Analyzing Land Cover and Land Use Changes Using Remote Sensing Techniques: A Temporal Analysis of Climate Change Detection with Google Earth Engine

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***Abstract*—The detection of changes in land cover and land use (LCLU) is crucial for various geospatial applications, including urban development and environmental management. One vital aspect of LCLU research involves identifying modifications in impervious surface cover, which has significantly increased due to global economic growth and the rising urban population in many parts of the world. This investigation employs Landsat 9 OLI- 2/TIRS-2 imagery with a 30m spatial resolution to map structures in the Ziarat District of Pakistan, encompassing forests, water bodies, and barren land. It aims to detect changes in tree cover and canopy height. A time series of Landsat 9 OLI-2/TIRS-2 images were utilized to create change detection and land cover maps. The Analysis of Land Cover and Land Use (LCLU) for the Ziarat District was conducted using the GEE platform. The satellite images were classified into broad land cover classes, which include impervious surfaces, forest/tree cover, grassland/cropland, and water. The generated change detection map facilitates the identification of locations that have undergone modifications due to new constructions, offering valuable insights for the implementation of urban development policies and disaster management on a global scale.**

***Index Terms*—Land Cover Land Use, Operational Land Imager 2, Thermal Infrared Sensor 2, Google Earth Engine**

I. Introduction

The information about land cover and land use (LCLU) is essential for many geospatial applications, including urban development and environmental management. It also serves as a basis for understanding the ongoing alterations to the Earth's surface and related socio-ecological interactions. Impervious surface change detection is a major topic in the LCLU research realm. The impermeable surface areas have significantly increased due to economic growth and rising urban population. It is important to understand the geographical distribution of impervious surface areas since this knowledge will be useful for analyzing urban heat islands and urban growth, as well as for implementing urban development policies and disaster management [1] [2]. To detect recent changes in impervious surfaces, satellite-based sensors with various spatial resolutions have been used. However, the majority of these sensors operate at a 30-meter resolution, with detection often relying on Landsat images [3] [4]. In particular, the emergence of new satellite platforms and advanced remote sensing technologies provides valuable alternatives to overcome these resolution constraints.

Land Use and Land Cover (LULC) information is important for a wide range of geospatial applications, including natural disaster management and environmental monitoring. The availability of remotely sensed images with higher spatial and spectral resolutions has enabled more comprehensive LULC information extraction. One important tool for fine spatial resolution global monitoring (at 30m) and change detection in land cover is Landsat 9, an Earth observation project created by the Google Earth Engine (GEE). Landsat provides satellite images for different years, which aids in the collection of datasets and enables better comparisons of forest degradation [5]. Landsat has a better resolution and provides Operational Land Imager (OLI) data, which is the best satellite image with a 30m resolution. In comparison, Landsat has shown better results as compared to MODIS and VIIRS in detecting forest fires [6] [7].

II. Related Work

This section focuses on temporal analysis for comparing satellite data. The analysis involves satellite images from Sentinel-2 and Landsat-8, executed on the Google Earth Engine (GEE) platform. The objective is to map areas of Australia affected by wildfires by comparing the data from Sentinel-2 and Landsat-8. Sentinel-2's satellite images outperformed Landsat-8 due to their superior resolution, providing clearer detection of burned areas [5].

While most remote sensing approaches yield similar satellite results, this paper explores atmospheric correction. It evaluates whether this correction method consistently provides accurate outcomes. To do this, two satellites, Landsat-8 and Sentinel-2, are compared. Both satellites independently yield precise and consistent atmospheric correction results, aligning with the same Earth surface characteristics and offering improved data quality [8].

This paper adopts a comparative approach to assess the performance of two different satellites, Landsat-8 and Sentinel-2, in estimating wheat production [9]. The images of the satellite they get from the approach of USGS. Both satellites provide satellite data and cover the whole earth in just 3 to 5 days and provide better resolution images from the satellite with a resolution of 10 to 30m, which provides accurate images with fewer errors [10]. The study utilizes data from both satellites to estimate wheat production, achieving an error reduction of up to 1.8 times compared to using a single satellite.

Time series analysis is a valuable method for detecting land use and land cover changes (LULCC) [11]. However, it faces challenges such as false detections and high omission errors. Previous research has explored decomposing time series data into seasonal, linear trend, and noise components to maintain low omission rates. Efforts to reduce false alarms involve combining information from spectral bands and post-classification results. Additionally, neighboring pixel data are utilized to further minimize false alarms. Our novel approach addresses these challenges, offering effective and stable LULCC detection while significantly reducing false detections without compromising omission rates.

