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REAL TIME INTEGRATED ANALYSIS OF LAND USE URBAN GROWTH AND CLIMATE CHANGE USING MACHINE LEARNING AND DEEP LEARNING

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Abstract— Land use change, climate variability, and quick urban growth are closely integrated and significantly impact environmental feasibility and urban planning. This project, titled "Real-Time Integrated Analysis of Land Use, Climate, and Urban Growth using Machine Learning and Deep Learning." Presents on smart structure that merges geospatial, climatic, and urban development data to monitor and evaluate these dynamic changes in real time. The planned system utilizes satellite imagery, climate records, and urban underlying framework data to determine land use patterns, notice climate trends, and predict urban growth. Machine Learning algorithms are applied for data categorization and prediction, while Deep Learning models, particularly Convolutional Neural Networks (CNNs), are used for correct image study and land shield classification. The combination of these practical methods enables efficient monitoring, improved prediction accuracy, and timely decision-making. The created framework helps sustainable urban planning, environmental conservation, and calamity risk management by supplying consistent realization into transforming land use and climate conditions. The results illustrate that integrating Machine Learning and Deep Learning method with real-time geospatial data significantly enhances the accuracy and effectiveness of urban growth and environmental analysis.

Keywords: Google Earth Engine, Remote Sensing, Sentinel-2, Land Use/Land Cover (LULC), Urban Growth, Climate Change, NDVI, NDWI, NDBI, Land Surface Temperature (LST), Rainfall Analysis, Random Forest, Machine Learning, Deep Learning, CNN-LSTM, NDVI Prediction, Time-Series Analysis, Environmental Monitoring, Karnataka.

I. Introduction

The project provides useful knowledge to executive urban planners, environmental agencies, and researchers for material improvement and quality of a place judgment. By socializing land use, climate, and urban growth analysis into a single system, Rapid urbanization, climate change, and land use evolution have become major universal challenges because of their effect on environmental viability, natural resources, infrastructure, and human well-being. Constant urban growth can convert forests, agricultural land, and open spaces into built-up areas, creating environmental humiliation and increasing pressure on natural resources. Climate variations such as changes in temperature, rainfall, and humidity can also affect land use and urban improvement. Therefore, continuous observation of these factors is essential for sustainable urban planning, environmental conservation, and disaster management.

Conventional methods of monitoring land use and urban growth are often time-consuming, process that takes a lot of time, and hard to apply over large areas. Latest making something better in satellite remote sensing, Geographic Information Systems (GIS), Machine Learning (ML), and Deep Learning (DL) have made it possible to analyze large amounts of spatial and temporal data more efficiently and accurately. Anderson et al. [1] developed a standardized land use and land cover classification system using remote sensing data, which provided a foundation for land resource mapping and monitoring. Long et al. [2] introduced the Fully Convolutional Network (FCN), which improved pixel-level classification and segmentation of satellite images. Zhu et al. [3] highlighted the effectiveness of Deep Learning and CNNs in remote sensing applications such as image classification and land-use analysis. Li et al. [4] demonstrated the use of Machine Learning and GIS data for predicting urban growth and supporting sustainable city planning. Reichstein et al. [5] emphasized the importance of Artificial Intelligence in climate science for processing large datasets, improving prediction, and environmental monitoring.

Based on these studies, it is clear that ML, DL, remote sensing, and GIS supply strong devices for environmental and urban analysis. However, many extant systems focus mainly on individual areas such as land-use classification, climate analysis, or urban growth prediction rather than calculating an integral in math all three. This project, titled "Real-Time Integrated Analysis of Land Use, Climate, and Urban Growth using Machine Learning and Deep Learning," aims to expand an clever system that combines satellite imagery, climate data, and urban development information. CNN-based Deep Learning is used for land-cover classification, while Machine Learning models are used for climate analysis and urban growth prediction. GIS used to visualize and analyze the geographical allocation of these changes. The suggested a plan give a fact eco-friendly managing natural resources, working well without wasting resource management, climate resilience, catastrophe management, and smart city progress.To develop a real-time integrated system for analyzing land use, climate, and urban growth. To collect and process satellite imagery, climate data, and geospatial information from multiple sources. To apply Machine Learning algorithms for data analysis and prediction of land use and urban growth patterns.

