iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 Issue: VIII Month of publication: August 2024

DOI: https://doi.org/10.22214/ijraset.2024.64020

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue VIII Aug 2024- Available at www.ijraset.com

Dynamic Forest Monitoring: Real-Time Land Use Change Alerts Powered by Cloud Computing

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Abstract: This paper presents a near real-time alert system for detecting land use changes using Google Earth Engine (GEE). The system processes Dynamic World V1 data and Sentinel-2 imagery to generate alerts in KML and CSV formats, highlighting significant land cover changes. It also provides true-color and NDVI visualizations to support decision-making. A case study demonstrates its effectiveness for forest management.

I. INTRODUCTION

Forests are dynamic ecosystems, constantly shaped by natural forces and human activities. Monitoring these changes is crucial for preserving biodiversity and ensuring sustainable management. Traditional methods, relying on periodic surveys and manual satellite image interpretation, often fall short due to delays and inefficiencies.With Google Earth Engine (GEE), we now have the capability to monitor land use changes almost in real-time. This paper introduces a GEE-based alert system designed to provide forest managers with timely, actionable insights. By integrating Dynamic World V1 and Sentinel-2 imagery, the system generates detailed reports in KML and CSV formats, highlighting areas of concern. These real-time visualizations enable forest managers to respond swiftly and effectively to emerging threats.

II. STUDY AREA

The study area includes all forest areas in guna district which comprises 2300 sq km .

III. METHODOLOGY

A. *Data Collection*

The system gathers data from two primary sources:

1) *Dynamic World V1:* This dataset, derived from Sentinel-2 imagery, offers preprocessed, high-resolution (10m) land cover classifications, ideal for real-time monitoring across multiple land cover types such as crops, bare soil, shrubland, built-up areas, grassland, and forested areas.
2) *Sentinel-2 Imagery:* Used for true-color visualizations and NDVI calculations, ensuring high-quality data through cloud-masking.

B. *Date Selection and Image Filtering*

Users define a date range of interest, and the system filters the Dynamic World and Sentinel-2 image collections based on these dates and the geographical boundaries of the forest area. Images are further refined for cloud-free conditions to ensure precision.

C. *Change Detection*

1) *Land Cover Changes:* The system compares land cover classifications between two dates, highlighting significant changes.
2) *Label Changes:* It identifies specific transitions, such as from forest to agricultural land, to detect deforestation or land conversion.
3) *NDVI Analysis:* NDVI differences between the selected dates highlight areas of declining vegetation health.

D. *Customizability and Integration*

The system is adaptable to various monitoring needs, allowing customization of date ranges, geographical boundaries, and sensitivity settings. It supports integration with additional data sources like radar or LIDAR, enhancing its capabilities.

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E. Alert Generation

Alerts are generated in KML and CSV formats, providing detailed information about detected changes, including type and location. These formats enable easy visualization and reporting, with Sentinel-2 imagery integration offering robust validation through true-color and NDVI analysis.The system leverages cloud-based processing via Google Earth Engine, ensuring scalability, rapid data analysis, and timely responses to environmental changes. Compared to traditional methods, this approach offers a faster, more efficient solution for real-time land use change detection.

