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Extraction of Built-Up Areas Using Landsat Satellite Images and Deep Learning Algorithms: A Case Study Over Hyderabad, Southern India

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ABSTRACT

Built-up is one of the Land use classes representing the impervious surface of the earth, which is indicative of various developmental factors of the region. Built-up growth analysis is important to understand the growth factors and harness the resources in the vicinity and regional planning. Availability of long-term satellite data, advancement of data processing techniques, and computational infrastructure enable application of Deep Learning techniques. This study aims to developing a Dense Neural Network (DNN) model to derive the built-up layer from multi-spectral optical satellite data from Landsat series satellites with 30m spatial resolution. Multi-temporal satellite data are used to carry out the growth analysis for Hyderabad city and its environments of Telangana State in India or 3 decades at an interval of 5 years. For extracting the built-up online resources are used which include Google Earth Engine and Google Colab and which are integrated get the best potential of cloud platform resources to Analysis. With 400 reference points that Built-up is obtained an accuracy of about 80%. Further, two Spatio-temporal analysis are used one is radial graph analysis and Shannon's relative entropy.

Index Terms— *Built-up, Deep Learning, Spatio-temporal analysis, Optical Data, SAR Data, Tensor flow*

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I. INTRODUCTION

India is growing at a speedier pace and will emerge as the country with the largest population in the world in the coming years. As the population increases, the infrastructure needs to enhance to match the same in terms of residential, industrial, recreational, educational, etc., and the majority of the population is in urban areas, and it is still growing. As per the census of 2011, 30% of a population residing in urban India. There are about 8000 cities with a population above 1,00,000. The per capita availability of arable land in India has decreased from 0.5 ha in 1950–1951 to 0.15 ha in 1999–2000, owing to population escalation. It is expected to reach 0.09 ha by 2031[4]. To streamline the growth and harness resources, the Indian Government of India various projects such as AMRUT, Jal Jeevan Mission, Jal Shakti Abhiyan etc.,[6].

In recent years, several studies have been done with regard to population distribution, social systems, and urbanization. The built-up layer enables understanding of the hydrological impact on urban water bodies and development of climatic models etc. [5].

Remote sensing (RS) technology enhances the availability of spatially explicit and temporally consistent land use and land cover change information. Urban growth typologies and landscape metrics are widely used to quantify the dynamics of urban land composition and configuration, which enable conceptualizing the processes of urbanization and further understanding its underlying organization and mechanism. The diffusion- coalescence hypothesis has been examined based particularly on spatiotemporal patterns of urban expansion [2]. Impervious surfaces are promoted as useful environmental indicators and one environmental condition [1].

Considering the advances in satellite data acquisition, processing and deriving information, particularly in the context of extracting Built-up. This study adopts the Deep learning approach for optical and microwave datasets using open source tools, technologies and platforms.

II. STUDY AREA, DATA, TOOLS AND TECHNOLOGIES

2.1. Subheadings

The study area covers Hyderabad city and the surrounding area. The spatial extent of the study area is bounded by latitude 17° 9' 03" N to 17° 40' 17" N and longitude 78° 11' 37" E to 78° 44' 13" E. Hyderabad is one of the major Cities of India with rapid growth in urban development. In addition to Built-up, it also has large number of water bodies, scrubland, sparse vegetation etc. The Location map of the Study area is depicted in figure 1.

2.2. Tools and technologies Used

Various tools and technologies are used in the study for different activities such as data pre-processing, processing, Analysis and representation purposes. The List of such tools/technologies are enlisted in Table 1.

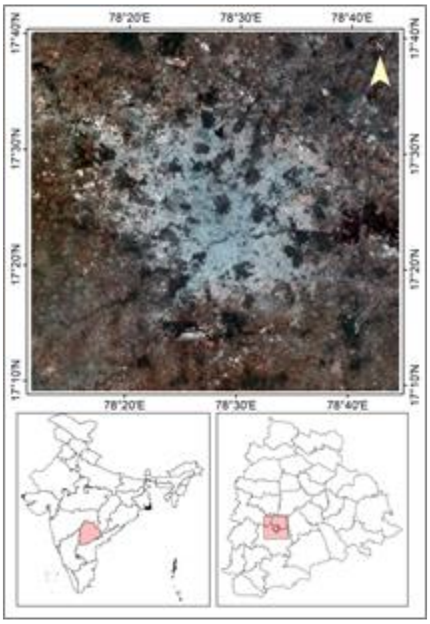

Figure1. Location Map of Study Area

Table 1. List of tools and technologies

Purpose	**Tool/Technology**
Online Satellite data Resource	Google Earth Engine
Online Deep Learning Platform	Google Colab
Geo-spatial Data Analysis	QGIS, PyQGIS
Python Libraries	GDAL, Numpy and Skimage
Deep learning Libraries	Tensor Flow and Keras

III. METHODOLOGY

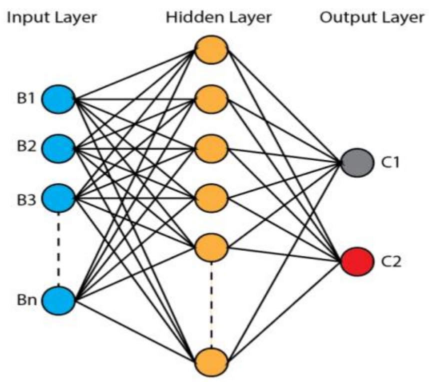

Figure 2.Dense Neural Network Architecture

The methodology consists of Setting up the Deep Learning (DL) model framework and developing the suitable model. Then applying it to various satellite datasets to extract Built-up. Subsequently the derived Built-up layers are used to carry out Analysis, which are described further.

