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Application of advanced processing of the remote sensing data on land use and land cover changes in Zangilan, East Zangezur

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Land use and land cover (LULC) changes covering the 32-year period during which the Zangilan region was occupied and liberated from occupation were carried out in this study. The process was compared using and classified open-source Landsat 4, 5, 8, 9, and Sentinel 2 data with 10-year periods, plus the data ingested after the liberation date. The discrete indexing method was developed and applied for this study. The method we applied was based on calculating various indices and their application in the classification process to increase accuracy. The indices we used include the Normalized Difference Vegetation Index (NDVI), Modified Normalized Difference Water Index (MNDWI), and Salinity Index (SI). The validity of the process has been checked using the SNAP ESA algorithm, based on Java Approximator, resulting in over 96.7% correct predictions using the testing dataset.

Keywords: *Land use and land cover, remote sensing, MNDWI, urbanization, vegetation, agriculture, salinity*

INTRODUCTION

Human societies are constantly transforming nature to obtain food, fibre, fuel, and other materials provided by ecosystems. Human activities have indirectly or directly impacted 83% of the earth's surface (Sanderson et al., 2002). These land use/land cover (LULC) changes are associated with resource availability, climate fluctuations, and a wide variety of socioeconomic factors (Lambin et al., 2003). LULC use change, or simply land change, is a term used for the changes that human beings have brought about on the earth (Erle and Pontius, 2007). Changes in land cover and land changes can negatively affect sustainability in the ecosystem, and human activities are considered one of the most important factors that can accelerate this process (Agarwal et al., 2001). Therefore, it is important to identify any temporary land-use changes and establish plans and a suitable management strategy based on the obtained results.

The advancement of science and space technology has increased access to fast, reliable, up-to-date, and analyzable information is more reachable. Nowadays, Remote Sensing (RS) and Geographic Information Systems (GIS) are used to detect LULC changes. RS and GIS are among the most effective methods used to monitor LULC use changes.

MATERIALS AND DATASETS

The Zangilan region was chosen for the application of our method. The region is located along the Okhchuchay river, 39°03′56″ N/46°41′49″ E (Google Earth, 2022).

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Fig. 1. Landsat 8, June 2020 Satellite imagery of the AOI

The data obtained due to research purposes, and the feature of the high frequency of revisit time, enable the production of geographic information on local and regional scales. In this research, Landsat 4, 5, 8, and 9 images from June 1990, June 2000, August 2010, June 2020, and July 2022, and Sentinel 2 images from June 2020 and July 2022 were used, respectively.

Using these data sources, users interested in subject areas including land management, agro-based conditions, hydrology, nature reserve and vegetation, black carbon, natural resource management, and global agricultural monitoring can modify and alter the information.

The Sentinel Application Platform (SNAP) architecture is used for Earth observation (EO) processing and analysis. The SNAP architecture is optimal for processing and analyzing Earth observation (EO) data due to its extensibility, modular platform, portability, tiled memory management, generic EO data abstraction, and graph processing framework. SNAP and the other Sentinel Toolboxes support several other sensors in addition to Sentinel sensors. The SNAP user tool is made available to the Earth Observation Community without charge by ESA/ESRIN. Considering the mentioned characteristics, the SNAP architecture and the Sentinel 2 datasets provide excellent analytical research and procedures opportunities.

METHODS

Pre-processing: Graph Builder feature of the SNAP architecture has been used in Image pre-processing which consists of the following steps: uploading supported files, reprojecting each data using Optical Sentinel 2 Reprojection tool, resampling each dataset, and masking out the study area (Fig. 1**)**

Indices: The method we apply is based on calculating various indices and their application in the classification process to increase accuracy. The indices we used include the Normalized Difference Vegetation Index (NDVI), Modified Normalized Difference Water Index(MNDWI), and Salinity Index.

