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Monitoring Land Use-Land Cover (LULC) change (2021-2023) in Mount Abu, Rajasthan using Machine Learning in GEE

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ABSTRACT: Land use and land cover (LULC) changes are continuous and dynamic processes shaping the Earth's surface, playing a vital role in resource management and environmental monitoring. Detecting and analyzing these changes is essential for assessing, conserving, and managing natural resources effectively. Such transformations influence regional environments, socio-economic development, and ecological stability. This study focuses on Mount Abu, a well-known hill station in the Sirohi district of Rajasthan, India, characterized by its cool climate, elevated rocky plateau, and surrounding forested areas. Covering an area of 1,069.22 sq. km, the research investigates the spatial and temporal dynamics of LULC using Machine Learning (ML) techniques within the Google Earth Engine (GEE) framework. LULC mapping, a key aspect of remote sensing, offers accurate and efficient insights into land surface changes. Using Sentinel-2 satellite imagery from 2021 to 2023 and the Random Forest ML algorithm, the analysis reveals notable shifts in land use patterns. These variations signify the positive influence of improved management strategies and policy measures by local authorities. The integration of ML with GEE provides a detailed understanding of Mount Abu's LULC transitions, supporting effective evaluation of land-use policies and promoting sustainable land management practices.

KEY WORDS: LULC, Machine Learning (ML), Google Earth Engine (GEE), Monitoring, Forecasting.

I. INTRODUCTION

Monitoring Land Use and Land Cover (LULC) changes is fundamentally connected to observing environmental transformations. Therefore, analysing environmental dynamics through LULC mapping is essential for understanding how these changes evolve over time. Remote sensing data provides an effective and reliable means of mapping and monitoring LULC variations. Numerous studies have utilized satellite imagery, image classification methods, and advanced processing techniques to detect LULC changes across regional, national, and global scales. Change detection serves as a critical tool for assessing land degradation, which is often influenced by factors impacting biodiversity and ecosystem health. Remotely sensed observations of the Earth's surface have proven invaluable for identifying major LULC alterations across diverse spatial extents. LULC maps, in particular, play a central role in detecting environmental changes such as biodiversity loss, agricultural expansion, deforestation, urbanization, and shifts driven by globalization, socio-economic development, and biophysical processes. [1].

Mount Abu, a biodiverse region known for its unique flora and fauna, has encountered several challenges resulting from rapid urbanization and expanding tourism activities. Google Earth Engine (GEE), a cloud-based geospatial platform, provides access to extensive satellite imagery and diverse spatial datasets, enabling robust image processing, analysis, and visualization capabilities. Utilizing GEE facilitates efficient large-scale analysis of LULC changes, offering valuable insights into the complex interactions between human activities and the natural environment. This approach supports evidence-based decision-making aimed at promoting sustainable land management and environmental conservation. The LULC dynamics of Mount Abu are primarily influenced by factors such as urban expansion, tourism development, agricultural practices, and forest conservation efforts [2]. As Mount Abu has grown into a prominent tourist destination, the urban area has expanded to accommodate the rising number of visitors and residents. This growth has resulted in an increase in built-up areas, driven by the construction of hotels, resorts, restaurants, and other infrastructure facilities. The surrounding regions of Mount Abu, particularly along the Banas River, are known for their agricultural activities, with

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fruit and vegetable cultivation being predominant. However, the growing demand for land for urban and commercial purposes has led to the conversion of some agricultural land into other land uses. Notably, Mount Abu hosts the only rainforest within the Aravalli Range. Ongoing conservation initiatives have contributed to the preservation and, in some areas, enhancement of forest cover, reflecting the positive outcomes of sustainable management practices.

