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APPLICATIONS OF GOOGLE EARTH ENGINE IN GEO-SPATIAL ANALYSIS OF VARIOUS INDICES

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ABSTRACT :

The increasing demand for efficient monitoring of land use and environmental changes necessitates advanced geospatial tools capable of handling large-scale data analysis. Google Earth Engine (GEE), a cloud-based geospatial processing platform, offers robust capabilities for analyzing multi-temporal satellite data across vast geographic regions. This study explores the application of GEE in computing and analyzing the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Built-up Index (NDBI) for Srikakulam district, Andhra Pradesh. NDVI is utilized to assess vegetation health and coverage, while NDBI is used to detect and monitor urban and built-up area expansion. Through the use of high-resolution datasets such as Landsat and Sentinel-2, the study highlights spatial and temporal variations in vegetation and urban development . The results demonstrate the effectiveness GEE in rapidly processing and visualizing these indices, offering valuable insights for sustainable land use planning, urban growth management, and environmental conservation in Srikakulam district.

Keywords: Google Earth Engine(GEE), NDVI, NDBI, Srikakulam district, Remote sensing, Land use/land cover (LULC), Vegetation analysis, Urbanization, Geospatial analysis, Satellite imagery

CHAPTER 1 INTRODUCTION

Background

The integration of satellite remote sensing with cloud-based geospatial platforms has revolutionized the way earth observation data is processed and analyzed. Google Earth Engine (GEE) is a powerful cloud-computing platform that enables researchers and decision-makers to access, visualize, and analyze vast amounts of satellite imagery and geospatial data. Its capabilities are particularly well-suited for monitoring land surface changes and conducting temporal-spatial assessments of environmental and urban dynamics.

Srikakulam district, located in the northeastern part of Andhra Pradesh along the Bay of Bengal coast, is characterized by a diverse landscape comprising coastal plains, agricultural lands, and urban settlements. In recent years, the district has witnessed rapid land use changes due to population growth, urban expansion, and agricultural intensification. These changes have significant implications for environmental sustainability, urban planning, and resource management.

To effectively monitor and manage these transformations, geospatial technologies have become indispensable tools. Among them, Google Earth Engine (GEE) stands out as a cloud-based platform that facilitates the processing and analysis of large volumes of satellite imagery. It allows for near real-time, multi-temporal, and large-scale geospatial assessments with high computational efficiency.

Two of the most critical indices used in land surface monitoring are the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Built-up Index (NDBI). NDVI is essential for assessing vegetation health and coverage, making it highly relevant in agricultural regions like Srikakulam. Conversely, NDBI is designed to detect built-up areas and track urban growth—key factors in understanding the spatial footprint of human development.

By applying NDVI and NDBI through GEE, researchers and planners can gain valuable insights into the spatial-temporal dynamics of vegetation and urbanization in Srikakulam district. This
supports data-driven decision-making for sustainable land management, urban planning, and environmental conservation efforts.

Problem Statement

1. **Geographical Context**

Srikakulam district, located in the northeastern part of Andhra Pradesh, features a diverse landscape of coastal plains, agricultural zones, and expanding urban centers. The region is witnessing notable changes in land use due to urbanization and agricultural development.

2. **Environmental and Urban Challenges**Rapid land transformation has led to concerns regarding vegetation degradation, unplanned urban growth, and strain on natural resources. These challenges necessitate reliable tools for continuous monitoring of both environmental health and built-up area expansion.

3. **Limitations of Traditional Methods**

Conventional geospatial analysis techniques are often hindered by:

High computational demands,

Restricted access to multi-temporal satellite data, and Complex preprocessing requirements.

These limitations reduce their practicality for regional-scale, long-term monitoring.

4. **Significance of NDVI and NDBI**

NDVI (Normalized Difference Vegetation Index) serves as a key indicator of vegetation cover and health.

NDBI (Normalized Difference Built-up Index) is crucial for identifying and analyzing urban/built-up land. Despite their importance, both indices are not fully leveraged in local geospatial studies of Srikakulam.

5. **Potential of Google Earth Engine (GEE)**

Google Earth Engine offers a cloud-based platform that simplifies the analysis of large-scale, multi-temporal satellite data. It supports rapid processing and visualization of indices like NDVI and NDBI, making it ideal for monitoring land use and land cover dynamics.

