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Monitoring and Mapping rangeland health using remote sensing and GIS methods: a case study in the foothill Artemisia-ephemeral rangeland region in Samarkand

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Abstract. This paper describes the use of NDVI analysis to assess the health condition of the rangeland in a specific study area. NDVI values were used to determine the vegetation cover and its condition by dividing the values into different classes based on field samples. The study found that the rangeland health condition could be classified into four classes based on the NDVI values ranging from -0.26 to 0.63. The results indicated the presence of both healthy and unhealthy vegetation cover in the study area. However, the study emphasizes that NDVI values can vary depending on different factors, such as season, weather conditions, and vegetation type, and therefore, these factors must be considered when interpreting the results. Overall, the study highlights the importance of using NDVI analysis as a valuable tool to assess the health condition of rangelands and to inform management practices. The paper presents the results of a study on rangeland health classification in a particular study area. The study utilized remote sensing and GIS technologies to classify the rangeland into healthy and degraded categories. The results showed that only 4.4% of the land area was classified as healthy rangeland, while most of the study area was classified as degraded. Specifically, 36.1% of the land area was classified as moderately degraded, 24.3% as low degraded, and 35.2% as highly degraded. These findings suggest that the health of rangelands in the study area is poor and requires effective management and restoration practices to improve productivity. The study demonstrates the usefulness of remote sensing and GIS technologies in monitoring rangeland health and supporting sustainable management practices.

1. Introduction

Uzbekistan has one of the highest rates of land degradation in the world due to a variety of factors, including unsustainable land use practices, climate change, and desertification [5]. Afforestation and soil conservation and provide examples of successful restoration methods in the Uzbekistan condition [8;9;10]. The restoration and sustainable management of natural rangelands are critical for the long-term development of the agricultural sector and food security in the country. By addressing the underlying causes of rangeland degradation and implementing appropriate management practices, it is possible to restore and maintain healthy rangeland ecosystems that can support sustainable livestock production and provide important ecosystem services to local communities [4;10]. In addition, promoting sustainable livestock production practices can also help to reduce the pressure on rangelands and ensure their long-term health and productivity. This can include improving animal health and nutrition, promoting the use of locally adapted livestock breeds, and encouraging the adoption of sustainable grazing and herd management practices [8;10]. Rangeland health is critical for maintaining the ecological balance of arid and semi-arid regions. The use of remote sensing and geographic information systems (GIS) is becoming increasingly popular for monitoring and assessing rangeland health. Rangeland health is a multidimensional concept that includes ecological, economic, and social aspects. Ecological indicators are used to assess rangeland health, including vegetation cover, composition, and diversity, soil characteristics, and water availability [9;10]. Vegetation cover is a critical indicator of rangeland health.

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Satellite imagery can be used to map vegetation cover and monitor changes over time. The normalized difference vegetation index (NDVI) is a commonly used index to estimate vegetation cover and productivity [10]. The NDVI is calculated using the red and near-infrared bands of satellite imagery [9;10]. High NDVI values indicate high vegetation cover and productivity, while low values indicate low vegetation cover and productivity [9;10;12]. Vegetation composition and diversity are other essential indicators of rangeland health. These indicators can be assessed using remote sensing data by identifying and mapping different vegetation types. Land cover classification techniques such as maximum likelihood classification, decision trees, and object-based image analysis can be used to identify and map different vegetation types [9;10;13]. Remote sensing and GIS techniques provide a cost-effective and efficient way to monitor these indicators at a large scale [1;9]. Mapping rangeland health condition using remote sensing and GIS methods has become an increasingly important tool for understanding the ecological condition of rangelands. The review also highlights the importance of selecting appropriate satellite imagery and analytical techniques for rangeland health monitoring, as well as the need for interdisciplinary collaboration to integrate remote sensing and GIS data with ecological and socio-economic data. The availability of remote sensing data such as Sentinel-2 MSI imagery, which covers large spatial scales and has been available since 2015, has revolutionized the way we monitor and manage natural resources and the environment. The Sentinel 2 MSI provides a valuable source of high-resolution optical data that can be used to monitor and manage natural resources, such as forests, crops, and water resources, and to support a wide range of environmental and agricultural applications [9]. The Sentinel 2 Multi-Spectral Instrument (MSI) is a spaceborne imaging system developed by the European Space Agency (ESA) that provides high-resolution optical images of the Earth's surface. The instrument is designed to provide data with a spatial resolution of 10 meters for most of its 13 spectral bands. The red band (Band 4) and the near-infrared band (Band 8) are two of the most important bands for remote sensing applications, particularly for vegetation analysis [9;11]. The red band is sensitive to the chlorophyll content of vegetation and is used to estimate vegetation biomass and density, while the near-infrared band is sensitive to the structure and moisture content of vegetation and is used to estimate vegetation health and stress [3;7;14]. Importance of remote sensing and GIS methods in monitoring rangeland health, and their potential for providing valuable information for sustainable land use practices and conservation efforts. In this case study, we explore the use of remote sensing and GIS methods for monitoring rangeland health in the foothill Artemisia-ephemeral rangeland region in Samarkand. The objectives of this study aim to provide a better understanding of the current state of rangeland health in the study area and to support efforts to monitor and manage rangelands in a sustainable way. By using remote sensing techniques such as NDVI analysis and mapping, this study can contribute to the development of effective strategies for the management and conservation of rangelands, which are crucial for the long-term development of the agricultural sector and the food security of the local population.

