

Assessing the Expansion of Quarries and Land Cover Dynamics Using Satellite Imagery and GIS in Hebron and Bethlehem Districts, Palestine

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Abstract—Quarrying activities in the Hebron and Bethlehem districts have caused considerable environmental impacts, including the removal of native vegetation, soil degradation, air pollution, and changes in land surface temperature (LST). This study aims to monitor the spatial expansion of limestone quarries and associated land cover changes between 1995 and 2021 using Remote Sensing (RS) and Geographic Information System (GIS) tools. Landsat satellite images from 1995, 2004, 2014, and 2021 were analyzed using supervised maximum likelihood classification. Four land cover classes were identified: agricultural land, barren land, built-up land, and quarry/rock land. To assess environmental change, indices such as the Normalized Difference Vegetation Index (NDVI) and Bare Soil Index (BSI) were applied. The results reveal a significant increase in built-up and quarry/rock areas at the expense of agricultural lands. Notably, quarry sites in Bani Naim, Ash-Shuyukh, Taffuh, and Beit Fajar showed marked expansion. These areas exhibited low vegetation cover, low to medium NDVI values, and high proportions of bare and rocky land. The findings provide critical insights to support environmental protection strategies and guide regional land use planning.

Keywords—Quarry Expansion, Remote Sensing, GIS, Land Cover Change, Hebron, Bethlehem, NDVI, LST, BSI.

I. INTRODUCTION

Quarrying involves using land to extract nonmetallic rocks and aggregates, and it has long been a part of local culture and heritage. This process produces materials like building stones, dimension stones, and crushed stones, which serve many different uses in our daily lives [1].

Remote Sensing (RS) and Geographic Information System (GIS) techniques provide powerful tools for data acquisition and analysis of the Earth's surface. In this paper, we demonstrate their application in environmental monitoring and land cover mapping for the selected area. We also analyze temporal changes in surface temperature and chlorophyll levels using multispectral imagery over different time intervals. [2], [3].

The mining industry has used remote sensing a lot. However, it's also important to use this technology to check the environmental effects of mining, like quarrying [4], [5]. That's why it's useful to regularly monitor areas with many quarries using detailed satellite images over time. This helps

local governments get the information they need to make informed decisions about the environment and the economy [6], [7].

Land cover changes are an important issue that affects the global environmental changes. Today, a lot of factors such as the spreading of urban areas, increasing population, decreasing land availability, rising demand for production, and advancing technologies are key drivers behind land cover changes worldwide [8], [9].

The main objective of this research is to highlight the expansion of limestone quarry surface areas and to monitor associated land cover changes using Landsat multispectral satellite imagery downloaded from the USGS website [10] and a supervised maximum likelihood classification approach. These changes were assessed over 26-years (1995–2021) by pursuing the following specific objectives:

1. Conduct a comprehensive analysis and monitoring of land cover changes in certain major quarry sites within the Hebron and Bethlehem districts including: Bani Naim, Ash-Shuyukh, Taffuh, Beit Fajar.
2. Calculate and map the Normalized Difference Vegetation Index (NDVI) and other relevant spectral indices (ex. BSI and LST) over the same study area.
3. Explore the potential for mapping limestone rock distributions using multispectral satellite imagery.

NDVI [11] is a numerical indicator that uses the red and near-infrared spectral bands. It was computed to distinguish between the amounts of vegetation in the study area. NDVI aimed to separate healthy green vegetation from all other features (such as soil moisture, man-made features, and water), and therefore, any feature with prominent vegetation would yield a high NDVI value. Formally, NDVI is given as:

$$NDVI = \frac{NIR-RED}{NIR+RED} \quad (1)$$

The Bare Soil index (BSI) enhances the identification of bare soil areas and barren lands. BSI can be used in numerous remote sensing applications, like soil mapping, crop identification (in combination with NDVI) etc. The BSI can be calculated with the following formula:

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$$BSI = \frac{(Red+Blue)-Green}{(Red+Blue)+Green} \quad (2)$$

To calculate the Land Surface Temperature LST the thermal bands and NDVI are needed. Equation (3) shows the different parameters of LST.

$$LST = BT + W \times \frac{BT}{P} \times \ln E \quad (3)$$

where:

LST: Land Surface Temperature.

BT: Brightness Temperature.

W: Wavelength.

P: 1438.

E/LSE: Land Surface Emissivity.

II. STUDY AREA

Bethlehem and Hebron districts in the southern West Bank, Palestine are well-known for their large number of quarries, and are considered among the most important stone industries in Palestine. The extracted stone is renowned for its quality and distinctive color. It is used in construction both inside and outside Palestine.

Quarries in this part of the West Bank are of high economic importance; the stone industry accounts for a high percentage of Palestinian industrial output. It provides thousands of direct and indirect job opportunities. Also, it is considered one of the most important exports of the West Bank. Beside the economical values of quarries there are several negative environmental impacts such as: Removal of vegetation and distortion of the natural landscape, generation of large amounts of dust that affect public health, changes in Landcover and conversion of agricultural areas to barren lands, some quarries are located close to residential areas, causing noise and environmental and visual pollution, for that this study aims to analyze quarries in Hebron and Bethlehem districts in the West Bank Figure 1 using Remote Sensing and GIS technologies, this figure shows the distributions of the quarries locations in the districts according to different Oslo accords areas A B and C.

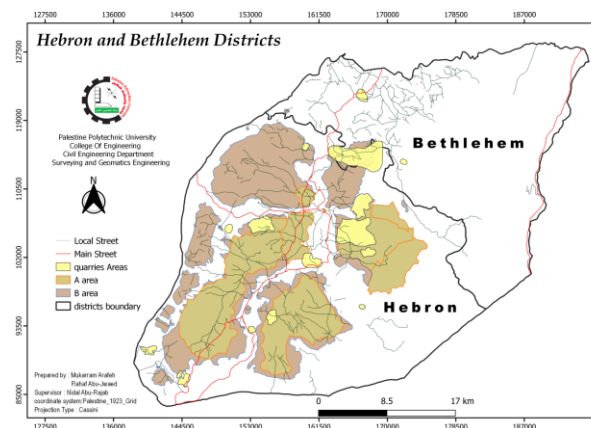


Figure 1. Quarry locations in Hebron and Bethlehem District.

III. DATA AND METHODOLOGY

A. Data Sources and Work Methodology

In this research Landsat satellite images have been downloaded from the USGS website as shown in Table I. The land cover (LC) classification maps for the Hebron and Bethlehem districts were prepared from various satellite image series, as shown in Table 1, using the Maximum Likelihood classification method. In parallel, different indices were extracted for the same areas from the same satellite images, along with the Land Surface Temperature (LST) calculated according to Equation (3). The expansion areas of each quarry were determined using the most recent satellite image, and these boundary areas were used as reference zones to clip the various thematic maps produced for each quarry, which were then monitored and analyzed accordingly. The sequence of the overall methodology appears clearly in Figure 2. To facilitate the map's production and analysis process an automated Model builder were generated for all the process steps which is appear in Figure 3.

TABLE I. DATA USED FROM MULTISPECTRAL SATELLITES

Date	Sensor	No. Bands	Spatial Resolution (m)
29/3/1995	Landsat 4-5 TM	7	30 m
21/3/2004			120 m (Thermal Band)
18/4/2014	Landsat 8 OLI/TIRS	11	30 m
5/4/2021			120 m (Thermal Bands)

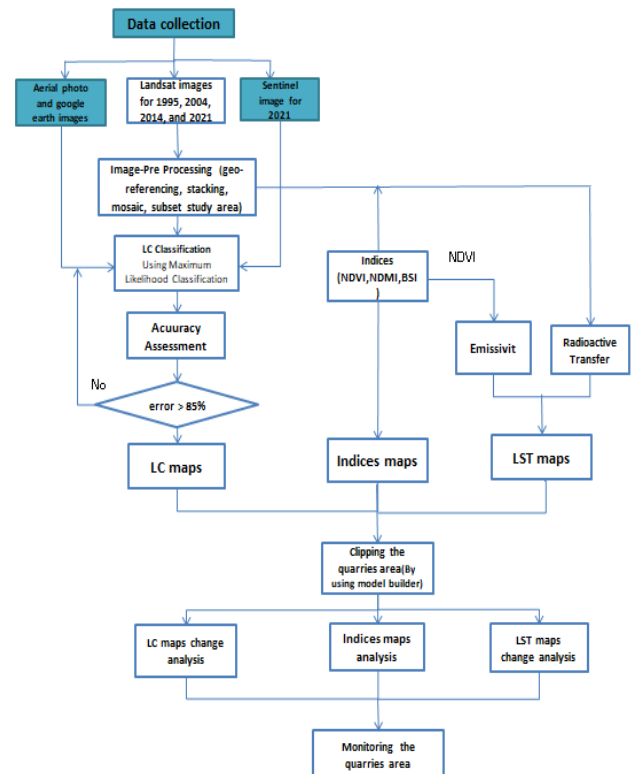


Figure 2. The overall methodology applied in this paper.