6. **Identified Gap**

There is a lack of comprehensive, GEE-based studies focused on simultaneous NDVI and NDBI analysis in Srikakulam district. This gap limits informed decision-making in areas such as urban planning, agricultural management, and environmental conservation.

Objectives of the Study

1. **Platform Utilization**

To utilize Google Earth Engine (GEE) for efficient acquisition, processing, and analysis of multi-temporal satellite imagery for the Srikakulam district.

2. **Vegetation Monitoring**

To compute and analyze the Normalized Difference Vegetation Index (NDVI) to assess the spatial and temporal distribution of vegetation cover and health.

3. **Urbanization Analysis**

To compute and map the Normalized Difference Built-up Index (NDBI) to detect and monitor the extent and pattern of built-up and urban areas.

4. **Temporal Change Detection**

To examine seasonal and interannual variations in NDVI and NDBI values between 2020 and 2025, reflecting land use and land cover dynamics.

5. **Spatial Correlation Assessment**

To analyze the spatial relationship between vegetation decline (NDVI) and urban expansion (NDBI), identifying critical zones undergoing rapid transformation.

6. **Demonstrating GEE's Applicability**

To highlight the advantages of GEE as a cloud-based geospatial platform for integrated, large- scale environmental and urban studies using NDVI and NDBI.

CHAPTER 2 LITERATURE REVIEW

Introduction

Overview of Google Earth Engine (GEE) in Geospatial Analysis Google Earth Engine (GEE) has become an essential tool for large-scale geospatial analysis, particularly in environmental monitoring and land management. The platform provides access to an extensive repository of satellite imagery, geospatial data, and powerful cloud computing capabilities, making it accessible for researchers, policymakers, and environmental managers. GEE enables users to analyze vast amounts of satellite imagery from various sources, including Landsat, MODIS, and Sentinel, allowing for high-resolution, time-series, and multi-temporal studies over large areas.

Applications of NDVI in Environmental Monitoring

The Normalized Difference Vegetation Index (NDVI) is widely recognized for its ability to assess vegetation health and productivity based on the reflectance of light in the red and near- infrared regions. NDVI has been used in several studies to monitor vegetation dynamics, land degradation, and changes in agricultural productivity. In Srikakulam district, NDVI has been used to evaluate crop health, seasonal variations, and forest cover changes, providing essential data for agricultural and forest management.
The formula for NDVI is:

NDVI = (NIR - Red) / (NIR + Red)

where:

NIR is the reflectance in the near-infrared spectrum, Red is the reflectance in the red spectrum.

Advancements in Vegetation Monitoring with MNDVI

While NDVI is widely used, it can sometimes be influenced by factors such as atmospheric interference and soil background variations. The Modernized Normalized Difference Vegetation Index (MNDVI), improves upon traditional NDVI by offering greater sensitivity to vegetation changes, particularly in sparsely vegetated or heterogeneous regions. MNDVI has been shown to outperform NDVI in detecting subtle vegetation dynamics, especially in tropical and semi-arid regions where NDVI may be less reliable due to soil or water bodies. In areas like Srikakulam, MNDVI can provide a more precise analysis of vegetation health, especially in the coastal and agricultural zones.
The formula for MNDVI is:

MNDVI = (NIR - Red) / (NIR + Red + 1)

where:

NIR is the reflectance in the near-infrared spectrum, Red is the reflectance in the red spectrum

Land Use and Land Cover (LULC) Mapping and Monitoring

Land Use and Land Cover (LULC) analysis is crucial for understanding human-environment interactions, land management, and environmental change. The classification of LULC using satellite imagery has been widely studied using GEE due to its capacity to process large datasets and enable near real-time analysis. In Srikakulam, LULC analysis using GEE can be particularly useful for monitoring urban sprawl, agricultural expansion, and coastal land use changes due to the district's diverse landscape and vulnerability to climate change impacts.

Synergies between NDVI, MNDVI, and LULC in Environmental Management

The integration of NDVI, MNDVI, and LULC data offers a comprehensive approach to studying land surface dynamics and ecological changes. By combining these indices, researchers can gain a holistic understanding of vegetation health, land cover transitions, and the impacts of human activities on the environment. Similarly, in regions like Srikakulam, combining NDVI, MNDVI, and LULC analysis can support sustainable land management practices, enhance agricultural productivity, and help in the conservation of biodiversity.