Normalized Difference Vegetation Index: A prevalent and commonly utilized remote sensing index is the NDVI (Bhandari, Kumar, & Singh, 2012). The TOA reflectance of a red band at 0.66 m and a near-infrared (NIR) band at 0.86 m are used to determine NDVI. While water and built-up regions will be represented by near-zero or negative values, the NDVI of a highly vegetated area will lean toward positive values (**Fig. 2**). Orderly, NDVI is given as (Braun and Herold, 2004):

$$\mathbf{NDVI} = \frac{\boldsymbol{\rho}_{\mathbf{nir}} - \boldsymbol{\rho}_{\mathbf{red}}}{\boldsymbol{\rho}_{\mathbf{nir}} + \boldsymbol{\rho}_{\mathbf{red}}}$$

Modified Normalized Difference Water Index: The Modified NDWI (MNDWI) can effectively reduce or even eliminate build-up texture noise, plant noise, and ground noise while enhancing open water characteristics. Therefore, the area of the water samples is exaggerated. This is because the increased water information on the NDWI often masks noise from buildings. MNDWI uses green and SWIR bands to enhance open-water functionality. It also reduces the characteristics of urban areas that often correlate with open water in other indicators (Xu, 2006). The MNDWI has the advantage of reducing and even eliminating constructed land noise over the NDWI, making it ideal for augmenting and extracting water information for bodies of water dominated by background-constructed land areas (**Fig. 3**).

$$MNDWI = \frac{\rho_{Green} - \rho_{SWIR}}{\rho_{Green} + \rho_{SWIR}} = \frac{\mathbf{B3 - B12}}{\mathbf{B3 + B12}}$$

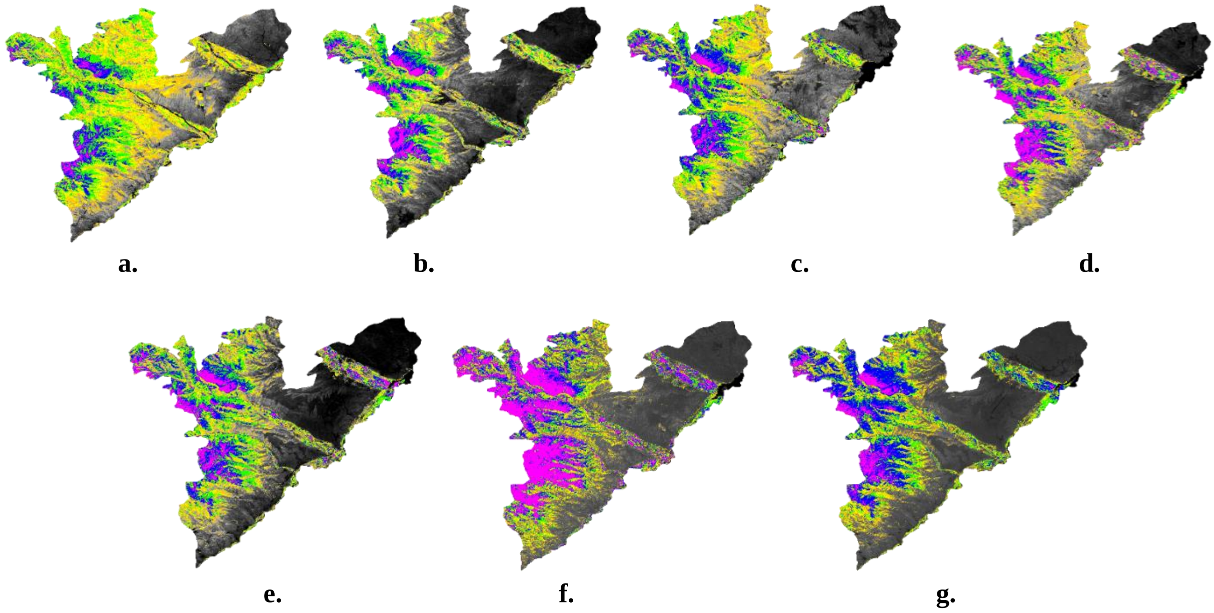


Fig. 2. NDVI visualisation of Landsat 4, 5, 8, 9; a) June 1990, b) June 2000, c) August 2010, d) June 2020, e) July 2022, Sentinel-2; f) June 2020, g) July 2022

