Classification of seasonal dynamics of soil moisture according to satellite data Sentinel-2, Jizzakh region, Uzbekistan

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Abstract. Regular analysis of soil moisture is important for assessing the condition of soil fertility for adaptation to climate change, for the subsequent determination of the reasons for the deterioration of soil conditions, and for the preservation of sustainable agricultural development. Traditional field methods for studying land are laborious and costly. The aim of this scientific work is to develop an effective methodology for using Sentinel-2 satellite data to analyse changes in the condition of land moisture in the Republic of Uzbekistan, using the example of the pilot region under study in the Jizzakh region. The proposed methodology can be adapted in other regions for the effective monitoring of land resources. To conclude, the process of planning and organizing work on the conservation of crops is greatly simplified. It can be possible to save tens of thousands of hectares of highly productive land in agricultural circulation.

1 Introduction

Currently, for agriculture, capturing satellite images of individual fields, regions, and districts with a certain cycling period is one of the most applicable approaches.

Considering the possibility of obtaining information about the state of the soil, including recognition of crops, determination of the acreage of agricultural land, and the condition of crops, is an innovative approach in this area. Satellite data are used to manage and monitor agricultural performance at different levels [13]. This data is used to optimize farming and space-based management of technical operations. Satellite images significantly help to determine the location of crops and land depletion, and can then be used to develop

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and implement a land reclamation plan to improve the use of agricultural chemicals [2]. The statistics are known as NDWI, or Normalized Water Difference Index, which is usually calculated using data from optical remote sensing of the Earth. Normalized values of the near-infrared and vortex ranges were used to determine it. It is based on the high reflectivity of vegetation in certain bands, and changes in leaf moisture affect this indicator. In the same year, another MNDWI approach to land assessment was developed [13]. The processed Sentinel-2 data can be used as input parameters for the next Agro modelling chain, an open-access program such as DSSAT promoted in Central Asia to improve sustainable farming, increase profitability, reduce losses, and predict climate change adaptation [11].

2 Materials and methods

2.1 Study area

2.1.1 Location and its characteristics

The Jizzakh region is located between the Syr Darya and Zarafshan rivers in the central part of Uzbekistan, bordering the Republic of Kazakhstan and the Syr Darya region in the north and northeast, the Republic of Tajikistan in the southeast, Navoi and Samarkand regions in the west and southwest (Figure 1). The region's total territory is 21.2 thousand km^2, or 4.8 % of the territory of Uzbekistan [3].

At the northern foot of the Nuratau Mountains, in the southern part of the Mirzachul steppe, 180 km southwest of Tashkent, 90 km northeast of Samarkand, the region's regional centre, the region, the city of Jizzakh, is located on the Sanzar River. The town of Jizzakh borders this area with the Jizzakh and Gallaaral regions [12].

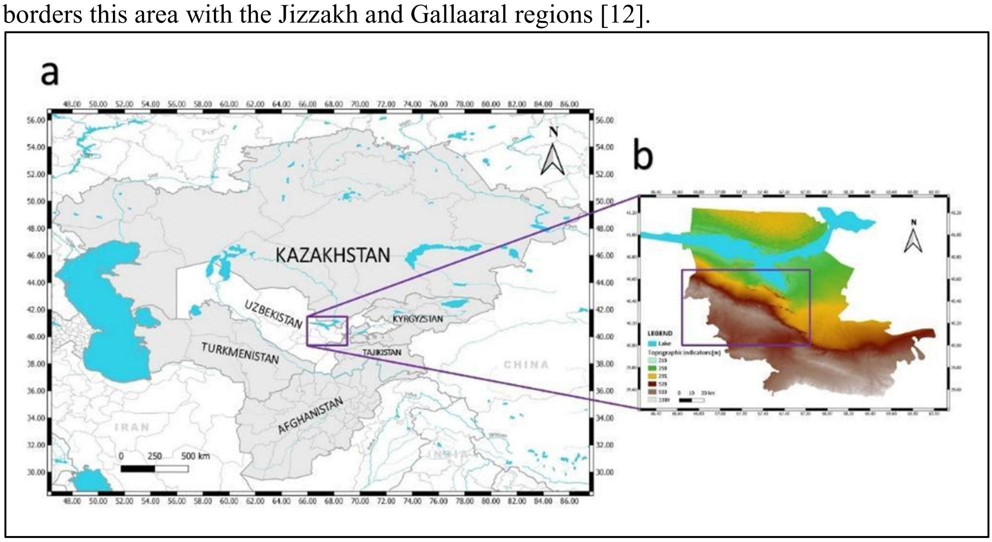

Fig. 1. a) Map of Central Asia and Afghanistan, b) Map of the study site Jizzakh region, the area marked in red, shows the position of the study area - an image built using Topographic Maps of the World (n30e060) ([16]).

