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ANALYSIS OF CHANGES IN FOREST AREAS BASED ON REMOTE SENSING DATA
(on the example of Syunik Region)

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Remote sensing technologies provide an effective means of monitoring forest ecosystem changes without the need for direct field observations. This study investigates changes in forested areas of the Syunik Region, focusing on the impacts of forest fires, illegal logging, and tailings dumps. SENTINEL-2 satellite imagery was processed and analyzed using the Normalized Burn Ratio (NBR), Normalized Difference Vegetation Index (NDVI), and Normalized Difference Moisture Index (NDMI) to detect and quantify vegetation loss and degradation over different time periods. Comparative analysis of multi-temporal satellite data revealed significant alterations in forest cover, highlighting the effectiveness of remote sensing methods for detecting deforestation trends and assessing environmental consequences. The findings underscore the importance of satellite-based monitoring for sustainable forest management and conservation efforts.

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***Keywords*:** remote sensing, forest monitoring, deforestation, wildfires, vegetation indices, SENTINEL-2, environmental impact assessment, NBR, NDVI, NDMI.

Introduction. Forest ecosystems play a critical role in maintaining biodiversity, regulating carbon cycles, and ensuring soil stability. However, these ecosystems are increasingly threatened by various environmental and anthropogenic factors, leading to significant changes in forest cover. In Armenia, and particularly in the Syunik Region, deforestation is primarily driven by forest fires, illegal logging, and the expansion of tailings dumps. These processes not only alter the ecological balance, but also contribute to climate change and biodiversity loss. Advancements in satellite remote sensing technology provide a powerful tool for monitoring forest cover dynamics without the need for direct field surveys. Remote sensing techniques enable the detection of changes in vegetation cover, assessment of damage caused by wildfires and human activities, and evaluation of moisture levels, all of which are crucial for sustainable forest management. This research utilizes SENTINEL-2 satellite data, which offers high-resolution multispectral imaging, allowing detailed

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analysis of vegetation health and environmental changes over time. The primary objective of this study is to analyze and assess forest area changes in the Syunik Region using remote sensing methods. By employing spectral indices such as the Normalized Burn Ratio (NBR), Normalized Difference Vegetation Index (NDVI), and Normalized Difference Moisture Index (NDMI), this research aims to quantify the extent of forest degradation, identify affected areas, and evaluate environmental conditions. The findings contribute to the broader understanding of deforestation trends and highlight the potential of remote sensing for forest conservation efforts in Armenia.

Materials and Methods. This study utilized SENTINEL-2 satellite imagery to analyze changes in forest areas within the Syunik Region. During the course of the research, relevant published sources were thoroughly reviewed and utilized, particularly those focused on the study of forest landscapes within our republic [1–3]. The satellite data were obtained from the EOSDA LandViewer platform [4] and processed using ArcMap software. To assess vegetation dynamics and detect environmental disturbances, several spectral indices were calculated, including. To obtain the satellite images necessary for our work, we utilized websites offering satellite imagery of various resolutions, including EOSDA LandViewer [4], Copernicus Open Access Hub [5], USGS Earth Explorer [6], and NASA Earth Observing System Data and Information System (EOSDIS) [7].

Normalized Burn Ratio (NBR) – used to identify burned areas by leveraging the reflectance difference between near-infrared (B8a, NIR) and shortwave infrared (B12, SWIR) bands.

Normalized Difference Vegetation Index (NDVI) – measures vegetation health by comparing near-infrared (B8, NIR) and red (B4) reflectance values, providing insights into vegetation vigor and density.

Normalized Difference Moisture Index (NDMI) – assesses changes in vegetation moisture content using near-infrared (B8, NIR) and shortwave infrared (B11, SWIR) bands, helping to monitor drought conditions and forest stress.

Additionally, multi-temporal analysis was conducted by comparing satellite images taken at different time intervals. This approach enabled the detection of deforestation trends, evaluation of forest loss due to fires or human activities, and assessment of moisture variations affecting vegetation health.

Results and Discussion.