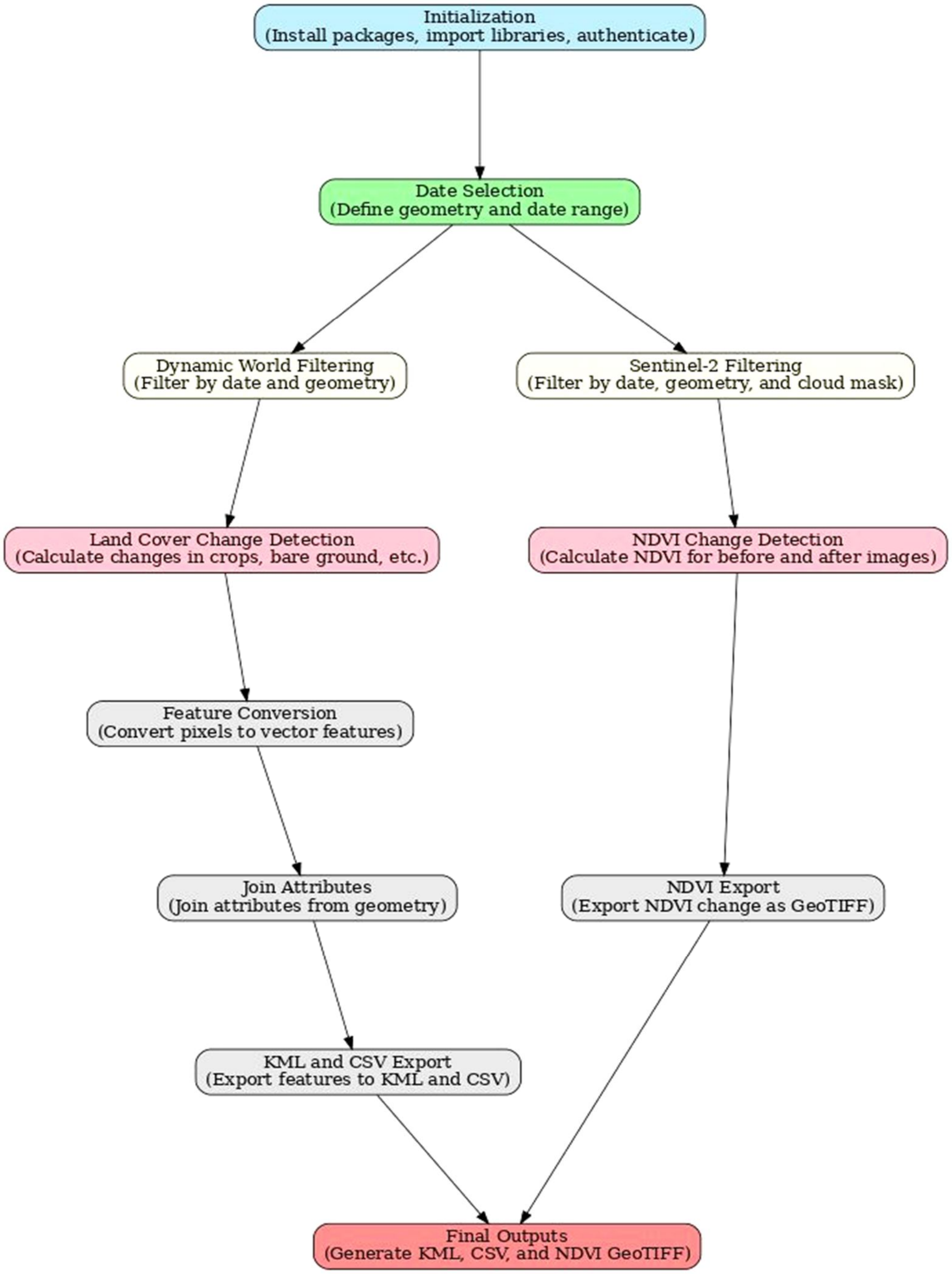


Fig.1 Flow Chart of whole process

The code used for land use change detection and alert generation is available in a public GitHub repository. The repository includes all scripts, dependencies, and instructions needed to replicate the analysis. The code can be accessed at:
https://gist.github.com/Slllyio/0c9002737b9a101a2177593d0308437b