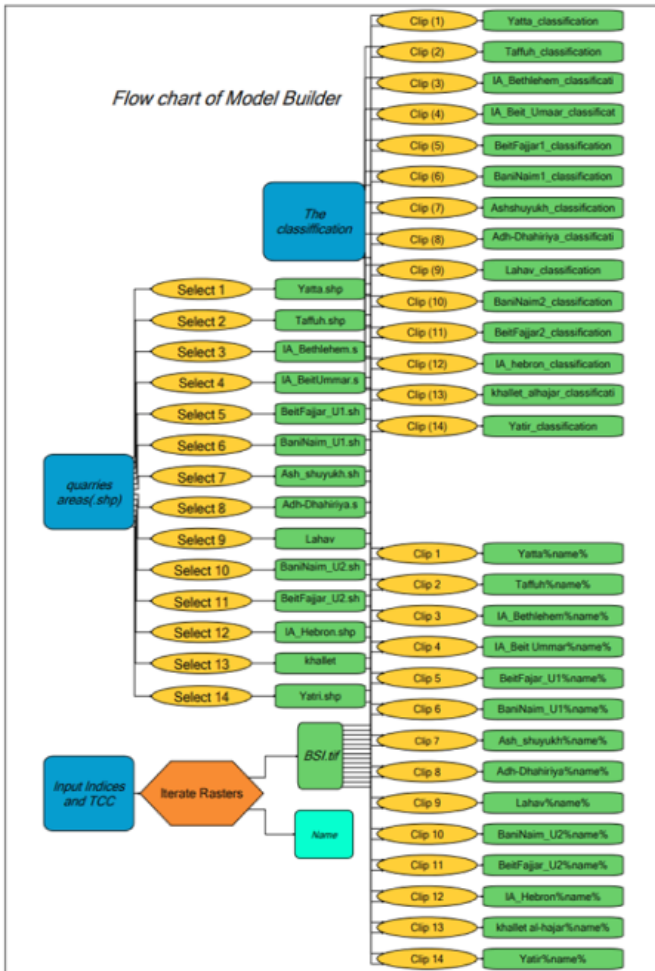


Figure 3. Model builder for the working process.

B. Image Preprocessing

Pre-processing operations in RS involve correcting radiometric and geometric distortions caused by sensor characteristics, platform movement, atmospheric conditions, and scene illumination. In this study, satellite images from USGS (already georeferenced to WGS 84 / UTM zone 36N) were geometrically corrected and were clipped to the study area.

C. Results and discussion for Image Classification and Indices calculation

A supervised Maximum Likelihood Classification (MLC) was applied on the Multispectral images to identify four land cover classes (Table II) based on the USGS Land Use/Land Cover (LU/LC) system:

TABLE II. LAND COVER CLASSES AND THEIR DESCRIPTION

Class	Description
Built-up Land	Residential, industrial, and commercial structures and motorways.
Agricultural Land	Where the potential natural vegetation is predominantly grasses, grass-like plants, forbs, or shrubs, pastures, orchards, groves vineyards, nurseries and other agriculture land.
Barren Land	Unvegetated land and burnt-out areas.
Rock Land	Exposed rocks, and rock industry facilities.

The different series of Landsat multispectral images and their corresponding land cover classifications for the years 1995,

2004, 2014, and 2021 in the Hebron and Bethlehem districts are presented in Figure 4. The chart in Figure 5 illustrates the land cover changes between the years 1995, 2004, 2014, and 2021 in the same areas.

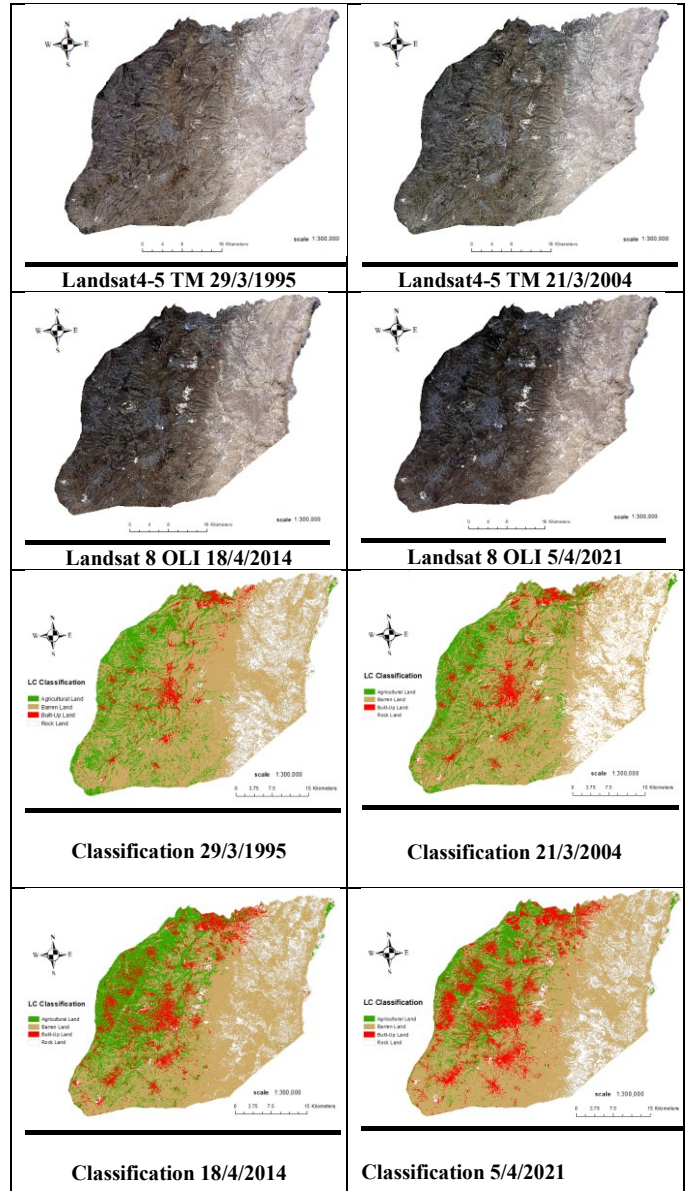


Figure 4. Landsat multispectral images and their classification for the years 1995, 2004, 2014, and 2021 in the Hebron & Bethlehem districts.

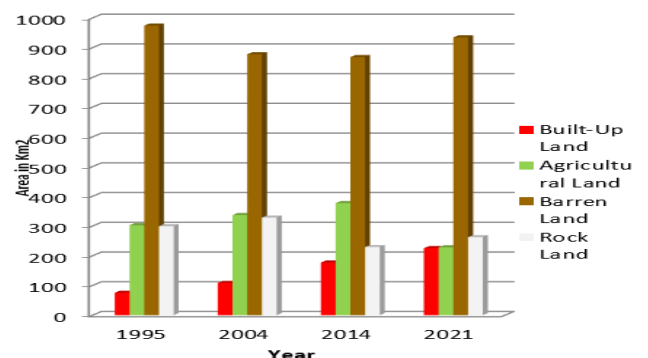


Figure 5. The chart shows land cover changes between 1995, 2004, 2014, and 2021 years in the Hebron & Bethlehem districts.

D. Analysis of certain major Quarries in Hebron and Bethlehem districts:

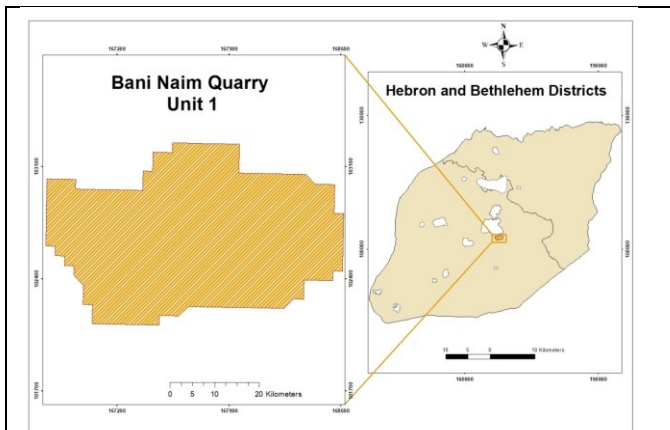


Figure 6. Location map of Bani Naim "Unit 1 Quarry.