3.1. Deep Learning Frame Work

The concept of Deep Learning is establishing the relationship between a few characteristics (features or Xs) of an entity with its other property (value or label or Y) — we provide plenty of examples (labeled data) to the model so that it learns from it and then predicts values/ labels for the new data (unlabeled data) [9]. A dense Neural Network (DNN) architecture is adopted for this study. It consists of three layers: Input/Feature layer, Hidden Layer, and Output Layer. Nodes in the Input layer depend on the number of bands and the output layer depend on number classes. In this study there are two output classes, namely Built-up and Non Built-up. The activation functions used are "RELU" for the Hidden layer and "SIGMOID" for output layer, respectively. The DNN Architecture is shown in Figure 2.

3.2. Binary Thresholding

The output of the DL method would be probability image values ranging between 0-1. To obtain a binary image, we need to apply thresholding. In this study, the Otsu method is adopted. The Otsu method is one of the most successful methods for image thresholding [3]. It is non-parametric and unsupervised [8]. For the current study, the Otsu method is adopted by using python libraries

3.3. Built-up extraction

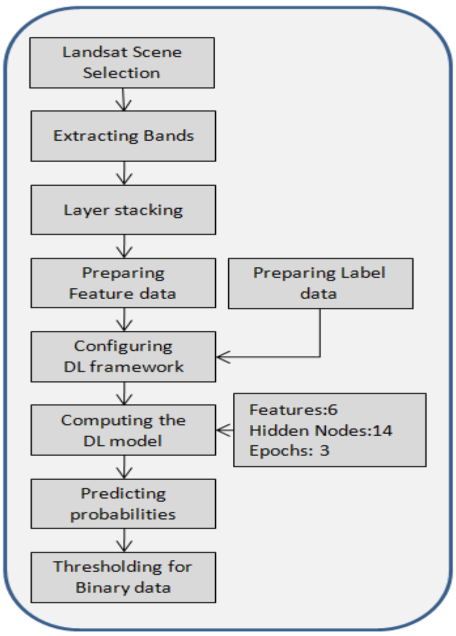

Figure 3. Flow Chart for Built-up Extraction

Extraction of built-up involves selecting 6 bands as feature data and a label data which is the built-up layer. Hence, the DN model arrived having an Input layer with 6 nodes, the Hidden layer with 14 nodes, and the output layer with 2 nodes. The flowchart of activities is given in the following figure 3.

3.4. Spatio-Temporal Analysis of Built-up

3.4.1 Spatial directions

The principle of spatial directions is based on evaluating and measuring urban growth patterns based on spatial and geographical directions. The number of zones in the spatial directions approach is carried out according to known geographical trends, either four or eight [7]. In this study, 8 directions are considered for the Analysis.

3.4.2 Shannon's Entropy

Shannon's Entropy is a powerful technique for measuring the compactness and dispersion of urban growth. In addition, this technique is commonly used to determine and quantify the occurrence of growth in a specific area. The values of Shannon's Entropy[10].

IV. RESULTS AND DISCUSSOIN

4.1. Built-up extraction

Generating a Built-up image requires an existing built-up as label data, which shall be older than the satellite data and a satellite image for which built-up to be generated.

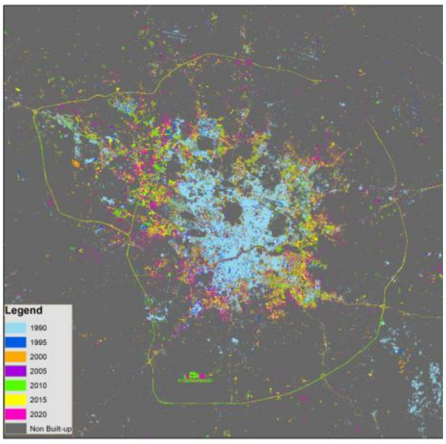

Figure 4. Stacked Optical Built-up images

Using predicted built-up again later time satellite image to predict built-up. This way built-up for all the seven images is generated. This way Built-up for all the optical data are generated. The DL model was obtained with an accuracy of 95% and P-score of 77%. The built-up extracted are validated using 400 sample points, which are well distributed across the study area. Using these samples overall accuracy is computed which is having a range of 75-80%.