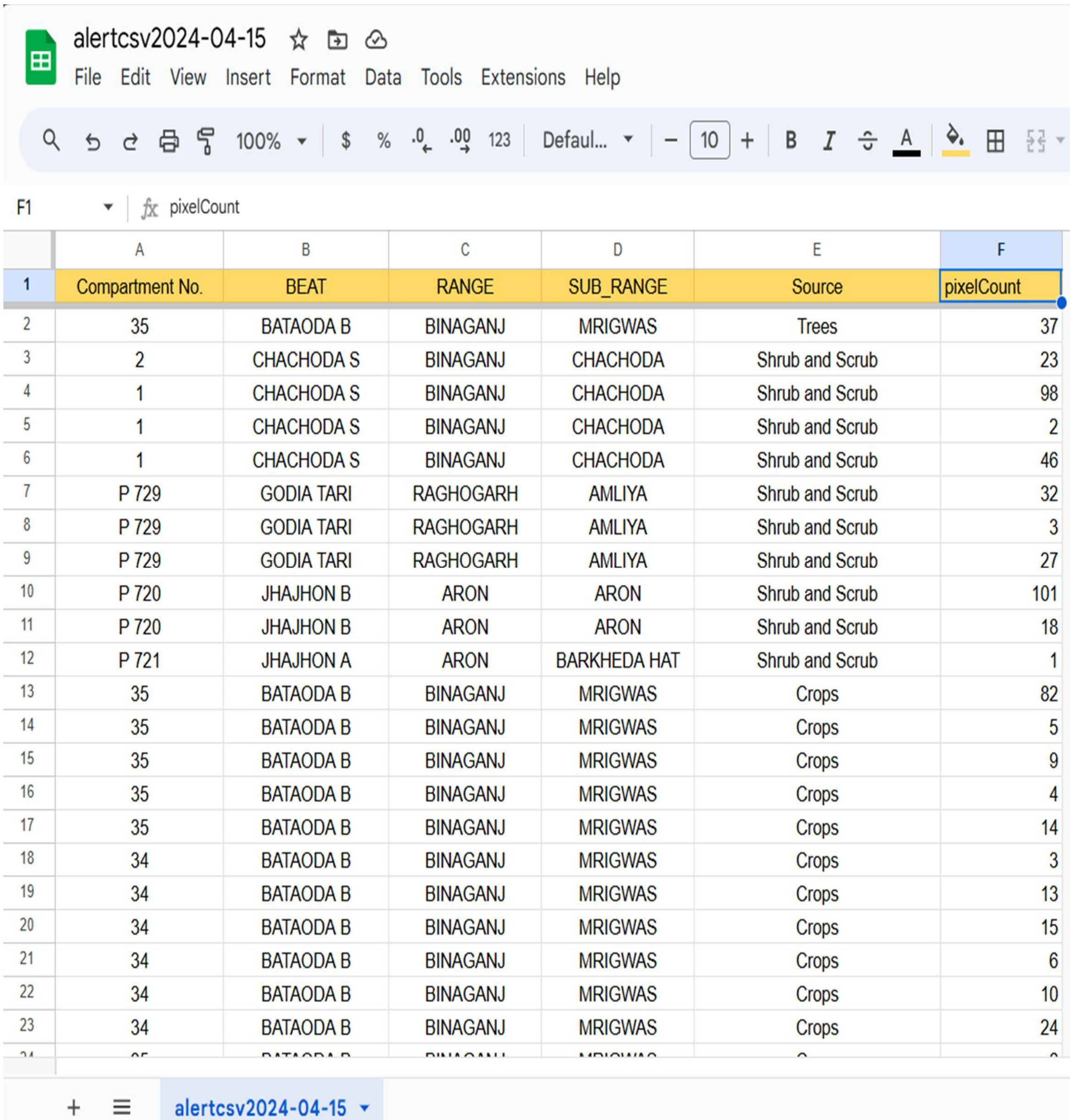
IV. RESULTS

The alert system was tested on a specified forest area, demonstrating its ability to detect significant land use changes over short time intervals. The system successfully generated KML and CSV files that highlighted areas where forest cover had been reduced, either due to conversion to agricultural land or other disturbances.

The below screenshot (Fig.2) shows a Google Sheets document titled "alertcsv2024-04-15," which is a CSV output generated by a forest management alert system. The sheet includes data on detected land use changes within specific forest compartments. Key columns include:

1) *Compartment No., BEAT, RANGE, SUB_RANGE:* These columns provide detailed location identifiers for each detected change within the forest.
2) *Source:* This column indicates the type of land cover change (e.g., "Trees," "Shrub and Scrub," "Crops").
3) *pixelCount:* This column quantifies the extent of the change by listing the number of pixels affected.

This document enables forest managers to quickly identify and assess areas where significant land cover changes have occurred, facilitating timely and informed management decisions.



Compartment No.	BEAT	RANGE	SUB_RANGE	Source	pixelCount
35	BATAODA B	BINAGANJ	MRIGWAS	Trees	37
2	CHACHODA S	BINAGANJ	CHACHODA	Shrub and Scrub	23
1	CHACHODA S	BINAGANJ	CHACHODA	Shrub and Scrub	98
1	CHACHODA S	BINAGANJ	CHACHODA	Shrub and Scrub	2
1	CHACHODA S	BINAGANJ	CHACHODA	Shrub and Scrub	46
P 729	GODIA TARI	RAGHOGARH	AMLIYA	Shrub and Scrub	32
P 729	GODIA TARI	RAGHOGARH	AMLIYA	Shrub and Scrub	3
P 729	GODIA TARI	RAGHOGARH	AMLIYA	Shrub and Scrub	27
P 720	JHAJHON B	ARON	ARON	Shrub and Scrub	101
P 720	JHAJHON B	ARON	ARON	Shrub and Scrub	18
P 721	JHAJHON A	ARON	BARKHEDA HAT	Shrub and Scrub	1
35	BATAODA B	BINAGANJ	MRIGWAS	Crops	82
35	BATAODA B	BINAGANJ	MRIGWAS	Crops	5
35	BATAODA B	BINAGANJ	MRIGWAS	Crops	9
35	BATAODA B	BINAGANJ	MRIGWAS	Crops	4
35	BATAODA B	BINAGANJ	MRIGWAS	Crops	14
34	BATAODA B	BINAGANJ	MRIGWAS	Crops	3
34	BATAODA B	BINAGANJ	MRIGWAS	Crops	13
34	BATAODA B	BINAGANJ	MRIGWAS	Crops	15
34	BATAODA B	BINAGANJ	MRIGWAS	Crops	6
34	BATAODA B	BINAGANJ	MRIGWAS	Crops	10
34	BATAODA B	BINAGANJ	MRIGWAS	Crops	24