The climate of Jizzakh is considered to be moderately warm, and continental, with dry and warm summers and relatively cold winters. The average annual temperature is +15.6 °C (Figure 2). The average temperature ranges from +1 to +4 °C in January and from +26 to +28 °C in July. There is little rainfall throughout the year, with an average of 400-500 mm and an average annual rainfall of 370 mm. In summer, the growing season lasts 240-260 days, air humidity is from 78 to 80 %: from 20 to 40 % [14].

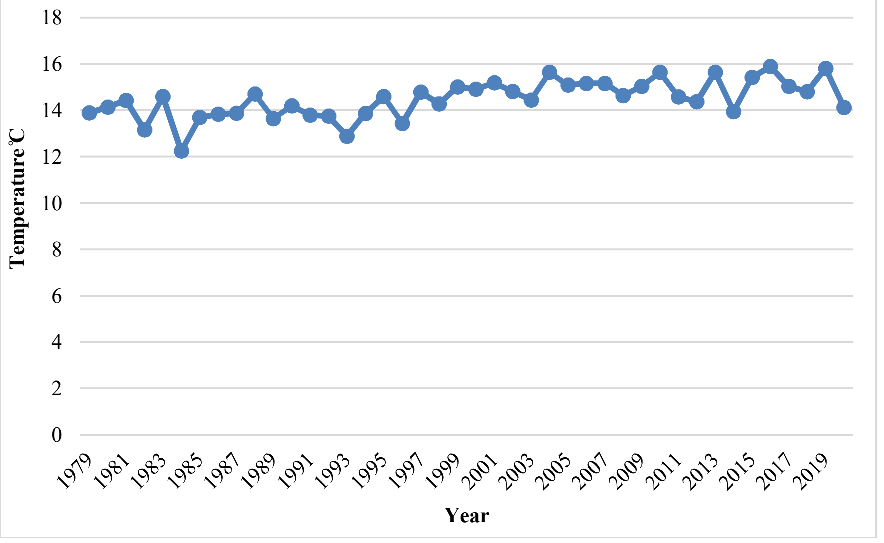

Fig. 2. Average air temperatures in the Jizzakh region for the period 1979-2020 (built from electronic data [9]).

2.1.2 Soils

Gray earth-meadow soils are widespread in the territory under consideration, mainly in the flat proluvial plain of the peripheral parts of the merged alluvial fans, the middle part of the Zominsu river alluvial fan and the lower part of the proluvial plain of the Lomakino Plateau. These soils are developed under conditions of soil moisture and are close to several hydromorphic soils [10]. Serozem-meadow soils, in comparison with meadow-serozem soils, are characterized by increased soil moisture, high hydromorphism, and a more intense accumulation of salts. The morphological profile shows increased meadows, stretching of the humus horizon, better structure, compaction, the presence of signs of restored processes from a depth of 1-1.5 m or more, and an intense manifestation of solonchak processes [10].

According to the data of the State Committee of "Landgeodezcadastre" of the Republic of Uzbekistan for 2015, the following information is provided on the salinization of soils in the Jizzakh region: 47 % of the land is slightly saline, 35 % of the land is moderately saline, and 18 % of the land is subject to severe salinization [1].

2.1.3 Water resources

In the Jizzakh region, the water resources of the Zarafshan - the South Mirzachul main canal and the Syr Darya are used for various purposes. There are 4 water reservoirs built artificially in the region with a total displacement of about 219.0 million m3 [12].

2.1.4 Agriculture

The Jizzakh region has vast land plots - an important factor in agricultural production. Thus, out of 2.05 million hectares of land, 1.3 million hectares are used for agriculture, 0.8 million hectares are allocated for pastures and 390.5 thousand hectares are sown (grain, cotton, melons, vegetables, and orchards) [17].

The Bakhmal district alone accounts for 16.1 % of the total agricultural, forestry, and fisheries production in the region, and is the leader in the districts with 14.6 % and 11.1 %, respectively, in the Gallaaral and Zomin districts. Jizzakh city (2.5 %) and Yangiobod district have the lowest rate (2.9 %) [4].

The growth of agricultural production from January to September 2019 amounted to 102.7 % compared to the same period last year, including 100 % of agricultural production and 104.3 % of livestock production [4].

An analysis by category of farms shows that the share of peasant (personal subsidiary) farms accounts for 77.0 % of the total agricultural production, 21.9 % - of farms, and 1.1 % - of organizations engaged in agricultural activities [4].

2.2 Input data

The purpose of the article is to determine the seasonal dynamics of the humidity of the open surface for various types of soil cover in the irrigation zone of Jizzakh, Uzbekistan.
- to study the current state of the irrigation system in the agricultural sector;
- to study the advantages of using Geographic Information System (GIS) technologies in agriculture and creating terrain maps.

