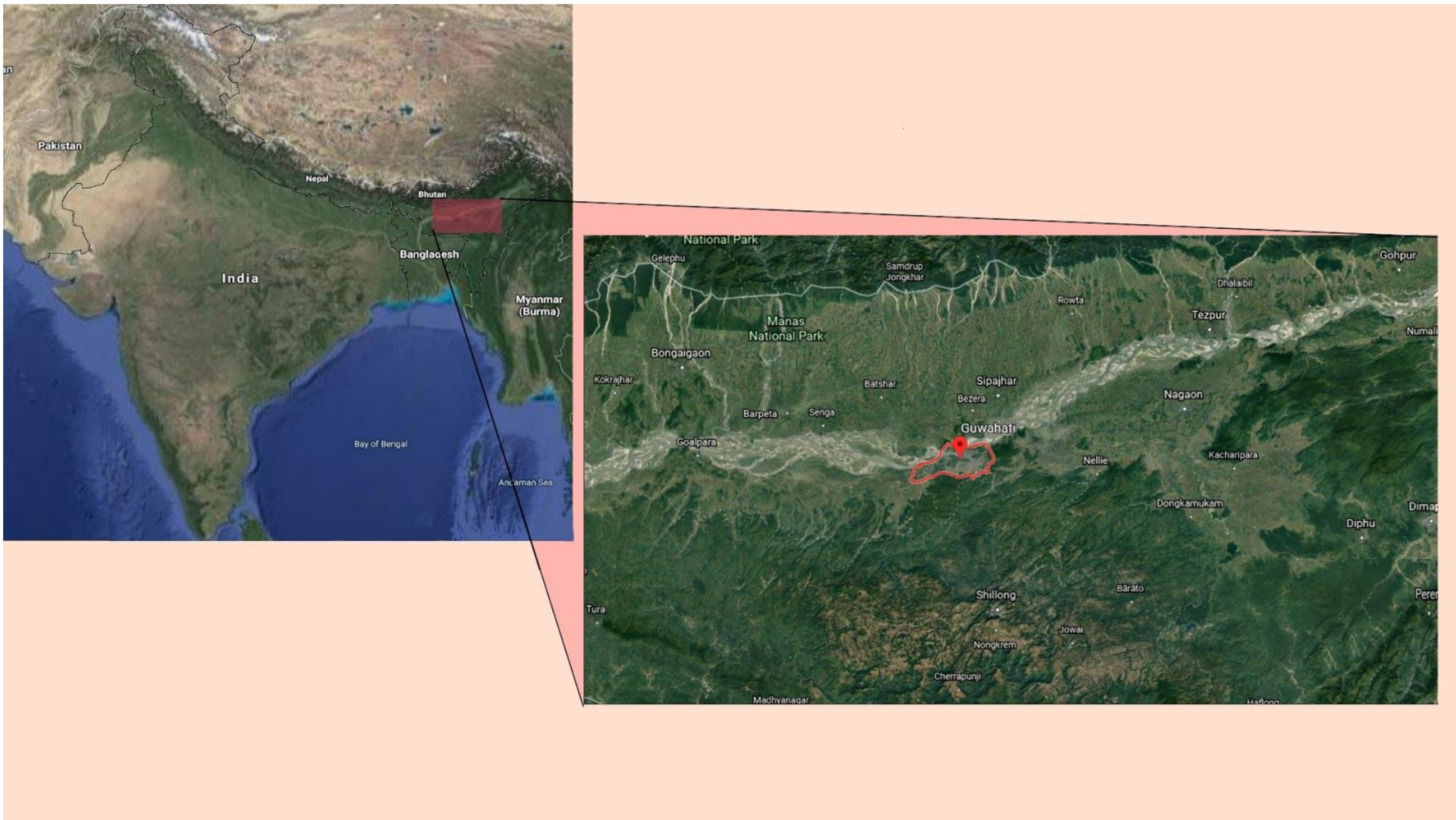

Figure 2. Location map of the study region. The map shows the location map of Guwahati. The box in the red shows its location in Assam, India.

3. METHODS: Data Acquisition and Software for Data Processing

Methods of satellite data acquisition and data processing using Geographic Information Systems (GIS) are described in this section.