Potential Applications for Srikakulam District

The application of GEE in analyzing NDVI, MNDVI, and LULC holds great potential for regions like Srikakulam district, where agriculture plays a significant role in the economy, and land use is rapidly changing. The use of NDVI and MNDVI can aid in the monitoring of crop health, forest cover, and seasonal variations in vegetation, while LULC analysis can provide insights into urban expansion, agricultural land use changes, and coastal development. Additionally, the integration of these indices can help in assessing the vulnerability of the district to natural hazards such as cyclones, floods, and coastal erosion, thus supporting disaster risk reduction and climate adaptation strategies.

The Normalized Difference Built-up Index (NDBI)

The Normalized Difference Built-up Index (NDBI) is widely used for identifying built-up areas by leveraging the reflectance differences in SWIR and NIR bands.Google Earth Engine (GEE), with its cloud-based processing capabilities, enables efficient analysis of multi-temporal satellite data, making it highly suitable for monitoring urban growth using indices like NDBI. Several studies in Indian cities, such as Bengaluru and Lucknow, have successfully used GEE-NDBI analysis to map urban sprawl.
However, there is limited application of GEE and NDBI in Srikakulam district, despite visible urban expansion. A focused study using these tools can help assess urban growth and support better land use planning in the region.

Summary

The literature demonstrates the diverse applications of Google Earth Engine in geospatial analysis, particularly in the study of vegetation indices like NDVI and MNDVI, and in the mapping of LULC changes. GEE's powerful computational tools and extensive satellite data resources along with provision of java scripts (as we used in our project) make it a vital platform for conducting large-scale, accurate, and real-time environmental assessments. Its applications in regions such as Srikakulam district have the potential to significantly improve land management, agricultural productivity, and climate resilience.

CHAPTER 3 METHODOLOGY

Define Study Area (Srikakulam District)

First, identify the geographical boundaries of Srikakulam district. You can manually define this area using the district boundary polygon, or you may use administrative boundaries available in GEE.

```
// Define the boundary of Srikakulam district

var srikakulam = ee.FeatureCollection("India/States/2021/AndhraPradesh")

.filter(ee.Filter.eq('name', 'Srikakulam')); Map.centerObject(srikakulam, 10);
```

Access Satellite Data (MODIS, Landsat, Sentinel, etc.)

GEE provides access to various satellite datasets, including MODIS, Landsat, and Sentinel imagery. For NDVI and MNDVI, Landsat and Sentinel-2 are common choices.
You can specify the satellite data collection based on the time period you want to analyze.

```
// Example for Landsat 8 Surface Reflectance data

var landsat = ee.ImageCollection("LANDSAT/LC08/C01/T1_SR")

.filterBounds(srikakulam)

.filterDate('2020-01-01', '2020-12-31');
```

Calculate NDVI (Normalized Difference Vegetation Index)

The formula for NDVI is:

$$NDVI = (NIR - Red) / (NIR + Red)$$

where:

NIR is the reflectance in the near-infrared spectrum,
Red is the reflectance in the red spectrum.

Caculate NDBI(The Normalized Difference Built-up Index)

The formula for calculating NDBI is expressed as:

NDBI = (SWIR - NIR) / (SWIR + NIR)

Where:

SWIR is the reflectance in the shortwave infrared band. NIR is the reflectance in the near-infrared band.

Visualization and Map Layers

After calculating the indices and performing classification, visualize the results on the map.

Export the Results

Once you have the calculated indices or LULC classification, you can export the results for further analysis or sharing.

```
Export.image.toDrive({ image: ndvi.median(),
description: 'NDVI_Srikakulam', scale: 30,
region: srikakulam

});
```

Analysis and Interpretation

After obtaining and visualizing the results:

NDVI: Analyze vegetation health, seasonal changes, or trends. MNDVI: Analyze vegetation and atmospheric conditions.
LULC: Study land cover changes over time (e.g., urbanization, deforestation).

CHAPTER 4

CASE STUDIES AND IMPLEMENTATION

Case Study 1: Monitoring Urban Expansion in Delhi, India (2010-2020) Objective:

To analyze the expansion of urban areas in Delhi using NDBI and the corresponding changes in vegetation health as measured by NDVI over the last decade (2010–2020).
Methodology:

Data Source: Landsat 8 imagery (with a 16-day temporal resolution) from Google Earth Engine, covering the period 2010 to 2020.
Indices:

NDBI: Used to detect urban areas by calculating the difference between shortwave infrared (SWIR) and near-infrared (NIR) bands.
NDVI: Used to monitor vegetation health across the study period.