Main Research. The main objective of this research is to detect and analyze changes in forested areas in the Syunik Region using remote sensing data. The study utilizes multispectral satellite imagery and vegetation indices to assess the impact of forest fires, illegal logging, and industrial activities on forest cover.

General Characteristics of Remote Sensing. Remote sensing is the process of detecting and monitoring the physical characteristics of an area without direct contact. This is primarily achieved using sensors mounted on satellites, aircraft, or unmanned aerial vehicles. These sensors capture data over vast geographic areas, providing insights that are not possible through ground-based observations alone [8].

Remote sensing sensors can be classified into two main types based on their energy source and method of data acquisition.

Active Sensors. These sensors have their own energy source, typically a radar or laser, which emits signals toward the Earth’s surface and measures the reflected energy. Because they generate their own illumination, active sensors can capture data at any time of the day or night, regardless of weather conditions. Examples include synthetic aperture radar (SAR) and LiDAR (Light Detection and Ranging).

Passive Sensors. Unlike active sensors, passive sensors do not have their own energy source and rely on external illumination primarily solar radiation to capture data. They detect and measure sunlight that is reflected or emitted by objects on the Earth's surface. Since passive sensors depend on sunlight, they can only operate during daytime hours and are affected by cloud cover and atmospheric conditions. Examples include optical and infrared sensors such as those onboard SENTINEL-2 and Landsat satellites [9].

The science of remote sensing is based on the theory of electromagnetic radiation. Electromagnetic radiation is a beam of radiation, where the rays are distinguished by their wavelength. The wavelengths of electromagnetic radiation range from nanometers to meters. The spectrum of electromagnetic radiation is divided into the following main parts [10].

1. *Ultrashort waves* – we do not use these waves in remote sensing.
2. *Visible radiation waves.* It includes the spectrum of electromagnetic radiation visible to the human eye, which is the spectrum of waves with a length of 0.36 *nm* to 0.79 *nm*.
3. *Near-infrared waves* – cover the range from 0.79 *nm* to 1 *nm*.
4. *Thermal or infrared* – covers the range from 1 *nm* to 12 *nm*.
5. *Radio waves* – covers from 12 *nm* to 1 *m*.

In the science of remote sensing, the visible range is divided into 3 parts: Blue range rays 0.36–0.45 *nm*; Green range rays 0.45–0.56 *nm*; Red range rays 0.56–0.79 *nm*.

SENTINEL-2 satellite band characteristics [12]

SENTINEL-2 Bands	Central Wavelenghth, *nm*	Resolution
Band 1 – Coastal aerosol	0.443	60
Band 2 – Blue	0.490	10
Band 3 – Green	0.560	10
Band 4 – Red	0.665	10
Band 5 – Vegetation Red Edge	0.705	20
Band 6 – Vegetation Red Edge	0.740	20
Band 7 – Vegetation Red Edge	0.783	20
Band 8 – NIR	0.842	10
Band 8a – Vegetation Red Edge	0.865	20
Band 9 – Water vapour	0.945	60
Band 10 – SWIR -Cirrus	1.375	60
Band 11 – SWIR	1.610	20
Band 12 – SWIR	2.190	20

The survey in the three mentioned ranges is called multispectral. The basis of multispectral survey is the physicochemical properties of objects on the earth’s surface. Moreover, different objects can absorb and reflect different amounts of rays. Multispectral survey is carried out with separate spectra of light or rays, using special filters, and for each range, separate images of the same area of the earth’s surface are obtained. The images obtained from multispectral acquisition are subjected to decoding, which allows both visible and invisible phenomena to be decoded and mapped [10]. One of the satellites equipped with a multispectral sensor is the SENTINEL-2 satellite, which was launched into space on June 23, 2015 [11]. The satellite sensor provides 13 spectral bands (see Table).

Since decades, remote sensing (RS) has been used to map forest change and quantify the corresponding climatic effects. The spatial and temporal characteristics of land cover change map are measured easily by using remote sensors. Satellite RS is viable means to, map, assess, and monitor forest cover at a range of spatial and temporal scales. However, remote sensors offer a quick, and low cost way to map and to monitor deforestation, logging, and other disturbances [13].