III. Background

The Ziarat District in Balochistan, Pakistan, stands as a true gem among Asia's most stunning landscapes. Ziarat District, located in the northeast of Balochistan, is a geographical marvel, featuring a diverse landscape of hills, mountains, and valleys. The district is bounded by the districts of Pishin, Loralai, Sibi, and Quetta and boasts the picturesque Ziarat Valley, known for its mesmerizing beauty. The valley is named after Kharwari Baba, a Pashtun saint who is believed to have rested there and imbued it with his spiritual aura and is a popular tourist destination in the summer. The town of Ziarat serves as the district headquarters. One of the district's main attractions is the largest and oldest juniper forest in the world, with some trees reaching the age of 5,000 years. Additionally, the district is famous for its honey. Despite the warm summer months, the region is adorned with large flowers, lush green grass, and cold temperatures that provide a delightful experience. The district's highest point is 3,488 meters above sea level, and the lowest point is 1,800 meters above sea level.

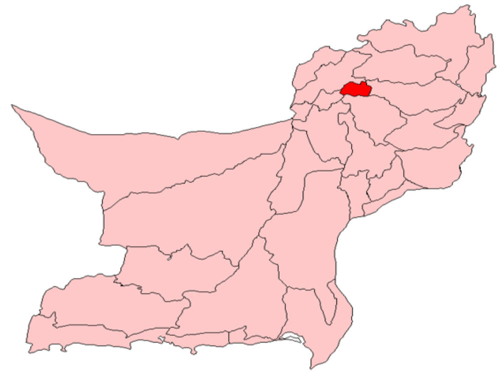

Fig. 1: Ziarat District highlighted on Balochistan map [12]

The Ziarat district, nestled in the picturesque landscapes of Balochistan, Pakistan, is an ideal vacation spot that offers a unique and refreshing experience to visitors. The district is home to one of the largest and oldest juniper forests in the world, with some juniper trees dating back over 5,000 years, making it a significant attraction for nature lovers and researchers alike. The district is also renowned for its high-quality honey, which is considered to be Ziarat's magic and a source of pride for the locals. Even during the warmest summer months, the district's natural beauty, including the large flowers, luxuriant green grass, and cool temperatures, leaves an enchanting and invigorating effect on visitors, making it a must-visit destination for tourists from all over the world [13] [14].

IV. An Overview of the Land Cover

This satellite image shows the Ziarat area from an altitude of 1-20 km above the surface, with the shapefile uploaded to Google Earth Engine for further classification. The image is the most recent available, from 2022, and the platform provides access to satellite images from various sources, including Modis, Landsat, and Sentinel. Landsat offers 60 years of satellite imagery with a resolution of 30 meters, while Sentinel, a more recent satellite, provides data for up to 8 years with a better resolution of 10 meters.

To classify the Ziarat area, the Shapefile of the district is uploaded to Google Earth Engine, and different classes are added, including forest, barren land, and water. Historical Landsat imagery is used to detect changes in land use. The Ziarat district encompasses a total forest area of 61,731 hectares, with 49% having improved drinking water [14], and 51% relying on unimproved drinking water sources. A significant portion of the district is covered by forest, much of which has been protected as a state forest or wildlife-protected