II. RELATED WORK

Recent urban and regional LULC change studies link land cover transitions to climate, urban sustainability and resource management, reinforce claim that short-term LULC monitoring (2021–2023) in a fast-changing tourist hill station has planning and policy relevance [3]. Sentinel-2–based LULC mapping studies report that spectral bands and biophysical indices (NDVI, MNDWI, NDBI, etc.), can achieve high user's and producer's accuracy for classes such as agriculture, built-up, water and barren land, validating choice of Sentinel-2 plus Machine Learning for short-period change detection [4]. Another GEE-based LULC work integrates RF and SVM on Sentinel imagery for precise mapping of vegetation, built-up, barren land and water, and demonstrates that ML on GEE supports accurate, scalable classification suited for urbanization and land degradation studies [5]. A recent case study on Mount Abu wetlands evaluates changing wetland health, water quality and ecosystem services under growing tourism and land use pressures, and can be used to justify your focus on environmental sensitivity and ecosystem services in Abu [6]. Broader discussions on Aravalli forest loss and climate buffering stress that degradation in this range intensifies heat extremes, groundwater decline and monsoon disruption, which can contextualize why even short-term (2021–2023) LULC transitions in Mount Abu are critical.

III. DATA AND MATERIAL

Study Area

Mount Abu is situated in the Aravalli Range in the Sirohi district of Rajasthan, India (Figure 1). It is the highest peak within the Aravalli Range, located in the SW part of Rajasthan, near the Gujarat border [3]. The study area lies between latitudes 72°36' and 73°4' N and longitudes 24°12' and 24°48' E. The region rises to an elevation of 1,165 meters on a distinct rocky plateau, stretching approximately 22 km in length and 9 km in width. The highest point in the area is Guru Shikhar, which stands at 1,730 meters. Mount Abu is a well-known hill station and popular tourist spot. The GPS coordinates for Guru Shikhar, as recorded in the field, are 24.4833° N latitude and 72.9167° E longitude

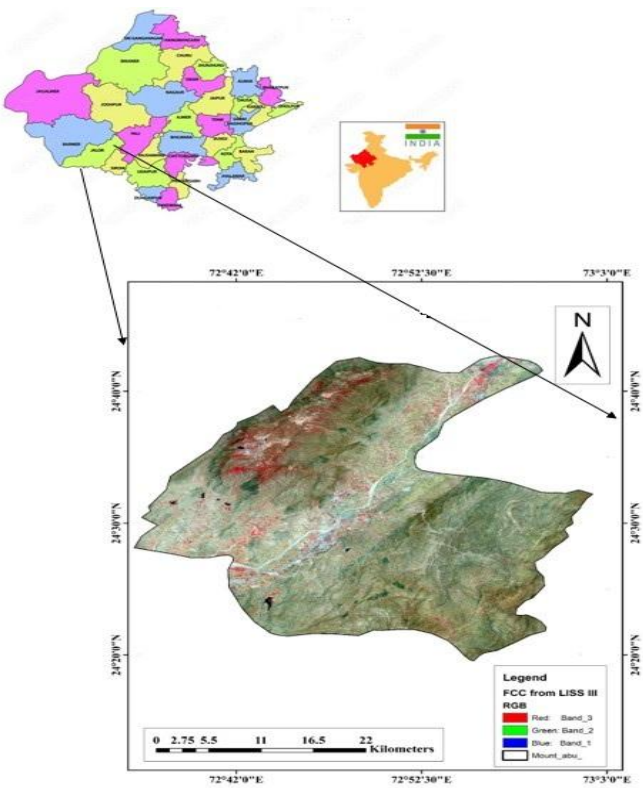

Figure 1. *Location and Base Map of study area*

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Data and Material

Monitoring of LULC change in Mount Abu is performed using remote sensing data i.e., LISS III imagery data for base map (Figure 1) creation and better understanding of various aspects of study area were taken from Bhuvan portal of ISRO and shapefile (.shp) data from Survey of India website. Sentinel 2 imagery used in Monitoring LULC changes has a time span of 2021-2023. This data i.e. Sentinel 2 Data is acquired and processed by using Google Earth Engine (GEE). The output results from GEE were exported to google drive and imported in ArcGIS 10.7 for final maps preparation with layouts, scale, direction and legends [1].