As in all forest ecosystems of the Republic of Armenia, the main factors of forest change in Syunik Region are: fires, illegal logging.

Fires as a Factor of Change in Forested Areas. Forest fires are the spontaneous spread of fire in the forest, as a result of which the forest is completely or partially destroyed. They reach large sizes in dense and especially coniferous forests. They occur naturally (from lightning, spontaneous combustion of peat) and due to human carelessness (from cigarettes or glass, which acts as a lens). World statistics show that 97% of fires occur solely due to human fault. The fire hazard of forests is due to a significant lack of precipitation, which increases air temperature and reduces relative humidity [14].

To detect areas burned by RS methods, we calculated the NBR index in ArcMap, for which EOSDA LandViewer was created by EOS Data Analytics (EOSDA), a trusted global provider of satellite image analysis. It presents a catalog of satellite images obtained from multiple data sources, such as SENTINEL-2, LANDSAT-8 OIL+TIRS, LANDSAT-7, LANDSAT-4-5 MSS, CBERS-4 MUX, NAIP. Download the images of the Sentinel-2 satellite: B8a NIR (near infrared) and B12 SWIR (wide-wave infrared). Where we present the Lehvaz-Vardanidzor section of Syunik Region as of 10.08.2019, when there was no fire in that section yet (Fig. 1). Fig. 2 shows the same section as of 12.08.2019, the image is already the burned section after the fire.

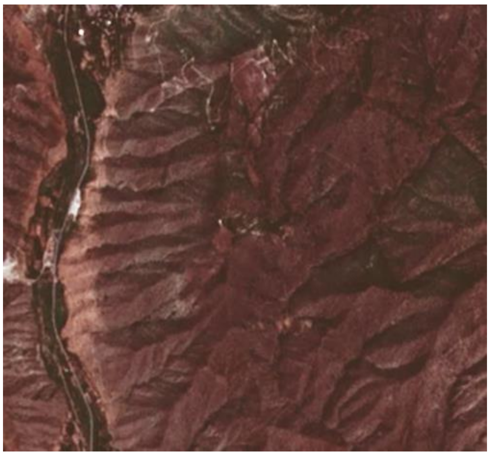


Fig. 1. Lehvaz-Vardanidzor before the fire on fire on 10.08.2019.

Fig. 2. Lehvaz-Vardanidzor after the 12.08.2019.

Normalized NBR for Burned Area Detection. The NBR is a widely used RS index designed to detect and assess burned areas in large fire zones. It utilizes the reflectance properties of vegetation and burned surfaces in two key spectral bands [15].

The NBR index is calculated using the following formula [15]:

$$NBR = NIR - SWIR / NIR + SWIR, \qquad NBR = B8a - B12 / B8a + B12,$$

where Near-Infrared (NIR) – Band 8a, Shortwave Infrared (SWIR) – Band 12.

Interpretation of NBR Values. Healthy vegetation exhibits high reflectance in the NIR band (B8a) and low reflectance in the SWIR band (B12). Burned areas exhibit the opposite behavior: they show low reflectance in the NIR band and high reflectance in the SWIR band. A high NBR value indicates dense and healthy vegetation [15]. A low NBR value corresponds to burned areas, bare soil, or areas with minimal vegetation cover.

Visual Representation. Fig. 3 illustrates the application of the NBR index in detecting burned areas. Areas with high NBR values appear in shades representing healthy vegetation, while areas with low NBR values correspond to fire-affected zones and bare soil [4, 15].

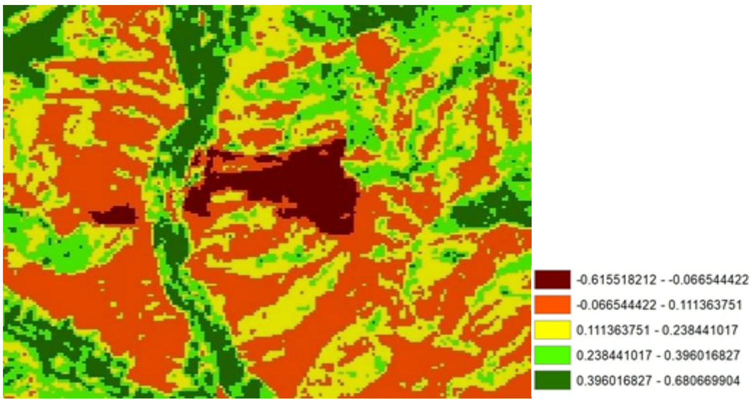


Fig. 3. NBR raster map.