The objectives of this study are:

To evaluate the current condition of rangelands in the foothill artemisia-ephemeral regions of the Samarkand province using Normalized Difference Vegetation Index (NDVI) as a measure of vegetation health. NDVI is a commonly used index for monitoring vegetation health and can provide valuable information on the amount and quality of vegetation cover.

To create a map that shows the condition of rangeland health in the study area. The map will be created based on the results of the NDVI analysis and will provide a visual representation of the current state of rangeland health in the study area. The map can be used to identify areas that need intervention or management strategies to improve rangeland health.

2. Materials and Methods

2.1 Study area

The semi-arid Aktau Foothill Rangelands Region, which is in the western Tien-Shan's periphery and interfaces with the Kyzyl Kum desert, is devoted to the study area surrounding Charlak and Tash-Bakal hamlet in the Kushrabat district of the Samarkand region in Uzbekistan [10]. The area is characterized by dry basin filled with sandy and stony deposits and has a landscape structure ranging from low to high relief. Depending on the weather, the foothill rangeland's aboveground biomass could vary from 0.8 t/ha to 1.0 t/ha. The predominant soil type in the region is light sierozem, with significant deposits of stone and a layer of gypsum. The research area is situated between 500 and 1200 meters above sea level. The Aktau foothill rangelands are situated in the southeastern part of Uzbekistan and cover an area of approximately 9,000 km² [10]. The region is characterized by a semi-arid climate with hot summers and cold winters. The vegetation in the area is dominated by shrubs, grasses, and herbs, which provide important grazing resources for livestock in the region. The rangelands in the Aktau foothills have been subject to overgrazing and land degradation, leading to a decline in rangeland health and productivity. The semi-arid foothill rangelands in Samarkand Province of Uzbekistan are a unique ecosystem with its own set of characteristics and challenges. Semi-arid environments are characterized by low rainfall and high evapotranspiration rates, resulting in limited water availability for plant growth.

Foothill rangelands, on the other hand, are areas of land that are transitional between mountainous regions and flat plains, and often consist of slopes and valleys. The dominant soil types in the area, light sierozem and gravelly, stony, and sandy loamy soils, are both characteristic of semi-arid regions with limited water availability. These soils are often low in organic matter and nutrients, which can pose challenges for plant growth and productivity. The continental climate of the region, with high fluctuations in daily and seasonal temperatures, can also impact the growth and survival of plants and animals. Some species may be better adapted to these conditions than others, and understanding these adaptations can be important for managing the ecosystem. The mean annual air temperature of 13.9°C is relatively cool for a semi-arid region, which could affect the timing and productivity of plant growth. The limited precipitation in the area, ranging from 350 to 400 mm, is also a key factor in determining the types of plants that can grow and the productivity of the rangelands [7]. The combination of semi-arid conditions, limited soil diversity, and a continental climate with high temperature fluctuations and limited precipitation creates a unique and challenging environment for plant and animal life in the Samarkand Province of Uzbekistan.

