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AI-DRIVEN IMAGE PROCESSING &MULTI-MODEL ANALYSIS OF URBAN EXPANSION GREEN AREA, WATER BODY DEGRADATION WITH POLLUTION DYNAMICS

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ABSTRACT

Urbanization and environmental degradation are major challenges affecting sustainable urban development. This paper presents an AI-driven image processing and multi-model analysis framework to monitor urban expansion, green-area reduction, water-body degradation, and pollution dynamics. The proposed system uses satellite imagery from Sentinel-2 and Landsat, along with Geographic Information System (GIS) techniques, to analyze environmental changes over time. Spectral indices such as the Normalized Difference Vegetation Index (NDVI), Normalized Difference Built-up Index (NDBI), and Normalized Difference Water Index (NDWI) are used to identify vegetation, built-up areas, and water bodies. Machine learning algorithms, including Random Forest, Support Vector Machine (SVM), and XGBoost, are considered for land-cover classification, while deep learning techniques such as Convolutional Neural Networks (CNNs) and U-Net support image-based feature extraction and segmentation. Pollution-related datasets are integrated to examine potential relationships between urban growth and environmental quality. The proposed framework aims to generate thematic maps, statistical graphs, and change-detection outputs that help visualize environmental trends and identify vulnerable regions. This approach can support urban planners, environmental researchers, and policymakers in making informed decisions for sustainable city development. The framework is designed to provide a scalable and data-driven approach to urban environmental monitoring.

INTRODUCTION

Urbanization is one of the major factors responsible for environmental changes in rapidly developing cities. The expansion of residential areas, industries, roads, and infrastructure leads to the reduction of green spaces, degradation of water bodies, and increased pollution. Monitoring these changes is essential for protecting the environment and supporting sustainable urban development.

Traditional environmental monitoring methods require significant time, effort, and resources. With advancements in remote sensing, satellite imagery, Geographic Information Systems (GIS), and Artificial Intelligence (AI), environmental changes can be analyzed more efficiently. Satellite images from Sentinel-2 and Landsat provide valuable information about land use, vegetation, built-up areas, and water bodies.

This project proposes an AI-driven framework to analyze urban expansion, green-area degradation, water-body degradation, and pollution dynamics. It uses indices such as the Normalized Difference Vegetation Index (NDVI), Normalized Difference Built-up Index (NDBI), and Normalized Difference Water Index (NDWI), along with machine learning techniques, to identify environmental changes. The system aims to generate thematic maps, graphs, and change-detection results that help visualize environmental trends.

The proposed approach can support urban planners, researchers, and policymakers in understanding environmental changes and making informed decisions for sustainable city planning and environmental protection.

PROBLEM STATEMENT AND LITERATURE SURVEY

Rapid urbanization leads to the expansion of built-up areas, loss of green spaces, degradation of water bodies, and increasing pollution. Traditional monitoring methods are time-consuming, costly, and inefficient for analyzing large geographical areas. Therefore, an integrated AI-based image-processing system is required to analyze satellite images, detect land-use changes, assess environmental degradation, study pollution patterns, and predict possible future urban expansion.

- **Huang et al. (2025):** Reviewed deep-learning techniques for extracting urban green spaces from remote-sensing images and monitoring vegetation changes.
- **Mohd et al. (2026):** Examined GIS, machine learning, and CA-Markov modelling for predicting urban growth and supporting sustainable city planning.

- **Hemmati et al. (2026):** Investigated automated urban expansion and land-use change detection using Sentinel-2 satellite images, U-Net++ models, and NDVI.
- **Kulkarni et al. (2026):** Studied urban expansion and green-cover loss in Hyderabad using Sentinel-2 imagery, land-use classification, and MLP-Markov modelling.
- **Mondal et al. (2025):** Examined the effects of urbanization on the East Kolkata Wetland ecosystem using remote sensing, land-use analysis, and machine learning.