Fig.2 Alert In CSV File

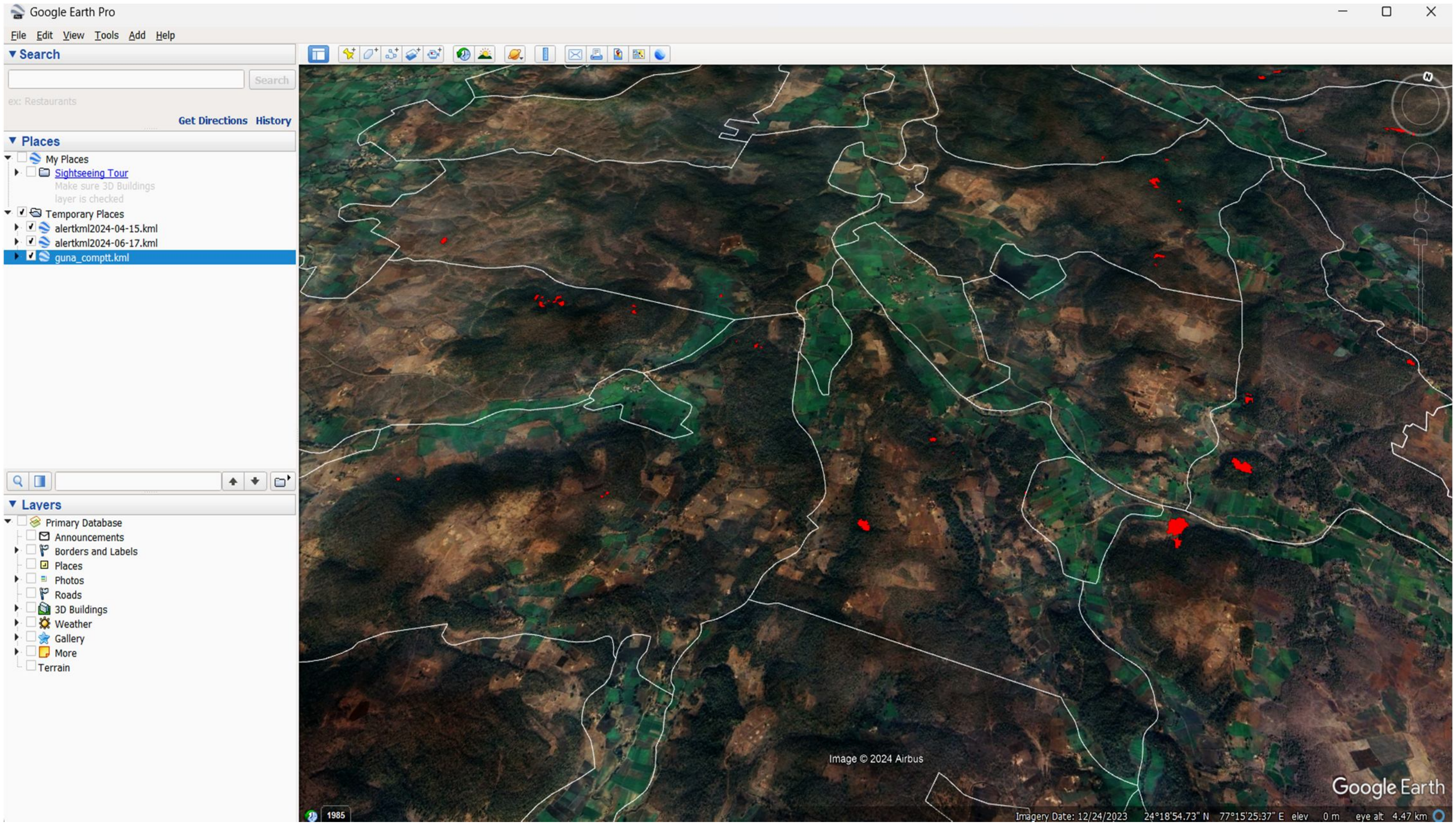


Fig.6 Alert In KML File

The integration of true-color Sentinel-2 imagery allowed for visual verification of the detected changes, enhancing the credibility and usability of the alerts.