IV. METHODOLOGY

The process of detecting land use and land cover changes over time, known as "Land use and Land cover change detection," leverages remote sensing data, GIS technology, and Google Earth Engine with Machine Learning. This approach is beneficial in various fields, such as urban planning, resource management, climate change studies, and analysing shifts in vegetation, including increases in forest cover and decreases in barren land. In this study, LULC classification is performed using advanced machine learning techniques in Google Earth Engine, where samples are tracked and trained for each land cover type (Figure 2). The classification aims to identify the different land cover categories within the study area, which has been divided into five groups: Settlement area, Water body area, Farmland area, Vegetation area, and Barren land area. The results of this LULC classification provide the basis for analysing changes and generating detailed LULC maps. The study utilized Sentinel-2 datasets from 2021 to 2023, available through GEE, selecting data with less than 1% cloud cover and creating composites from the first six months of each year. The Random Forest Machine Learning Algorithm in Google Earth Engine was employed for the classification, producing LULC maps for both 2021 and 2023 (Figure 2). The accuracy of the results was measured using overall accuracy and kappa accuracy methods within GEE [1].

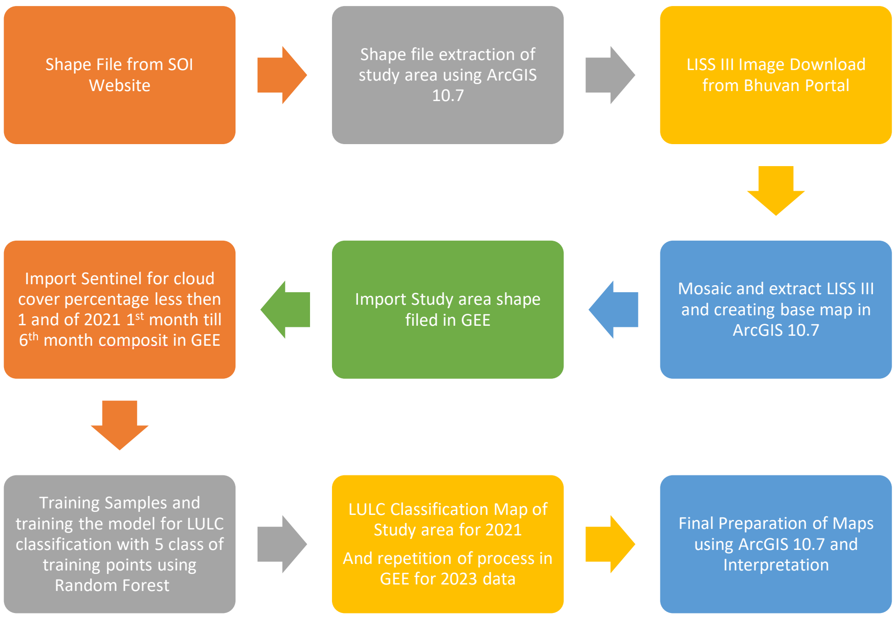

Figure 2. *Flow Chart of Methodology opted for research*

V. RESULTS AND DISCUSSION

Based on Figure 3 it is found that in year 2021 the forest area covered of Mount Abu was considerably good i.e. 207.60 sq. km as Mount Abu is popular Hill station it is considerably known for its Vegetative area and cool climate. Area covered by water was 56.40 sq. km. which is quite average area it is also found that the settlement area of Mount Abu was 11.90 sq. km. which was very less (Table 1) but comparatively the Barren area was very high i.e. 657.20 sq. km. than the settlement area. Surprisingly the area covered by Agriculture was very High i.e. 136.20 sq. km. (Table 1) over all this LULC data 2021 of Mount Abu shows that the environmental, vegetative and ecological conditions of Mount Abu was average in 2021. From the year 2023 (Figure 4), the vegetative area of Mount Abu experienced a substantial

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increase, reaching 275.80 sq. km (Table 1). In comparison to the 2021 data, this vegetative condition was notably favourable. Surprisingly, the area covered by water has seen a significant increase from 2021 to 2023, rising from 56.40 to 182.00 sq. km. This indicates that there has been a great monsoon impacting the region over the past two years. Additionally, another positive aspect is the reduction in barren land in 2023, which is considered very good. However, there is a decrease in the agricultural area, dropping from 136.20 to 57.60 sq. km (Table 1) [4].