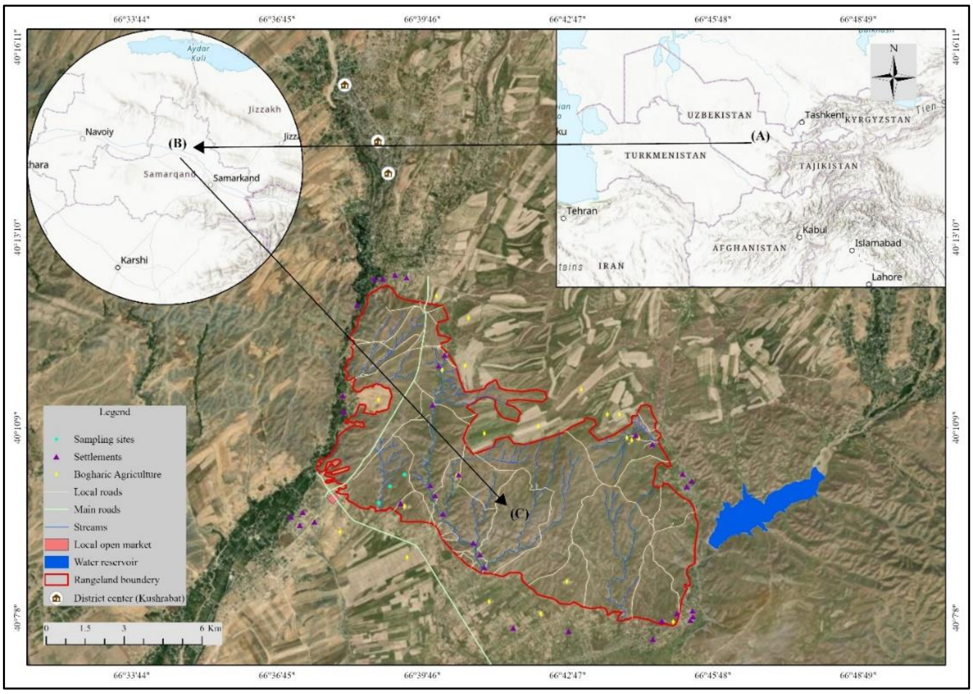

Fig. 1. Location of study area (Location name is Charlak and Tash-Pakal village in the Aktau foothill rangelands in Samarkand Region of Uzbekistan). Source: (ESRI Open Street Map contributors, HERE; Garmin, FAO, NOAA, USGS; Esri, CGIAR; USGS 2023)

The precipitation pattern of the area, with a maximum in winter-spring followed by a drought in summer and fall, is a common characteristic of many semi-arid regions. This can have significant impacts on the productivity and composition of vegetation, as plants must be adapted to survive long periods of drought. The vegetation cover in the area, consisting of various semi-shrub and ephemeral plant communities, is also typical of semi-arid regions. Sagebrush (Artemisia diffusa) is a dominant perennial species in the area, which is well adapted to dry conditions and can survive on limited water resources [7;10;11]. The grass layer is dominated by Poa bulbosa and Carex pachystylis, which are also adapted to semi-arid conditions and can withstand periods of drought [7;10;11]. Understanding the composition and productivity of the vegetation cover in the area is important for managing the rangelands and ensuring the sustainability of grazing and other land uses. Overgrazing and other human activities can have significant impacts on the vegetation cover, which can in turn affect the health and productivity of the ecosystem [7;10;11]. The semi-arid foothill rangelands in Samarkand Province of Uzbekistan are a unique and valuable ecosystem that provide habitat for a variety of plant and animal species, as well as supporting the livelihoods of many people.

2.2 Satellite data and details

The Sentinel-2 Multispectral Instrument (MSI) series is a valuable tool for remote sensing and monitoring of land use and land cover changes. Its high spatial resolution of 10 meters and temporal resolution of 5 days (2-3 days in mid-latitudes) allows for detailed and frequent monitoring of the study area [8]. The Sentinel-2 provides images with 13 spectral bands, ranging from visible to infrared, allowing for analysis of vegetation health, soil moisture, and other land surface characteristics (Figure 2.). The surface reflectance products provided by the Sentinel-2 series allow for correction of atmospheric effects, which can improve the accuracy and reliability of the data. The availability of free and open access Sentinel-2 data from the Copernicus Open Access Hub (COAH) is a significant advantage for researchers and users who may not have access to other satellite data sources (https://scihub.copernicus.eu/dhus/#/home). The user-friendly nature of the data and the high spatial and temporal resolution make it a valuable tool for a wide range of applications, including monitoring of rangelands and other ecosystems. The atmospheric correction of the images from the Sentinel-2 missions since 2017 makes them more user-efficient for analysis. By downloading a cloud-free Sentinel-2 L1C image from COAH for the summer season, you were able to advance your period of analysis using the data.