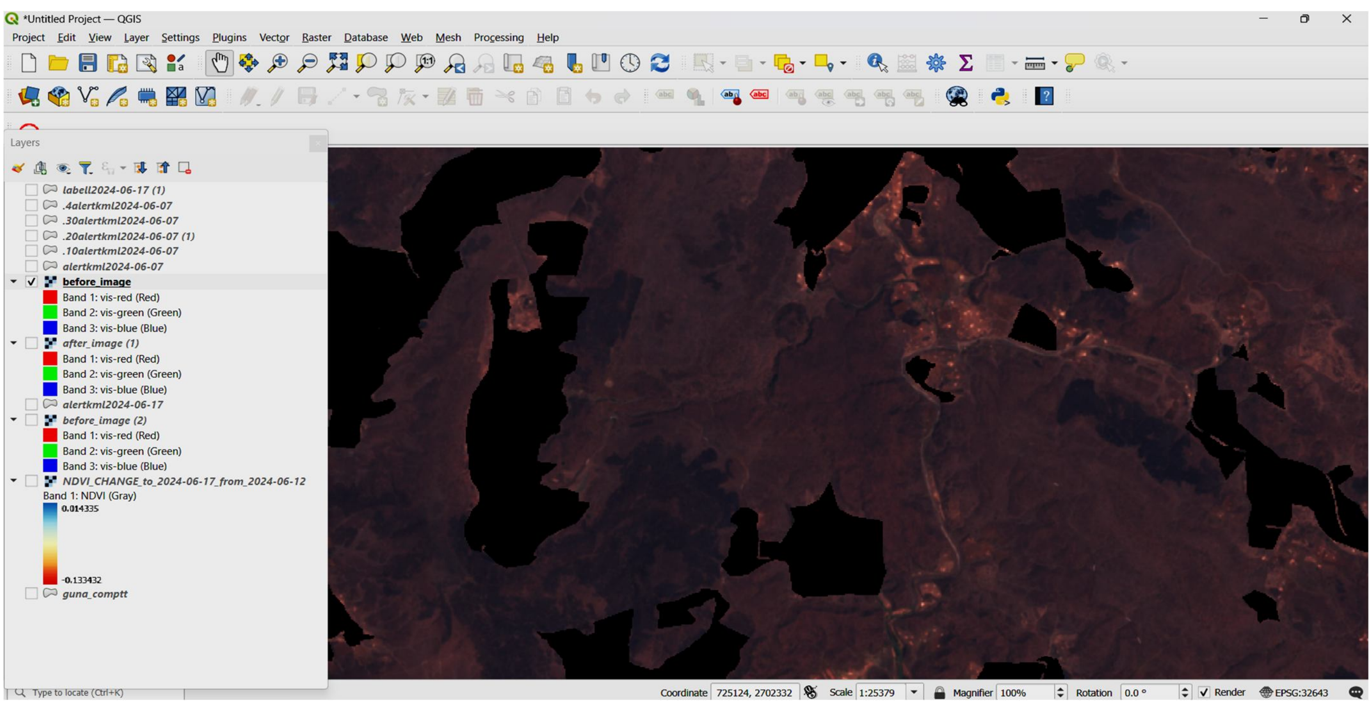


Fig.6 Sentinel Imagery Visualization

The NDVI analysis provided additional insights, with maps showing areas of declining vegetation health.