The Sentinel-2 imagery covering the western part of the Jizzakh Irrigation Zone published by the US Geological Survey was obtained from the web service: United States Geological Survey [16]. Selected data packages were for the following periods: April 5, 2018, May 25, 2018, June 24, 2018, and July 24, 2018.

The Copernicus Sentinel-2 mission includes a constellation of two polar-orbiting satellites located in the same sun-synchronous orbit, phased at an angle of 180° to each other [13]. Earth surface monitoring is performed with a bandwidth of 290 km, a revisit time of 10 days at the equator with one satellite, and 5 days with 2 satellites in clear conditions, resulting in 2-3 days at mid-latitudes. Sentinel-2A has an MSI scanner (multichannel, 13 channels: visible - shortwave infrared, λ=0.4÷2.3 nm, spatial resolution 10.20 m [5].

Thus, the major crop in the area is wheat, so it is provided as an example, and maps based on Sentinel-2 images and land cover samples were created with the assistance of the Quantum Geographic Information System (QGIS) program.

The results are applicable to hydrological, landscape, and environmental studies.

2.3 Methods

The main discovery is the structure of crop fields, which had a special irrigation regime, different from other types of soil cover.

We analysed the data of the Sentinel-2A apparatus, MSI scanner (multichannel, 13 channels: visible - shortwave infrared range, λ=0.4÷2.3 nm, spatial resolution 10.20 m), obtained from the website of the European Space Agency [7].

The water index MNDWI is calculated using the formula:

$$MNDWI = \frac{(GR-SWIR)}{(GR+SWIR)} \tag{1}$$

where: GR - spectral brightness in the wavelength range 510-600 nm (green range). SWIR - spectral brightness in 1500-1600 nm (shortwave infrared range).

MNDWI is used to monitor changes in water content in water bodies. Since water bodies strongly absorb light in the visible and infrared electromagnetic spectrum, MNDWI uses green and NIR to identify water bodies [6].

In the scientific work, rural fields were selected for the study. Satellite imagery from Sentinel-2 was utilized over the period from April to July 2018.

2.4 Location of key sites

Following the classification applying the MNDWI, Normalized difference vegetation index (NDVI) indices, 4 main types of the surface were distinguished in the study area (Figure 3): natural grass cover (67.6 %), agricultural land (23.1 %), land plots (3.9 %) and water surface (5.4 %).

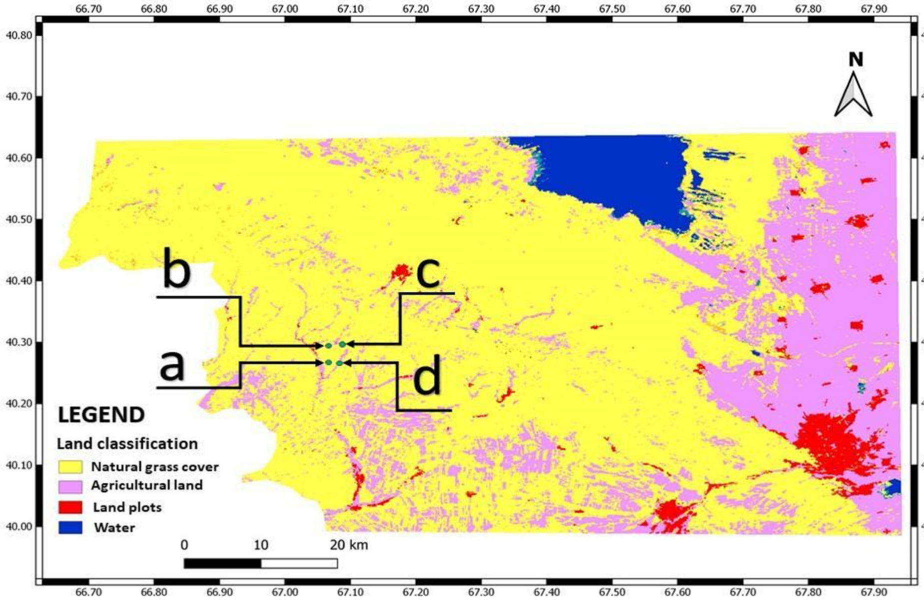

Fig. 3. Map of surface types [8]. Field research sites are marked at points a, b, c, d: a) the photograph is shown in Figure 4; b) the photograph is shown in Figure 5; c) the photograph is shown in Figure 6; d) the photograph is shown in Figure 7

The key site (a) corresponds to a natural grassy surface; the key site (b) corresponds to a natural grassy surface; the key site (c) is located on a natural grassy surface; the key site (d) is located on an agricultural field.