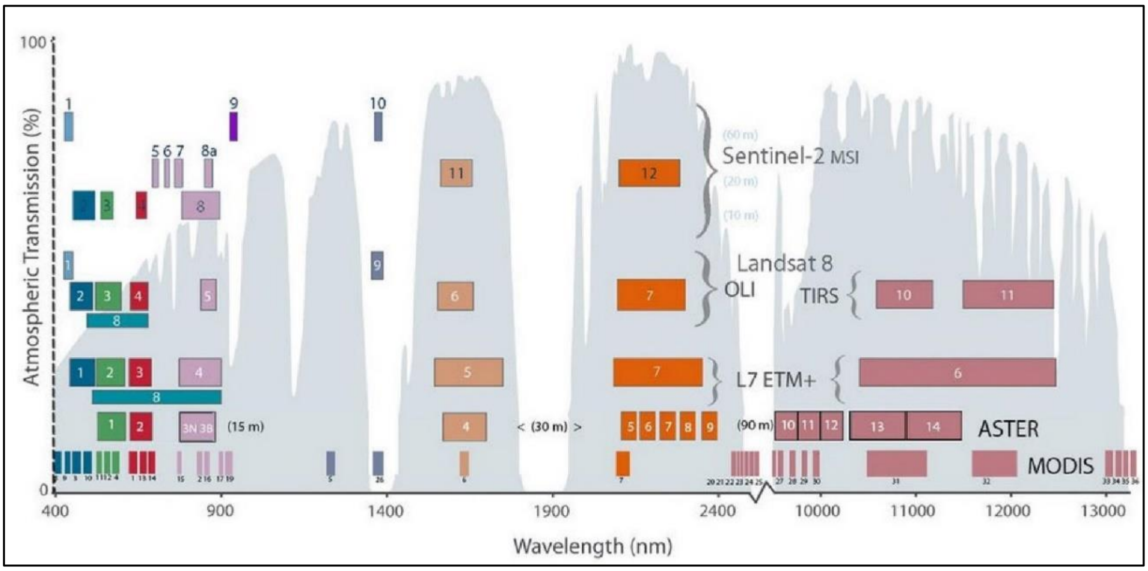

Fig. 2. Comparison of spectral ranges and spatial resolution across MODIS, ASTER, Landsat 7 ETM+, 8 OLI and Sentinel 2 satellite sensors. (Source From: ttps://www.icimod.org/capacitybuilding/2021/WoGIT%20Bangladesh/D2_RS_Concept_RBT.pdf)

3. Project Methodology Flowchart

1-step: Acquiring atmospherically corrected and cloud-free Sentinel-2 images: Many tools are available, such as the Sentinel Application Platform (SNAP) and the Atmospheric Correction for the OLCI (ACOLITE) software, to generate cloud-free and atmospherically corrected Sentinel-2 images. These tools can process the Sentinel-2 images to remove atmospheric effects, including aerosols and water vapor, and to correct for the effects of clouds.
2-step: Image processing using ArcGIS Pro: Once the Sentinel-2 images have been obtained and processed, the next step is to use ArcGIS Pro for image processing. ArcGIS Pro provides a range of tools for image processing, such as image enhancement, classification, and analysis.
3-step: NDVI calculation: The NDVI is a commonly used vegetation index that can provide valuable information about vegetation health and condition. To calculate NDVI using ArcGIS Pro, the raster calculator tool can be used, with the NDVI equation (Equation 1) that you provided.
4-step: Classification: In this study, an unsupervised classification method was used to identify and classify the pixels into different groups based on their spectral characteristics. The Iso Cluster Unsupervised Classification tool in ArcGIS Pro was used to classify the Sentinel-2 images. This tool divides the image into clusters of similar pixels based on their spectral characteristics.
5-step: Labelling the resulting clusters: The resulting clusters were then labelled based on their spectral characteristics and field observations. This can help to identify different land cover and vegetation types in the study area, and to assess their health and condition.