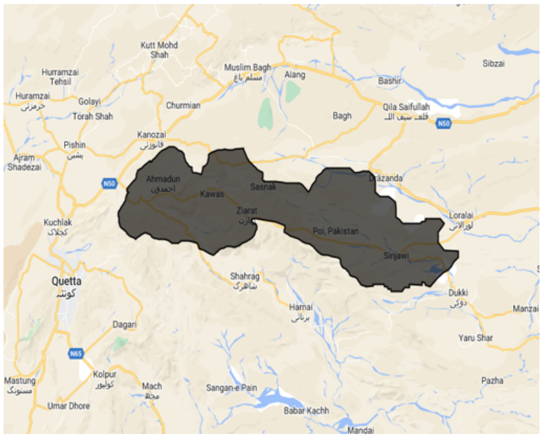

Fig. 2: Illustration of Ziarat District Shapefile

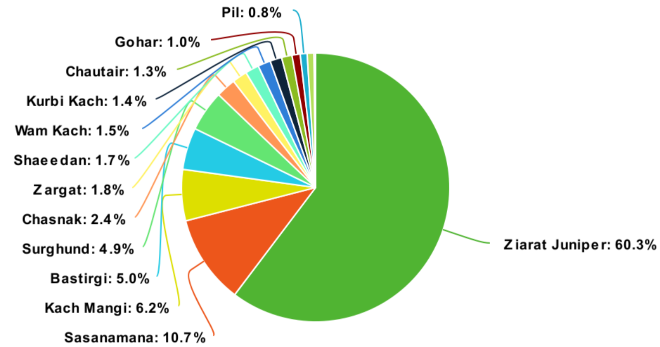

Fig. 3: Pie Charts Illustrating Total Forestry Land Use Area [22]

area. The dominant plant species in the forests are juniper and its associates. These classes are further consolidated through coding and are then utilized for training classification. Each class has a training point, enhancing the accuracy of the training classification.

Changes in Land Use and Land Cover (LULC) are a major driving force behind global development [15]. To comprehend the changes that occur, it is essential to understand how LULC impacts and interacts with the global world system, as well as where and when they occur [16]. SSatellite data has proven particularly helpful for monitoring changes in LULC structures over the years, and Geographic Information Systems (GIS) can be employed to measure such changes when geographic datasets of varying scales/resolutions are generated [17]. Over the past 20 years, researchers have developed, tested, and evaluated various methods for detecting changes in satellite images. LULC change is a crucial topic in the analysis of environmental changes on a global scale [18].

For the spatial distribution of LULC changes over extensive areas, remote sensing, and GIS provide rapid and precise spatial data collection [19]. Change detection necessitates a flexible framework for collecting, storing, displaying, and comprehending digital data [20]. The use of satellite imagery in agricultural and forested regions is common, and the extensive coverage and high-resolution spectral capabilities of satellite images are the primary reasons for their use [21].

To analyze the LULC of the Ziarat region from 2002 to 2022, GIS and RS tools were employed. To the best of the author's knowledge, no studies have been conducted on how land use and land cover have changed in the Ziarat district. This research is the first to investigate shifts in land use and land cover in the study's region. Openly available satellite imagery was utilized to complete the research. Using multi-temporal and multi-spectral imagery together can be highly advantageous for this type of research, as demonstrated in the present study. Maximum likelihood-guided classification was found to be one of the top classification techniques for this type of research.

V. Forestry Land Use

The Ziarat Juniper forest, in particular, has some trees estimated to be over 5,000 years old, and it serves as one of the world's largest and oldest juniper forests. It plays an important role in maintaining the local ecosystem and providing habitat for various wildlife species.

In addition to regulating water cycles, preventing soil erosion, and providing numerous forest products to the local communities, these forests also offer various benefits. Deforestation, overgrazing, and climate change pose major threats to these valuable natural resources, so conservation efforts are crucial in order to preserve them [22].

VI. Tree Cover and Canopy Height

Currently, there are 4.06 billion hectares of forest in the world, but this has decreased by 178 million hectares since 1990. The juniper forest in the Ziarat region, which covers approximately 110,000 hectares, including the Ziarat Juniper Forest Reserve, is one of the world's largest juniper forests [13]. In the arid mountains of Pakistan's Balochistan Province, juniper forests and the diverse accompanying flora and fauna constitute a distinctive ecosystem. These forests are recognized as among the biggest, oldest, and longest-lived (greater than 3000 years) on the entire globe. They are frequently referred to as "Living Forest Fossils" [23]. The vast majority of juniper woods have an open canopy. Trees of the juniper family grow slowly and exhibit weak natural regeneration [24].

The juniper forest in the Ziarat region, covering around 110,000 hectares [25] and considered the largest of its kind in the world, is also the largest in Pakistan. The junipers of Ziarat are among the world's oldest still-standing trees. Despite the absence of dendrological research, it has been suggested that mature trees can be thousands of years old. Due to their extraordinary lifespan, enabling the study of past weather conditions in the area, locals refer to the trees as "living fossils," underscoring their significance for ecological and climate change studies. The Ziarat Juniper Forest ecosystem, a part of the world's forest vegetation, holds enormous importance as a carbon stock due to its size