3 Results

3.1 Surface classes

The third Figure reveals the classification of the study area according to the first colour fields of the crops that they describe (Figure 4, Figure 5, and Figure 6).

The second class is agricultural fields, an overview of which is shown in Figure 4. In the example of a wheat field.

Fig. 4. Pastures of Gallaaral district of Jizzakh region, date of image 07.10.2020, coordinates 40°00'42.0"N 67°23'23.9"E (Source: [Compiled by the authors]).

Camel thorn is considered to be the main vegetation in the region. The roots of these plants are far deeper and therefore they grow well in such areas. This type of thorn in green form serves as food for small cattle. Camel thorn can also be harvested and left for the winter, it can serve as fodder for cattle in winter, and also as firewood.

Fig. 5. Vegetation of the Gallaaral district of the Jizzakh region, image date 07.10.2020, coordinates 40°00'54.0"N 67°23'40.6"E (Source: [Compiled by the authors]).

As above aforementioned, camel thorn grows well even on roadside pastures. Figure 5 reveals how this plant has adapted well even along the roadway.

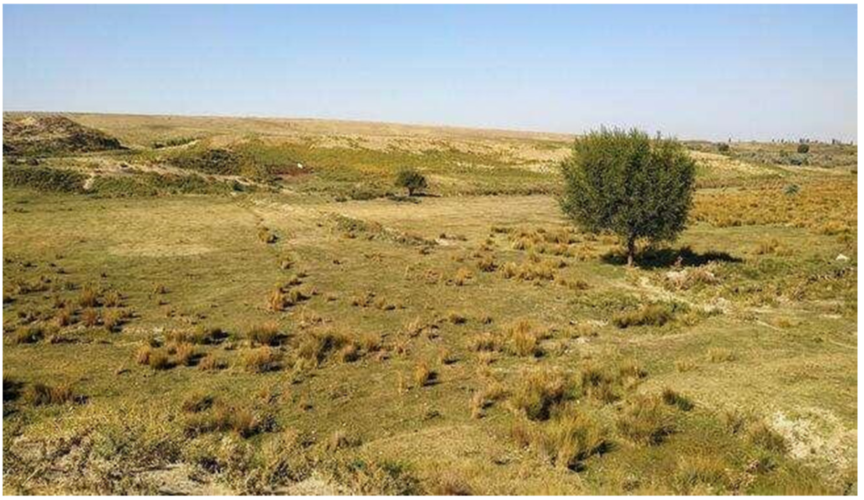

Fig. 6. Pastures of Gallaaral district of Jizzakh region, date of image 07.10.2020, coordinates 40°00'17.5"N 67°23'21.6"E (Source: [Compiled by the authors]).

In Figure 6, it can be observed the pastures of the Gallaaral district of the Jizzakh region. These lands can also be utilized for animal husbandry.

Fig. 7. Wheatfields (mowed), photo date 07.10.2020, coordinates 40°01'29.9"N 67°23'05.1"E (Source: [Compiled by the authors]).

Figure 7 delineates wheat fields. Wheat fields are the main type of agricultural crop in the study area.

This picture supplied demonstrates the picture after the harvest and the closure of all irrigation systems. The green plant shown in the picture is called "Camel Thorn" and plays a large role in the ecosystem of the area, as it assists to retain moisture in the soil.

3.2 Ranges of MNDWI values

The preliminary results of the study reveal that the results of the analysis showed a range of values from -0.67 to 0.14. It was found that the minimum values correspond to dry surfaces. Positive maximum values correspond to open surfaces. The latter corresponded to agricultural areas with seasonal fluctuations (Figures 8, 9, 10, and 11).

Figures 8, 9, 10, and 11 show all monthly changes in the histogram results.

In the bar charts, we can see all the details about the changes at each time of the month. Statistical distributions of the MNDWI. The final results are histograms. Here, alterations in the quality of the field can be observed in the study area.