To implement Deep Learning models, such as Convolutional Neural Networks (CNNs), for accurate land use and land cover classification. To monitor climate variations and analyze their impact on land use and urban development. To provide effective visualization of spatial data using Geographic Information Systems (GIS). To support sustainable urban planning, environmental monitoring, and informed decision-making through accurate and timely insights.

PROPOSED SYSTEM AND ARCHITECTURE

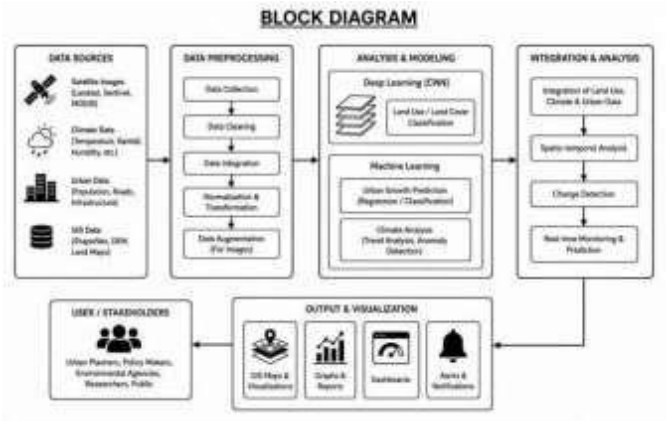
The proposed system, "Real-Time Integrated Analysis of Land Use, Climate, and Urban Growth using Machine Learning and Deep Learning," is intention to provide an intelligent stage for observation, analyzing, and predicting technological and urban changes in real time. The system integrates satellite imagery, climate data, and urban development knowledge about something to generate exact and timely awareness. Machine Learning algorithms are used to evaluate historical and real-time datasets for identifying patterns and forecasting future land use and urban growth. Deep Learning models, particularly difficult to understand a physical location in Neural Networks (CNNs), are put into service to classify satellite images with high accuracy and discover changes in land cover. The integration of Geographic Information Systems (GIS) enables efficient visualization of spatial data and help decision-making. The proposed system processes large capacity of geospatial and climate data efficiently, allowing continuous monitoring of land use changes, climate different versions, and urban extension. It provides faithful information that can assist urban strategist, environmental active power, and decision makers in maintainable resource control, disaster preparedness, and smart city planning. By doing two task at once of Machine Learning, Deep Learning, remote sensing, and GIS specific methods into a single framework, the proposed system to present an effective solution for real-time environmental monitoring and urban development analysis.

METHODOLOGY

The proposed methodology follows a acting according to a fixed plan strategy to integrate land use, climate, and urban growth analysis using Machine Learning (ML) and Deep Learning (DL) techniques. At first, satellite images, climate datasets such as temperature, rainfall, and humidity, and urban development data are collected from dependable reference to serve as inputs for the analysis. The collected datasets are then preprocessed by removing lacking convictions and contradictions, normalizing numerical data, and space to make it larger and amplify satellite images to improve model performance. After organizing things in advance, important spatial, environmental, and climatic features are removed from the datasets. Deep Learning models automatically recognize relevant prospect from satellite imagery, while Machine Learning techniques process numerical and environmental data to identify expressive a predictable sequence of events. The selected Machine Learning algorithms are aiming something at a target to analyze land use patterns and predict urban growth, while Convolutional Neural Networks (CNNs) are trained on satellite images for precise Land Use and Land Cover (LULC) categorization. Once trained, the behavior are used to process current and real-time geospatial and climate data to identify land use changes, monitor climate slightly different versions of something, and identify patterns of urban expansion.

Based on historical and current data, the system predicts future land use changes and urban growth trends. The prediction results are imagine through GIS-based maps, graphs, and interactive dashboards, making the discoveries easier to perceive and interpret. Finally, the analyzed results provide useful decision-support insights to urban planners, environmental agencies, and policymakers for product urban development, successful environmental monitoring, and improved resource management. As the below figure shows the workflow diagram represents the overall method of the suggested system for land use, climate, and urban growth analysis using Machine Learning and Deep Learning techniques. The process begins with the gathering of data from various origins, including orbital pictures such as Landsat, Sentinel, and MODIS, climate data such as temperature, rainfall, and humidity, urban data such as population, roads, and facilities, and GIS data such as shapefiles, Digital Elevation Models (DEM), and land charts. The collected data is then passed through the data preparation stage, where it is filtered to remove missing values and flaws, combined from different sources, standardized and transformed into a suitable format, and expanded in the case of satellite images to improve model efficiency. After preprocessing, the data is examined using Deep Learning and Machine Learning models. Convolutional Neural Networks (CNNs) are used for accurate Land Use/Land Cover (LULC) classification from satellite images, while Machine Learning algorithms are used for urban growth forecasting through regression or classification techniques and for climate analysis, including trend and anomaly detection. The results