The results reveal significant land use and land cover (LULC) changes over the study period. Forest areas have notably expanded by 68.19 sq. km, while settlement areas have grown by 9.16 sq. km. Additionally, the area covered by water bodies has significantly increased by 125.68 sq. km. On the other hand, there has been a substantial reduction in farmland, which decreased by 153.62 sq. km, and barren land, which shrank by 124.39 sq. km. By utilizing Machine Learning algorithms within GEE, this study enhances the understanding of Mount Abu's current LULC dynamics and provides insight into future trends. The findings are valuable for identifying potential environmental and socio-economic risks, while also informing sustainable land management strategies that can help conserve natural resources and ecosystems in the region [1].

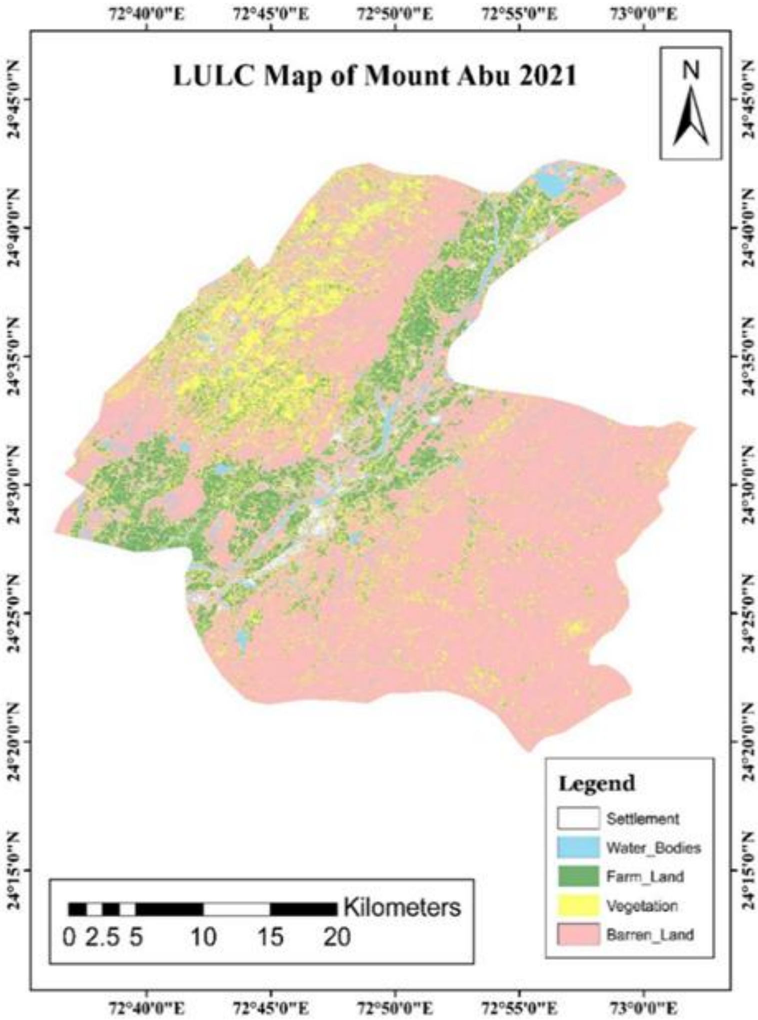

Figure 3. *LULC Map of Study area for year 2021*

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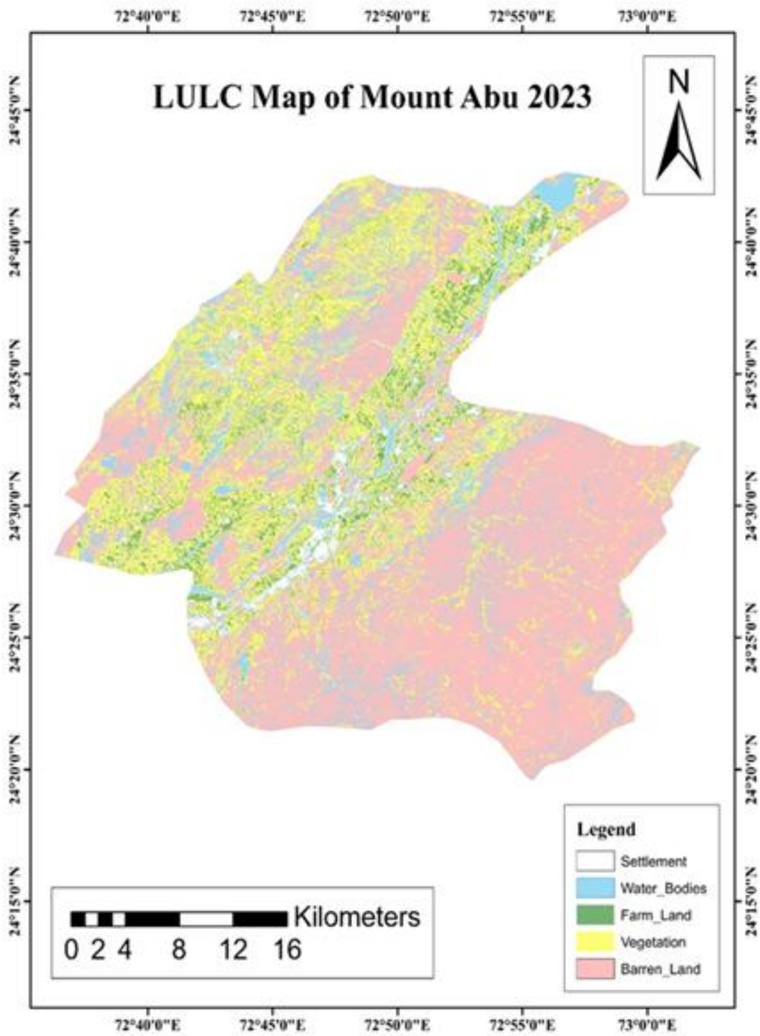

Figure 4. *LULC Map of Study area for year 2023*

Accuracy

Kappa Accuracy measure the functioning of classification i.e. how perfect the classification is performed. Overall accuracy is complete number of accurately classified pixels to the total number of reference pixels. While making the LULC map of the study Area we have Run two types of accuracy i.e. Kappa Accuracy and Overall Accuracy. The obtain kappa Accuracy of year 2021 is 91% and overall accuracy is 88%, while the Kappa Accuracy of year 2023 is 88% and overall Accuracy is 85% which suggest that the data accuracy of data is quite reliable for the research purpose [5]. Following is the equation for kappa coefficient:

$$\text{Kappa Accuracy} = \frac{(TSxTCS) - \sum(Column\ Total\ x\ Row\ Total)}{TS2 - \sum(Column\ Total - Row\ Total)} \quad (1)$$