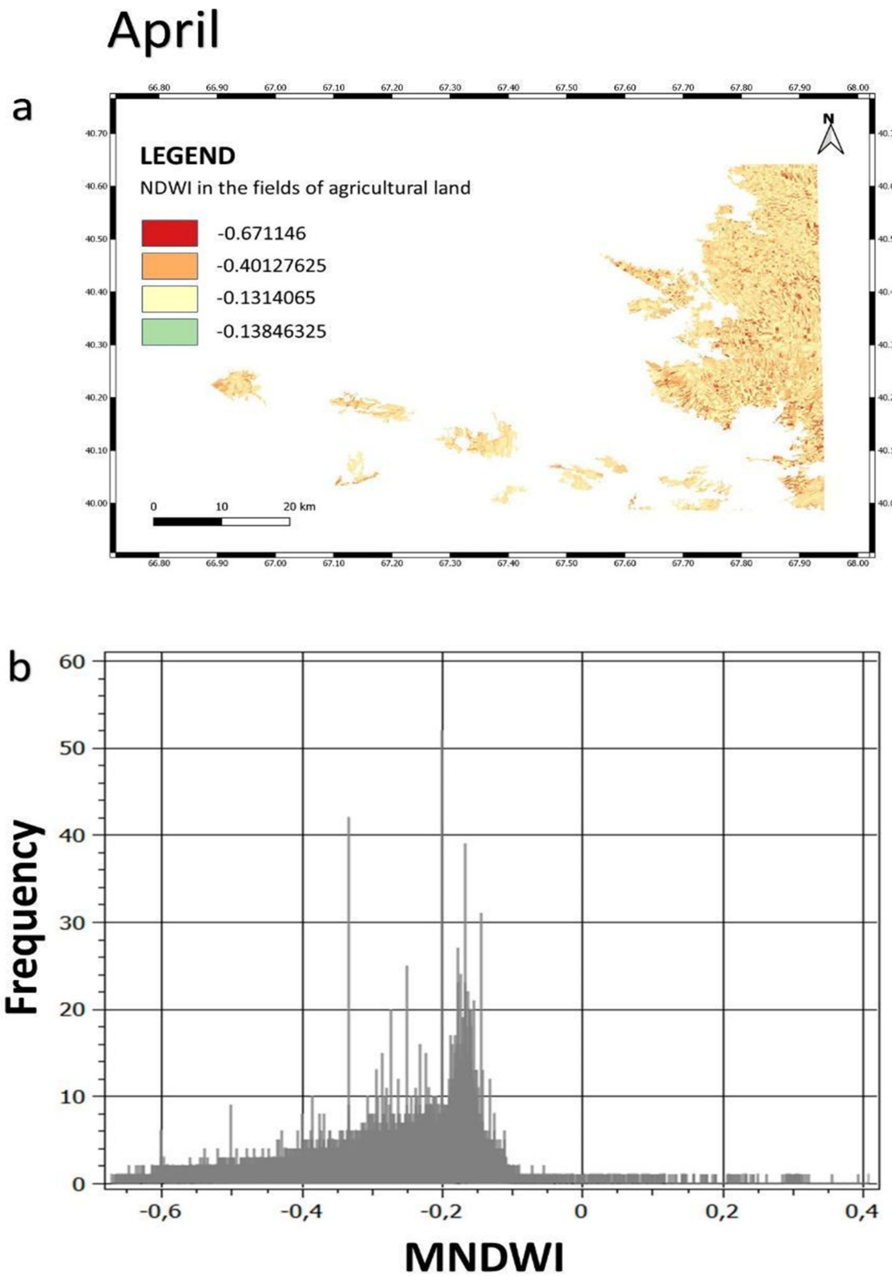

Fig. 8. a) Types of agricultural coverage in April 2018. b) The result of the histogram in April 2018 (Source: [Compiled by the authors]).