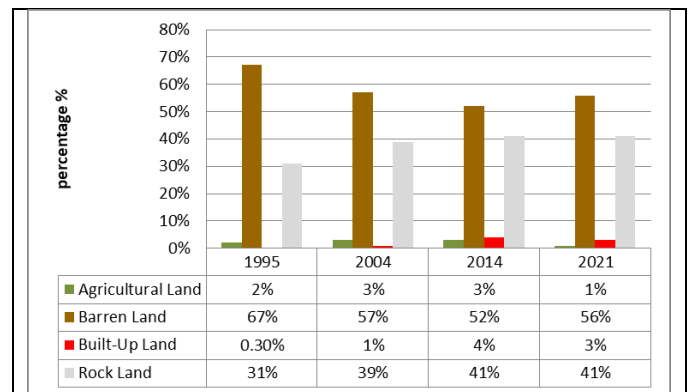
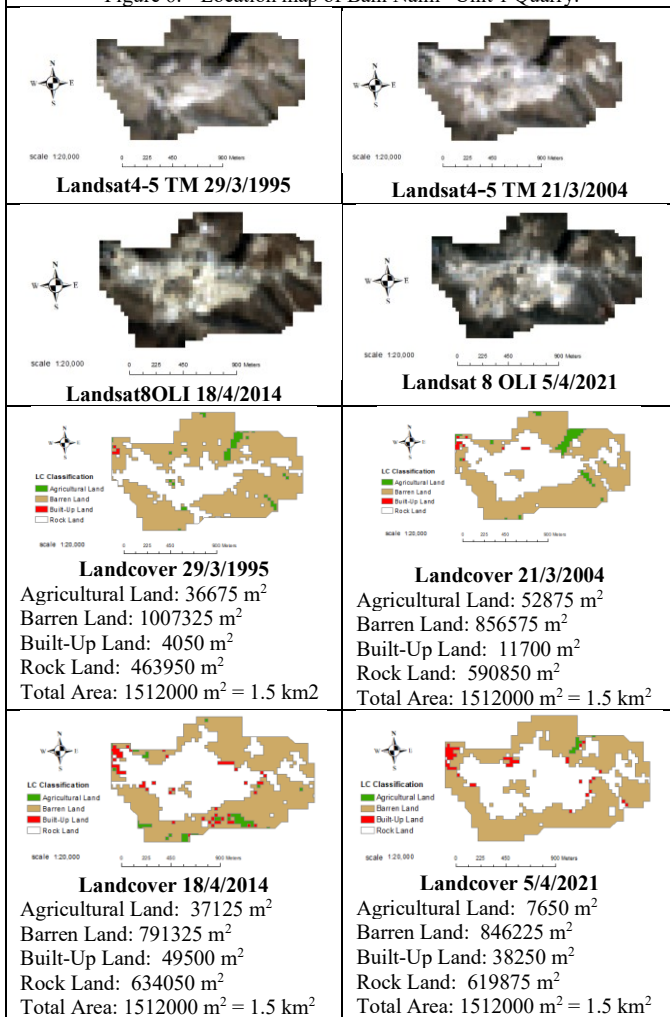
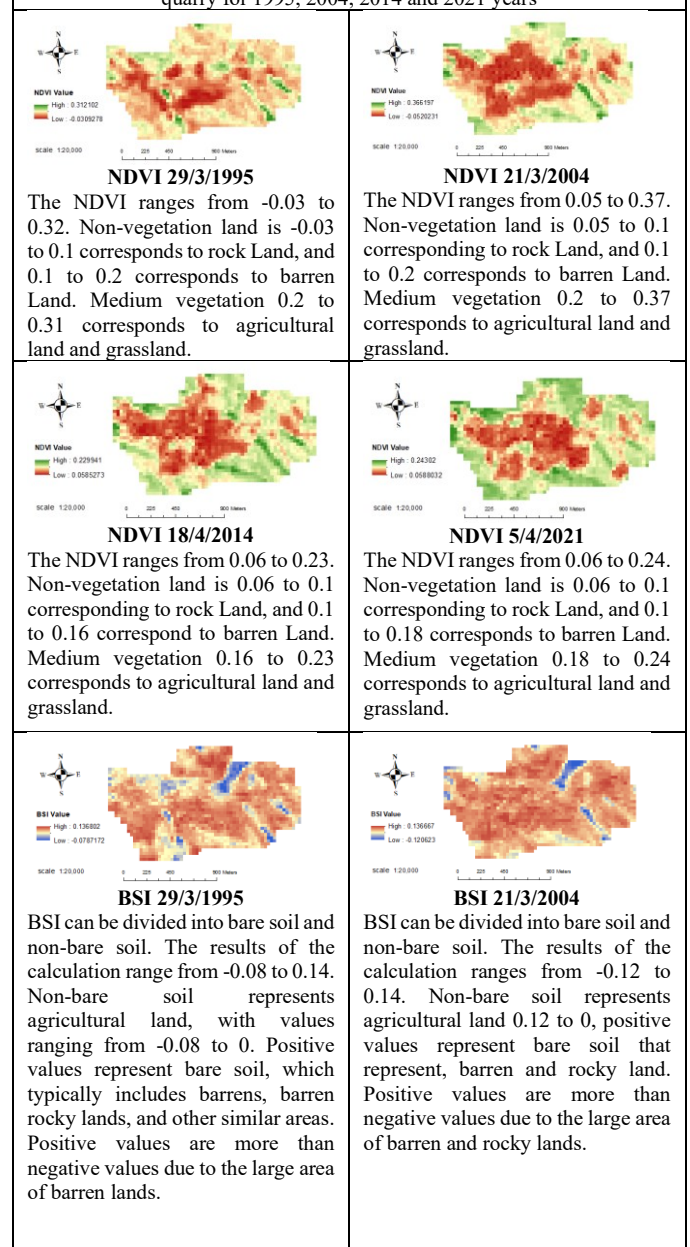


Figure 7. Percentage of each class from the total area of Bani Naim U1 quarry for 1995, 2004, 2014 and 2021 years



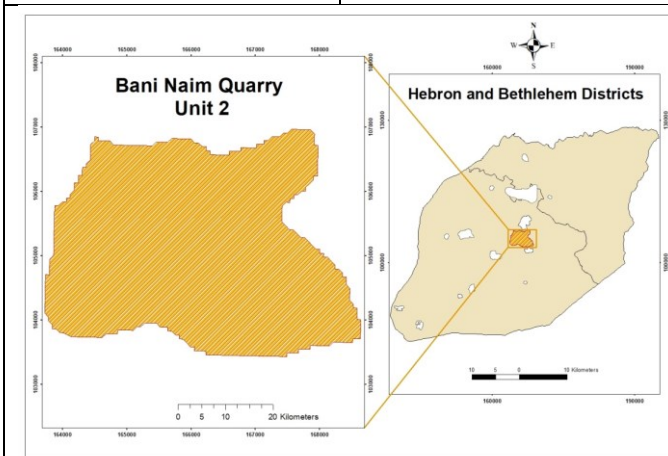
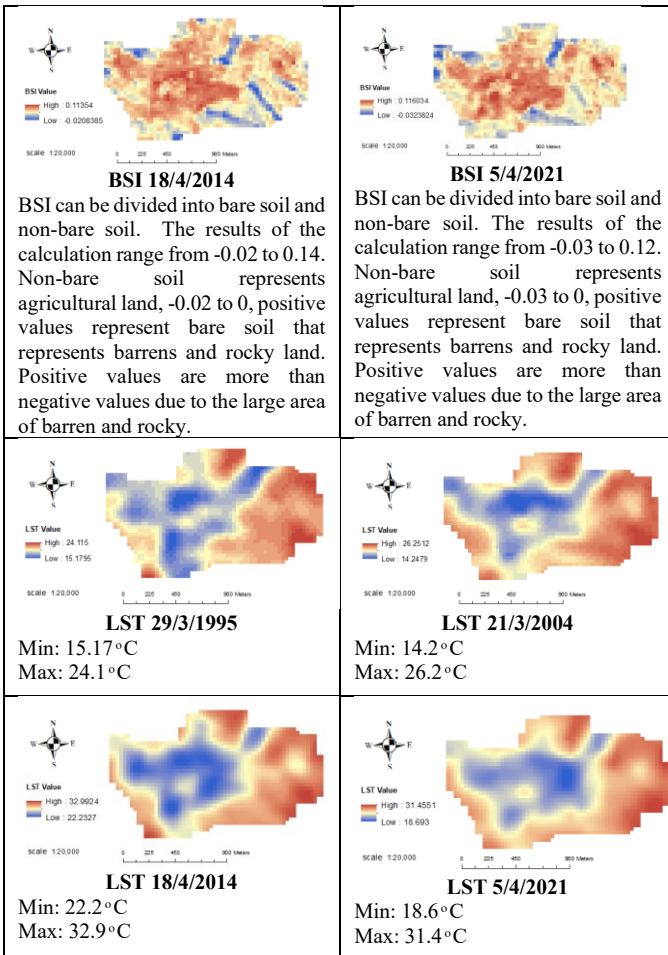


Figure 8. Location map of Bani Naim "Unit 2 Quarry.

