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Analysis of Vegetation Change Trends Using Satellite Data and Remote Sensing Techniques (Case Study: BAGRAM-Afghanistan)

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ABSTRACT

Garden and agricultural species are closely related phenomena mainly observed in different regions of the world. Wherever there is agriculture, there are bound to be both fruitful and non-fruitful trees. Bagram district is one of the districts of Parwan province, where most of the people of this district are engaged in agriculture for their livelihood. The main objective of this research is to use satellite data, and an effort was made to extract the areas under plant cover and separate garden and crop species. The normalized vegetation cover index was used to obtain the areas covered by vegetation. All the areas covered by vegetation were extracted, and then the supervised maximum likelihood classification method was used to separate garden and agricultural species from each other. This research applied the vegetation index to Sentinel-2 imagery from 2018 and 2023, followed by supervised classification on the same datasets. Finally, the result was that the area of agricultural land in 2018 was equal to 92 square kilometers, but it reached 100 square kilometers in 2023. Also, the land area of the gardens was 15.92 square kilometers in 2018. However, by 2023, it reached 27 square kilometers, and the area of agricultural lands and gardens in the Bagram district has increased by almost 20 square kilometers from 2018 to 2023.

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INTRODUCTION

Both horticultural and agricultural species are interconnected phenomena mainly observed in different regions of the world(Liu et al., 2021). Wherever there is agriculture, will see fruitful and unfruitful trees. In developed countries, most of them use satellite data to analyze and classify garden and agricultural species. Remote sensing data, especially digital aerial images with high spatial and radiometric resolution, can be suitable for identifying tree and crop species (Ebrahimi-Khusfi, 2023). With the growing trend of remote sensing data with high spatial resolution, such as Quick Bird and IKONOS, the wide use of these data in various fields, problems for phenomena larger than pixel dimensions in using the pixel-based approach that Basically, they were designed for data with medium spatial resolution, but it produced acceptable classification results in extracting the desired phenomena (Pettorelli, 2013). In this research, based on the supervised classification, the maximum probability for extracting garden species and separating them from agricultural species is from Sentinel-2 images with a spatial resolution of 10 meters because Sentinel-2 images are free, and Satellite images with high resolution are free and unavailable.

Determining the area under cultivation and knowing the composition and area of each horticultural product has a key role in planning and managing this area(Running et al., 1995). The distribution of institutions, marketing, price determination, adjusting the balance between the import and export of products, insurance and damage estimation, and other matters in agricultural management are somehow related to the knowledge of the cultivated area of products (Tenreiro et al., 2021). Both types of multispectral and hyperspectral remote sensing are used to classify vegetation. However, multispectral data such as Landsat and Spot images can be used to identify general types of plants (Tenreiro et al., 2021; Gao et al., 2020), while hyperspectral remote sensing can be used to distinguish plants at the level of varieties and species (Hedayat et al., 2024).

One of the world's fundamental problems today is the rapid increase in population, especially in developing countries (Safi et al., 2024). With the increase in population and demand, land exploitation has increased. On the other hand, due to the lack of arable land, farmers have changed the use of erosion-sensitive land under suitable vegetation and put it under cultivation (Afzali et al., 2022). Continue This work without sufficient knowledge of the soil environment can cause the destruction of the soil quality and reduce the ability of the soil to support the production process (Xue & Su, 2017). In recent years, scientists and soil users have found that many soils in the world are being degraded, and They want to understand the destruction better and reverse it (Meili et al., 2021). Therefore, in this research, an attempt has been made to separate garden and crop species using the maximum probability supervised classification on sentinel images and calculate the area of each. Unfortunately, in Afghanistan, there is very little ground data recorded regarding vegetation, and the same small amount of recorded data is not available to the public, especially researchers; that is why satellite data is a suitable substitute for ground data. Although the satellite data has errors, it is considered the most suitable data without suitable data.

The issue of overpopulation is one of the hot topics around the world. As the population increases, so does the amount of demand and consumption. Bagram district is not isolated from this, and the population in this district is increasing daily. Garden and agricultural products are the primary sources of income for these people, and most of the people of this region use these products for their livelihood. The land data recorded about the garden and agricultural species in this district is low, and the same amount of data is not available; that is why, in this research, I have tried to use satellite products first to determine the number of areas under cultivation (Wheater & Evans, 2009). I will specify the garden and agricultural species and later classify the garden and agricultural species separately using Sentinel-2 images.