3.1. Data Acquisition

In this study, we use imagery acquired by the Landsat series of satellites to evaluate the spatial features and characteristics of the region around the city of Guwahati. The Landsat series of satellites provides the longest continuous record of satellite-based Earth observations from 1972 to till date. We are specifically analyzing imagery from 1989 and 2011 acquired by the Landsat 5 Satellite with the Thematic Mapper (TM) Sensor, Bands 1-7, Spectral Range 0.45-2.35 µm (bands 1,2,3,4,5,7) and 10.4-12.5 µm (band 6)with a pixel resolution of 30m. Details of the datasets used for spatial analyses in this study are listed in Table 1 below.

Approximate Date Range	Landsat	Landsat Imagery	Path	Row	Date of Acquisition
1989	Landsat 5	TM	137	42	09-03-1989
1999	Landsat 5		137	42	05-03-1999
2011	Landsat 5	TM	137	42	06-03-2011

Table 1. Landsat datasets used for qualitative and quantitative spatial analyses of the region around Guwahati, India.

All datasets used in this study were downloaded from the USGS Earth Explorer from the following URL: https://earthexplorer.usgs.gov/

3.2. Geographic Information Systems Software

All qualitative and quantitative spatial analyses including image processing and enhancement were carried out using open source Geographic Resources Analysis Support System (GRASS

GIS) software. The software is available for download at (https://grass.osgeo.org) for various operating systems and platforms.

4. Qualitative Spatial Data Analyses

In this section, the results of the qualitative spatial analyses of the region around Guwahati city are described. The necessary first step towards analyzing and interpreting the spatial data involved creating a location in GRASS with appropriate spatial bounds, map projections, datum, and spatial resolution; and then importing different bands of various datasets into this location. As an exploratory first step towards documenting the spatial expansion of the city of Guwahati, We visually compared the spatial extent of the built urban area in 1989, 1999 and 2011. Using falsely colored red-green-blue (RGB) composites of different band combinations of these two datasets we qualitatively analyzed the expansion of the city. Shown in the figures below are six such false-colored RGB composites (1989 Bands 7,5,3 RGB, 1999 Bands 7, 5, 3 RGB, 2011 Bands 7, 5, 3 RGB and 1989 Bands 4, 3, 2 RGB, 1999 Bands 4, 3, 2 RGB, 2011 Bands 4, 3, 2 RGB). We used two different RGB bands to compare the disparity between all three years,

The first set of bands has band 7 assigned to red, 5 assigned to green and 3 to blue. This combination of bands provides a "natural-like" aesthetic, with vegetations appearing in shades of dark and light green, and urban features are more oriented towards grey, cyan or purple. Sand, soil, mineral, etc also appear in a variety of colors. Along with this, the almost complete absorption of Mid-IR bands in water, ice and snow highlights water sources with a well-defined coastline. This also provides a bit more clearer distinction between water and snow or ice, with snow being highlighted in a lower range of dark blue, while water is marked with either black or still darker shade of blue. This band also helps in spotting hot surfaces such as forest fires or volcano calderas. These surfaces saturate the Mid-IR bands and appear in shades of red and yellow.

Image 3(a) - Guwahati, Year 1989, Band 753

Image 3(b) - Guwahati, Year 1999, Band 753

Image 3(c) - Guwahati, Year 2011, Band 753

The above three images show a clear change in the land to forest ratio, It is clear from image 3(c), that more ice has melted to form water as the shade of blue color changes towards darker tones. The increase in the amount of grey also signifies the increase in urbanization in the past decades. The increase in grey areas is accompanied by a decrease of dark green areas validating that the amount of heavy vegetation or forests has disappeared in recent decades.

The next set of bands has band 4 assigned to Red, band 3 to Green, and 2 to Blue. This is the standard "false color" composite. Vegetations appear in various shades of red with Coniferous trees appearing in darker red than hardwood, while urban areas are in versions of cyan blue with densely populated areas being shown in light blue and the soils vary in range from dark to light brown. This band combination's color results tend more towards traditional infrared aerial photography, and is more popular and useful in vegetation studies, monitoring drainage and soil patterns along with various stages of crop growth. As a general rule of thumb, deep red hues indicate broad leaf and/or healthier vegetation, while lighter reds grasslands or sparsely vegetated areas. As compared to the 753 band combination, 432 is better for showing the rate of change of green cover, while 753 is more suitable if you want to track urban growth and is easier on the eyes or for the general audience, which is more accustomed to green signifying vegetation.