3.1 NDVI calculation

The NDVI is a widely used vegetation index that can provide valuable information about vegetation health and condition. The use of NDVI in your study to determine the health status of the Artemisia-Ephemeral Rangeland is appropriate and can help in identifying changes in vegetation cover over time. Using ArcGIS Pro 2.6 and the raster calculator toolbox for NDVI calculation is a common approach. The NDVI equation (equation 1) that you used is appropriate for Sentinel-2 imagery, where Band 4 corresponds to the red band and Band 8 corresponds to the near-infrared band. It is also good to see that you have calculated NDVI for different areas of interest, including the total rangeland area, the mining area, streams, and roads. This can help in identifying potential impacts of mining activities and road construction on the vegetation health and condition of the rangeland.

$$\text{Sentinel} - 2, NDVI = \frac{Near\ infrared\ (band\ 8) - Red\ (band\ 4)}{Near\ infrared\ (band\ 8) + Red\ (band\ 4)} \qquad \text{(Equation 1)}$$

3.2 Classification

For rangeland health classification used a supervised classification method in ArcGIS Pro 2.6. In this approach, the software identifies the classes and assigns pixels to them based on the spectral values. In this study, the unsupervised classification method was used to identify and classify the pixels into different groups based on the spectral characteristics of the images. From there, I classified the image into four categories: healthy, regular, moderate, and unhealthy.The Iso Cluster Unsupervised Classification tool in ArcGIS Pro 2.6 was used to classify the Sentinel-2 images. This tool divides the image into clusters of similar pixels based on their spectral characteristics. The number of clusters was determined based on visual interpretation of the resulting clusters and comparison with known ground truth data. The resulting clusters were then labelled based on their spectral characteristics and field observations.

4. Results and Discussion

4.1 NDVI analysis

I have used NDVI analysis to assess the health condition of the rangeland in the study area. The NDVI values can provide valuable information on the vegetation cover and its condition. By dividing the NDVI values into different classes based on the field samples, able to interpret the results and classify the rangeland health condition into 4 classes. The values you obtained ranged from -0.26 to 0.63, indicating the presence of both healthy and unhealthy vegetation cover (Figure 3.). It is important to note that NDVI values can vary depending on various factors such as season, weather conditions, and vegetation type, among others. Therefore, it is crucial to consider these factors when interpreting the NDVI results. The NDVI, EVI, and SAVI were all effective for monitoring vegetation cover and biomass production on semi-arid rangelands in southwestern Uzbekistan [9;10]. They also found that the Landsat 8 imagery provided better results than Landsat 7 for monitoring rangeland health, due to its higher spatial and spectral resolution.

