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International Journal for Modern Trends in Science and Technology
Volume 9, Issue 10, pages 41-45.
ISSN: 2455-3778 online
Available online at: http://www.ijmtst.com/vol9issue10.html
DOI: https://doi.org/10.46501/IJMTST0910005

Urban Development Analysis using Multi Temporal Satellite Data

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To Cite this Article
P. Giri Prasad, P. Gnana Prasanna Kumar, Sk. Abdul Raheem, Sk. Samdani Basha, P. Yuva Naga Teja. Urban Development Analysis using Multi Temporal Satellite Data, International Journal for Modern Trends in Science and Technology, 2023, 9(10), pages. 41-45.https://doi.org/10.46501/IJMTST0910005

Article Info
Received: 12 October 2023; Accepted: 21 October 2023; Published: 24 October 2023.

ABSTRACT

Urban development studies are essential for analyzing the growth and changes in urban areas over time. Sentinel-2 satellite data can play a crucial role in such studies as it provides high-resolution imagery of urban areas. The satellite imagery can be used for various applications such as land use and land cover classification, mapping urban expansion, monitoring construction activities, and tracking changes in urban infrastructure. In this project the high-resolution images captured by Sentinel-2 are processed using remote sensing techniques to extract information about the built-up areas. The data is then analyzed to understand the spatial distribution of urban development and the changes that have occurred over time.
Overall, Sentinel-2 satellite data provides a valuable tool for urban development studies, offering a cost-effective and efficient way to gather and analyze data on urban areas using SNAP (Sentinel Application Platform) and QGIS (Quantum Geographic Information System) tools.

KEYWORDS: Sentinel-2, Remote Sensing, QGIS, SNAP.

1. INTRODUCTION

Increasing population in cities is a major concern to urban planners, especially in developing countries like India as it results in unprecedented growth of cities in recent decades. More people are migrating from rural to urban areas for better job opportunities and living conditions and this is one of the major reasons for urbanization in the country. Urbanization is inevitable in a developing country like India. However, if urbanization is not controlled properly, it may result in decrease in agricultural land and productivity, cutting down of trees, crowded habitats, air and noise pollution, water distribution problems, public health issues, road traffic congestion, etc. Accurate and up-to-date urban land cover information is an essential data required by urban planners and policy makers for various purposes such as detection of human encroachment on natural resources, urban infrastructure facilities planning, preparation of master plan and detailed development plans, identification of open and green spaces, selection of suitable site for solid waste disposal, etc.

The fundamental question behind the present research work is, "How can the open-source satellite data like Sentinel-2A and Google images be best utilized to prepare accurate land cover maps and perform change detection analysis?" The specific objectives of the research work are: (1) to propose an image classification approach for accurate land cover map preparation using Sentinel-2A and Google satellite images. (2) to perform change detection analysis to understand how the city grew over the years, in what direction, the causative factor behind its growth and the type of urban sprawl.

2. LITERATURE SURVEY

Urban growth analysis using multi-temporal Sentinel-2 satellite data is a rapidly growing field in remote sensing and GIS. In recent years, researchers have utilized various remote sensing techniques to monitor urban growth and land-use changes.

One of the early works in this area was by Stow et al. (2018) who used Sentinel-2 data to analyze urban growth in the San Francisco Bay Area, California, USA. The study used multi-temporal Sentinel-2 data from 2015 to 2017 and found that urbanization increased at a rate of 1.6% annually. The study also showed the potential of Sentinel-2 data for mapping and monitoring urbanization at a fine spatial resolution.

Another study by Deng et al. (2019) utilized multi-temporal Sentinel-2 data to analyze urban growth in the Beijing-Tianjin-Hebei region, China, from 2016 to 2018. The study utilized a combination of supervised and unsupervised classification techniques to map urban land-use and found that the built-up area increased by 344.9 km² during the study period.

Cao et al. (2020) used Sentinel-2 data to analyze urban growth in the Pearl River Delta, China, from 2015 to 2019. The study used machine learning algorithms to classify urban land-use and found that the built-up area increased by 321.5 km² during the study period. The study also showed the potential of Sentinel-2 data for mapping urbanization and its impacts on the surrounding environment.

A study by Zhang et al. (2021) used Sentinel-2 data to analyze urban growth in Wuhan, China, from 2015 to 2020. The study used machine learning algorithms to classify urban land-use and found that the built-up area increased by 64.31 km² during the study period. The study also showed the potential of Sentinel-2 data for mapping and monitoring urbanization in densely populated urban areas.

In summary, the use of multi-temporal Sentinel-2 data to analyze urban growth is an emerging field, and the above studies show its potential in mapping and analyzing urbanization and land-use changes at a fine spatial resolution. The field is expected to grow further with the launch of new Sentinel satellites and the development of more sophisticated remote sensing techniques.