Hedayat and Yosufi conducted their research by assessing the impact of precipitation on vegetation using satellite data and remote sensing techniques. A case study of Yakawalang-Afghanistan in 2024 is as follows: Water is too essential for human life and all living creatures. Precipitation directly affects plant growth because when enough water reaches the plant, the plant grows sufficiently, but when the region is in a drought. The plant does not receive enough water, does not grow properly, and dries up. Therefore, in this research, we investigate the effects of precipitation on vegetation. The data used in this research are NDVI vegetation data from the MODIS Terra satellite for vegetation and GPM (Global Precipitation System) data for precipitation in this district. The non-parametric Mann-Kendall test was used to find the changes in the obtained data. The time range in this research is from 2010 to 2020. This research shows that the precipitation in Yakawalang district has been increasing from 2010 to 2020, and the amount of vegetation has also been increasing in the mentioned years. In 2010, the lowest amount of precipitation was recorded, equal to 277 mm. Still, the amount of vegetation was recorded as the highest amount, equal to 0.100, but in 2015, the amount of precipitation was recorded as equal to 510 mm. However, the amount of vegetation has been recorded as the lowest value, equal to 0.079. Based on the temperature calculation in 2015, I conclude that the temperature was low this year and caused a decrease in vegetation growth. Finally, the conclusion is reached that precipitation alone does not increase vegetation, and other parameters are needed for vegetation growth, such as appropriate temperature (Hedayat & Yosufi, 2024).

The primary purpose of this research is to find the process of vegetation changes using supervised classification of satellite images, and the secondary goal of this research is to find the trends of changes in crop-covered areas and horticultural areas in the Bagram area using remote sensing techniques. Also, the central question of this research is as follows: Can it be examined by using satellite products between 2018 and 2023 for vegetation changes in the Bagram area?

MATERIALS AND METHODS

This section will discuss in detail the introduction of the study area, the data obtained, and the method of data analysis.

In this research, multispectral images have been used to classify garden and agricultural species due to the lack of available hyperspectral images. In this research, the supervised classification method and the application of the vegetation index were used to classify garden and agricultural species. First, to obtain additional vegetation in the Bagram district, the normalized index of vegetation was applied to the Sentinel 2 image, and all vegetation covered was extracted. A supervised classification method was then used to separate garden and crop species. The supervised classification method is divided into six sections, each of which has its working method, and in this research, the maximum likelihood supervised classification method has been used. In this method, all the pixels with the same characteristics as the educational pixel are matched with the same educational pixel and assigned to the same class.

In this research, the data used by the Google Earth Engine was first prepared. NDVI data was used to obtain the trend of vegetation changes, and the Mann-Kendall test was used to analyze this data. Then, the NDVI index was applied to the Sentinel 2 images, and the vegetation area was obtained. The maximum likelihood supervised classification was also applied to the Sentinel 2 images, and the area of vegetation and wasteland was obtained. Finally, all the obtained results are displayed as maps and graphs.

Due to the low spatial resolution of the Sentinel-2 image, the grapevine is not included in this classification because the grapevine is a low plant, and its height is not much different from the agricultural species. It is not possible to separate the grapevine from the agricultural species.