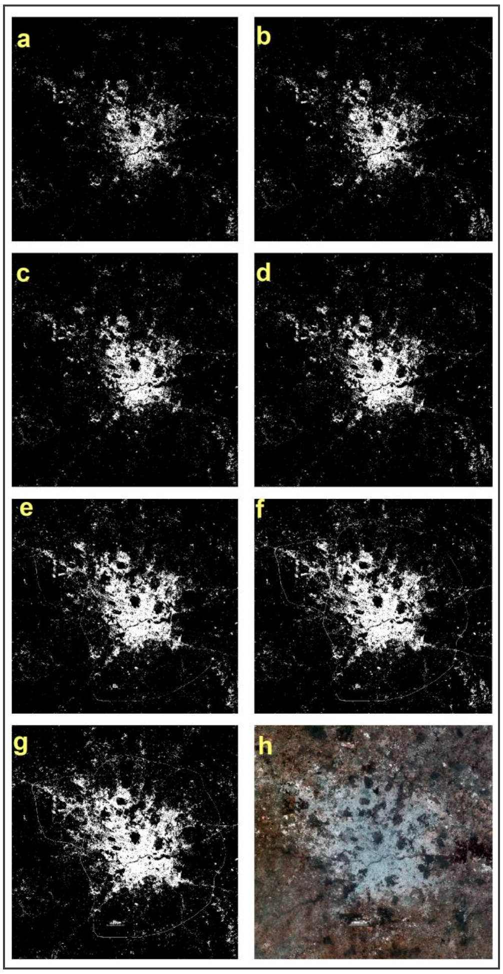

Figure 5.Optical Built-up images (a) 1990 (b) 1995 (c) 2000 (d) 2005 (e) 2010 (f) 2015 (g) 2020 (h) NCC of 2020

4.2. Spatio-Temporal Analysis of Built-up

The built-up in study area is divided in 8 directions taking center near to Secretariat/Hussain Sagar as shown Figure 6. The percentage of built-up in each direction for every year is computed and represented in graphical format as displayed in Figure 7.

4.2.1 Spatial directions

From this Analysis it is observed that the old city present in the southeast direction, which is highly populated in 1990 while the growth gradually taken place in all the directions but rapid growth taken place in the Northwest Direction of the city which also correlates with shape of the Outer Ring road. While there is narrow growth in the direction of Southwest direction due to the presence of large water bodies, namely Osman Sagar and Himayat Sagar reservoirs.

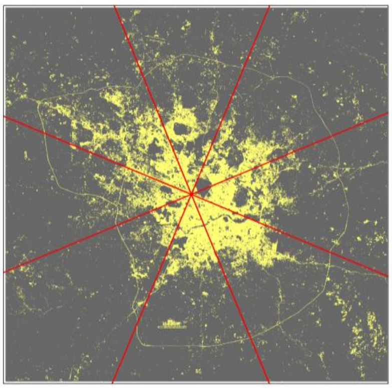

Figure 6. Directional Distribution

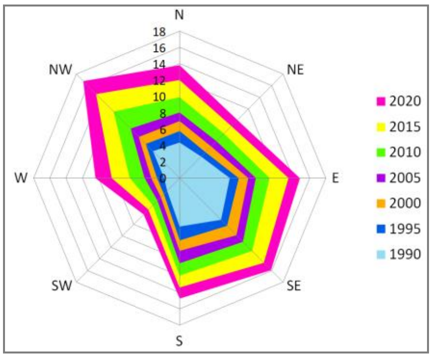

Figure 7. Built-up Spatial Directions

4.2.2 Shannon's Entropy

To conduct the analysis 11 concentric circles of each 3 km have been formulated as shown in Figure 8.

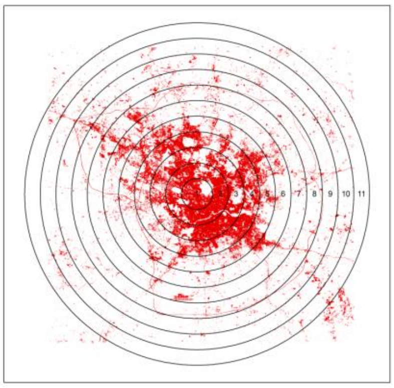

Figure 8. Built-up Spatial Directions

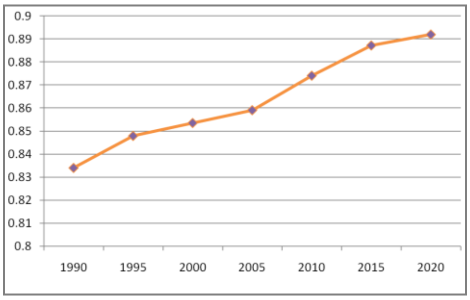

Figure 9. Shannon's Relative Entropy

V. CONCLUSIONS

The Deep Learning approach can be implemented over a cloud platform for built-up images, which are validated and using 400 reference points. This study can potentially derive built-up images with an accuracy of 80% from optical data. This can be improved with fine-tuning of model and increasing datasets. Both the spatial directions and Shannon's entropy gave growth direction and patterns which can help planners make necessary infrastructure.

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