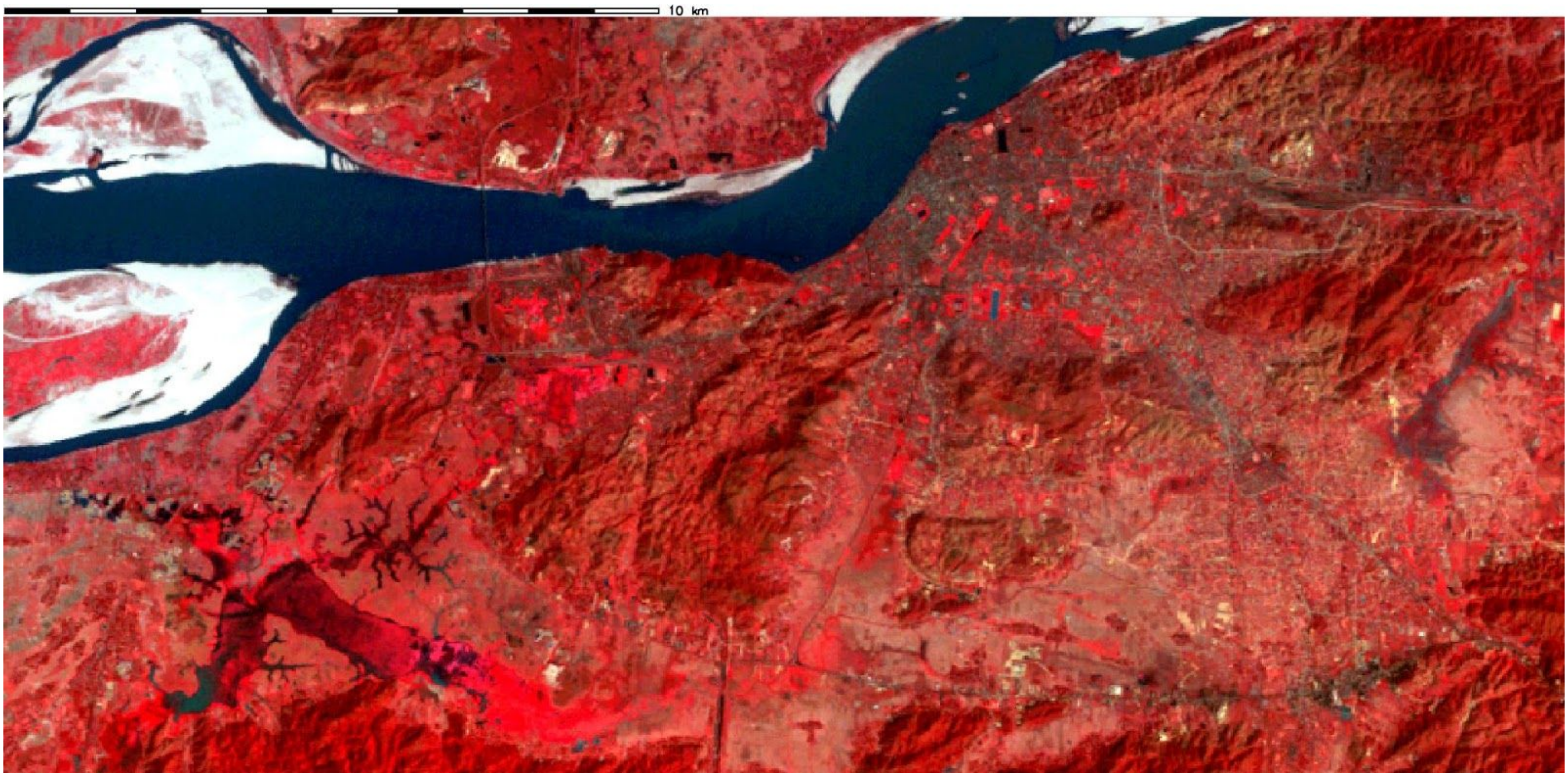

Image 4(a) - Guwahati, Year 1989, Band 432

Image 4(b) - Guwahati, Year 1999, Band 432

Image 4(c) - Guwahati, Year 2011, Band 432

While the previous image set was more oriented towards showing urban changes, this image set more suited to tracking and comparing the vegetation. The red areas represent vegetation, with deeper shades of red signifying board leaf and healthier vegetation, while lighter reds signify grasslands or sparsely vegetated areas. Comparing the above three images show that the amount of lighter hues of red have risen over the years, with the deeper reds decreasing consistently. Confirming observations made in-band 432s image set, the amount of urban area has increased, represented by cyan blue colors.