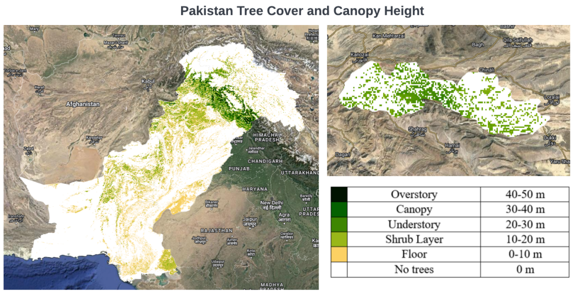

Fig. 4: Tree Cover and Canopy Height in Pakistan and Ziarat District

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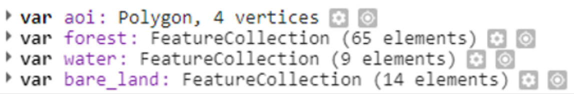

Fig. 5: Classification of Land Cover Types in the Study Area

and the presence of old-growth trees.

VII. Classification of Study Area

In the methodology of this research, we systematically classify the Ziarat study area in Pakistan. We first categorize the area into specific land cover types (Forest, Barren Land, Water) using Google Earth Engine, assigning unique property numbers for differentiation. Then, we mark training points for each class (green for forest, blue for water, yellow for barren land). These points serve as the foundation for training the classification algorithm. Finally, we employ supervised learning techniques to merge the training data and perform land cover classification. This rigorous approach ensures precise delineation of land cover classes in Ziarat, offering valuable landscape insights.

A. Classifying Land Cover

In the initial phase of our research, we undertake the task of categorizing the Ziarat area into specific and well-defined land cover types, including Forest, Barren Land, and Water. This classification process is executed within the Google Earth Engine platform, where each layer introduced signifies a distinct land cover category within Ziarat. To ensure clarity and differentiation, unique property numbers are assigned to each class, commencing with 0 for the initial class, 1 for the subsequent class, and so forth. These distinct property numbers are allocated to facilitate a clear and unambiguous distinction between the various land cover types in our study area.

B. Training Data Acquisition

In the subsequent phase of our methodology, we focus on the acquisition of essential training data points for each of the distinct land cover classes, which encompass Forest, Barren Land, and Water. These training data points are indispensable for the effective training of our classification algorithm. The

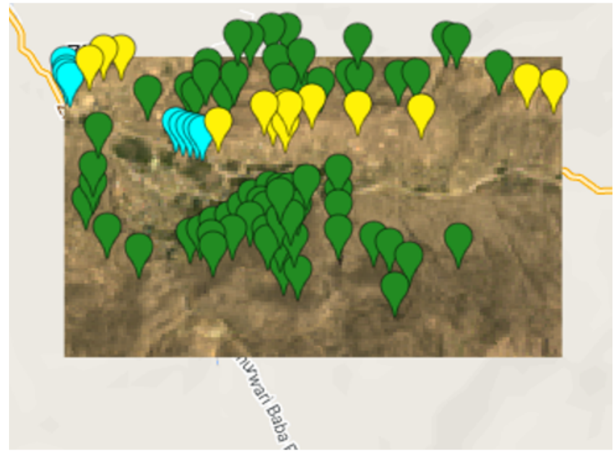

Fig. 6: Training points of Land Cover Types in the Study Area

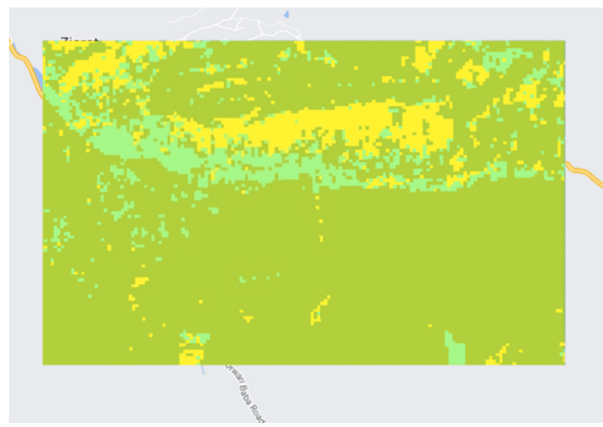

Fig. 7: Classified Land Cover of the Study Area

delineation of the various land cover categories is visually depicted through the use of color coding: green is employed to represent forestry areas, blue designates water bodies, and yellow signifies barren land. This meticulous data acquisition process serves as the foundational step in our methodology, enabling precise training for subsequent land cover classification.