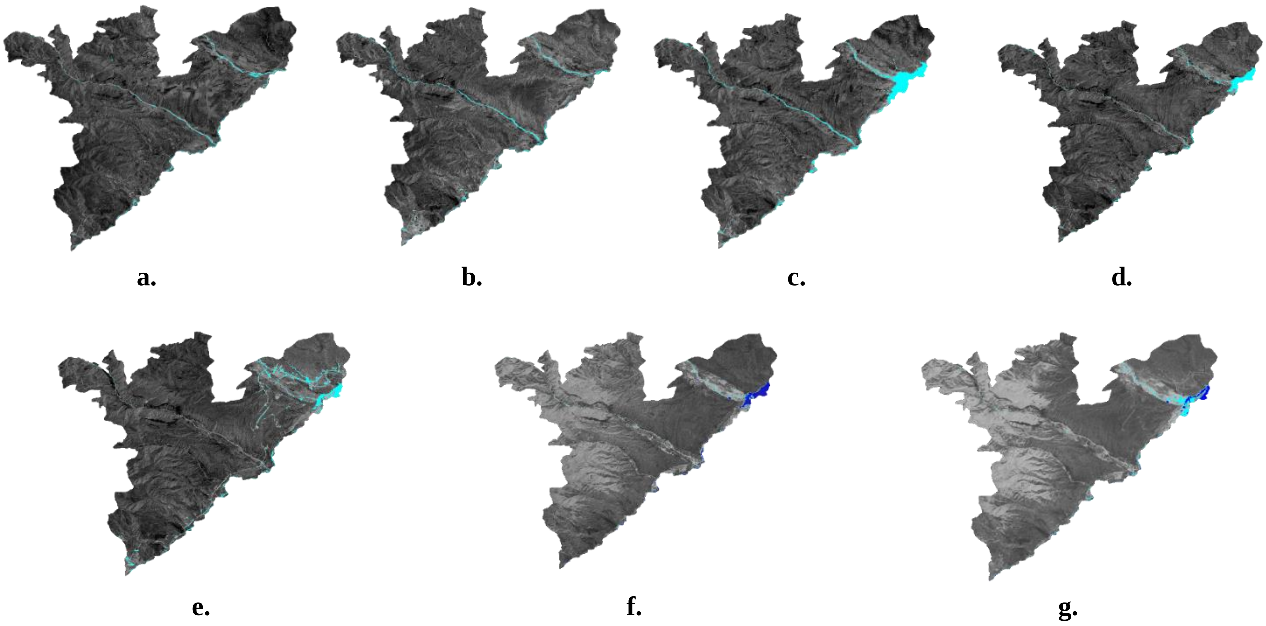


Fig. 3. MNDWI visualisation of Landsat 4, 5, 8, 9; a) June 1990, b) June 2000, c) August 2010, d) June 2020, e) July 2022, Sentinel-2, f) June 2020, g) July 2022

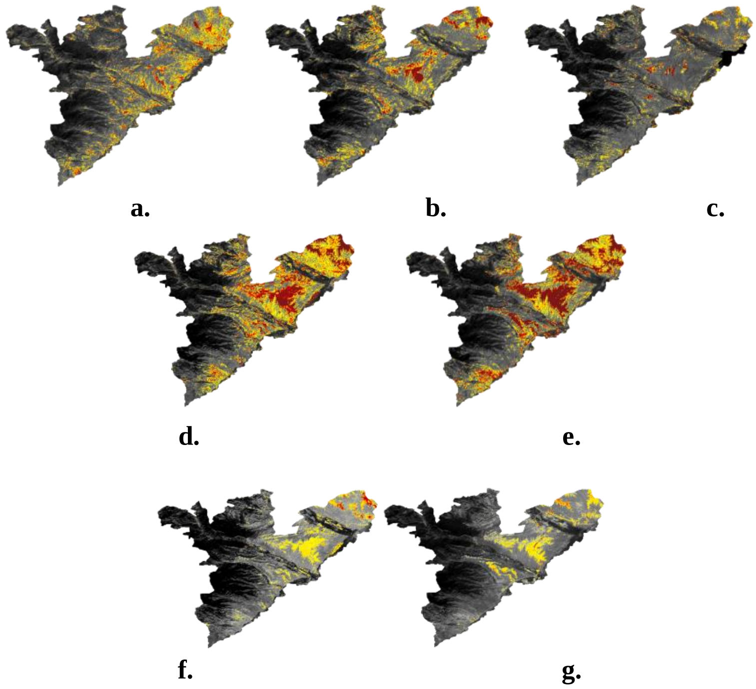


Fig. 4. SI visualisation of Landsat 4,5,8,9; a) June 1990, b) June 2000, c) August 2010, d) June 2020, e) July 2022, Sentinel-2, f) June 2020, g) July 2022

Salinity index: The lack of vegetation can be an indirect indication of the presence of salt in the soil. Saline soils are often characterized by poorly vegetated areas (Fig. 4). The salinity index is the ratio of the red band to the near-infrared (NIR) band (Dehni and Lounis, 2012). The salinity index is calculated as follows:

$$SI = \frac{B3 * B4}{2}$$

Classification: Classification is the method of analyzing multiple images or bands that are georeferenced to each other and bringing together the ones with similar statistical properties in these images into groups. As a result of classification, image data with a certain number of thematic classes are obtained.