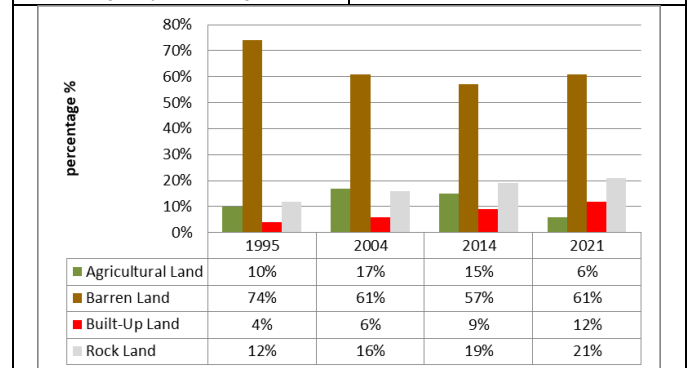
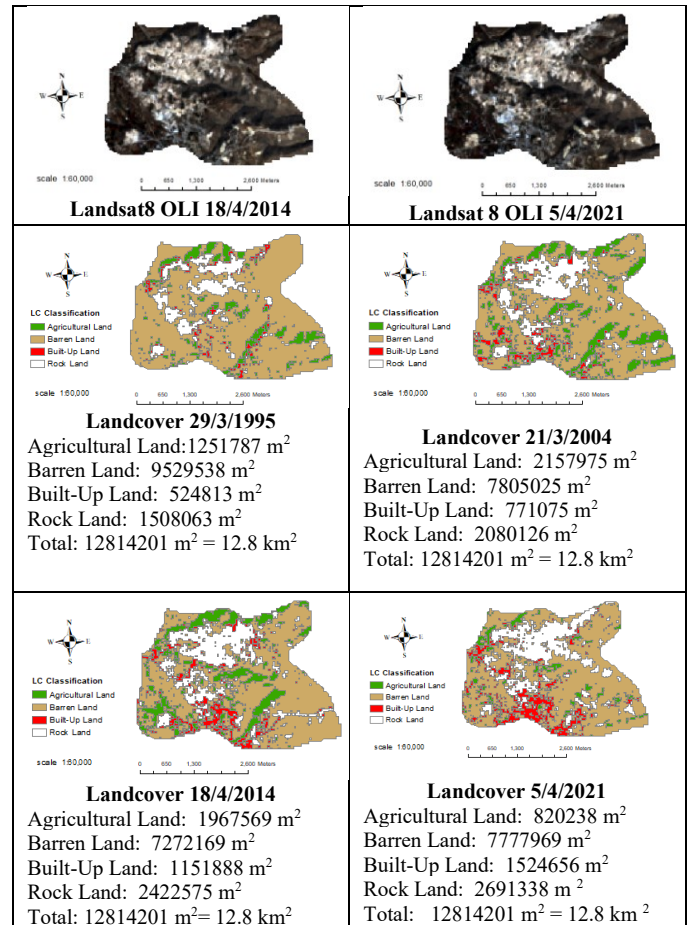
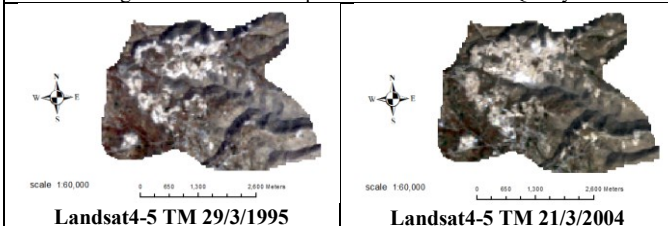
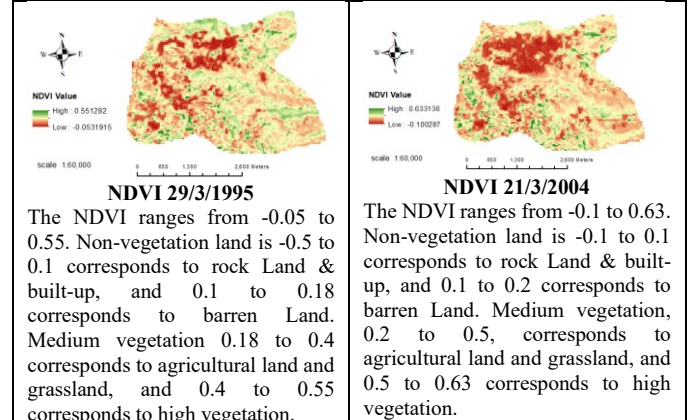


Figure 9. Percentage of each class from the total area of Bani Naim U2 quarry for 1995, 2004, 2014 and 2021 years.