C. Supervised Land Cover Classification

In the methodology employed for this study, after meticulously training the data points, the subsequent pivotal step involves the utilization of supervised learning techniques to merge and process all three land cover classes. This sophisticated approach ensures the precise classification of land cover within the study area. Once the coding process is completed, the resulting land cover classification is presented, providing a robust foundation for the analysis and interpretation of landscape patterns. This meticulous methodology enhances the accuracy and reliability of our findings, contributing significantly to the quality of our research in the context of land cover assessment.

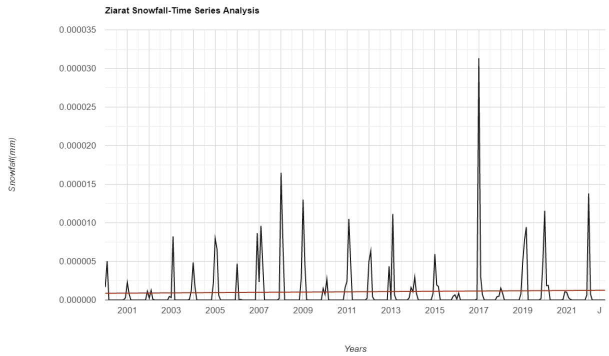

Fig. 8: Snowfall Time-Series Analysis (22 Years): Depicting Snowfall Trends and Changes

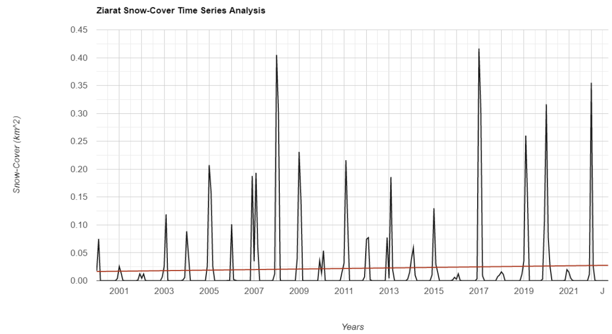

Fig. 9: Snow-Cover Time-Series Analysis (22 Years): Illustrating Snow-Cover Trends and Changes

VIII. Climate Change Detection

Google Earth Engine (GEE) contains several datasets that facilitate climate change detection. In this study, we analyzed the area over a 20 to 22-year period to observe the changes induced by climate. The resulting graphs provide clear insights into the transformations that have occurred during this time frame. Climate datasets, such as the Famine Early Warning Systems Network (FEWS NET) Land Data Assimilation System (FLDAS), were utilized for detecting climate change.

A. Snowfall Time-Series Analysis

To gain a better understanding of snowfall patterns, trends, and fluctuations in a specific region, we conducted a time-series analysis of historical snowfall data. This type of analysis serves various purposes, including managing winter tourism activities, assessing the impact of climate change on snowfall, and predicting future snowfall. Snowfall time-series analysis allows us to determine the frequency of snowfall events, their temporal distribution, and duration

This information aids in resource allocation and snow management decisions by offering valuable insights into snowfall patterns. In this context, the graph illustrating snowfall rates as kilograms per square meter per second (kg/m²/s) provides a clear insight into the region's snowfall time series over 22 years. The graph is interpreted using a unit of measurement called "mass flux," representing the mass of snowfall per unit area per unit time. Therefore, assuming a constant mass flow rate of 0.000032, about 124,261 kilograms of snowfall would be deposited over an area of 1,489 square kilometers in a month.

B. Snow-Cover Time-Series Analysis

Snow-cover time-series analysis is a crucial technique for studying patterns of snow accumulation and melt over time. This analysis utilizes 22 years of data from the FLDAS (FEWS NET Land Data Assimilation System) dataset, available on Google Earth Engine, to examine snow cover patterns in a specific area. Snow cover refers to the amount of snow covering the ground, and it can be measured using satellite images. Time-series analysis enables the identification of trends in snow cover duration, extent, and peak coverage. These patterns have practical applications in forecasting water supply, managing winter tourism activities, and assessing the effects of climate change on snow cover. The availability of high-quality datasets and advanced remote sensing techniques has made snow-cover time-series research possible.

Decision-makers across various industries value snow-cover time-series analysis as a useful tool. Pixels are employed to represent snow cover, with each pixel corresponding to a specific section of the landscape. This information is essential for various purposes, including water resource management, organizing winter tourism activities, and monitoring climate change. In summary, snow-cover time-series analysis is a valuable technique for understanding snow cover dynamics and its role in local and regional ecosystems.