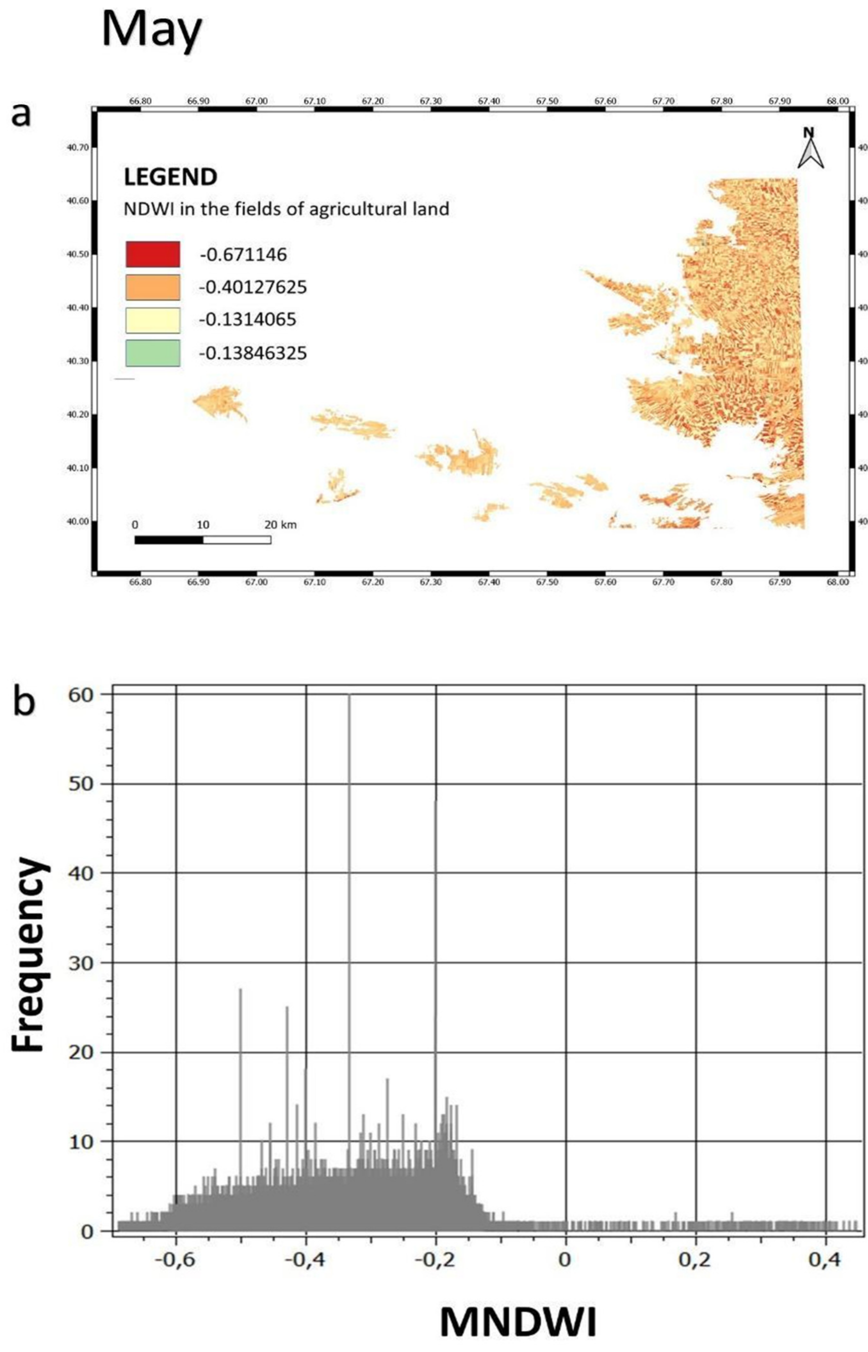

Fig. 9. a) Types of agricultural coverage in May 2018. b) The result of the histogram in May 2018 (Source: [Compiled by the authors]).