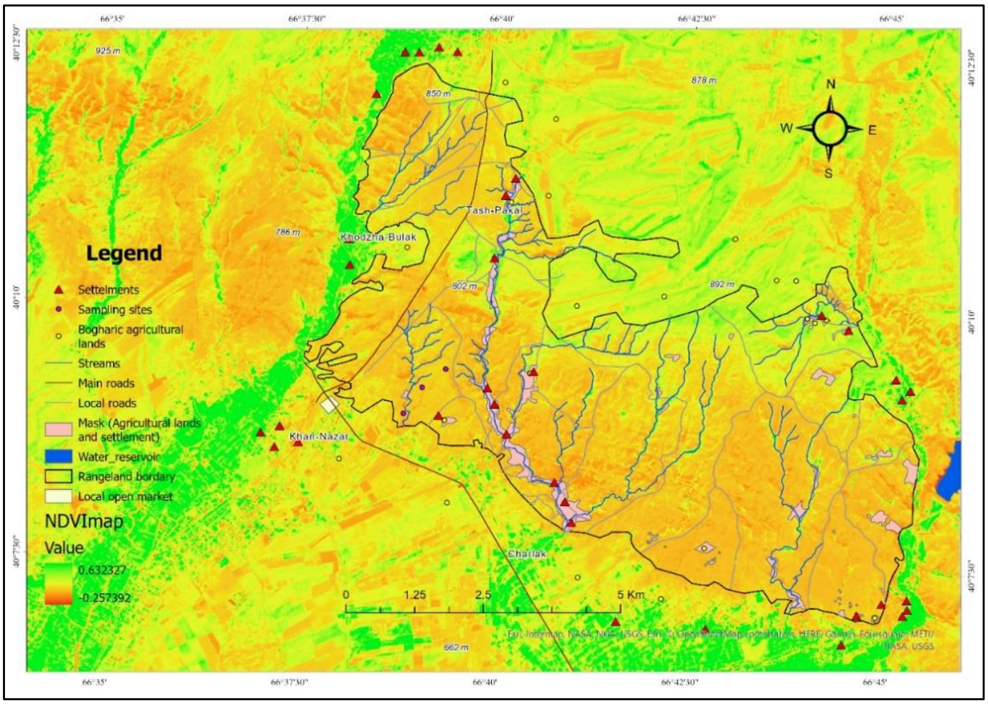

Fig. 3. NDVI values of the study area

The NDVI and SAVI (Soil Adjusted Vegetation Index) algorithms were the most used algorithms for estimating FVC (fractional green vegetation cover), while the EVI (enhanced vegetation index) and MTVI (modified triangle vegetation index) algorithms showed promise in certain applications and the accuracy of FVC estimates varied depending on the vegetation type, scale of analysis, and environmental conditions [2]. The normalized difference vegetation index

(NDVI) and the enhanced vegetation index (EVI), to assess changes in vegetation cover over a period of 30 years and the climatic variables, such as temperature and rainfall, to assess the impact of changes in vegetation cover on these variables [6]. The use of NDVI analysis to assess rangeland health is a common practice in remote sensing studies. The results obtained from the NDVI values can provide useful information on the vegetation cover and its condition. In this study, the NDVI values were divided into different classes to interpret the results and classify the rangeland health condition into four classes. The presence of both healthy and unhealthy vegetation cover was observed, which highlights the need for effective management and restoration practices to improve the health and productivity of rangelands in the study area. It is important to consider various factors that can affect NDVI values when interpreting the results, such as season, weather conditions, and vegetation type. Furthermore, the accuracy of NDVI results can vary depending on the satellite used and its spatial and spectral resolution. The use of NDVI analysis can provide valuable information on rangeland health and productivity. The findings of this study highlight the need for effective management and restoration practices to improve the health and productivity of rangelands in the study area.

4.2 Rangeland Health Status Classification Results

The Table 1. shows the results of the rangeland health classification in terms of land area for the study area. According to the classification, the healthy rangeland covers 229.78 hectares, which represents 4.4% of the total land area. Most of the study area is classified as degraded rangeland, with 1897.63 hectares (36.1%) classified as moderate degraded, 1279.33 hectares (24.3%) classified as low degraded, and 1850.71 hectares (35.2%) classified as high degraded (Figure 4.). The results indicate that the health of rangelands in the study area is generally poor, with only a small proportion of the land area classified as healthy rangeland. This highlights the need for effective management and restoration practices to improve the health and productivity of rangelands in the study area. Remote sensing and GIS technologies can provide valuable tools for monitoring rangeland health and supporting sustainable management practices.