C. Precipitation

We conducted a 22-year time series analysis of precipitation data to measure the amount of precipitation (typically rain or snow) that falls on a specific area over a unit of time. This analysis was represented by a graph and expressed as kg/m²/s, where 'kg' represents the mass of water falling on the region, 'm²' indicates the area over which the precipitation is distributed, and 's' denotes the time span during which the precipitation occurs. The analysis utilized data from the FLDAS (FEWS NET Land Data Assimilation System) dataset available on Google Earth Engine.

To convert the precipitation rate to the depth of snow, we considered the snow-water equivalent (SWE) ratio. The SWE ratio, which represents the amount of water contained in a given volume of snow, varies with the type of snow but typically averages around 10:1. Therefore, 10 cm of snow contains 1 cm of water, and assuming a SWE ratio of 10:1, this amount of precipitation would be equivalent to 86.4 cm of snow.

IX. Conclusion

The study revealed the significant value of the historic juniper woodland in Ziarat due to its ancient juniper tree forest. Covering approximately 110,000 hectares, the juniper forest in the Ziarat region stands as one of the world's largest, and the Ziarat Juniper Forest Reserve plays a vital role in the local

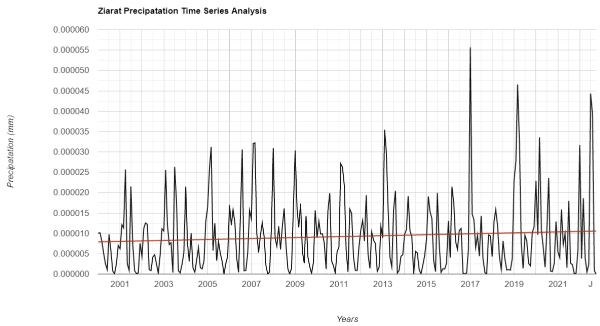

Fig. 10: Precipitation-Time Series Analysis Over 22 Years: Unveiling Patterns and Trends

ecosystem. Landsat provides satellite images of the region spanning several years, facilitating the collection of datasets for a more comprehensive comparison of forest degradation. Landsat's Operational Land Imager (OLI) data offers high-resolution satellite images with a 30-meter resolution, delivering superior results compared to MODIS and VIIRS in forest detection.

The Ziarat area's classification is performed using supervised learning techniques, with the forest, water, and barren land identified through training points and a supervised classification displayed. Additionally, a time series analysis is conducted on Ziarat's climatic water detection, revealing the snowfall, snow cover, and precipitation over 22 years.

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REFERENCES

[1] G. Xian, H. Shi, J. Dewitz, and Z. Wu, "Performances of worldview 3, sentinel 2, and landsat 8 data in mapping impervious surface," *Remote Sensing Applications: Society and Environment*, vol. 15, p. 100246, 2019.

[2] M. A. Cochrane, "Fire science for rainforests," *Nature*, vol. 421, no. 6926, pp. 913–919, 2003.

[3] R. C. Estoque and Y. Murayama, "Classification and change detection of built-up lands from landsat-7 etm+ and landsat-8 oli/tirs imageries: A comparative assessment of various spectral indices," *Ecological indicators*, vol. 56, pp. 205–217, 2015.

[4] X.-P. Song, J. O. Sexton, C. Huang, S. Channan, and J. R. Townshend, "Characterizing the magnitude, timing and duration of urban growth from time series of landsat-based estimates of impervious cover," *Remote Sensing of Environment*, vol. 175, pp. 1–13, 2016.

[5] K. S. Babu and V. Vanama, "Burn area mapping in google earth engine (gee) cloud platform: 2019 forest fires in eastern australia," in *2020 International Conference on Smart Innovations in Design, Environment, Management, Planning and Computing (ICSIDEMPC)*. IEEE, 2020, pp. 109–112.

[6] B. K. Suresh and V. S. K. Vanama, "Fire detection in a varying topography using landsat-8 for nainital region, india," in *2018 3rd International Conference for Convergence in Technology (I2CT)*. IEEE, 2018, pp. 1–4.

[7] W. Bin, Y. Jian, Z. Zhongming, M. Yu, Y. Anzhi, C. Jingbo, H. Dongxu, L. Xingchun, and L. Shunxi, "Parcel-based change detection in land-use maps by adopting the holistic feature," *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, vol. 7, no. 8, pp. 3482–3490, 2013.