from these models are then integrated with land use, climate, and urban data to perform geographic-temporal analysis, which helps spot changes occurring across different locations and time periods. The system performs change detection to track land-use changes and urban growth and supports real-time monitoring and prediction of future conditions. The analyzed results are displayed through GIS maps, graphs, reports, panels, and warnings or notifications, making the information easier to grasp and interpret. Finally, these outputs are provided to urban designers, decision-makers, environmental organizations, investigators, and the public, who can use the information for eco-friendly urban planning, environmental monitoring, infrastructure development, resource administration, and informed decision-making.



PROPOSED SYSTEM

The proposed system, "Real-Time Integrated Analysis of Land Use, Climate, and Urban Growth using Machine Learning and Deep Learning," is created to provide an intelligent platform for monitoring, analyzing, and predicting environmental and urban changes in real time. The system integrates satellite imagery, climate data, and urban development information to generate accurate and timely insights.

Machine Learning algorithms are used to analyze ancient and real-time datasets for identifying patterns and predicting future land use and urban growth. Deep Learning models, particularly Convolutional Neural Networks (CNNs), are employed to classify satellite images with high accuracy and detect changes in land cover. The integration of Geographic Information Systems (GIS) enables effective visualization of spatial data and supports decision-making. The proposed system processes large volumes of geospatial and climate data efficiently, allowing continuous monitoring of land use changes, climate variations, and urban expansion. It provides reliable information that can assist urban planners, environmental agencies, and policymakers in sustainable resource management, disaster preparedness, and smart city planning. By combining Machine Learning, Deep Learning, remote sensing, and GIS technologies into a single framework, the proposed system offers an effective solution for real-time environmental monitoring and urban development analysis.

FUTURE SCOPE

The proposed system can be further improved by integrating complex Machine Learning and Deep Learning conceptual framework to refine the exact of land-use taxonomy, climate analysis, and urban-growth prediction. In the future, keep going satellite imagery and updated climate data can be integrated for more efficient real-time monitoring. The system can also be figurative to support early exposure of floods, droughts, and other atmospheric hazards. A web-based GIS dashboard can be developed to provide real-time maps, forecast, and alerts to urban planners and government experts. moreover, the system can be combined with smart-city planning and maintainable resource management to better support and quicker decision-making.

climate prediction, environmental monitoring, and decision-making by processing large-scale climate datasets efficiently.

Based on the literature survey, it is observed that integrating real-time satellite imagery, climate data, Machine Learning, and Deep Learning provides a powerful framework for accurate land use classification, climate analysis, and urban growth prediction. However, many existing systems focus on individual domains rather than combining all three aspects into a unified real-time analysis platform. This project addresses that gap by integrating land use, climate, and urban growth analysis into a single intelligent system.

RESULT AND CONCLUSION



Figure 1: Geographical location and administrative boundary of Karnataka, India, used as the study area for the integrated land use, urban growth, and climate change analysis.

As shown in figure 1 The map represents the study area selected for the proposed analysis, which is the state of Karnataka, India. The red shaded region indicates the administrative boundary of Karnataka, while the surrounding regions provide geographical context. The map was generated using Google Earth Engine with the FAO/GAUL Level-1 administrative boundary dataset. Karnataka is selected as the study region for the integrated analysis of land use/land cover, urban growth, vegetation, and climate-related parameters. The Karnataka boundary is used to clip and process satellite imagery and other environmental datasets, ensuring that the analysis is restricted to the selected study area. The map also shows major surrounding regions and cities, which help in understanding the geographical location and extent of the study area.



The map shows the Sentinel-2 satellite imagery of Karnataka for the year 2024. The image is clipped to the administrative boundary of Karnataka, which is highlighted by the red outline. The natural surface features visible within the state represent different types of land cover, including vegetation, agricultural areas, forests, exposed/bare land, and urban regions. The surrounding areas are displayed to provide geographical context.