3. METHODOLOGY

A. Study Area:

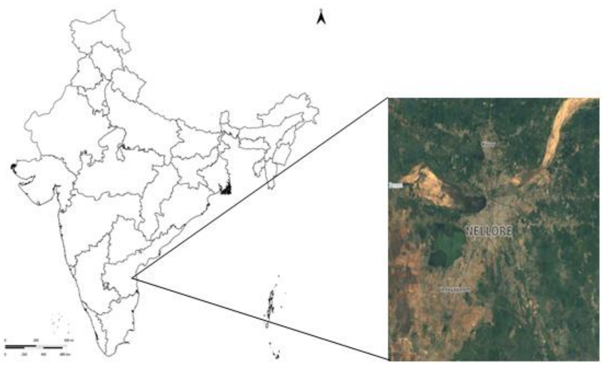

Figure. 1 Research Area

The study area is located between the latitude 14.34^0 - 14.48^0 N and the longitude 70.90^0-80.04^0 which extended the urban area of Nellore Town. The development of the city over time was analyzed using remote sensing. Multi-Temporal Sentinel-2 satellite images and Normalized Difference Built-Up Index (NDBI) was utilized to identify the growth of the area by processing using QGIS.

B. Data Used:

This study used a Sentinel-2 scene (date of acquisition: 03-04-2023), Planet Scope imagery and the Copernicus HRL imperviousness for the year 2019. Additionally, the Google Earth HR imagery and Open Street Map data were used for visual interpretation of the results. All image processing and analyses was carried out in ESA SNAP Desktop and QGIS Desktop.

1. *Sentinel-2 Imagery:*

SENTINEL-2 is a European wide-swath, high-resolution, multispectral imaging mission. The full mission specification of the twin satellites flying in the same orbit but phased at 180°, is designed to give a high revisit frequency of 5 days at the Equator. SENTINEL-2 carries an optical instrument payload that samples 13 spectral bands: four bands at 10 m, six bands at 20 m and three bands at 60 m spatial resolution. The orbital swath width is 290 km. The main objectives of this mission are systematic global acquisitions of high-resolution, multispectral images allied to a high revisit frequency, continuity of multispectral imagery provided by the SPOT series of satellites and the USGS LANDSAT Thematic Mapper instrument and observation data for the next generation of operational products, such as land-cover maps, land-change detection maps and geophysical variables. These high-level objectives, determined after consultation with users, will ensure that SENTINEL-2 makes a significant contribution to Copernicus themes such as climate change, land monitoring, emergency management, and security. (ESA)

2. *Copernicus High Resolution Layers:*

The Copernicus Open Access Hub was launched in 2014 and is operated by the European Space Agency (ESA). It provides access to data collected by the Sentinel satellites, which are a part of the Copernicus Programme. The Sentinel satellites are equipped with a range of sensors that capture data on a variety of environmental parameters, including land use, oceanography, and atmospheric composition.

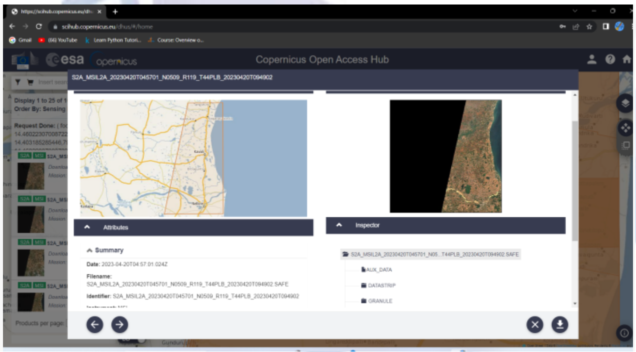

Figure. 2 Sentinel-2 Datafile

The Sentinel-2 Data files of the study area is downloaded in the same time period in different years i.e., 2019-2023.

Planet Scope satellite imagery is captured as a continuous strip of single frame images known as "scenes". Scenes may be acquired as a single RGB (red, green, blue) frame or a split-frame with a RGB half and a NIR (near-infrared) half depending on the capability of the satellite.

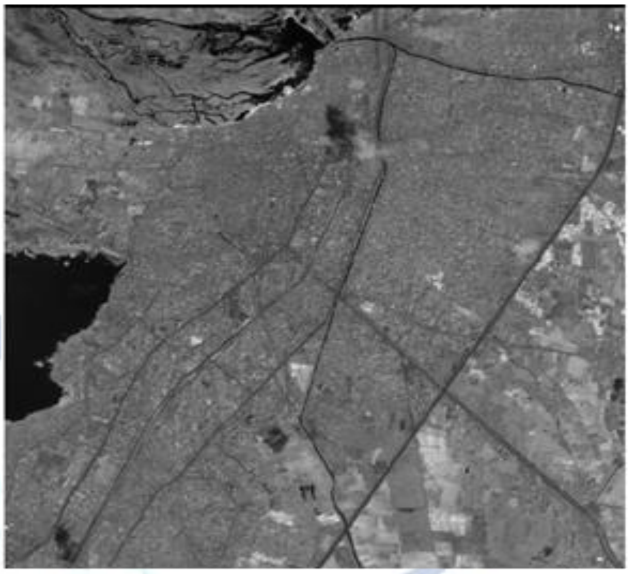

Figure. 3 Example of high-resolution planet scope image – part of Nellore city (2021).

