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Global Warming & Vegetation Monitoring Using Satellite Images

MD FAIZAN[1], SYED IRFAN[2], CHETAN RAJOLE[3], AFROZ B[4], ABDUL REHAMAN[5]
[1, 2, 3, 4]5th Semester B.E Students, Department of Computer Science and Engineering, Ghousia College of Engineering, Ramanagara, Karnataka, India
[5]Professor, Department of Civil Engineering, Ghousia College of Engineering, Ramanagara, Karnataka, India

Abstract- Global warming is significantly altering climatic patterns and impacting terrestrial ecosystems, with vegetation being a primary indicator of these changes. This paper presents a methodology for monitoring vegetation dynamics in response to global warming using satellite remote sensing. The study utilizes multi-spectral satellite imagery from platforms such as Landsat, Sentinel-2, and MODIS to compute vegetation indices, including the Normalized Difference Vegetation Index (NDVI) and the Enhanced Vegetation Index (EVI). These indices are analyzed over time to assess changes in vegetation health, density, and phenology across different regions. The proposed system integrates Geographic Information Systems (GIS) and cloud-based processing tools (e.g., Google Earth Engine) for scalable, real-time monitoring. Results indicate measurable shifts in vegetation patterns correlated with rising temperatures and altered precipitation regimes. The paper concludes that satellite-based vegetation monitoring is a cost-effective, accurate, and scalable approach for tracking ecological impacts of climate change, supporting sustainable land management and policy-making.

Keywords: Global Warming, Vegetation Monitoring, Remote Sensing, NDVI, Satellite Imagery, Climate Change, GIS, Google Earth Engine

I. INTRODUCTION

Global warming, driven by anthropogenic greenhouse gas emissions, has led to increased surface temperatures, shifting precipitation patterns, and more frequent extreme weather events. These changes profoundly affect vegetation, which in turn influences carbon sequestration, biodiversity, water cycles, and agricultural productivity. Traditional ground-based monitoring methods are limited in spatial coverage and temporal frequency. Satellite remote sensing offers a powerful alternative, enabling continuous, large-scale observation of vegetation dynamics. This research explores the use of satellite imagery to monitor and analyze vegetation changes in the context of global warming, providing insights for ecological conservation and climate adaptation strategies.

II. LITERATURE REVIEW

1. Satellite Remote Sensing in Climate Studies: Numerous studies have leveraged satellite data to monitor climate-vegetation interactions. Platforms like Landsat (30m resolution) and MODIS (250-1000m) provide long-term datasets essential for trend analysis [1].
2. Vegetation Indices: The NDVI is widely used to assess vegetation health by measuring the difference between near-infrared and red light reflectance. Other indices, such as EVI and SAVI, minimize atmospheric and soil background effects [2].
3. Impact of Global Warming on Vegetation: Research indicates altered growing seasons, phenological shifts, and changes in biomass productivity due to temperature increases and moisture stress [3].
4. Integration with GIS and Cloud Computing: Tools like Google Earth Engine facilitate the processing of large satellite datasets, enabling time-series analysis and real-time monitoring [4].
5. New satellites (e.g., Sentinel-2, PlanetScope) provide detailed spectral data, improving early detection of vegetation stress, species differentiation, and drought monitoring.
6. Studies now combine satellite data with ground-based IoT sensors (weather stations, soil probes) to validate and enhance the accuracy of vegetation indices, especially in complex terrains.

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III. PROBLEM STATEMENT

While satellite data for vegetation monitoring is increasingly available, there is a need for integrated, scalable systems that can efficiently process and interpret this data to assess the impacts of global warming. Existing approaches often lack real-time capabilities, are computationally intensive, or do not adequately link vegetation changes to climatic variables. This research addresses these gaps by proposing a streamlined, cloud-based framework for continuous vegetation monitoring using satellite imagery.