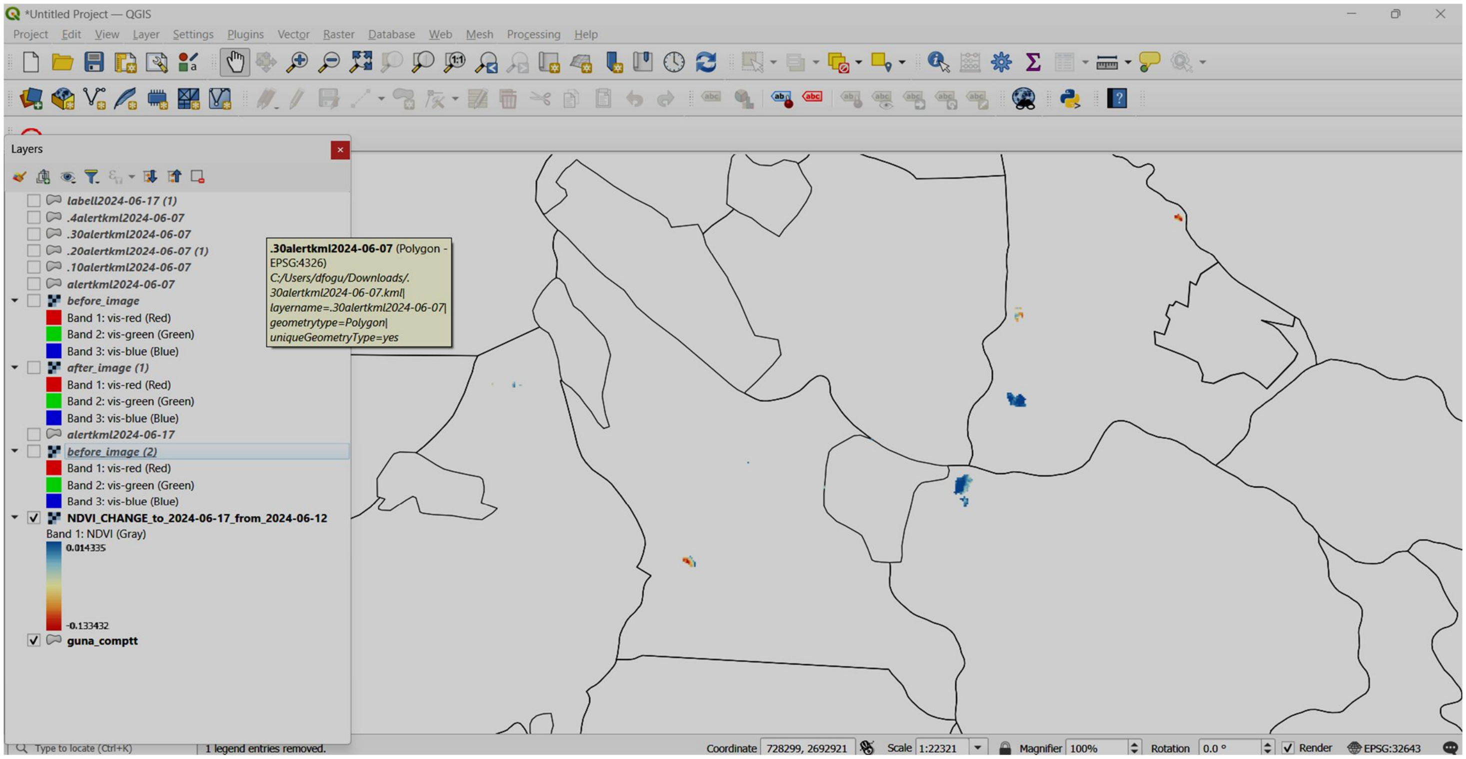


Fig.6 NDVI Change

V. DISCUSSION

The near-time alert system described in this paper represents a significant advancement in forest management tools. By leveraging GEE's cloud-based processing power and combining multiple datasets, the system can detect and report land use changes with minimal delay. The use of KML and CSV outputs ensures that the alerts can be easily integrated into existing management practices, facilitating rapid response to potential threats.

While the system's reliance on satellite imagery is a strength, it also presents challenges, particularly in areas with frequent cloud cover. Future enhancements could include the integration of additional data sources, such as radar or LIDAR, to improve detection in such conditions. Moreover, the potential for broader application of this system is significant. Beyond forest management, the system could be adapted for monitoring urban expansion, agricultural encroachment, or climate change impacts. Such versatility makes it a valuable tool not only for forest managers but for a wide range of environmental monitoring and policy enforcement activities.

VI. CONCLUSION

The proposed near-time alert system offers a powerful tool for forest managers, enabling them to monitor land use changes effectively and respond to emerging threats in a timely manner. By providing comprehensive reports that include both spatial and tabular data, the system supports informed decision-making and contributes to more effective forest conservation efforts. Its potential applications extend beyond forest management, making it a versatile tool for a wide range of environmental monitoring tasks.

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