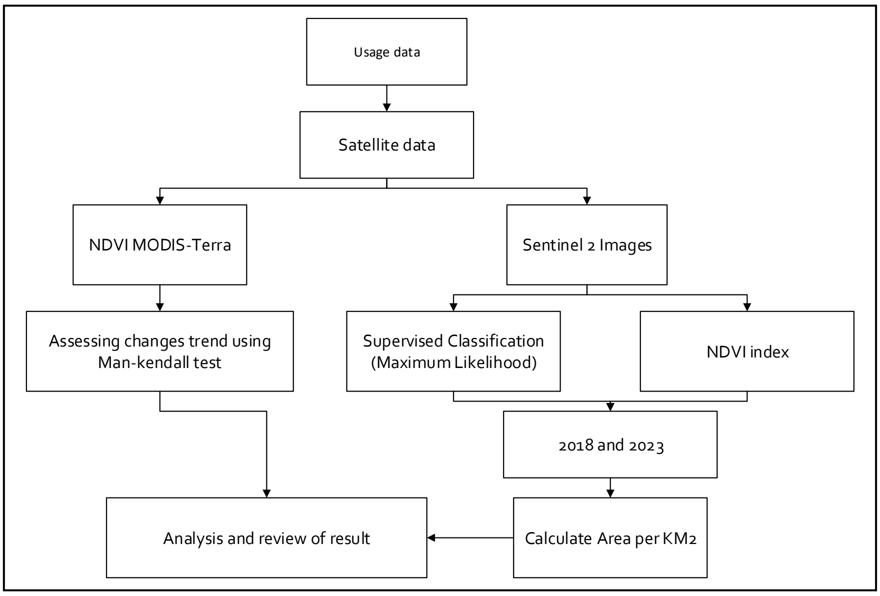

Figure 1. Methodology Flowchart

This research investigates the trend of changes in all parameters at different significance levels using the Mann-Kendall test. As a non-parametric method, this test has advantages that have caused it to be commonly and widely used in analyzing the trend of hydro-climatic series. In this test, the null hypothesis indicates randomness and the absence of a trend in the data series, and accepting the null hypothesis (rejecting the null hypothesis) suggests the existence of a trend in the data series(Gilabert et al., 2002). In the Mann-Kendall method, it is assumed that there is a time series as x1, x2........xn. Mann-Kendall test statistic is calculated using equation 1. In this relation, j and k are the order of observations, and the sign function sgn(x) is defined as equation 2.

$$(1)\ S=\sum_{k=1}^{n-1}\sum_{j=k+1}^{n} sgn(x_j + x_k)$$

$$(2)\ \mathrm{Sgn}(x)=\begin{cases}+1 & x>0\\ 0 & x=0\\ -1 & x<0\end{cases}$$

According to this test, if the value of S is not significantly different from zero, there is no trend. Otherwise, the trend will be upward or downward. To test the significance of the trend, the standard normal Z variable is used according to equation 3. The null hypothesis (Ho) in the Mann-Kendall test is the absence of a trend, and the hypothesis H1 is the presence of a trend (Salmi et al., 2002).

$$(3)\ \begin{cases}Z=\dfrac{S-1}{(var(S))^{\frac{1}{2}}} & if \quad S>0\\ 0 & if \quad S=0\\ \dfrac{S-1}{(var(S))^{\frac{1}{2}}} & if \quad S<0\end{cases}$$

$$(4)\ \mathrm{Var}\ (S) = \{n(n-1)\ (2n+5)\}$$

Study Area

Bagram is one of the Parwan province districts, centered in Bagram city in Afghanistan. The area of Bagram district is 407 square kilometers, and according to the statistics in 2019, its population is 117,181 people. This district borders Kabul province from the south, Shinwari district from the west, Charikar city from the north, and Kapisa province from the northeast. Bagram district is one of the important agricultural areas in Parwan province due to its fertile lands and suitable water resources. Agriculture in this area plays an important role in providing the livelihood of the local people, and various crops are cultivated there. Agriculture plays an essential role in Bagram's economy. Major crops such as wheat, corn, vegetables, and fruits such as apples, grapes, apricots, and pomegranates make up a large part of people's income. These products not only meet the domestic needs of the region but are also exported to other regions of Afghanistan. Agricultural practices in Bagram are carried out in traditional ways, although in recent years efforts have been made to improve agricultural infrastructure and use new technologies in agriculture, such as modern irrigation systems (Amiri & Hedayat, 2024).

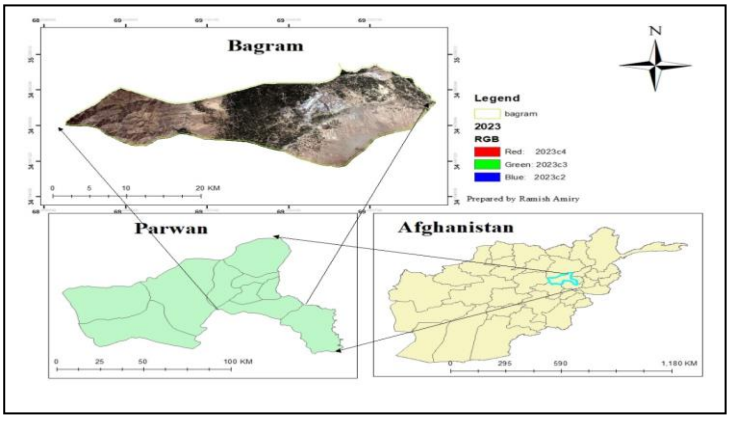

Figure 2. Map of the study area

Data Used

In this research, the following data were used to obtain the effects of precipitation on the vegetation of the Bagram district. The following data are obtained from the NASA space website.