Deforestation and Tailings Dumps as a Factor in Changing Forested Areas. The denudation of forest lands due to illegal logging is widespread in Syunik Region (Fig. 4). Illegal logging is mainly due to various socio-economic reasons and high demand for timber. Unsystematic deforestation still exceeds the volume of legal logging of natural timber. This is facilitated by the availability of timber, the difficulty of accessing energy resources, the needs of socially vulnerable groups of the population, and their low solvency. Based on the calculations conducted in ArcGIS, the burned area is approximately 24 *ha*.

To detect deforested areas, we again used the EOSDA LandViewer website, using images from the SENTINEL-2 satellite [4]. Presenting changes from June 18, 2019 and June 17, 2020 using the example of the Goris forestry area (Fig. 1).

Atmospherically Resistant Vegetation Index (ARVI) – this index is an improved NDVI, used to correct the influence of the atmosphere. It is most useful in regions with a high content of atmospheric aerosol, including tropical areas polluted with soot. Users use in conjunction with NDVI [4].

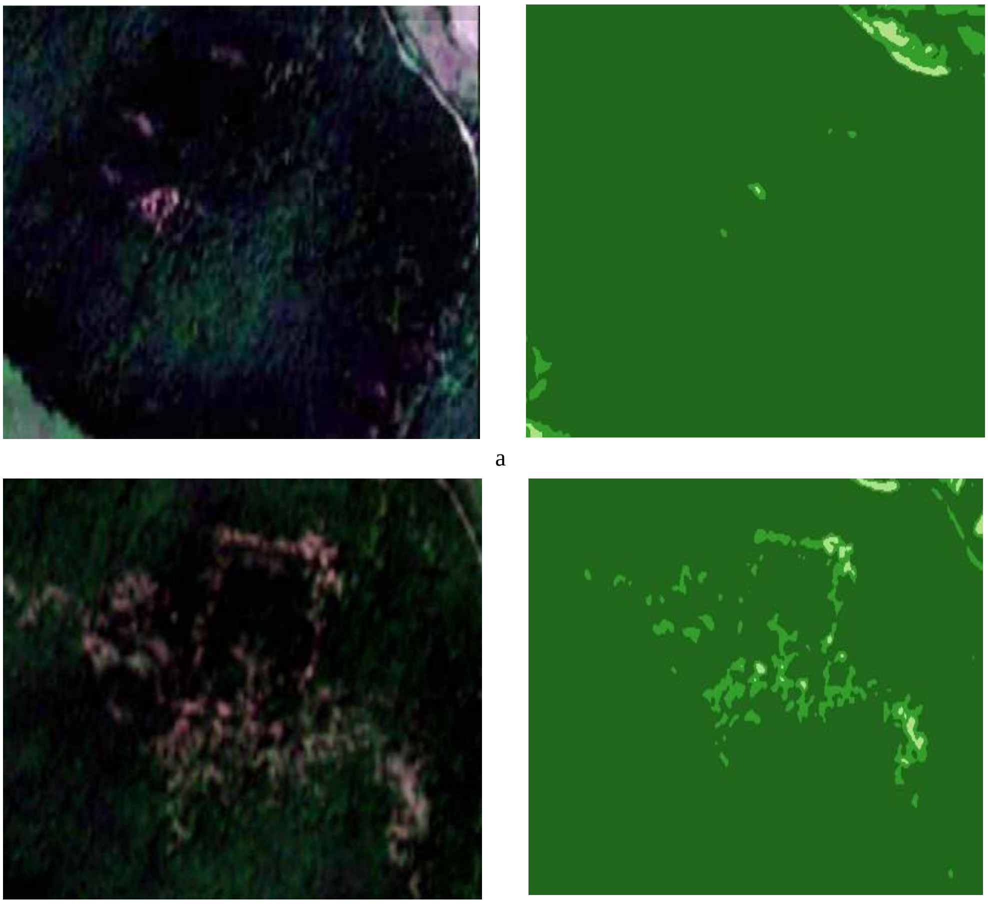
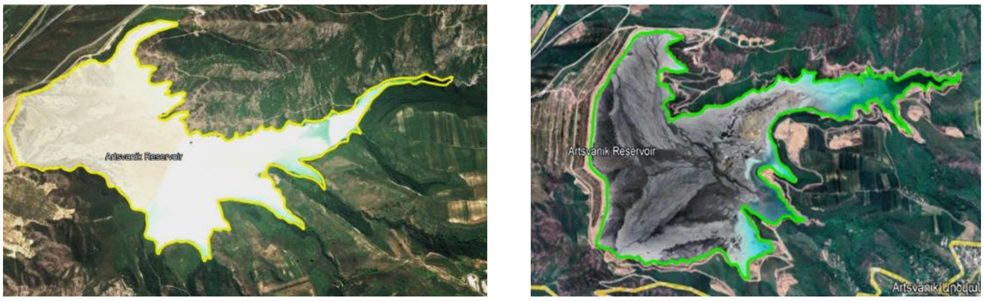