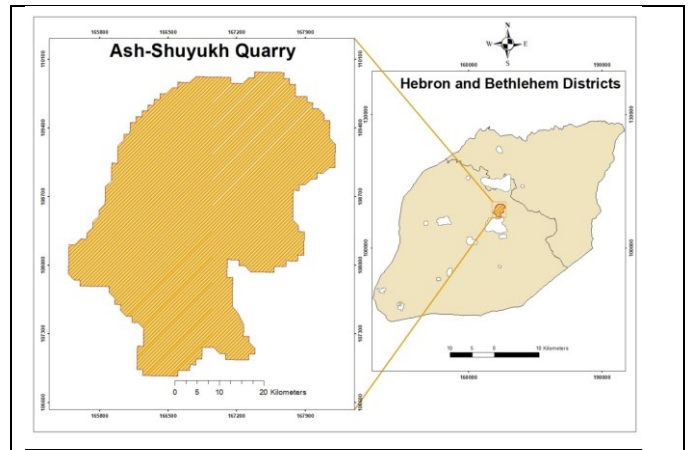
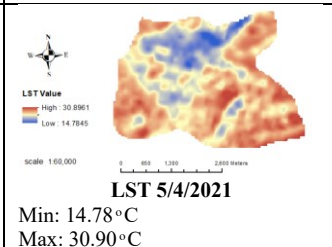
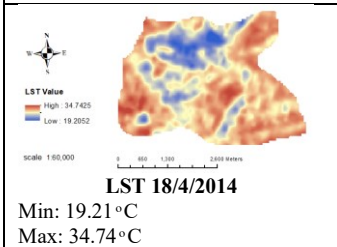
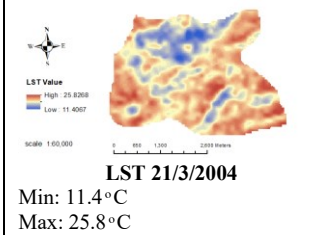
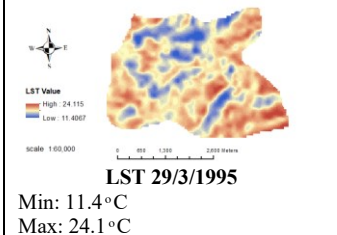
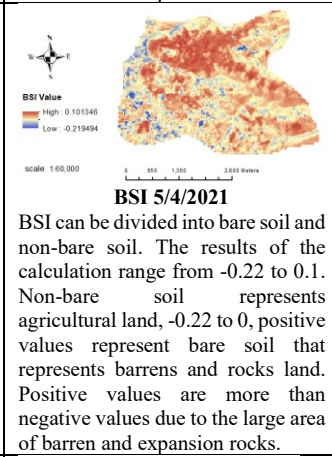
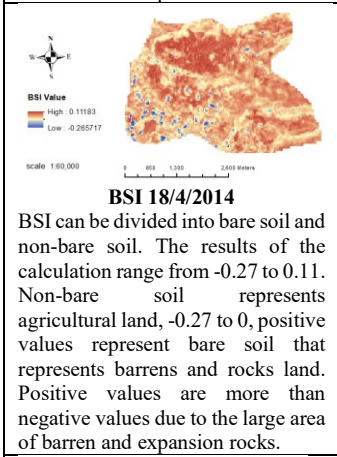
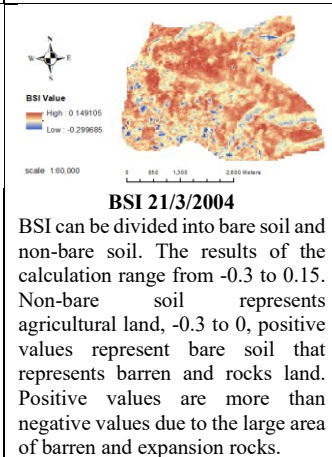
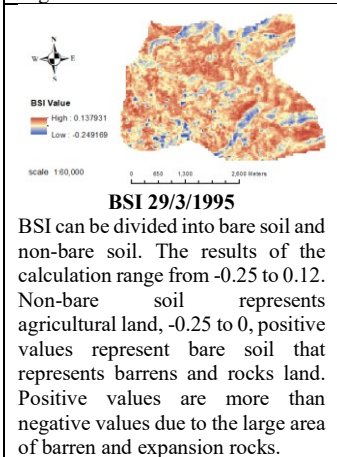
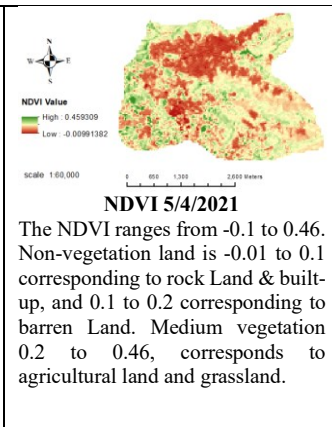
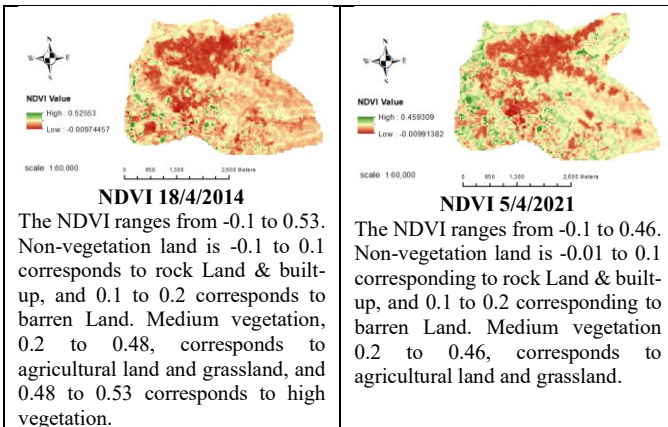
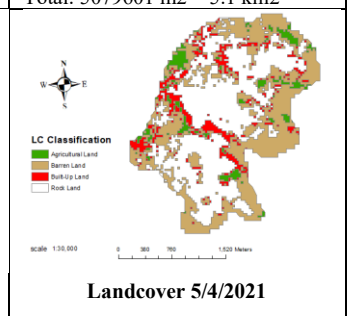
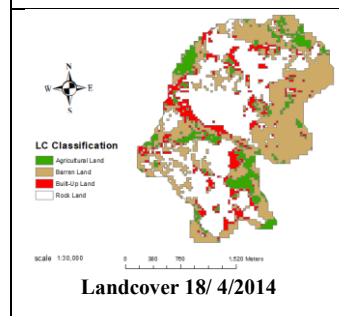
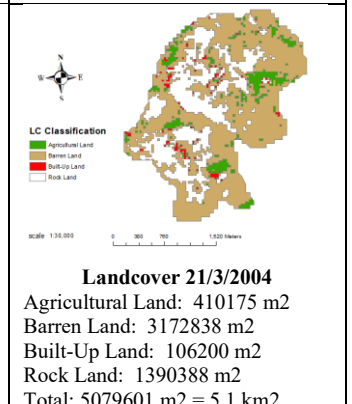
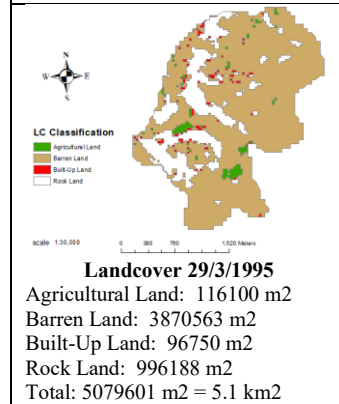
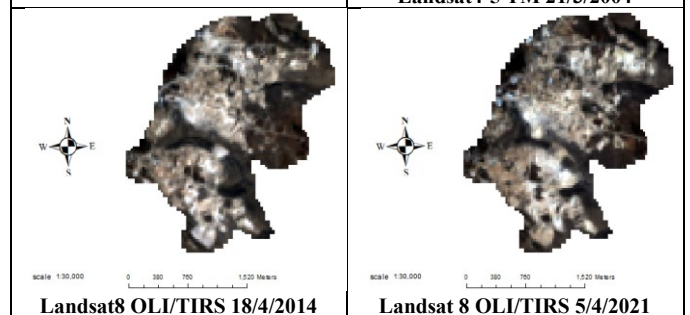
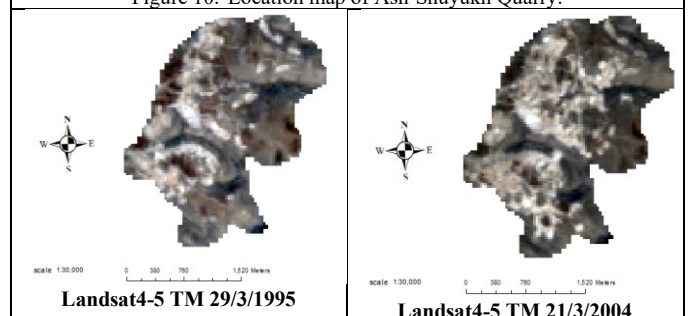


Figure 10. Location map of Ash-Shuyukh Quarry.



Agricultural Land: 511200 m ²	Agricultural Land: 273825 m ²
Barren Land: 2003850 m ²	Barren Land: 1996875 m ²
Built-Up Land: 525488 m ²	Built-Up Land: 530438 m ²
Rock Land: 2039063 m ²	Rock Land: 2278463 m ²
Total: 5079601 m ² = 5.1 km ²	Total: 5079601 m ² = 5.1 km ²