The Sentinel-2 satellite mission is part of the European Space Agency (ESA)'s Copernicus Program, designed to provide high-resolution optical imagery for land monitoring and environmental management. It comprises two identical satellites, Sentinel-2A and Sentinel-2B, ensuring a higher revisit frequency and global coverage.

Important Features of Sentinel-2

Launch and Orbit: Sentinel-2A was launched on June 23, 2015, and Sentinel-2 B was launched on March 7, 2017. They are in sun-synchronous orbit at approximately 786 km and a combined revisit time of 5 days at the equator (with both satellites operational). Spectral Bands: Covers a range of wavelengths from 443 nm to 2,190 nm. Sentinel's satellite has 13 spectral bands; spatial resolutions vary by band: 10 m resolution: Red, Green, Blue, and NIR. 20 m resolution: Red-edge, SWIR, and some NIR bands. 60 m resolution: Coastal aerosol, water vapor, and cirrus bands.

Applications of Sentinel-2

Agriculture: monitoring crop health and productivity using vegetation indices like NDVI, Enhanced Vegetation Index (EVI), and precision farming for irrigation and nutrient management. Land Cover and Ecosystems: mapping and classifying land use and cover and assessing deforestation, reforestation, and biodiversity conservation. Water Resources: monitoring water quality in lakes, rivers, and coastal zones and detecting algal blooms and sediment plumes. Disaster Management: assessing damage from natural disasters like floods, landslides, and wildfires and supporting emergency response and recovery efforts. Urban Development: urban growth monitoring and infrastructure planning and environmental impact assessments. Climate Studies: tracking changes in glaciers, deserts, and polar ice and studying the impacts of climate change on terrestrial ecosystems. Sentinel-2 stands out for its high spatial, temporal, and spectral resolution, making it a cornerstone in Earth observation for environmental monitoring, agriculture, and sustainable development(https://scihub.copernicus.eu).

NDVI Data from MODIS Satellite

The Normalized Difference Vegetation Index (NDVI) is a widely used remote sensing index that measures vegetation health and density by analyzing the difference in reflectance between near-infrared (NIR) and red light. NDVI data from the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard NASA's Terra and Aqua satellites is vital for environmental monitoring, agriculture, forestry, and climate studies.

Important Features of MODIS NDVI Data

The primary purpose of MODIS NDVI data is to detect vegetation health and cover by analyzing photosynthetic activity and To monitor seasonal and inter-annual variations in ecosystems. Spectral bands used for NDVI data are the red band (620–670 nm), Strong absorption by chlorophyll in plants, and the NIR band (841–876 nm), High reflectance due to plant cell structure. Spatial Resolution MODIS offers NDVI data at various spatial resolutions: 250m, 500m, 1km, and aggregated scales. The 250m resolution is beneficial for detailed vegetation studies (https://modis.gsfc.nasa.gov/).

Data Used

This research uses supervised classification (maximum likelihood) on Sentinel-2 satellite images. Applying vegetation index on Sentinel-2 satellite images. Vegetation data from MODIS Terra satellite from 2010 to 2020

The MODIS-Terra satellite is part of NASA's larger Earth Observing System mission, which is used to study Earth systems. Terra satellite is equipped with MODIS (Moderate Resolution Imaging Spectroradiometer). This tool collects critical data in various fields, including climate, vegetation, water quality, and wildfires. The following will examine the MODIS-Terra satellite's features, importance, and applications.

Features of MODIS-Terra satellite are: Global coverage: The Terra satellite covers the globe and collects extensive data from the land surface, atmosphere, and oceans. High accuracy: MODIS can measure in 36 different spectral bands and provides images with a spatial resolution between 250 meters and 1 km. Fast Time Lapse: This satellite collects data continuously and fully images the Earth's surface every 1-2 days. Multiple applications: MODIS can study many natural phenomena, such as climate change, forest fires, air pollution, and vegetation changes.

The importance of the MODIS-Terra satellite is Environmental change monitoring: This satellite is an essential tool for monitoring long-term ecological changes, including deforestation, ice melting, and temperature changes. Climate studies: MODIS data help researchers identify long-term climate trends and develop more accurate climate models. Natural resource management: MODIS data help manage natural resources such as forests, lakes, and agricultural areas. Disaster prediction: This satellite helps predict and manage natural disasters such as forest fires, droughts, and floods.