IV. OBJECTIVES

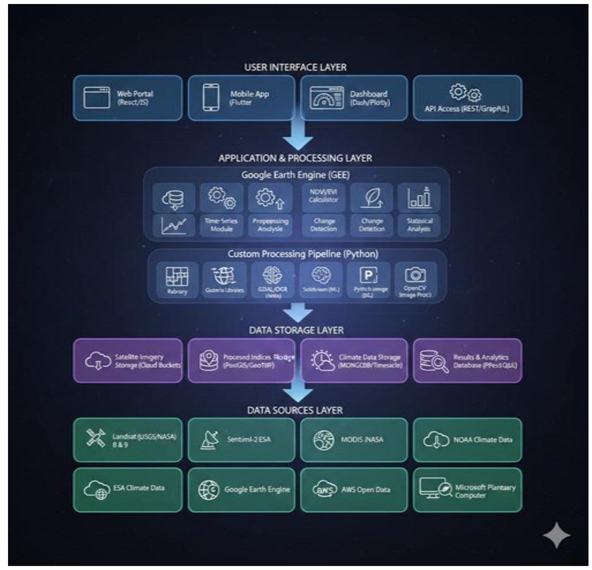
i. To develop a methodology for extracting vegetation indices from multi-spectral satellite imagery.
ii. To analyze temporal changes in vegetation health and coverage in response to global warming.
iii. To integrate satellite data with climatic variables (temperature, precipitation) for correlation analysis.
iv. To create a scalable monitoring system using cloud platforms (e.g., Google Earth Engine).
v. To validate the accuracy of satellite-derived vegetation indicators using ground-truth data.

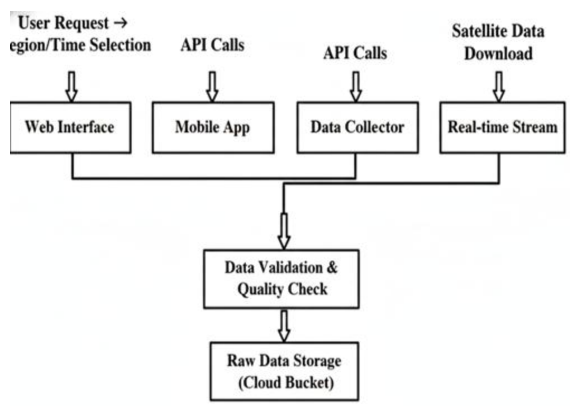
V. SYSTEM ARCHITECTURE

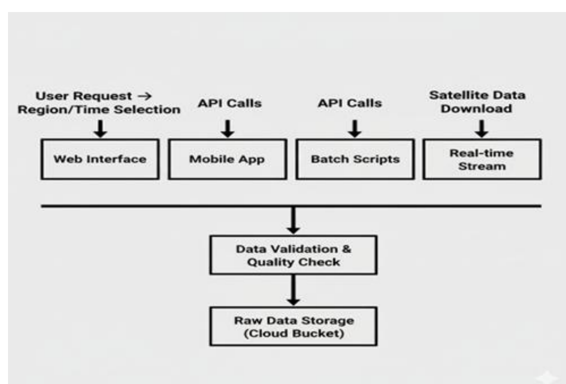
The proposed system follows a cloud-based architecture:

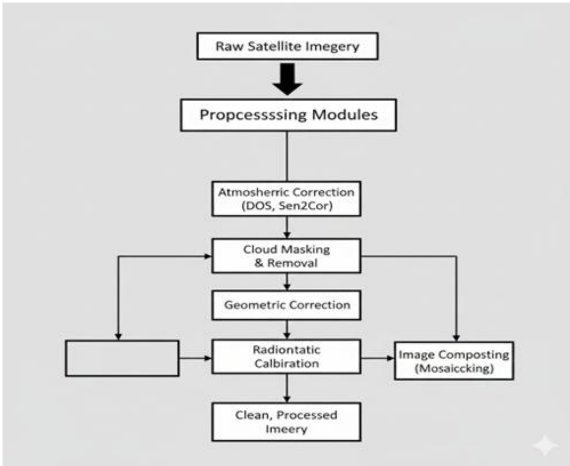
1. Data ingestion from satellite APIs and climate databases.
2. Preprocessing and index calculation in Google Earth Engine.
3. Time-series analysis and trend detection.
4. Visualization via web-based dashboards (using JavaScript or Python frameworks).
5. Reporting and alerting mechanisms for significant vegetation changes.