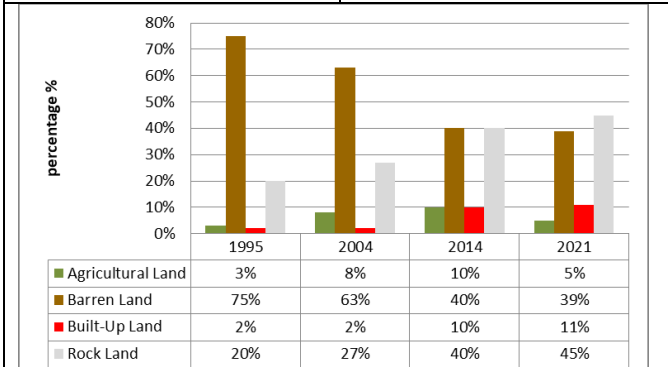
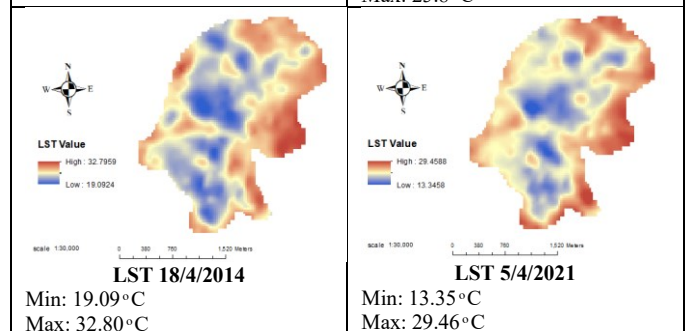
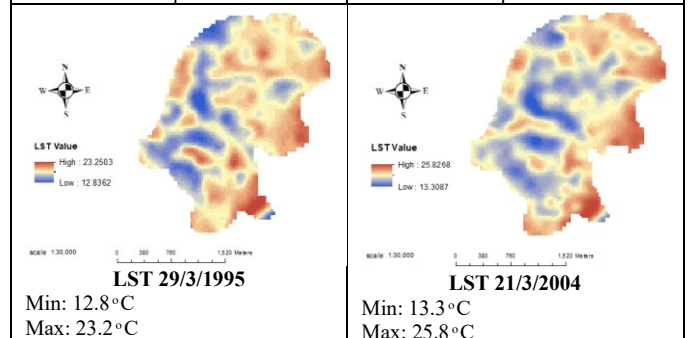
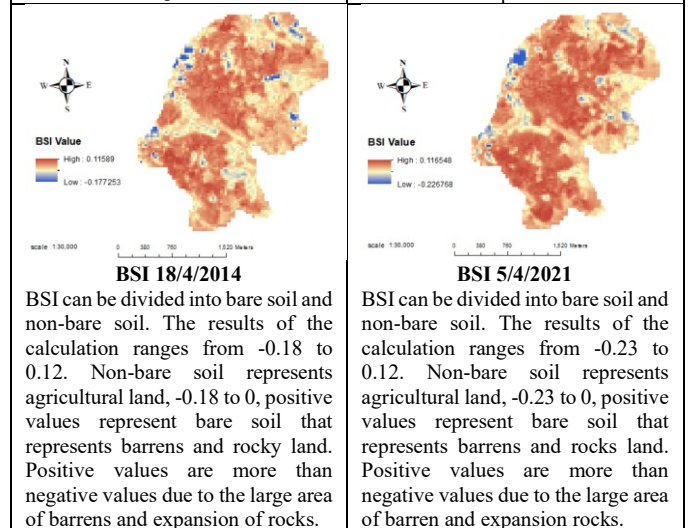
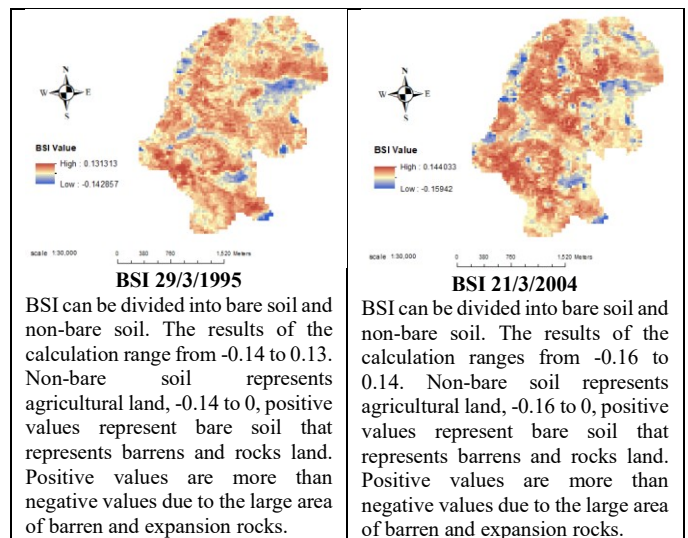
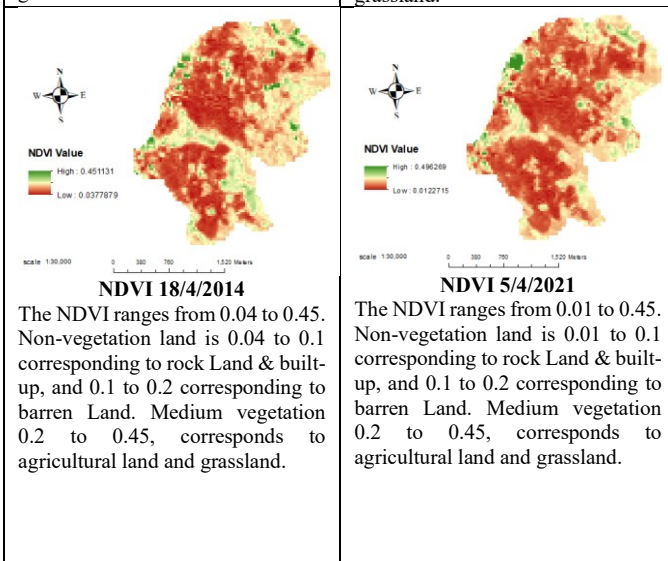
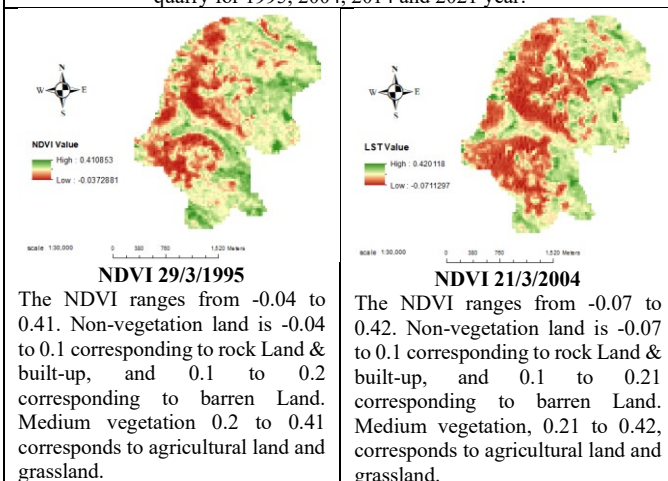


Figure 11. Percentage of each class from the total area of Ash-Shuyukh quarry for 1995, 2004, 2014 and 2021 year.