WORKING PRINCIPLE

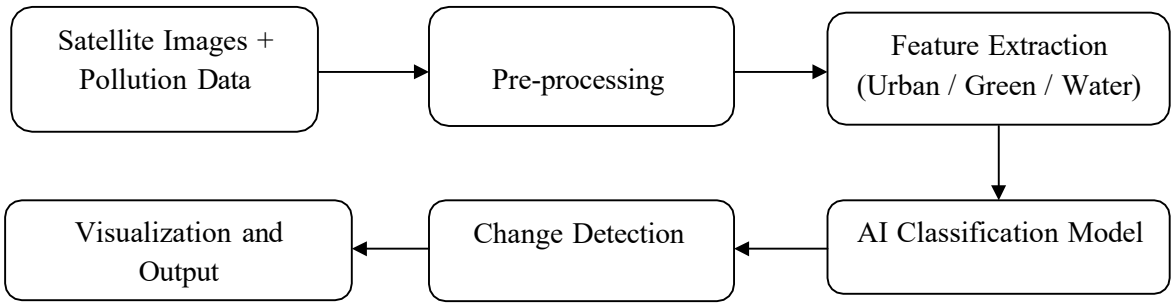

Fig: Block Diagram.

The proposed system collects satellite images and pollution data to analyze urban expansion, green-area changes, and water-body degradation in Bengaluru. The collected images are processed, and important features are extracted using AI-based classification. Changes between different time periods are detected and analyzed. The results are displayed through maps, graphs, and charts to understand environmental changes.

- **Satellite Images and Pollution Data:** Provides information about land cover and environmental conditions.
- **Pre-processing:** Removes noise and reduces image errors.
- **Feature Extraction:** Identifies urban areas, vegetation, and water bodies.
- **AI Classification Model:** Classifies different land-cover types.
- **Change Detection:** Identifies changes across different years.
- **Visualization and Output:** Displays the analysis results using maps and graphs.

METHODOLOGY

- **Data Collection:** Collect satellite images and pollution data for the selected study area.
- **Pre-processing:** Remove noise, cloud cover, and other errors from the collected images.

- **Feature Extraction:** Extract features related to urban areas, green areas, and water bodies.
- **AI-Based Classification:** Apply AI and machine-learning models to classify land-cover types.
- **Change Detection**: Identify changes in urban expansion, green cover, and water bodies over different time periods.
- **Pollution Analysis:** Analyze available pollution data to understand environmental changes.
- **Result Analysis**: Compare the results to identify urban growth, green-cover loss, and water-body degradation.
- **Visualization:** Generate maps, graphs, and visual outputs to present the results.
- **Future Prediction:** Use the analyzed data to estimate future urban expansion and environmental changes.

RESULTS AND DISCUSSIONS

The project synopsis describes the expected outputs of the proposed system rather than reporting a completed set of measured experimental results. Multi-temporal Sentinel-2 and Landsat images are expected to support the detection of changes in built-up areas, vegetation, and water-body coverage. NDVI can be used to examine green-area patterns, NDBI can help identify urban surfaces, and NDWI/MNDWI can support the mapping of water-body extent. Available pollution and water-quality indicators can provide additional information about environmental conditions.

The analysis should present the actual outputs generated from the selected study period. These may include land-use/land-cover maps, before-and-after comparisons, built-up and green-area statistics, water-body area estimates, pollution trend graphs, and model-performance measures. Random Forest, SVM, XGBoost, CNN, or other selected models may be compared using appropriate evaluation metrics. The results should state the data years, study boundary, training and validation approach, and any limitations that affect interpretation.

Future simulation using CA-Markov or CA-ANN may be used to estimate possible urban-growth patterns. The 2030 map should be described as a prediction scenario rather than a confirmed future outcome. Since the uploaded synopsis does not provide numerical measurements or completed validation results, exact area changes, pollution values, and model accuracy should be inserted only after the system has been run and the outputs have

been verified.

CONCLUSION

The proposed AI-driven image-processing and multi-model analysis framework provides a systematic approach to monitoring urban and environmental changes using satellite imagery, GIS, image processing, and artificial intelligence. By combining automated land-cover classification with multi-temporal change detection, the system can help identify urban expansion, changes in green areas, and variations in water-body extent. Available pollution and water-quality data can be incorporated to investigate environmental patterns associated with urban development. Maps, graphs, and model-performance measures can make the findings easier to interpret and can support environmental monitoring, water-resource management, and sustainable urban planning. The reliability of the findings depends on the quality of the datasets, model selection, and validation.

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