Fig. 4. Satellite image before deforestation 18.06.2019; Atmospherically Resistant Vegetation Index (a). The same area after deforestation 17.06.2020; Atmospherically Resistant Vegetation Index (b).

Calculations conducted within the ArcGIS system indicate that the deforested area covers approximately 7 *ha* in total.

In this research, we also examined tailings dams as a factor contributing to changes in forested areas. During the study, it became evident that a significant reduction in forest areas in the Syunik Region has occurred as a result of the expansion of tailings dams. Using the example of the Artsvanik tailings dam, we conducted a comparative study to track its growth over the years and the associated loss of forested land. We carried out the analysis of the Artsvanik tailings dam using Google Earth Pro [16]. From this platform, we extracted the area occupied by the tailings dam in 2004 (Fig. 5, a) and compared it with the area occupied in 2022 (Fig. 5, b). The results of this comparison revealed the following trends.



a b

Fig. 5. Artsvanik tailings dam in 2004 (a); Artsvanik tailings dam in 2022 (b).

We then made a comparison to more clearly see the increase in tailings area and the decrease in forest area (Fig. 6).

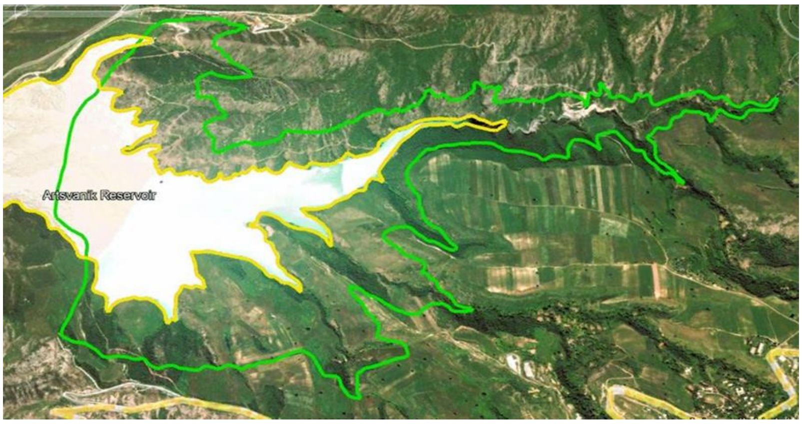
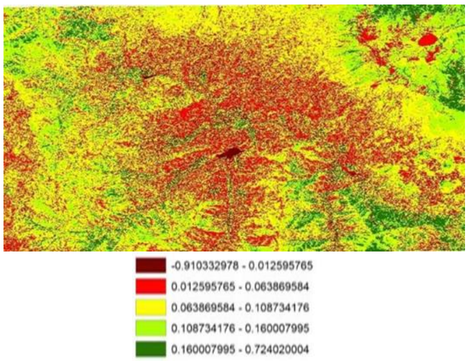


Fig. 6. Overlay of 2004 and 2022 images.