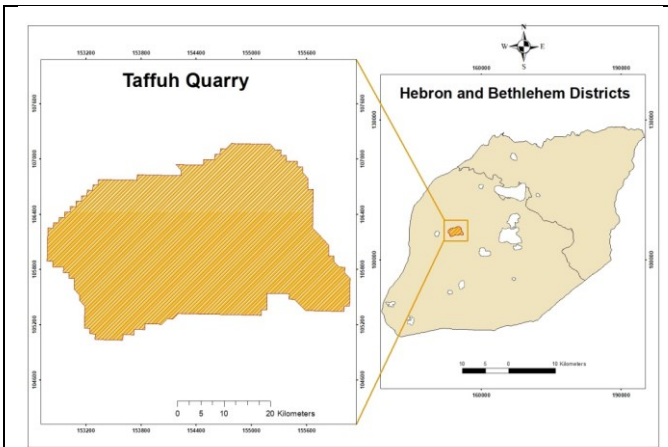


Figure 12. Location map of Taffuh Quarry

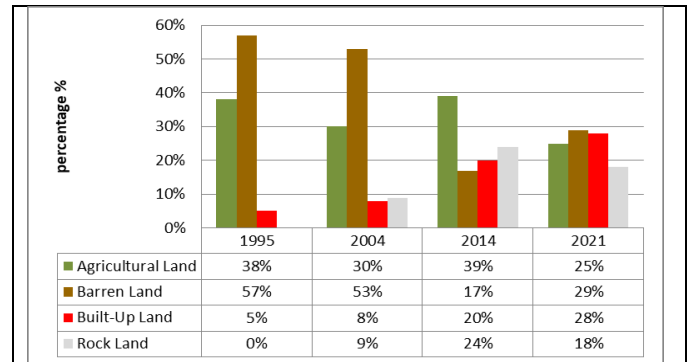
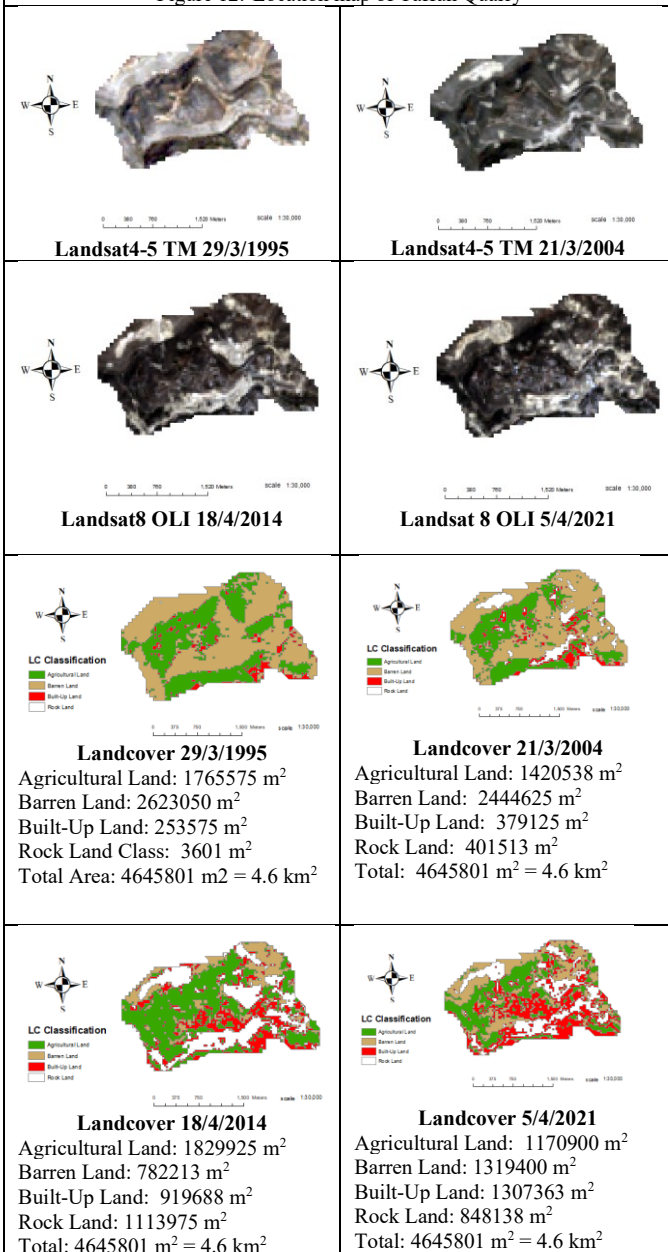
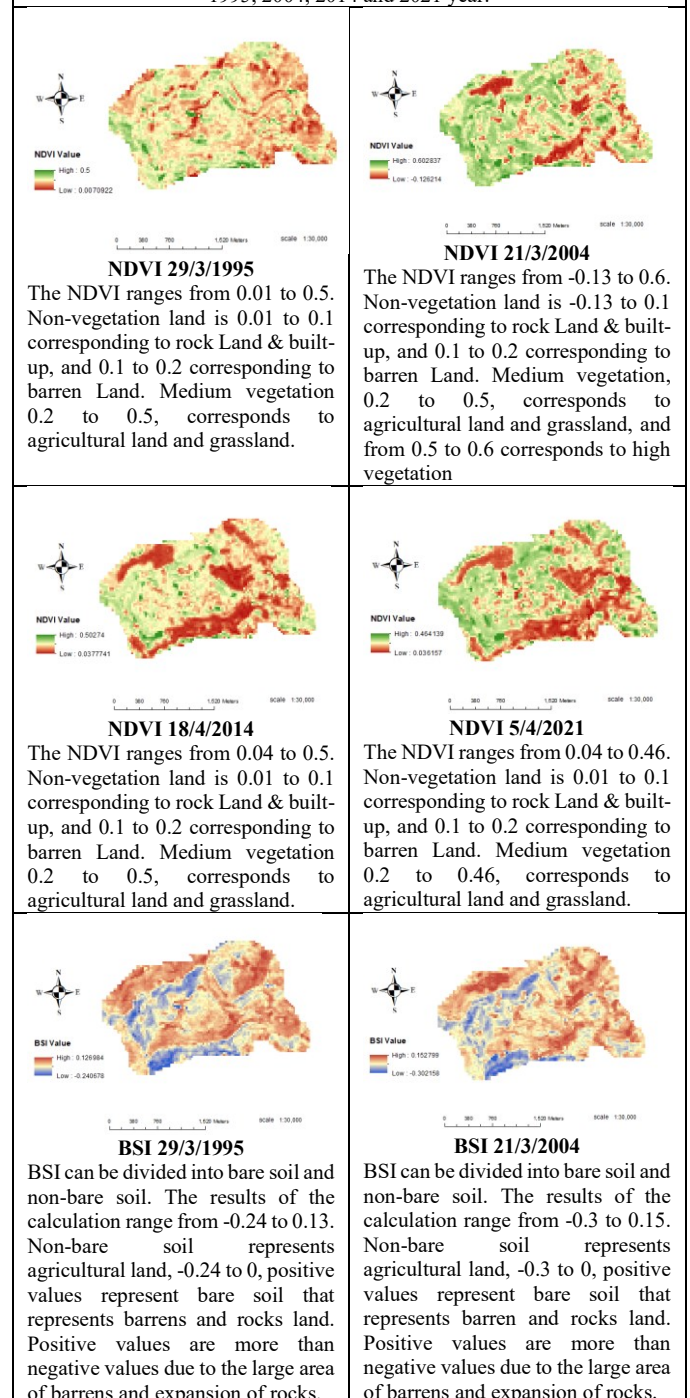


Figure 13. Percentage of each class from Taffuh Quarry in Bethlehem for 1995, 2004, 2014 and 2021 year.