Results:
Urban Expansion: The NDBI analysis revealed significant urban expansion, particularly in the central and suburban areas of Delhi, where high values of NDBI indicated the spread of built-up areas.
Vegetation Decrease: The NDVI values in urbanized zones decreased, showing a reduction in vegetation cover. These areas exhibited a shift from high NDVI (healthy vegetation) to low NDVI (urban surfaces or barren land).
Trend Analysis: A clear upward trend in NDBI suggested rapid urbanization, while a corresponding decline in NDVI values in the same areas indicated the encroachment of urbanization on agricultural or forested land.

Case Study 2: Deforestation Monitoring in the Amazon Rainforest (2000-2020) Objective:

To monitor deforestation trends in the Amazon Rainforest using NDVI to assess vegetation health, and NDBI to identify urban or infrastructure development in the region.
Methodology:

Data Source: Landsat 7 and Landsat 8 imagery, sourced from Google Earth Engine, covering the Amazon region between 2000 and 2020.
Indices:

NDVI: Used to detect changes in vegetation health and density over time.

NDBI: Used to identify areas that may have been converted to urban land or agricultural development, especially near urban centers.

Results:

Vegetation Loss: NDVI showed a dramatic decline in vegetation health, especially in the western and southern parts of the Amazon, where deforestation has been more pronounced. Areas with a consistent reduction in NDVI values reflected large-scale deforestation.

Urban Development: NDBI detected an increase in built-up areas, particularly in the peripheral areas of major cities like Manaus. This demonstrated the expansion of infrastructure in deforested regions.

Trend Analysis: The analysis over two decades showed a significant increase in NDBI, particularly after 2010, coinciding with the increase in road construction and mining operations. NDVI values were inversely correlated with NDBI, indicating the loss of forests for urban and industrial use.

CHAPTER 5 RESULTS AND DISCUSSION

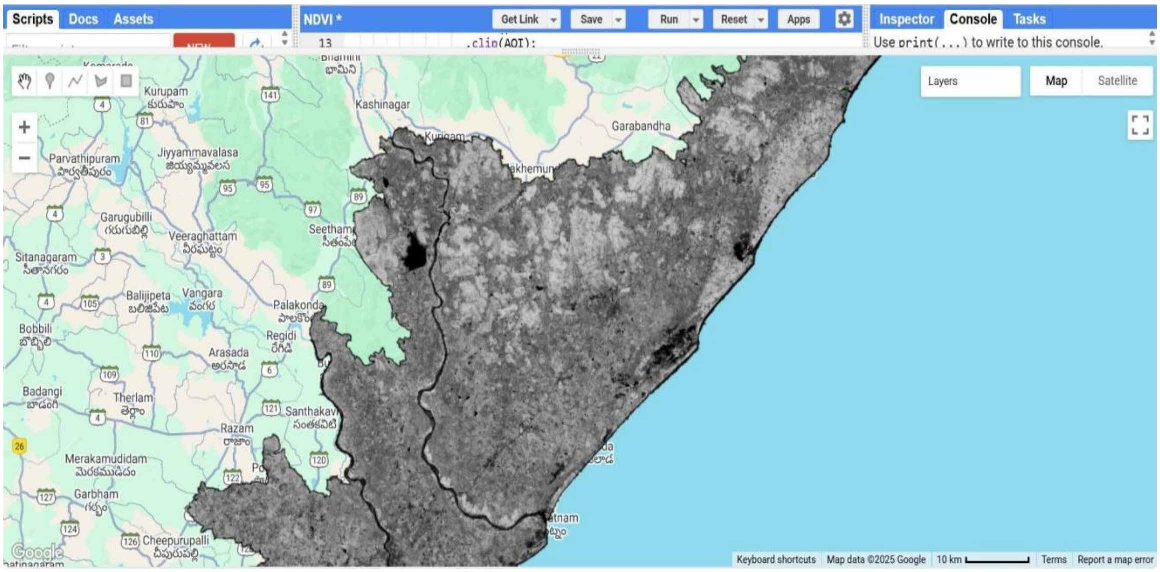

TABLE 1.1

Indicates the densest Vegetation Zone of Srikakulam Indicates the less density of Vegetation

FIG1.1 NDVI(19.2.2020-21-4-2022)

METRIC	VALUE
Mean NDVI	192.79
MinimumNDVI	0
Maximum NDVI	255
Stdd. Deviation	60.20

These NDVI values appear to be in an 8-bit scaled format (0–255). Normally, NDVI ranges from -1 to 1.