In this research, SWIR (shortwave-infrared), NIR (near-Infrared) split-frame Scene was used in order to urban areas mapping. This product is rectified, multispectral data from the satellite constellation that have been processed to allow researchers to provide information products for data science and other purposes.

Table 1. Sentinel-2 bands

Band	Resolution	Central Wavelength	Description
B1	60m	443nm	Ultra Blue (Coastal and Aerosol)
B2	10m	490nm	Blue
B3	10m	560nm	Green
B4	10m	665nm	Red
B5	20m	705nm	Visible and Near Infrared (VNIR)
B6	20m	740nm	Visible and Near Infrared (VNIR)
B7	20m	783nm	Visible and Near Infrared (VNIR)
B8	10m	842nm	Visible and Near Infrared (VNIR)
B8a	20m	865nm	Visible and Near Infrared (VNIR)
B9	60m	940nm	Short Wave Infrared (SWIR)
B10	60m	1375nm	Short Wave Infrared (SWIR)
B11	20m	1610nm	Short Wave Infrared (SWIR)
B12	20m	2190nm	Short Wave Infrared (SWIR)

C. Build-up areas mapping with NDBI:

The Normalized Difference Build-up Index (NDBI) highlights urban areas with higher reflectance in the shortwave-infrared spectral range (SWIR).

Therefore, the NDBI was computed as follows:

$$NDBI = \frac{SWIR(B12) - VNIR(B08)}{SWIR(B12) + VNIR(B08)}$$

In case of SENTINEL-2 imagery, the SWIR band is 20 m resolution, so before the calculation, it was need to resample data to lower resolution. Therefore, the final result will be also obtained with a resolution of 10 m.

The binary images were obtained following the calculation of the NDBI for the satellite image to assess the expansion of the urban area.

4. Results

The result obtained shows that the better accuracy was acquired for the NDBI based urban mapping. Fig. 4 and fig. 5 show a quantitative result of the urban growth zones obtained in 2019 and 2023 with OSM (Open Street Map).

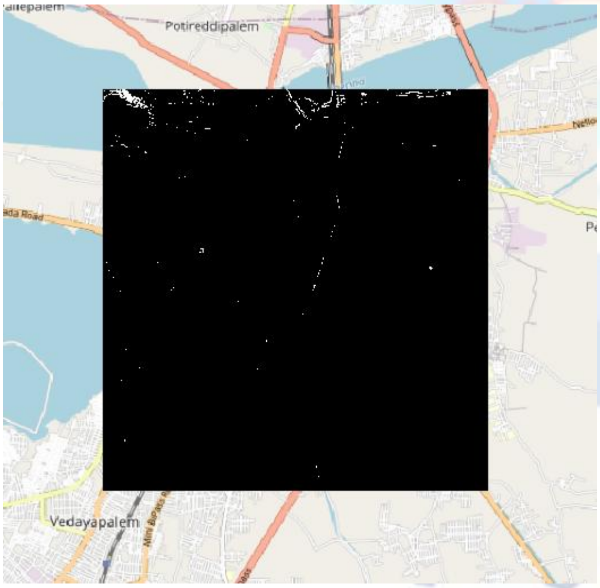

Figure.4 Urban expansion in year 2019

The white color in Fig. 4 above reflects the urbanization of the areas in 2019. Figure 5 below depicts the urban sprawl image for the year 2023. As we seen that in the year 2023 the urban development is more as compared to year 2019.

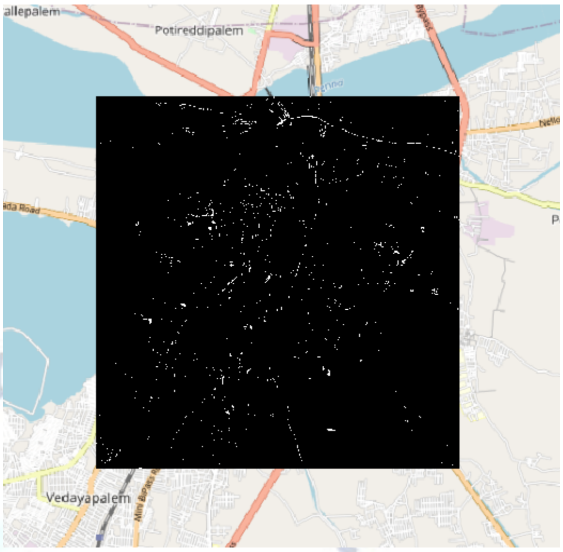

Figure. 5 Urban expansion in year 2023

5. Conclusion

In conclusion, Sentinel-2 data analysis of urban development offers important insights into the dynamics of metropolitan regions. In order to make decisions for urban planning and policy development, it is helpful to analyse urban development trends using Sentinel-2 data and QGIS. Urban development analysis will provide fascinating new potential for research and innovation as technology develops and more data becomes available.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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