As can be seen from Fig. 6, the boundaries of the tailings dam and forests have changed significantly between 2004 and 2022. As a result of the tailings dam expansion, a total of 245 *ha* of land cover, including forested areas, have been reduced.

In this study, we also conducted the separation of pure forest areas within the Sisian Forestry Enterprise area. To do this, we calculated the Normalized Difference Vegetation Index (NDVI). Satellite images were obtained from the SENTINEL-2 satellite via the EOSDA LandViewer platform [4]. We downloaded images corresponding to the red, green, and blue bands (B04, B03, B02, respectively) from the visible spectrum of light (Fig. 7, a), for the period of July–August 2022. We then selected the images, where cloud coverage was either absent or insignificant, ensuring it did not interfere with the study area (Fig. 7, b). We specifically chose the months of July–August, because these are the driest months in the Republic of Armenia, when grass cover is mostly dry. This allows the NDVI calculation to clearly differentiate shrub vegetation, which appears dark green. If the same analysis were conducted in May, it would have been nearly impossible to separate forest areas effectively using NDVI. May is the wettest month in Armenia due to the influence of Western weather systems, making the index less suitable for distinguishing forests.

a



b

Fig. 7. Visible range (RGB) image (a); NDVI raster map (b).

NDVI is calculated using the following formula:

$$NDVI = (NIR - R) / (NIR + R).$$

The calculation is based on the density of chlorophyll in the leaves of the plant. Near-infrared rays are reflected by the chlorophyll grains in the plant leaves, while red rays are absorbed by the leaf surface [17].

The NDVI values range from –1 to +1: in the range –1 to 0, vegetation is completely absent; in the range 0 to 1, the more lush the vegetation, the higher the NDVI value [4].

We then determined and created a raster map of the Normalized Difference Moisture Index (NDMI) in ArcMap using data from the EOSDA LandViewer website [4] (Fig. 8). NDMI utilizes the NIR and SWIR spectral ranges to indicate moisture content. SWIR waves reflect the water content in vegetation, while NIR waves reflect the dry matter content in the internal structure of the leaf. NDMI is commonly used to monitor changes in water content in leaves and assess water stress in plants.

The index is calculated using the following formula [4, 18]:

$$NDMI = (B8 - B11) / (B8 + B11)$$

or

$$NDMI = (NIR - SWIR) / (NIR + SWIR).$$

Negative NDMI values correspond to water stress or areas with a soil layer devoid of vegetation. Values above 0 indicate that the higher the water content, the higher the NDMI value. NDMI is also employed for monitoring changes in water content over time.

In addition, NDMI is similar to the Normalized Difference Water Index (NDWI), which is calculated using the following formula:

$$NDWI = (B3 - B11) / (B3 + B11)$$

or

$$NDWI = (Green - NIR) / (Green + NIR).$$

NDWI is determined using a combination of the green and NIR bands in the visible range, enabling the detection of subtle changes in water content in water bodies. It also allows the differentiation of water bodies from soil and vegetation [18].

Values greater than 0.5 typically correspond to water bodies. Vegetation generally corresponds to smaller values, while built-up areas have values up to 0.2. NDWI is widely used in monitoring and studies of water bodies [18].

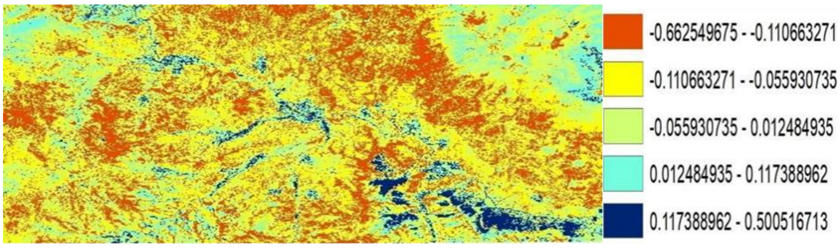


Fig. 8. NDMI raster map.