The total accuracy is determined by dividing the number of correctly classified reference pixels by the sum of the diagonal values in the confusion matrix. Traditional methods for assessing accuracy include the kappa coefficient, overall accuracy, producer's accuracy, and user's accuracy [5].

$$\text{Overall Accuracy} = \frac{Total\ Number\ of\ Correctly\ Classified\ Pixels\ (Diagonal}{Total\ Number\ of\ Reference\ Pixels} \times 100 \quad (2)$$

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VI. CONCLUSION AND FUTURE WORK

Analyzing changes in land use and land cover (LULC) has long been a key focus in remote sensing and GIS techniques for Earth observation. This research highlights the effectiveness and precision of combining Google Earth Engine (GEE) with Sentinel-2 time-series data to detect even subtle transformations within the study area. The Google Earth platform offers user-friendly algorithms and cloud computing capabilities, making it convenient for performing various analytical tasks. By integrating machine learning with the power of GEE, this study was able to accurately classify LULC into five distinct categories and monitor changes across the study area. One of the advantages of this system is its ability to quickly produce clear and easily interpretable maps that reveal the nature of LULC changes, facilitating timely interventions. The analysis shows that water bodies and built-up/settlement areas have increased, while the use of vegetated land, open land, and agricultural fields has varied. The growth in water bodies is largely attributed to favorable rainfall conditions and improved surface water management practices implemented by the government, aimed at boosting tourism and environmental conservation in the region. This study introduces a novel approach to LULC mapping for the Mount Abu region using machine learning algorithms within the Google Earth Engine platform. By incorporating these advanced techniques, it provides valuable insights into the current state and potential future trends of LULC dynamics in Mount Abu.

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