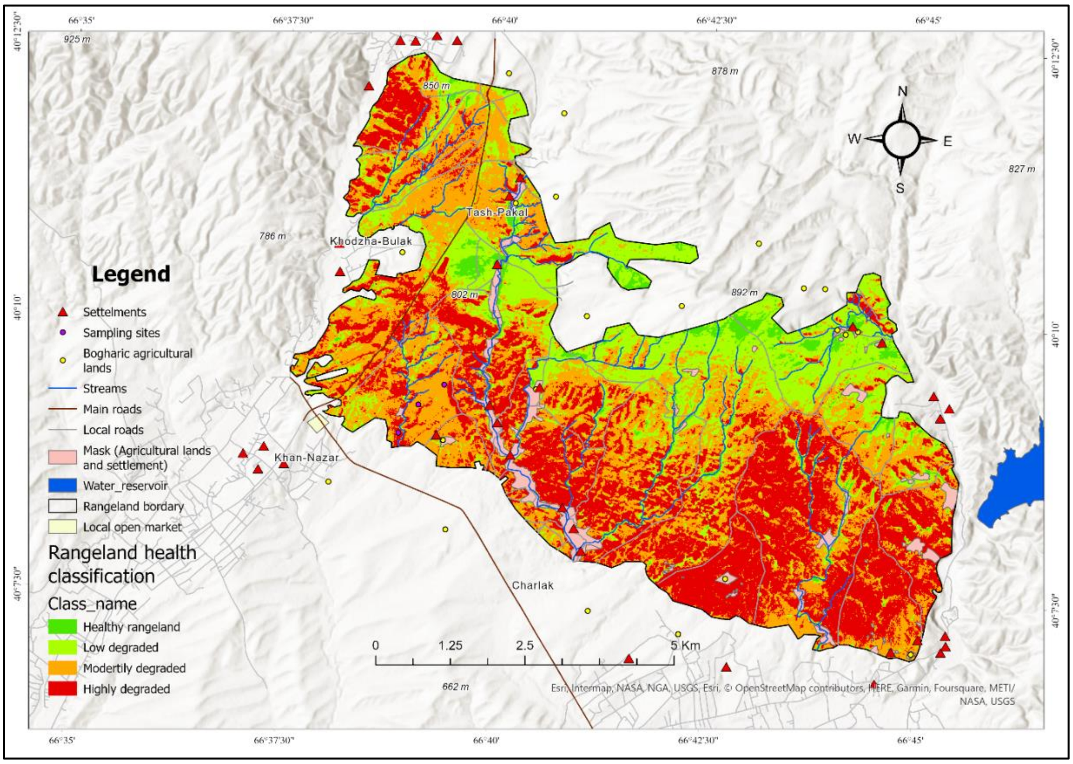

Fig. 4. Rangeland health classification of the study area

Ansari et al. (2020) found that remote sensing data can effectively be used for rangeland health assessment, and the use of GIS can provide useful information for spatial analysis and mapping of rangeland health indicators. Effective use of remote sensing data for monitoring vegetation cover, biomass production, and other indicators of rangeland health, as well as the use of GIS for spatial analysis and mapping of rangeland health indicators [8;9]. The authors also discussed the potential of these technologies for supporting the design and implementation of effective management strategies, such as rotational grazing and vegetation restoration programs. The remote sensing and GIS can provide valuable information on rangeland productivity, and the use of Sentinel-2 satellite imagery and GIS techniques can enable accurate and timely monitoring of rangeland health in Pakistan rangeland [4]. The data collected demonstrated that remote sensing, particularly in high-resolution satellite imagery, enables rapid and accurate assessment of huge areas in a short amount of time.

Table 1. Rangeland Health Status Classification Results

Rangeland heath classification	Land area	
	(ha.)	(%)
Healthy rangeland	229.78	4.4
Moderate degraded	1897.63	36.1
Low degraded	1279.33	24.3
High degraded	1850.71	35.2
Total	5257.45	100

The potential of applying the remote sensing technology are seen to be enormous, particularly in the sustainable management of rangelands. This research will help to support the execution of new initiatives in the future. The accuracy of rangeland health status classes will rise with the amount of field samples, which will advance this research.

5. Conclusions

To sum up, the study utilized NDVI analysis to assess the health condition of rangelands in a specific study area. The NDVI values provided valuable information on vegetation cover and its condition, which were used to classify the rangeland health condition into four classes. The results showed the presence of both healthy and unhealthy vegetation cover in the study area, with NDVI values ranging from -0.26 to 0.63. However, it is important to note that the NDVI values can vary depending on several factors, and therefore, it is crucial to consider these factors when interpreting the results. The study also presented the results of the rangeland health classification in terms of land area, which indicated that the health of rangelands in the study area is generally poor, with only a small proportion of the land area classified as healthy rangeland. This highlights the need for effective management and restoration practices to improve the health and productivity of rangelands in the study area. Remote sensing and GIS technologies were found to be valuable tools for monitoring rangeland health and supporting sustainable management practices. Overall, the study provides useful insights into the assessment of rangeland health using NDVI analysis and emphasizes the importance of effective management and restoration practices to improve rangeland productivity and health. We believe that classifying and mapping the present health of future rangelands is a crucial first step toward developing precise and useful strategic planning techniques for the primary issue facing contemporary rangeland management in Uzbekistan.

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