Due to our purpose, we applied Random Forest (RF) classification method provided by the SNAP ESA architecture. The method we applied is based on the calculation of various indices and their application in the classification process in order to increase accuracy. The indices we used include the Normalized Difference Vegetation Index (NDVI), Modified Normalized Difference Water Index (MNDWI), and Salinity Index (SI). The validation of the technique has been checked using the SNAP ESA algorithm, and the results are over 96.7% correct using the testing dataset.

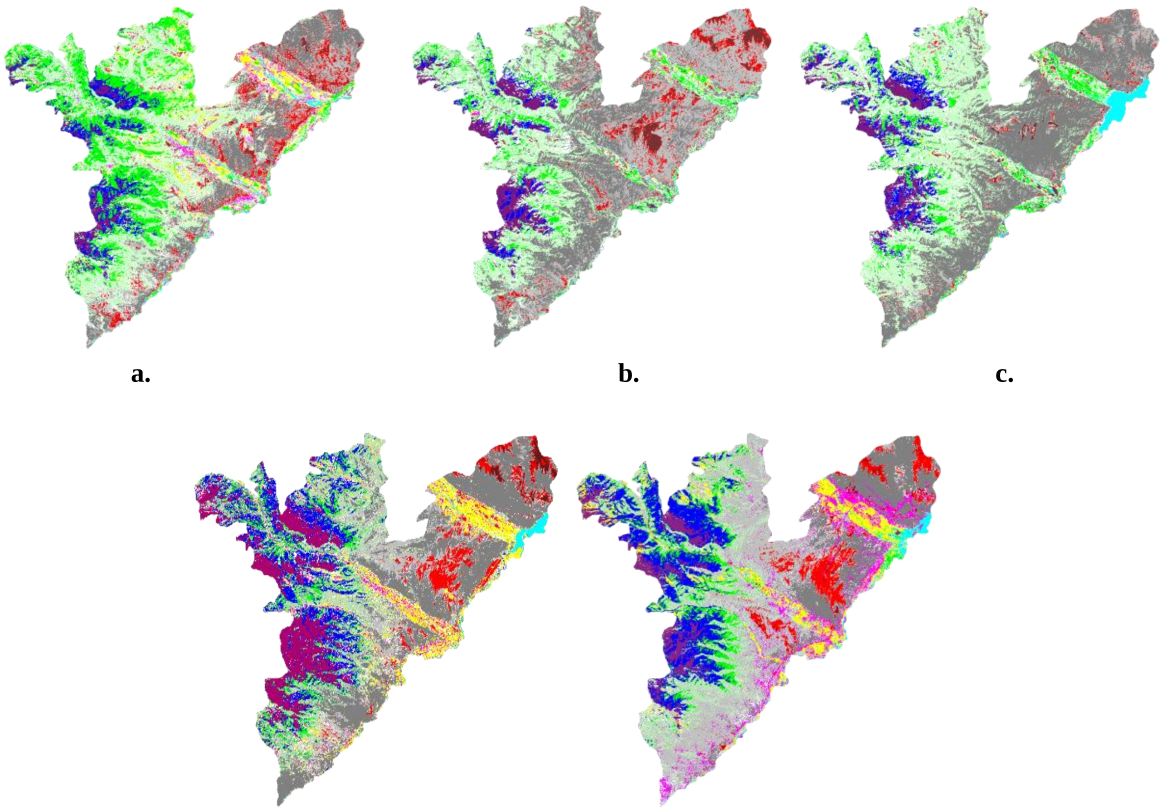
RESULTS

Table 1. Color manipulation of the results

no data	
urbanization	
salinity	
severe salinity	
light bare soil	
dark bare soil	
agricultural vegetation	
shrubland	
sparse forest	
mid-density forest	
higher density forest	
water stream	

According to the color distribution of the classification stated above (Table 1.), between the pre-occupation and 2000 data, the dramatic change observed in urbanization due to the deportation of the local population is evident. In the visualization of the data of the year 2000, we can observe the replacement of agriculture by natural vegetation. However, there is also a rapid decline in natural vegetation in the area.