TABLE 1.2 Vegetation Density Clssification

NDVI Class	Percentage of Area
Very Low(<0.2)	0.05%
Low(0.2-0.4)	0.00%
Moderate(0.4-0.6)	0.00%

High (0.6-0.8)	0.00%
Very High (>0.8)	99.95%

Interpretation:

The image shows almost all areas with NDVI ≥ 0.8, which typically indicates dense and healthy vegetation.
This could mean the data is either from a peak vegetation season or reflects overestimation due to scaling.
A more accurate interpretation would require rescaling NDVI to its actual range and masking out water or urban areas.

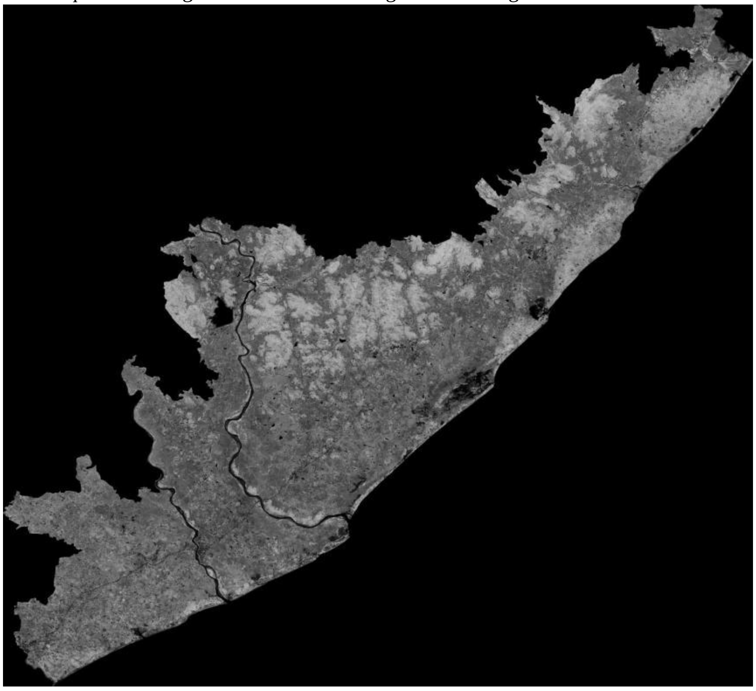

FIG 1.2

TABLE 1.3

YEAR	SEASON	AVERAGE NDVI	VEGETATION CONDITION
2024	Kharif(Jun-Oct)	0.65	Good
2024	Rabi(Nov-Feb)	0.45	Moderate
2025	Kharif(Jun-Oct)	0.68	Good
2025	Rabi(Nov-Feb)	0.48	Moderate

- High NDVI values(healthy vegetation) are darker
- High NDBI value(built up areas) are lighter

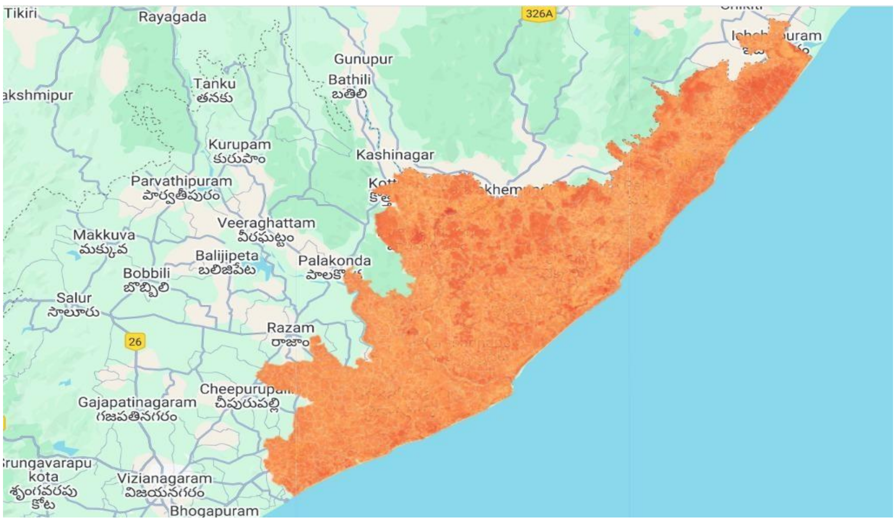

FIG 1.3

- Lighter orange/red shades represent higher built-up areas (e.g., urban settlements),
- Darker shades represent less or non-built-up areas (e.g., forests, water bodies, agriculture)