[8] B. Pflug, R. Richter, R. De los Reyes, and P. Reinartz, "Comparing atmospheric correction performance for sentinel-2 and landsat-8 data," in *IGARSS 2019-2019 IEEE International Geoscience and Remote Sensing Symposium*. IEEE, 2019, pp. 6433–6436.

[9] S. Skakun, B. Franch, E. Vermote, J.-C. Roger, C. Justice, J. Masek, and E. Murphy, "Winter wheat yield assessment using landsat 8 and sentinel-2 data," in *IGARSS 2018-2018 IEEE International Geoscience and Remote Sensing Symposium*. IEEE, 2018, pp. 5964–5967.

[10] I. Niemeyer and M. J. Canty, "Pixel-based and object-oriented change detection analysis using high-resolution imagery," in *Proceedings 25th Symposium on Safeguards and Nuclear Material Management*, 2003, pp. 2133–2136.

[11] Y. Lin, L. Zhang, and N. Wang, "A new time series change detection method for landsat land use and land cover change," in *2019 10th international workshop on the analysis of multitemporal remote sensing images (MultiTemp)*. IEEE, 2019, pp. 1–4.

[12] "Ziarat district - wikipedia," https://en.wikipedia.org/wiki/Ziarat_District, (Accessed on 10/16/2023).

[13] H. Jallat, M. F. Khokhar, K. A. Kudus, M. Nazre, N. u. Saqib, U. Tahir, and W. R. Khan, "Monitoring carbon stock and land-use change in 5000-year-old juniper forest stand of ziarat, balochistan, through a synergistic approach," *Forests*, vol. 12, no. 1, p. 51, 2021.

[14] "Ziarat-01," https://cms.ndma.gov.pk/storage/app/public/publications/January2021/Ym6mUSBiKbeSb9xb8QbG.pdf, (Accessed on 12/05/2022).

[15] P. M. Vitousek, "Global environmental change: an introduction," *Annual review of Ecology and Systematics*, vol. 23, no. 1, pp. 1–14, 1992.

[16] Y. Peter, B. L. Gadiga, and A. D. Mshelia, "Land use/land cover change detection of mubi metropolis adamawa state nigeria," *Sky Journal of soil science and environmental management*, vol. 4, no. 6, pp. 070–078, 2015.

[17] M. Li, S. Zang, B. Zhang, S. Li, and C. Wu, "A review of remote sensing image classification techniques: The role of spatio-contextual information," *European Journal of Remote Sensing*, vol. 47, no. 1, pp. 389–411, 2014.

[18] S. Chavare, "Application of remote sensing and gis in landuse and land cover mapping of sub-watershed of wardha river basin," in *Proceedings of National Conference on Development & Planning For Drought Prone Areas*, 2015, pp. 221–234.

[19] T. Carlson and G. A. Sanchez-Azofeifa, "Satellite remote sensing of land use changes in and around san jose, costa rica," *Remote Sensing of Environment*, vol. 70, no. 3, pp. 247–256, 1999.

[20] K. Ulbricht and W. Heckendorff, "Satellite images for recognition of landscape and landuse changes," *ISPRS Journal of Photogrammetry and Remote Sensing*, vol. 53, no. 4, pp. 235–243, 1998.

[21] S. Reis, "Analyzing land use/land cover changes using remote sensing and gis in rize, north-east turkey," *Sensors*, vol. 8, no. 10, pp. 6188–6202, 2008.

[22] "Ziarat-01," https://cms.ndma.gov.pk/storage/app/public/publications/January2021/Ym6mUSBiKbeSb9xb8QbG.pdf, (Accessed on 12/05/2022).

[23] A. M. Sarangzai, N. Khan, M. Wahab, and A. Kakar, "New spread of dwarf mistletoe (arceuthobium oxycedri) in juniper forests, ziarat, balochistan, pakistan," *Pak. J. Bot*, vol. 42, no. 6, pp. 3709–3714, 2010.

[24] A. M. Sarangzai, M. Ahmed, A. Ahmed, L. Tareen, and S. U. Jan, "The ecology and dynamics of juniperus excelsa forest in balochistan-pakistan," *Pak. J. Bot*, vol. 44, no. 5, pp. 1617–1625, 2012.

[25] "Ziarat juniper forest - unesco world heritage centre," https://whc.unesco.org/en/tentativelists/6116/, (Accessed on 12/05/2022).