Discussion. The study confirmed that RS methods, particularly those utilizing multispectral images from the SENTINEL-2 satellite, are highly effective in monitoring and assessing changes in forested areas. These methods enabled the detection not only of changes in the forest cover, but also the identification of the factors driving these changes. The NBR index proved especially effective in clearly identifying areas affected by fires. By comparing pre-fire and post-fire images, the index allowed for the distinction of burned areas from healthy vegetation. Additionally, the NDVI was instrumental in revealing trends related to vegetation loss, while the NDMI provided valuable insights into changes in moisture levels across different periods. The study also highlighted the significant impact of industrial activities, particularly the expansion of Artsvanik tailings dam, on forested areas in the region. The results showed that the increasing size of the tailings dam has led to a notable reduction in forest cover, with serious ecological consequences for the surrounding environment. This underscores the importance of monitoring the interaction between industrial activities and natural ecosystems to inform conservation efforts.

Conclusion. The results of this study demonstrate that remote sensing methods enable effective and continuous monitoring of both natural and anthropogenic factors influencing forest ecosystems. The analysis of forested areas in the Syunik Region confirmed that the combined use of various remote sensing indices facilitates the identification and characterization of changes caused by forest fires, illegal logging, pest infestations, and industrial activities. The study’s findings highlight several key environmental concerns. First, analysis using the NBR index revealed that forest fires in the Syunik Region have significantly impacted vegetation, emphasizing the urgent need for restoration and replanting efforts to prevent soil erosion and long-term ecosystem degradation. Second, instances of illegal logging, particularly in the Goris and Kapan Forestry Regions, underscore the necessity of strengthening forest protection measures through enhanced monitoring systems and the integration of satellite data into forest management programs. Third, changes in vegetation moisture levels, as assessed using the NDMI, provide valuable insights into water availability and ecosystem health. Finally, a comparative analysis of satellite images confirmed that industrial activities, particularly the expansion of the

Artsvanik tailings dam, contribute to forest loss and degradation. These findings highlight the need to incorporate forest resource protection into industrial planning and to adopt comprehensive strategies to mitigate ecological risks. Overall, this study underscores the effectiveness of remote sensing as a tool for environmental monitoring and resource management. Future research should focus on refining these methods and integrating them into broader conservation and policy frameworks to enhance sustainable forest management.

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REFERENCES

1. Sayadyan H. *Spatial-temporal Changes and Management Issues of Forest Geosystems of the Republic of Armenia*. Yerevan, YSU Publishing House (in Armenian).
2. Sayadyan H. *Valuation of Mountain Forests: Case Study Armenia. Annals of Agrarian Science.* Republic of Georgia (2011).
3. Avetisyan G.D., Margaryan V.G., et al. Analysis of Forest Cover Changes in River Basins Flowing into Lake Sevan. *Proc. of the YSU. Geol. And Geograph. Sci.* **57** (2023), 157–162. https://doi.org/10.46991/PYSUC.2023.57.3.157
4. https://eos.com/landviewer/?lat=40.0&lng=45.0&
5. https://www.copernicus.eu/en/access-data/conventional-data-access-hubs
6. https://store.usgs.gov/
7. https://www.earthdata.nasa.gov/learn/earth-observation-data-basics/remote-sensing
8. Han L., Zhao Y., et al. Enhancing RS Image Super-Resolution with Efficient Hybrid Conditional Diffusion Model. *Remote Sens.* **15** (2023), 3452. https://doi.org/10.3390/rs15133452
9. Estrada J.S., Fuentes A., et al. Machine Learning Assisted Remote Forestry Health Assessment: A Comprehensive State of the Art Review. *Sec. Technical Advances in Plant Science* **14** (2023).
10. Kolokolova L., Kelley M.S.P., et al. Interaction of Electromagnetic Radiation with Cometary Dust. *Comets III* (eds. K.J. Meech, M.R. Combi, et al.). Tucson, Univ. of Arizona (2025), 621–651. https://doi.org/10.48550/arXiv.2501.03117
11. Main-Knorn M., Pflug B., et al. Sen2Cor for Sentinel-2. *Conference: Image and Signal Processing for Remote Sensing*er (2017). https://doi.org/10.1117/12.2278218
12. https://www.researchgate.net/figure/Characteristics-of-Sentinel-2-satellite_tbl2_332593787
13. Khan S.A., Gulfishan M., et al. Forest Cover Change Detection through Modern Applications and its Environmental Impacts. A Review. *International Journal of Ecology and Environmental Sciences* **4** (2022), 75–82.
14. Wang H., Jin B., et al. Effectiveness in Mitigating Forest Fire Ignition Sources: A Statistical Study Based on Fire Occurrence. *Fire* **5** (2022), 215. https://doi.org/10.3390/fire5060215
15. Alcaras E., Costantino D., et al. Normalized Burn Ratio Plus (NBR+): A New Index for Sentinel-2 Imagery. *Remote Sens*. **14** (2022), 1727. https://doi.org/10.3390/rs14071727
16. http://earth.google.com/
17. Jovanović M.M., Milanović M.M. Normalized Difference Vegetation Index (NDVI) as the Basis for Local Forest Management. *Pol. J. Environ. Stud.* **24** (2015), 529–535.
18. Shomko O., Davydova I. Assessment of Forest Vegetation Potential of Reclaimed Areas after Ilmenite Mining Using the Remote Earth Sensing Method. *EP* **9** (2024), 14–20. https://doi.org/10.23939/ep2024.01.014