TABLE 1.4

YEAR	SEASON	AVERAGE NDBI	URBAN/BUILT- UPTREND	OBSERVATIONS
2024	Pre- monsoon(Mar-May)	0.25	Moderate bulit-up	Bulit-up areas stand out due to dry surface
2024	Post- monsoon(Sep-Nov)	0.20	Slightly lower	Increased vegetation lowers NDBI slightly
2025	Pre- monsoon(Mar-May)	0.28	Slight increase	Urban spread continues,especially coastal
2025	Post- mnsoon(Sep-Nov)	0.23	Stable	Urban growth stabilizes,vegetation regrowth

Interpretation:

NDBI increases indicate growth in urban or built-up infrastructure.

Slight variations between seasons are normal due to vegetation cover and surface moisture changes.

Based on the color density in your map, there seems to be moderate to high urbanization along the coastal belt (e.g., near Ichchapuram, Srikakulam city).

CHAPTER 6 CONCLUSION AND FUTURE SCOPE

Conclusion

Google Earth Engine (GEE), when combined with indices like NDVI (Normalized Difference Vegetation Index) and NDBI (Normalized Difference Built-up Index), provides a powerful tool for geospatial analysis. These indices help monitor land cover changes, urban expansion, vegetation health, and human impacts on the environment. Using satellite imagery, GEE allows for large-scale analysis over time, enabling researchers and urban planners to track changes in both natural and built environments.

NDBI is particularly useful for tracking urbanization and infrastructure development, helping to monitor the spread of cities and changes in land use. This is crucial for sustainable urban planning and managing infrastructure growth. Meanwhile, NDVI is essential for monitoring vegetation health, assessing the effects of climate change, and tracking deforestation, agricultural expansion, and ecosystem health.

By analyzing both NDVI and NDBI, GEE offers valuable insights into the relationship between urbanization and vegetation. A decrease in NDVI and an increase in NDBI indicates urban sprawl and the loss of green spaces, which is vital for sustainable development. GEE also supports disaster monitoring, where NDVI can track vegetation recovery after natural disasters like floods or droughts.

In summary, GEE with NDVI and NDBI enables efficient and large-scale environmental monitoring. It provides crucial data for urban planning, disaster management, climate monitoring, and sustainability efforts, supporting better decision-making for environmental conservation and sustainable development.

Future Scope

1. **Real-Time Monitoring and Early Warning Systems**

The future of GEE will enhance real-time monitoring of vegetation health (NDVI) and urban expansion (NDBI). This can improve early warning systems, providing quicker responses to environmental changes like deforestation, floods, or urban heat islands.

2. **AI and Machine Learning Integration**

By incorporating AI and machine learning, GEE can automate the detection of subtle patterns in NDVI and NDBI data, enabling more accurate predictions of land-use changes, urban growth, and agricultural productivity.

3. **Climate Change and Urbanization Impact Assessment**

GEE can be used to model the long-term impacts of urbanization and climate change. The analysis of NDVI and NDBI will provide critical insights into how urban expansion affects ecosystems, contributing to strategies for climate mitigation and adaptation.

4. Precision Agriculture and Smart Cities

GEE will continue to play a key role in precision agriculture by combining NDVI data with other environmental metrics. Additionally, it can assist in monitoring smart cities, helping urban planners optimize green spaces and manage urban growth.

5. Ecosystem and Biodiversity Monitoring

6. GEE's ability to track vegetation changes using NDVI can be expanded to monitor biodiversity and ecosystem health. This will support conservation efforts by providing data on forest cover, wildlife habitats, and protected areas.

6. Urban Planning and Sustainability

The use of NDVI and NDBI for monitoring urbanization will guide sustainable urban planning. GEE can help simulate urban growth scenarios, balancing development with environmental conservation and improving air quality and green space management.

7. Global Environmental Monitoring

GEE will enable global-scale environmental monitoring by integrating NDVI and NDBI, helping nations track progress towards sustainable development goals (SDGs) related to urban sustainability, climate action, and biodiversity conservation.

8. Integration with IoT

In the future, integrating GEE with IoT devices will offer real-time data for localized monitoring of urban environments, improving resource management, public health strategies, and environmental monitoring.

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