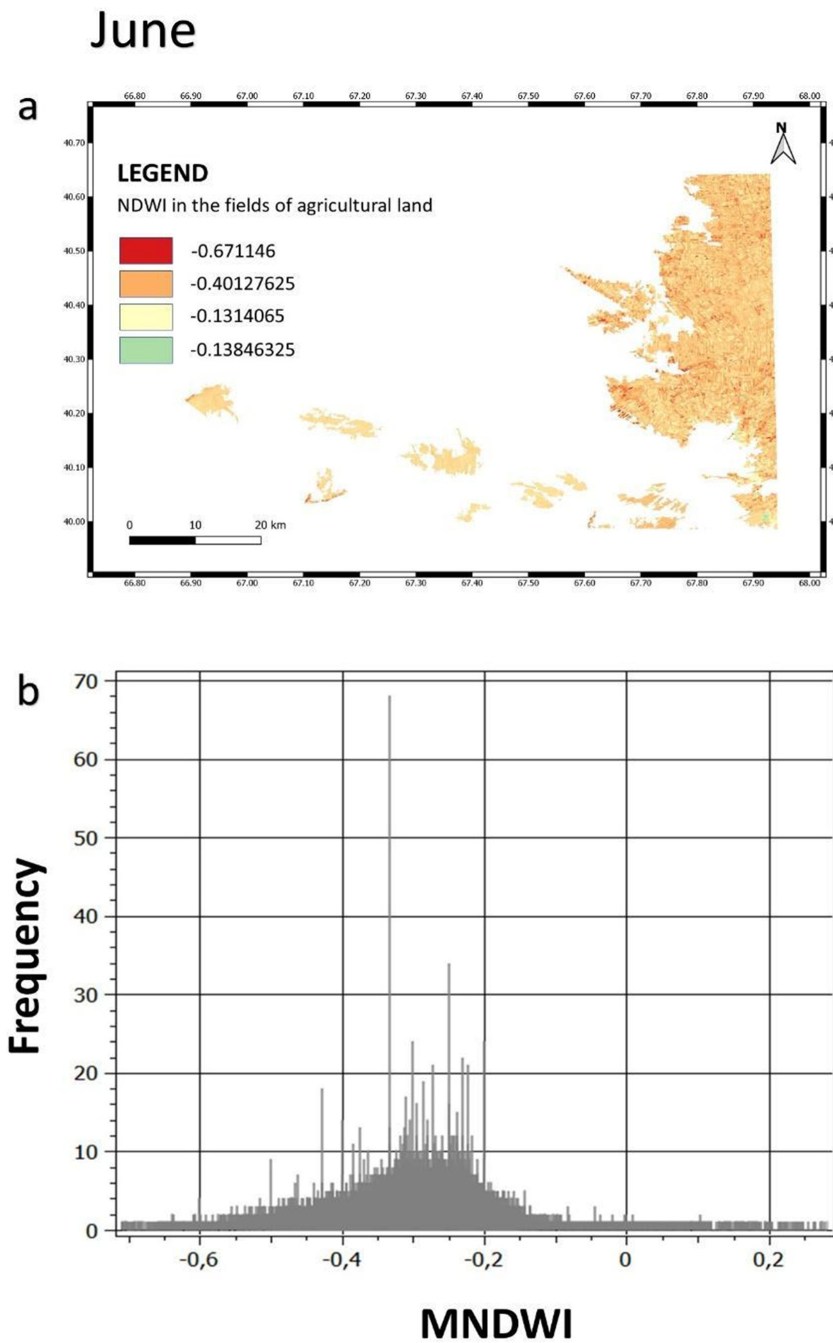

Fig. 10. a) Types of agricultural coverage in June 2018. b) The result of the histogram in June 2018 (Source: [Compiled by the authors]).

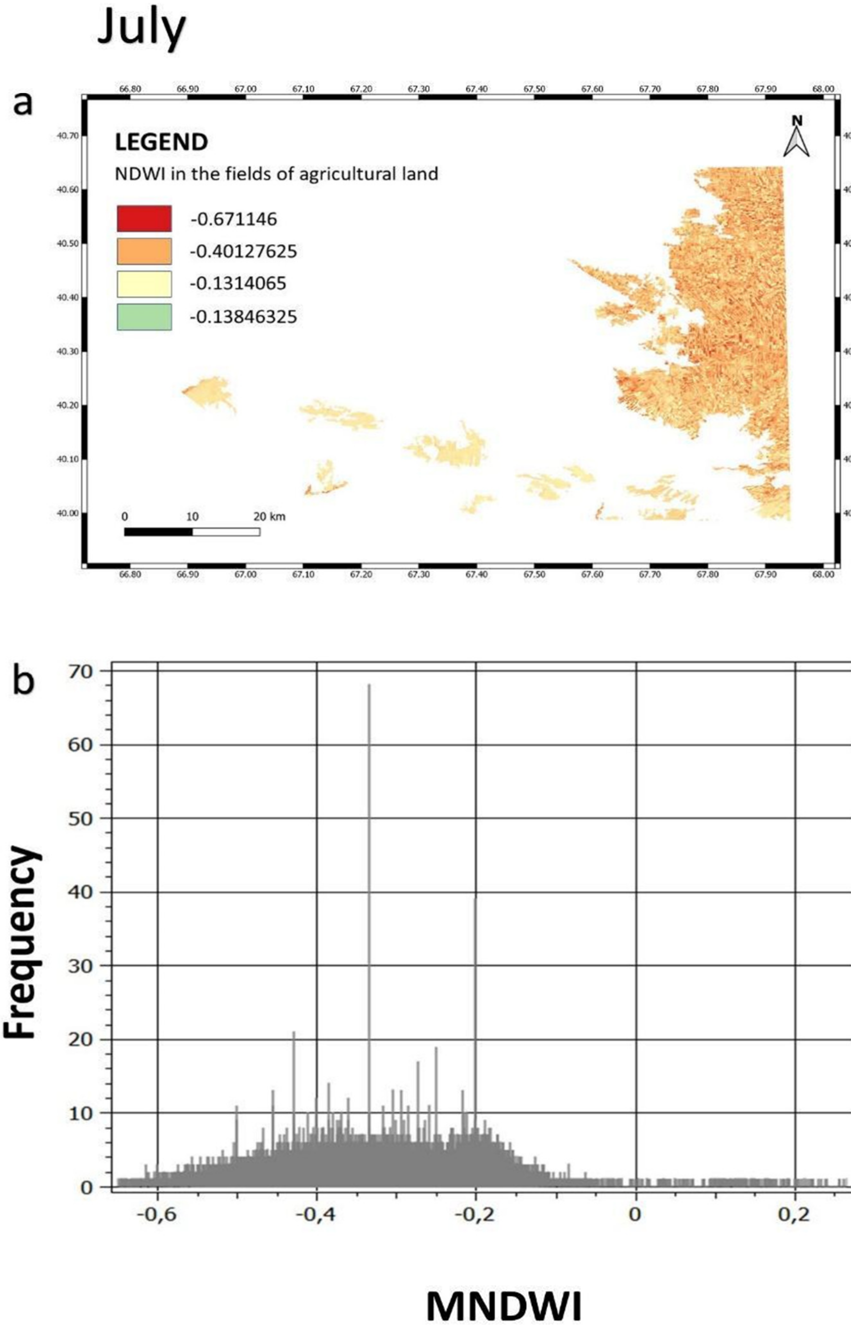

Fig. 11. a) Types of agricultural coverage in July 2018. b) The result of the histogram in July 2018 (Source: [Compiled by the authors]).