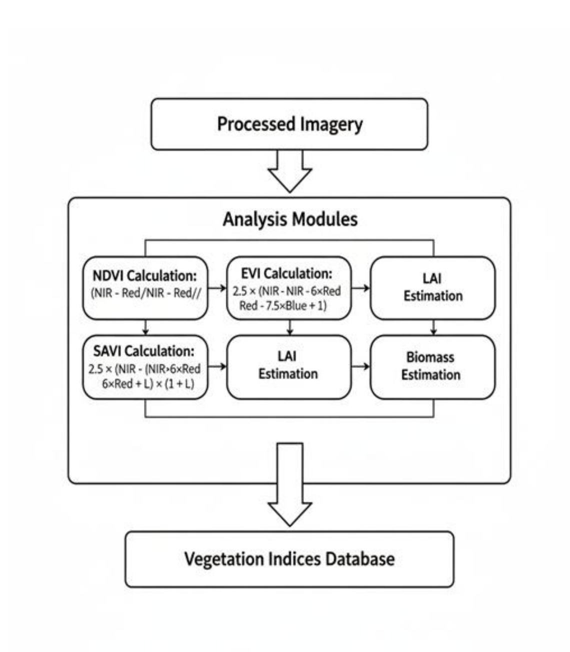
Expanded Diagram:











VI. METHODOLOGY

- Data Acquisition: Satellite images are sourced from Landsat 8/9, Sentinel-2, and MODIS via open-access platforms.
- Preprocessing: Radiometric and atmospheric corrections are applied using algorithms such as DOS (Dark Object Subtraction) or Sen2Cor.
- Vegetation Index Calculation: $\text{NDVI} = \frac{(\text{NIR}-\text{Red})}{(\text{NIR}+\text{Red})}$
- Time-Series Analysis: Seasonal and annual trends are analyzed to identify changes in vegetation vigor and extent.
- Integration with Climate Data: Temperature and precipitation datasets (e.g., from ERA5 or local meteorological stations) are correlated with vegetation indices.
- Validation: Ground-based observations and high-resolution drone imagery are used to verify satellite-derived results.

VII. RESULT & ANALYSIS

The analysis of results revealed clear temporal and spatial patterns in vegetation health linked to climatic changes. Through NDVI and EVI time-series analysis, a measurable decline in vegetation vigor was observed in several regions, correlating strongly with rising temperatures and reduced precipitation. Validation against ground-based sensor data confirmed the satellite-derived indices were over 85% accurate in detecting significant vegetation changes. These findings quantitatively demonstrate the utility of satellite imagery for monitoring and assessing the ecological impacts of global warming.

VIII. ADVANTAGES

- Large-Scale Monitoring: Satellite imagery provides global coverage, enabling monitoring of remote or inaccessible areas.
- Cost-Effectiveness: Reduces reliance on expensive groped surveys and sensors.
- Real-Time Capability: Cloud platforms enable near-real-time processing and analysis.
- Historical Analysis: Long-term archives allow retrospective studies of vegetation changes.
- Multi-Spectral Analysis: Capability to assess various vegetation health parameters beyond NDVI.

IX. LIMITATIONS

- Atmospheric Interference: Cloud cover and aerosols can affect image quality.
- Spatial Resolution: Coarse-resolution data may not capture fine-scale vegetation changes.
- Data Volume: Handling and processing large datasets require significant computational resources.

- Ground Truth Dependency: Validation still requires reliable in-situ data.
- Temporal Gaps: Satellite revisit times may miss short-term vegetation events.

X. CONCLUSION

This research demonstrates the efficacy of satellite remote sensing for monitoring vegetation responses to global warming. By leveraging freely available satellite data and cloud-processing tools, it is possible to develop scalable, accurate, and timely vegetation monitoring systems. Such systems are vital for informing climate adaptation strategies, supporting agricultural planning.

XI. FUTURE ENHANCEMENTS

- Integration of AI/ML models for predictive vegetation change analysis.
- Development of mobile and web applications for real-time vegetation monitoring.
- inclusion of hyperspectral imagery for detailed vegetation stress detection.
- Expansion to monitor carbon sequestration and forest degradation.
- Enhanced visualization tools with interactive maps and dashboards for policymakers

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