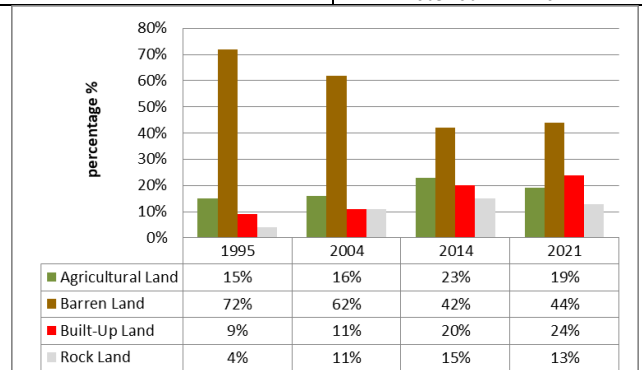
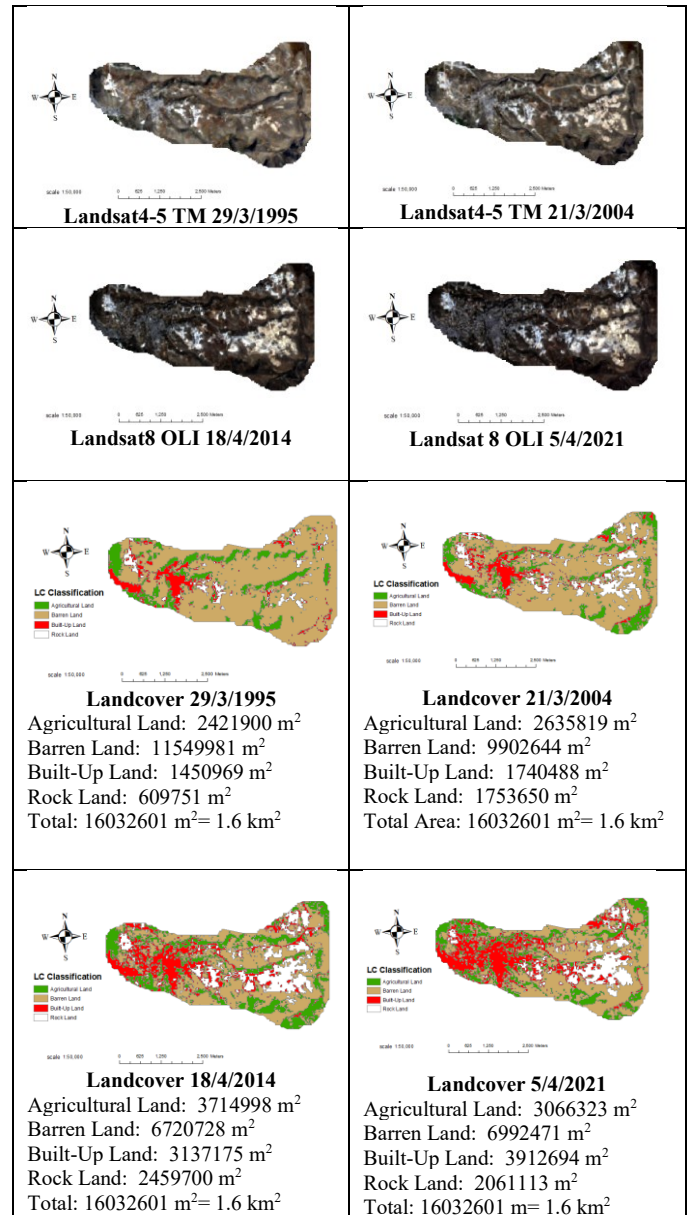
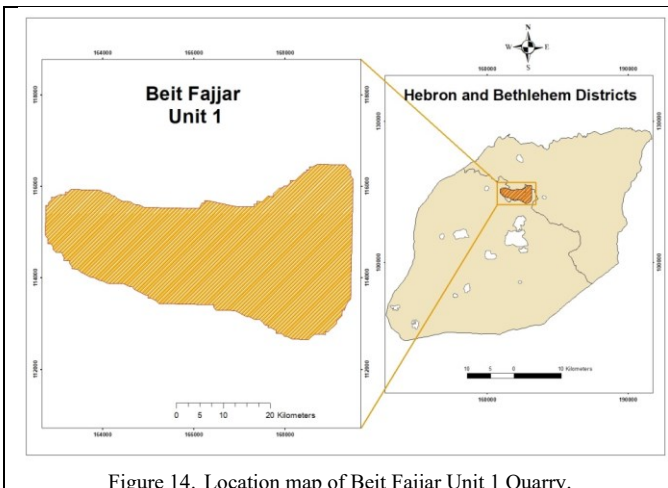
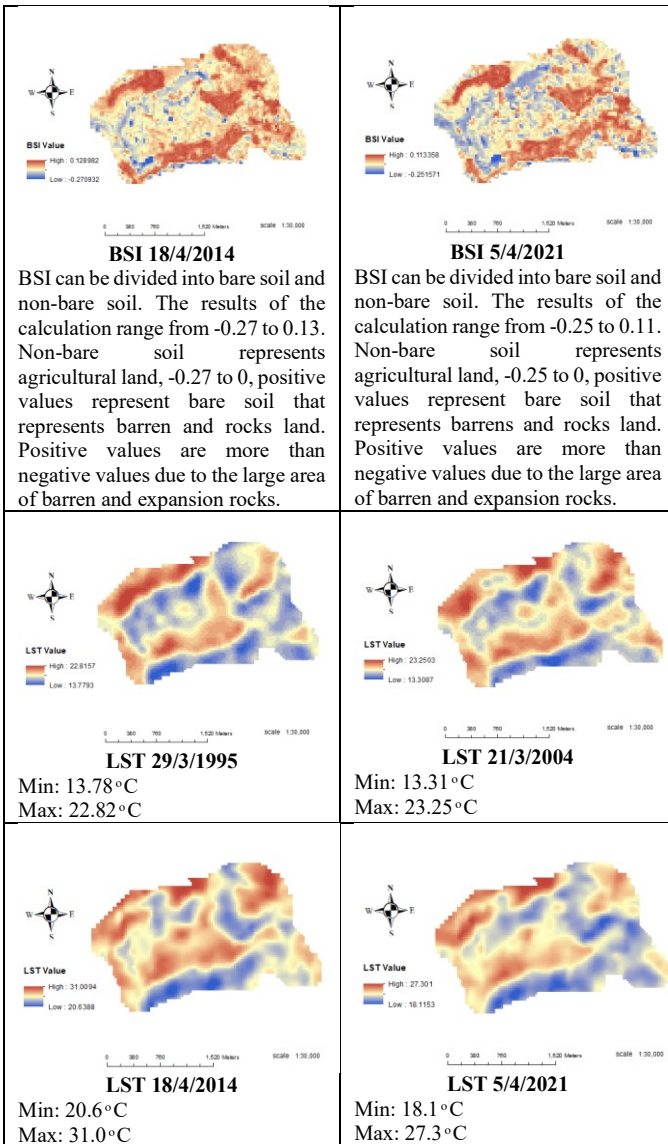
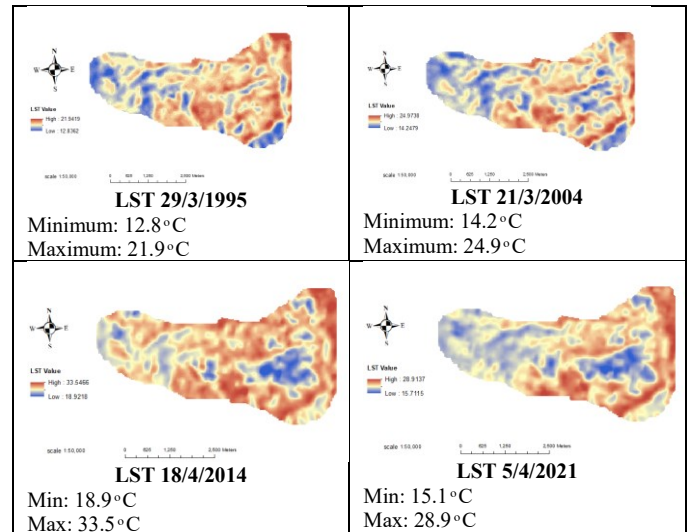
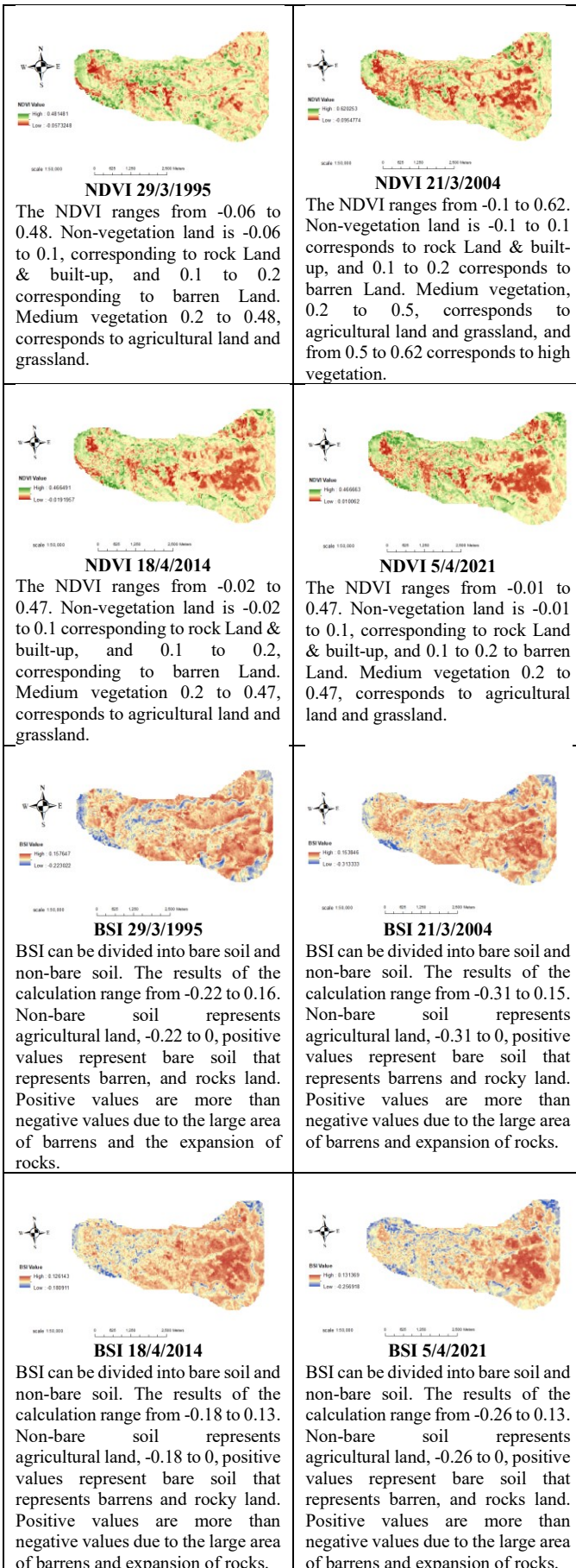


Figure 15. Percentage of each class from Beit Fajjar U1 quarry for 1995, 2004, 2014 and 2021 year.



The general results of the land cover statistics, as shown in Figure 4 for the classified images of 1995, 2004, 2014, and 2021, indicate a significant increase in built-up areas and a notable decrease in agricultural land. Additionally, there is a marked increase in barren and rocky land areas, which are the main focus of this study concerning the quarries distributed within the study area.

The different maps produced for each quarry indicated a significant increase in rock cover across all analyzed sites. This increase has a noticeable effect on the rise of land surface temperature (LST) in the quarry areas, primarily due to the evident imbalance in vegetation cover. This imbalance is clearly reflected in the NDVI values, as shown by the NDVI maps for each quarry.

IV. CONCLUSION

This study provided a comprehensive spatiotemporal assessment of quarry expansion and associated land cover changes in the Hebron and Bethlehem districts between 1995 and 2021 using remote sensing and GIS techniques. The results revealed a clear and consistent pattern of rapid quarry proliferation accompanied by a significant decline in agricultural land and vegetative cover, as confirmed by NDVI and BSI indices. The increase in barren and rock land surfaces, coupled with elevated land surface temperatures (LST), underscores the ecological stress imposed by unregulated quarry activities.

Supervised classification proved effective in detecting subtle land cover variations across multispectral imagery, validating its applicability in complex landscapes like quarry zones. The environmental implications are critical: the transformation of fertile lands into rocky, degraded surfaces poses threats to biodiversity, food security, and local climate regulation. Moreover, the health risks from dust and noise pollution,

especially in quarries close to residential areas, demand immediate attention.

In light of these findings, it is imperative to integrate remote sensing-based monitoring into regional planning policies. A regulatory framework that enforces sustainable quarrying practices, supported by continuous geospatial monitoring, is essential to balance economic interests with environmental protection. This study serves as a scientific foundation for informed policy-making, environmental restoration initiatives, and further interdisciplinary research in resource-extraction landscapes.

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