Wheat sowing in the area begins in March. Thus, we can see that there is no water requirement in Figure 8a since this map is based on the April 5 Sentinel-2 image and the image shown here does not require water. This is because wheat is planted in the last decade of March. Figure 8b shows this month's histogram with maximum pixel points of -

0.2 and -0.1. And in May 2018, which coincides with the growing season, which can be seen in Figure 9a. In this picture, you can tell that the farmland is coloured red. In Figure 9b, similar pixel ratios from -0.6 to -0.16 may be seen, because a significant part of the growing season falls in May. June is the time to re-irrigate wheat, as the wheat is already harvested next month. In Figure 10a we can see that the MNDWI is averaging and in Figure 10b we see that it is and we can see a similar result in April which is after the growing season. In July, they harvest and prepare the land for a new crop. In Figure 11a it can be seen that the water demand in the region is very low as the harvest will be completed by the third decade of July and the bottom part of the wheat remains on the plot and this part can be used as winter feed for sheep and goats. Moreover, according to the Figure , the MNDWI of this area is normal, and the histogram in Figure 11b reveals the result.

The results delineated a significant change in water surfaces over the considered time intervals. Their values on agricultural land varied significantly between April and August. The increase in the values of the water surface on them was associated with the irrigation of wheat fields. The predominance of land with MNDWI values below 0 in April corresponds to the time of land cultivation before its growth phase.

4 Discussion

They were prepared for flooding due to their irrigation regime, as mentioned earlier by other researchers. As can be seen from Figure 9, there was a lack of water in May, since the growing season of wheat falls on this month. Since, in the second decade of June, the crop was harvested, the water demand dropped sharply, as can be seen in Figure 11a.

The irrigation regime of dense grassy lands differs from arable lands and demonstrates an increase in vegetation and a decrease in the humidity of open surfaces from April to July. The acreage was also heavily overgrown with vegetation, and due to seasonal changes, they increased in the period from April to July. The restoration of agricultural areas is mentioned as important for improving the quality of life of the population and their socio-economic status [13]. Moreover, agricultural areas could be used as a source of ecosystem services for the population such as provision, the type of soil cover mainly occupied open or less vegetated land, and most pixels had values below zero, with some areas with high vegetation.

The irrigated lands have not undergone any special changes, since they were sown with vegetation on the dates under consideration. Rare herbaceous types of soil cover were mostly without vegetation and had low values. The lands corresponded to vegetation. Rivers and lakes were well reflected with the maximum number of pixels in April.

Thus, it has been observed with the help of Sentinel-2 that it is likely to be monitored remotely for the need for water and monitor the condition of vegetation. In particular, determining the type of land use can be an easy task to conduct. Remotely monitoring allows the collection of data about the area of observation into a single database, which facilitates the work of all stakeholders [15].

Remote sensing data can be generalized into an agricultural development model. Based on such models, it is possible to obtain accurate information about the terrain and the most promising types for cultivation in this area.

5 Conclusions

In this study, MNDWI was applied to monitor seasonal changes in open water surfaces. The analysis showed the difference between open water in different types of vegetation cover. In the previous study, 4 main classes of soil cover were identified in the study area: natural grass cover, agricultural land, land plots, and water. The open water in the cropland type was found to change over a short period from April to July (Figures 8, 9, 10, and 11).

Among these classes of soil cover, arable lands demonstrated a specific MNDWI model associated with seasonal irrigation of rice arable lands with values up to 0.6. The irrigation season lasted approximately 2 months from the end of April to the end of June. Dense grassy areas had a different MNDWI pattern, where the humidity of open surfaces was displayed during April-May. In July, vegetation on the wetlands increased significantly. In general, MNDWI reflected the humidity of exposed surfaces and the water content in vegetation.

All calculations were made using the QGIS program, maps were also created according to the MNDWI water and NDVI vegetation indices, and all areas of the region's agriculture were analysed. These sections were divided into classes and histograms were created based on them.

MNDWI of wheat fields was characterized by a specific structure due to the special irrigation regime, different from other plots.

The conducted research methodology can be applied in many regions under climate change adaptation programs, monitoring of agricultural vegetation areas, hydrological studies, and soil cover classification.

The main discovery is the structure of rice fields, which had a special irrigation regime, different from other types of soil cover. The results can be used in hydrological studies, vegetation classification, and environmental studies related to climate change studies.

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