Given the decline in the urbanization index during that period, massive deforestation by Armenia to use natural wood as an energy source is the only satisfactory explanation (Fig. 5).



a. b. c.

d. e.

Fig. 5. The map represents LULC results of Zangilan a) 1990 b) 2000 c) 2010 d) 2020 e) 2022

After the Khoda Afarin dam, which construction began in 1999, began to inaugurate in 2008 (UNDP/GEF, 2013), a slight positive change in agriculture is noticeable. This can be seen in the controlled distribution of greenery in riverside areas and the observed intra-network trends in greenery.

However, in the period 2010-2020, the degree of salinity in the area increased rapidly. Deforestation and unplanned irrigation / fertilization are considered the main causes of this phenomenon. Although the development of agriculture has increased slightly in the last 10 years, the indicators of urban infrastructure in populated areas remained low due to the vandalism of already-built settlements. On the other hand, we can notice a considerable positive change (from 2% to 6%) in urbanization when we compare the results between the years 2020 and 2022 which was before and after the liberation.

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Şərqi Zəngəzurun Zəngilan rayonu ərazisində torpaqdan istifadə və torpaq örtüyü dəyişiklikləri üzrə məsafədən zondlama məlumatlarının tətbiqi

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Təqdim olunan tədqiqatda Zəngilan rayonu ərazisində işğaldan əvvəl, işğal ərzində və işğaldan azad edildikdən sonra 32 illik dövrü əhatə edən Torpaqdan İstifadə / Torpaq Örtüyü dəyişiklikləri siniflendirilərək analiz edilmişdir. Proses açıq mənbədən əldə edilmiş 10 illik müddətə sahib Landsat 4, 5, 8, 9 və Sentinel 2 məlumatlarından istifadə edilərək müqayisə və təsnif edilmişdir. Bundan əlavə, işğaldan azad edilmə tarixindən sonra bir illik dövrlə iki ilin nəticələri də analiz edilmişdir. Sinifləndirmə prosesinin dəqiqliyini artırmaq məqsədi ilə diskret indeksləmə metodundan istifadə edilmişdir. Bu metod müxtəlif indekslərin hesablanmasına və dəqiqliyi artırmaq üçün onların diskret sinifləndirilmə prosesində tətbiqinə əsaslanır. İstifadə edilmiş indekslərə Normallaşdırılmış Fərq Bitki Örtüyü İndeksi (NDVI), Modifikasiya edilmiş Normallaşdırılmış Fərq Su İndeksi (MNDWI) və Şoranlaşma İndeksi (SI) daxildir. Prosesin etibarlılığı "Java Approximator"-a əsaslanan "SNAP ESA" alqoritmi ilə yoxlanılıb və nəticədə test məlumat dəstindən istifadə etməklə 96,7% etibarlılıq proqnozu əldə edilib.

***Açar sözlər**: Torpaqdan istifadə və torpaq örtüyü, məsafədən zondlama, MNDWI, urbanizasiya, yaşıllıq, kənd təsərrüfatı, şoranlaşma*

Применение усовершенствующей обработки данных дистанционного зондирования земли по землепользованию и изменениям растительного покрова в Зангиланском районе Восточно-Зангезурской области

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В настоящей работе были классифицированы и анализированы изменения в землепользовании и растительном покрове, охватывающие 32-летний период, в течение которого Зангиланский район был оккупирован и освобожден от оккупации. Процесс сравнивался и классифицировался с использованием открытых спутниковых данных, таких как Landsat – 4, 5, 8,9, Sentinel – 2 с десятилетним периодом. Кроме того, к анализу были привлечены результаты однолетних и двухлетних наблюдений после освобождения от оккупации. Для повышения точности процесса классифицирования был разработан и применен метод дискретного индексирования. Используемый нами метод был основан на расчете различных индексов и их применении в процессе классификации для повышения точности. Эти индексы включают нормализованный разностный индекс растительности (NDVI), модифицированный нормализованный разностный водный индекс (MNDWI) и индекс солености (SI). Достоверность процесса была проверена с использованием алгоритма SNAP ESA на основе Java Approximator, в результате чего было получено более 96,7% правильных прогнозов с использованием тестового набора данных.

Ключевые слова: *Использование земель и структура землепользования, дистанционное зондирование, модифицированный нормализованный разностный водный индекс (MNDWI), урбанизация, растительность, сельское хозяйство, соленость*