Applications of MODIS-Terra satellite are: Vegetation change study: MODIS monitors seasonal and long-term changes in vegetation with high precision and provides detailed information on the distribution of vegetation on the earth's surface. Water quality monitoring: MODIS monitors the quality of surface waters, including lakes and oceans, by measuring water clarity and color parameters. Measurement of surface temperature: This satellite collects surface temperature data, which helps study climate change and predict weather patterns. Monitoring fires: MODIS provides critical information on the location and severity of wildfires by identifying hot spots on the Earth's surface. Air pollution monitoring:

This satellite can measure the amount of atmospheric pollutants such as suspended particles and ozone, which is essential for checking air quality and its effects on human health and the environment.

Advantages and characteristics of MODIS data are: Public access: The data collected by MODIS is freely accessible to the public and researchers. Variety of data: MODIS provides different data types related to land surface, atmosphere, and oceans. High analysis capability: These data can be used in advanced analysis for various applications (https://modis.gsfc.nasa.gov/).

FINDINGS AND DISCUSSION

The following results were obtained using the data and analysis. NDVI data from the MODIS satellite was used to obtain the trend of vegetation changes in Bagram district. This data was calculated using the Mann-Kendall test, and the result was displayed in the form of a table and graph. Then, to obtain the area of vegetation, the NDVI index was applied to the Sentinel-2 images of 2018 and 2023, and the total area of vegetation was obtained. Finally, the maximum likelihood supervised classification was applied to the Sentinel-2 images of 2018 and 2023. Three classes of soil, agricultural land and garden were divided and the area of each was obtained. Table 1 shows the vegetation data for the Bagram district over 10 years.

Table 1. NDVI data of Bagram from 2012 up to 2021

year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
2012	0.09	-0.04	0.23	0.39	0.49	0.49	0.46	0.45	0.41	0.30	0.13	0.21	3.60
2013	0.03	0.20	0.32	0.48	0.52	0.49	0.48	0.45	0.38	0.17	0.29	0.27	4.07
2014	0.24	0.24	0.31	0.44	0.55	0.50	0.49	0.47	0.41	0.19	0.29	0.25	4.37
2015	0.23	0.23	0.35	0.48	0.53	0.49	0.49	0.46	0.39	0.17	0.30	0.27	4.40
2016	0.25	0.27	0.33	0.54	0.55	0.50	0.47	0.45	0.39	0.32	0.14	0.25	4.47
2017	0.19	0.08	0.26	0.43	0.53	0.49	0.48	0.45	0.39	0.17	0.29	0.23	3.99
2018	0.23	0.22	0.33	0.48	0.54	0.51	0.48	0.45	0.40	0.17	0.28	0.23	4.33
2019	0.21	0.18	0.25	0.49	0.61	0.56	0.54	0.53	0.45	0.19	0.35	0.29	4.66
2020	0.00	0.27	0.40	0.62	0.64	0.58	0.55	0.56	0.49	0.37	0.15	0.27	4.91
2021	0.27	0.29	0.39	0.57	0.57	0.51	0.51	0.51	0.42	0.17	0.29	0.26	4.75

Table 1 shows the data recorded by MODIS satellite between 2012 and 2021. This satellite has recorded data until 2021; from 2021 onwards, its data has not yet been made available. For this reason, the latest data for this research is for 2021. The highest recorded data for vegetation cover was in 2020, and the lowest recorded data for vegetation cover was in 2012. Figure 3 shows the trend of vegetation changes in Bagram district between 2012 and 2021. Using this graph, it can be proven that the trend of vegetation changes in Bagram district has been increasing in these 10 years.