This satellite image serves as the base imagery for the subsequent analysis in the project. Spectral bands from Sentinel-2 are used to derive important environmental indices such as NDVI (Normalized Difference Vegetation Index), NDWI (Normalized Difference Water Index), and NDBI (Normalized Difference Built-up Index). These indices are subsequently integrated with machine learning techniques for land-use/land-cover classification and analysis of urban and environmental changes in Karnataka.

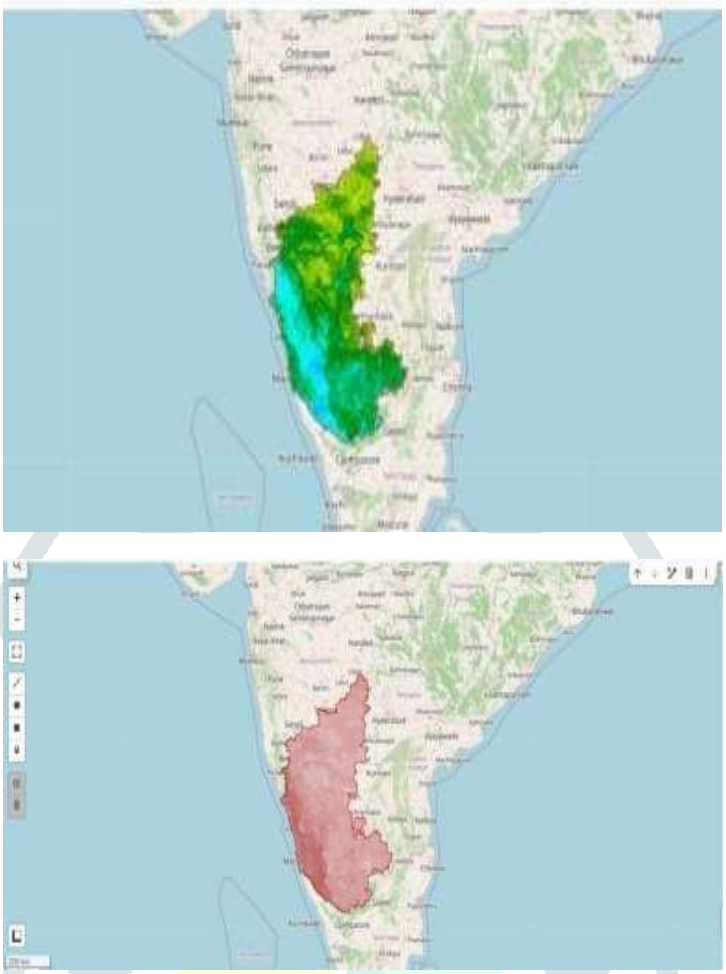


Figure:3 shows the Normalized Difference Vegetation Index (NDVI) map of Karnataka generated using Sentinel-2 satellite imagery.

As shown in figure 3 NDVI is used to assess the vegetation density and health of vegetation across the study area. The different colours represent variations in vegetation conditions. Green and yellow regions generally indicate higher vegetation density and healthier vegetation, while cyan/blue regions indicate comparatively lower vegetation cover or stressed vegetation. The spatial variation in NDVI is influenced by factors such as rainfall, land use, vegetation type, and climatic conditions. This map helps identify areas with healthy vegetation as well as regions experiencing lower vegetation activity

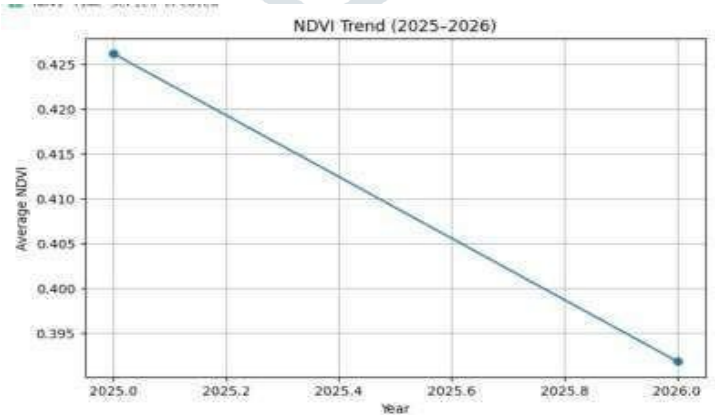


Figure 4: presents the average NDVI trend for Karnataka during 2025–2026.