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ԱՆՏԱՌԱՊԱՏ ՏԱՐԱԾՔՆԵՐԻ ՓՈՓՈԽՈՒԹՅՈՒՆՆԵՐԻ ՎԵՐԼՈՒԾՈՒԹՅՈՒՆԸ ՀԵՌԱԶՆՆՄԱՆ ՏՎՅԱԼՆԵՐԻ ՀԻՄԱՆ ՎՐԱ
(Սյունիքի մարզի օրինակով)

Ամփոփում

Հեռազննումը (RS) հնարավորություն է տալիս անտառային էկոհամակարգերի փոփոխությունների մոնիթորինգ իրականացնել առանց ֆիզիկական միջամտության: Սույն հետազոտության շրջանակներում ուսումնասիրվել են Սյունիքի մարզի անտառապատ տարածքների փոփոխությունները, որոնք պայմանավորված են անտառային հրդեհներով, ապօրինի անտառահատումներով և պոչամբարների ազդեցությամբ: Մշակվել և վերլուծվել են SENTINEL-2 արբանյակային տվյալները՝ օգտագործելով NBR (Normalized Burn Ratio), NDVI (Normalized Difference Vegetation Index), NDMI (Normalized Difference Moisture Index) ինդեքսները, ինչպես նաև իրականացրել տարբեր ժամանակ-ներում արված արբանյակային պատկերների համեմատում: Արդյունքները ցույց են տվել, որ հեռազննման մեթոդներն արդյունավետ են անտառային տարածքների փոփոխությունների բացահայտման և դրանց հետևանքների գնահատման համար:

С. Г. САРГСЯН, П. С. ЭФЕНДЯН

АНАЛИЗ ИЗМЕНЕНИЙ В ЛЕСНЫХ МАССИВАХ НА ОСНОВЕ ДАННЫХ ДИСТАНЦИОННОГО ЗОНДИРОВАНИЯ
(на примере Сюникской области)

Summary

Технологии дистанционного зондирования обеспечивают эффективный способ мониторинга изменений в лесных экосистемах без необходимости непосредственных полевых наблюдений. В данном исследовании изучаются изменения в лесных массивах Сюникского района с акцентом на воздействие лесных пожаров, незаконных рубок и хвостохранилищ. Спутниковые снимки SENTINEL-2 были обработаны и проанализированы с использованием нормированного коэффициента горимости (NBR), нормированного индекса разницы растительности (NDVI) и нормированного индекса разницы влажности (NDMI) для обнаружения и количественной оценки потерь и деградации растительности за различные периоды времени. Сравнительный анализ разновременных спутниковых данных выявил значительные изменения в лесном покрове, что подчеркивает эффективность методов дистанционного зондирования для выявления тенденций обезлесения и оценки экологических последствий. Полученные данные подчеркивают важность спутникового мониторинга для устойчивого управления лесами и их сохранения.