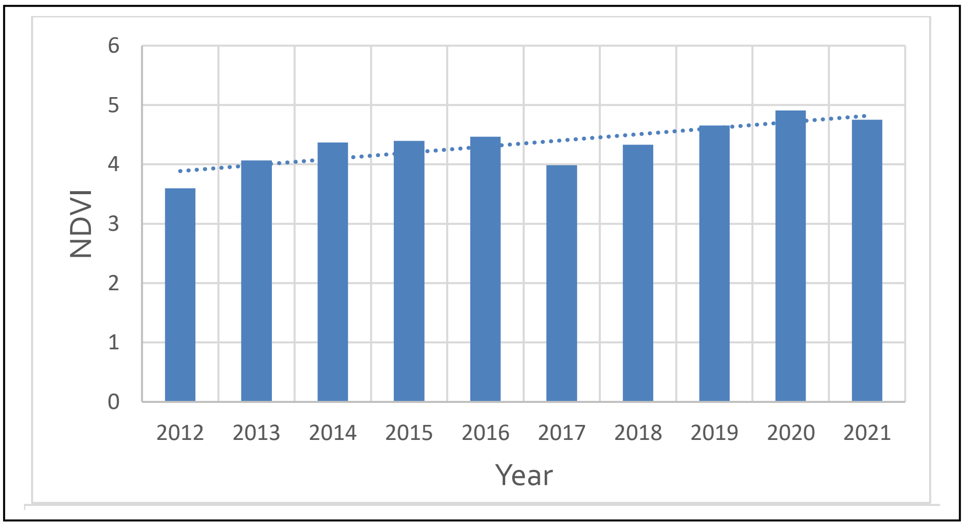

Figure 3. NDVI graph of vegetation data from 2012 up to 2021

Figure 3 shows the trend of vegetation changes: the highest vegetation cover was recorded in 2020, and the lowest was recorded in 2012.

Table 2 shows the final result of the Mann-Kendall test of vegetation data obtained from the MODIS satellite. In this table, data from 10 years has been examined.

Table 2 Man-Kendall test of NDVI data of Bagram from 2012 up to 2021

Man-Kendall test of Precipitation data of Yakawalang district			
Month	**Test Z**	**Definition level**	**Trend**
JAN	0.36		Increases
FEB	1.43		Increases
MAR	1.25		Increases
APR	2.33	*	Increases
MAY	2.42	*	Increases
JUN	2.50	*	Increases
JUL	2.33	*	Increases
AUG	1.53		Increases
SEP	1.53		Increases
OCT	-0.18		Decreases
NOV	0.63		Increases
DEC	0.72		Increases
Yearly	2.50	*	Increases
+Definition level ∝=0.1	Definition level *∝=0.05	Definition level ∝=0.01 **	Definition level ∝=0.001 ***

Figure 4, shows the NDVI vegetation index applied to the Sentinel-2 image in 2018. In this figure, the normalized vegetation curve is applied to the image, and the areas under vegetation are separated from those without vegetation.

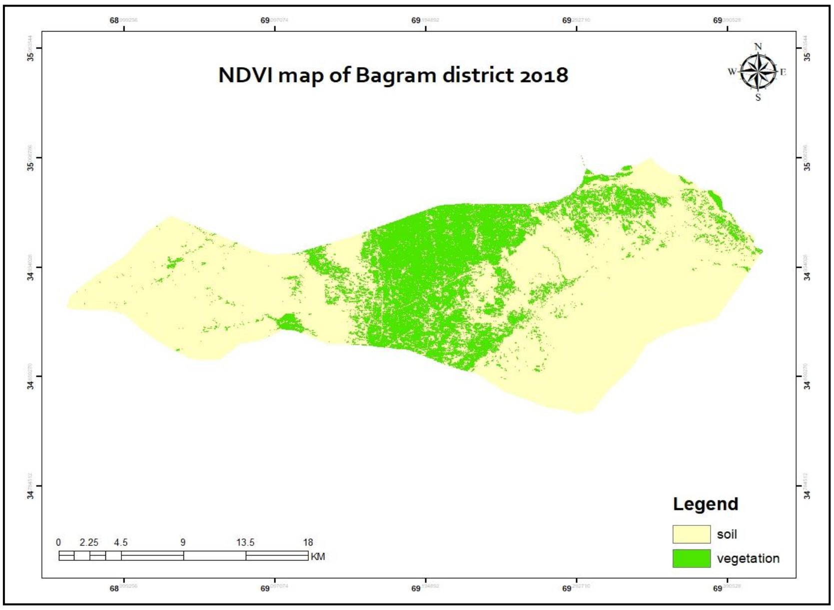

Figure 4. NDVI map of Bagram 2018

Figure 4 shows the NDVI vegetation cover index, which has been extracted from all areas covered by vegetation in Bagram district in 2018. By applying this index, the total vegetation area of this district has been calculated as equal to 107 KM^2, and the area of areas without vegetation is calculated to be equal to 300 KM^2.

Figure 5 shows the NDVI vegetation index applied to the Sentinel-2 image 2023. In this figure, the normalized vegetation curve is applied to the image, and the areas under vegetation are separated from those without vegetation.