As shown in figure 4 The graph shows a decrease in the average NDVI from approximately 0.426 in 2025 to approximately 0.392 in 2026. This indicates a reduction in vegetation activity or vegetation health during the analyzed period. The decrease may be associated with variations in rainfall, temperature, land-use changes, or other climatic and environmental factors. The trend demonstrates how satellite-derived NDVI can be used to monitor changes in vegetation conditions over time.

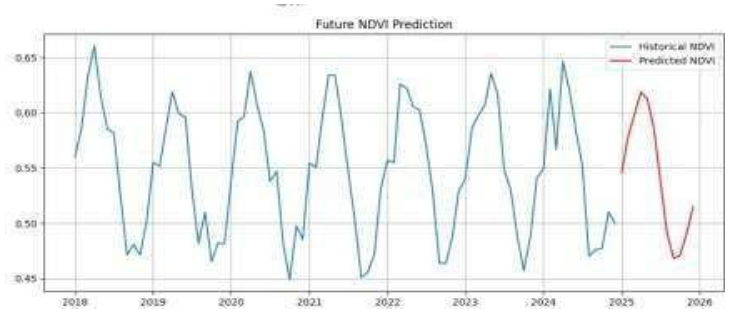


Figure 5: presents the historical and predicted NDVI values for Karnataka.

As shown in figure 5 The blue line represents the historical NDVI observations from 2018 to 2024, showing seasonal variations in vegetation conditions over time. The red line represents the NDVI values predicted by the trained model for the future period. The prediction shows that NDVI is expected to fluctuate, with values initially increasing to around 0.62 and then decreasing before showing a slight recovery. This demonstrates the capability of the proposed model to forecast future vegetation conditions based on historical NDVI patterns.

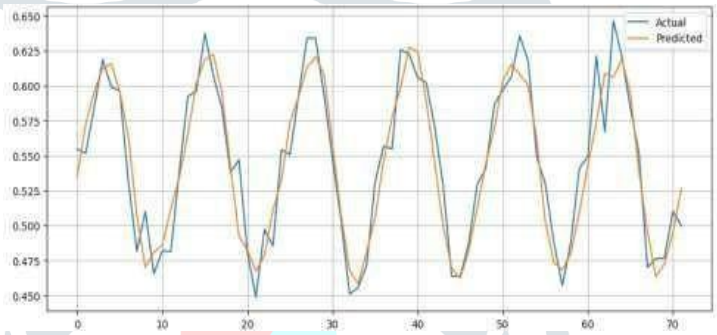


Figure 6: shows the comparison between the actual and predicted NDVI values obtained from the trained model.

The blue line represents the actual NDVI values, while the orange line represents the NDVI values predicted by the model. The predicted values closely follow the overall pattern of the actual NDVI values, including the increasing and decreasing seasonal trends. The close alignment between the two curves indicates that the model is able to learn the temporal pattern of vegetation changes and produce reasonable NDVI predictions. Some differences between the actual and predicted values can be observed, particularly around peak and minimum NDVI values.

CONCLUSION

This project has successfully developed an integrated framework for analysis of land use, urban growth, vegetation dynamics and climate related parameters in Karnataka using Google Earth Engine and machine learning techniques. Sentinel-2 satellite images were used to assess vegetation, water-related features and built-up areas using important spectral indices like NDVI, NDWI and NDBI. To identify the different land-cover classes, satellite bands and spectral indices were used in a

Random Forest classification model. The project also looked into urban growth with the help of comparing NDBI patterns, and MODIS Land Surface Temperature and CHIRPS rainfall data were also included to study climatic variations. Changes in the NDVI time series evaluation from Beside, a deep learning model (CNN + LSTM) was employed for NDVI prediction. The comparison of observed and predicted indicated that the model was able to capture the main seasonal patterns of vegetation dynamics, although there were some differences between observed and predicted values.

To summarize, the proposed system shows how remote sensing, Google Earth Engine, machine learning and deep learning can be combined for large-scale environmental monitoring and decision support. The approach can be further improved by using longer time-series datasets, more climate variables, more training samples, and rigorous validation, to improve the prediction accuracy and support sustainable land and environmental management.

REFERENCE

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[4] Li et al. proposed machine learning models for urban growth prediction using satellite imagery and GIS datasets. Their research demonstrated that ML algorithms can effectively forecast urban expansion and support sustainable city planning.

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