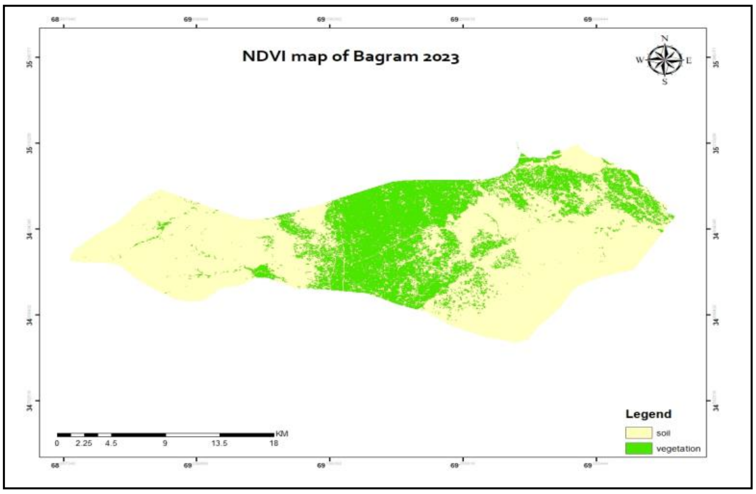

Figure 5. NDVI map of Bagram 2023

In Figure 5, the NDVI vegetation cover index, which was extracted from all areas covered by vegetation in Bagram district in 2023, has been applied. By applying this index, the total vegetation area of this district has been calculated, equal to 123 KM², and the area of areas without vegetation is calculated to be equal to 284 KM². Finally, by applying the NDVI index, the result is obtained that in six years between 2018 and 2023, the area of vegetation has increased by 16 KM².

Using the supervised classification of the maximum probability on the Sentinel-2 images of 2018 and 2023, areas without vegetation (soil), agricultural species, and garden species have been detected.

Figure 6 shows the maximum likelihood supervised classification map of the Bagram district. This classification is applied to Sentinel-2 images of 2018, which are divided into three classes: soil, agricultural species, and garden species.

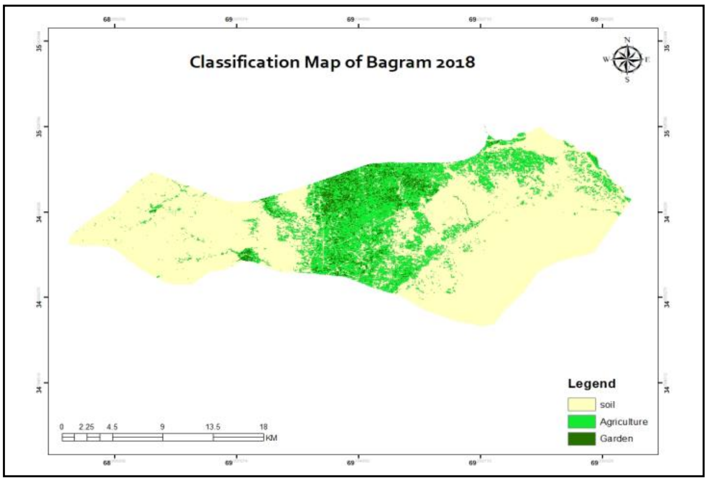

Figure 6 Classification map of Bagram 2018

Figure 6 shows the Bagram district's maximum likelihood supervised classification map, which is divided into three different classes. These classes include soil, agricultural species, and garden species. Using this classification, the area of each class has been obtained, which is as follows: the area of soil is 300 KM², and the area of agricultural species is 90 KM². The area of garden species is calculated as 17 KM².

Figure 7 shows the maximum likelihood supervised classification map of the Bagram district. This classification is applied to Sentinel-2 images of 2023, which are divided into three classes: soil, agricultural species, and garden species.

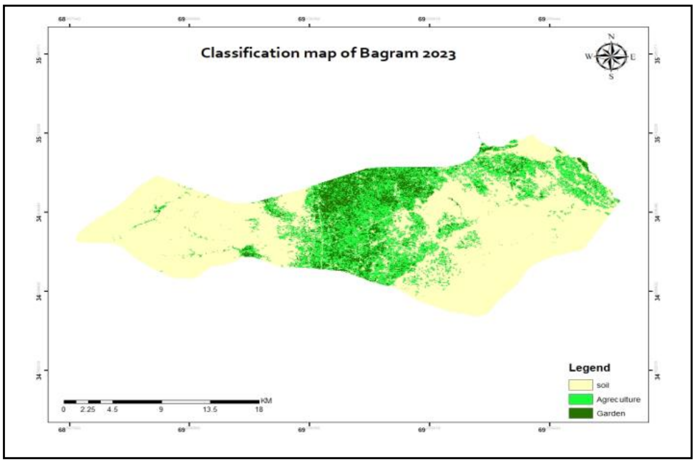

Figure 7 Classification map of Bagram 2023

Figure 7 shows the Bagram district's maximum likelihood supervised classification map, which is divided into three different classes. These classes include soil, agricultural species, and garden species. Using this classification, the area of each class has been obtained, which is as follows: the area of soil is 284 KM^2, the area of agricultural species is 87 KM^2, and the area of garden species is calculated as 36 KM^2.

From the calculations, it can be concluded that the soil area has decreased since 2018 compared to 2023, but the area of garden species has increased since 2018 compared to 2023.

Figure 8 shows the changes in classified parameters during the years 2018 and 2023 in KM^2.

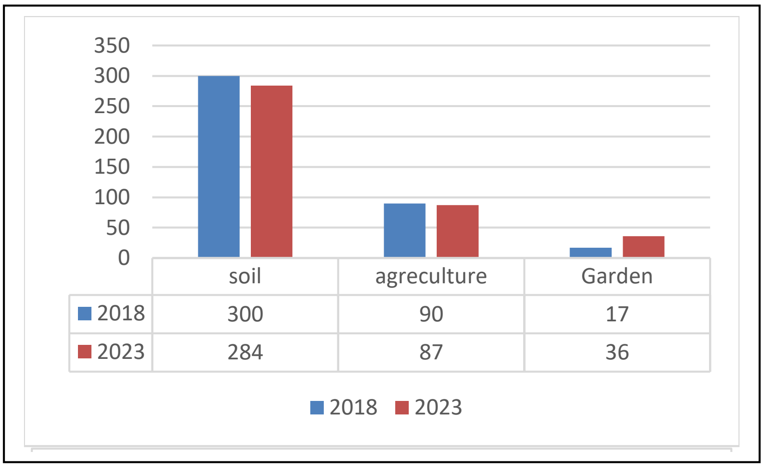

Figure 8. Graph of parameters area per KM^2

Figure 8 shows the graph of changes in the classification classes area. Using this graph, the result is that the area of areas without vegetation in 2018 was equal to 300 KM2, but in 2023, it reached 284 KM2; that is, it decreased by 16 KM^2. The area of agricultural land in 2018 was equal to 90 KM^2, but in 2023, it reached 87 KM^2, which means it has decreased; on the contrary, the garden area in 2018 was equal to 17 KM^2, which reached 36 KM^2in 2023, which means it has increased. Finally, the result is that the area without vegetation has decreased, and the area of cultivated areas has increased.

CONCLUSION

Vegetation is one of the changing phenomena all over the planet. Agriculture is one of the major parts of vegetation that most of the people on earth are engaged in agriculture. The people of Bagram district are engaged in agriculture for their livelihood. This research is about the process of vegetation changes in Bagram district, and the normalized vegetation index was used to obtain the areas covered by vegetation. This index has been applied in 2018 and 2023. In order to obtain the trend of NDVI vegetation changes in the Bagram district, vegetation data was obtained from the Modis satellite between 2012 and 2021, and using the Mann-Kendall test, the trend of vegetation changes in this district was obtained, which has a significant increasing trend. Applying this vegetation index makes it possible to determine the areas covered by vegetation. The area calculated for vegetation using the normalized index of vegetation in 2018 equals 107 square kilometers, and in 2023, it equals 123 KM^2. By using this index, the result is that the area of vegetation has increased by 16 KM^2 since 2018 compared to 2023. The supervised maximum likelihood classification method was used to identify agricultural and horticultural species. The horticultural and agricultural species in Bagram district were classified into three classes using Sentinel-2 images in 2018 and 2023: gardens, barren lands, and agricultural lands. Due to the low spatial resolution of the Sentinel-2 image, the grapevine is not included in this classification because the grapevine is a low plant, and its height is not much different from the agricultural species. It is not possible to separate the grapevine from the agricultural species. The calculation results show that in 6 years, the area of barren and agricultural lands has decreased. On the contrary, the area of garden species has increased, and the area of cultivated land in 2018 was 300 $KM^{2.}$ Still, in 2023, the cultivated land area is about 284 $KM^{2,}$ and in 2023, its area has decreased by almost 16 KM^2. The area of agricultural land in Bagram district was equal to 90 KM^2 in 2018, and in 2023, its area is about 87 KM^2, which in 2023 has decreased by almost 3 KM^2. The area of gardens in the Bagram district in 2018 was equal to 17 KM^2, and in 2023, its area will be about 36 KM^2, and in 2023, its area has increased by approximately 19 KM^2.

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