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Vegetation indices in the assessment and management of soil fertility

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Abstract

Spatial information technologies are deeply rooted in all spheres of human activity, including agriculture. Today we're talking about smart, precise, digital farming. Soil fertility assessment, field monitoring, yield forecasting, proper farming, soil fertility management include not only the collection and analysis of soil data, but also collection spatial information. In GIS Technologies, vejetatife indices provide information for precision farming, providing data on crop growth and health. With the help of global positioning, it is possible to accurately determine the location on the ground of each site, as well as monitor the development of crops from sowing to harvesting, identify moisture and nutrient deficiencies in time, and identify plant diseases. GIS technologies allow you to manage soil fertility and crop quality to the level of private fields. The study area was irrigated soils in the northern part of the Imishli region of the Republic of Azerbaijan, with an area of 3211.9 hectares. Important branches of agriculture in the region are cotton growing and grain growing. When assessing and managing soil fertility, we tried to use some vegetation indices, such as NDVI, MSAVI, NDRE, as a criterion for assessing fertility. Spatial analysis of soil data helps in agricultural planning and helps to make quick and correct decisions on soil fertility and land use management. Within the framework of agricultural fields, GIS technology is used to apply soil fertilizers with certain standards in accordance with the condition of the site, as well as for the proper organization of irrigation.

1. Introduction

Spatial information technologies have penetrated deeply into all areas of human activity, including agriculture. Today we are talking about smart, precise, digital agriculture. Soil fertility assessment, crop monitoring, yield forecasting, proper farming and soil fertility management include not only soil data collection and analysis, but also spatial information about the terrain and the environment.

Geographic information system and remote sensing are widely used in modern farming systems. Global positioning can be used to determine the exact location of each plot on the land, as well as to monitor crop development from sowing to harvesting, identify moisture and nutrient deficiencies, and detect plant diseases. GIS technology makes it possible to manage soil fertility and crop quality down to the level of private fields. Every farmer can obtain a forecast for the timing of sowing, irrigation, fertilisation and harvesting. Geographic information systems make it possible to store, retrieve and analyse spatial data based on satellite images and drone imagery, using computer hardware and software.

2. Method

Modern soil and land-use mapping requires three basic elements - topographic maps at different scales, aerospace imagery and GIS mapping software.

According to the methodology of soil mapping, an electronic soil map of the district was prepared and soil fertility was assessed on a closed scale using a 100-point system and on an open scale using coefficients on limiting factors (Mammadov, 2020).

We applied NDVI (Normalized Difference Vegetation Index), the most used index in agricultural research, to assess productivity and soil fertility management (Asgarova, 2021). This index is a numerical index using spectral bands and is closely related to moisture and green vegetation.

Besides NDVI, ArcGIS Pro has a large number of vegetation indices for different applications, such as

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SAVI (Soil Adjusted Vegetation Index), MSAVI (Modified Soil-Adjusted Vegetation Index), NDRE (Normalized Difference RedEdge), etc.

2.1. Study Area

Crops in the northern part of Imishli district of Azerbaijan Republic, at coordinates 48°5'17,157", 39°59'20,536", an area of 3210 ha "Fig.1" were selected as the study area. More than 90% of the area is between -7 and -12 m above sea level. The important spheres of agriculture in this area are cotton growing and grain farming. As can be seen from the picture, a new irrigation system "Figure 1" has been fully implemented in the district. The district was developed a few years ago. On the classic soil map, the area is marked as winter pasture "Figure 2".

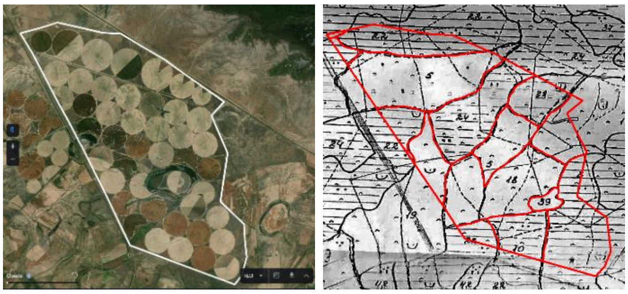


Figure 1-2. The study area in the 2021 satellite image and the classic soil map

The study area is fully irrigated and mainly used for cereals and cotton cultivation "Figure 3".

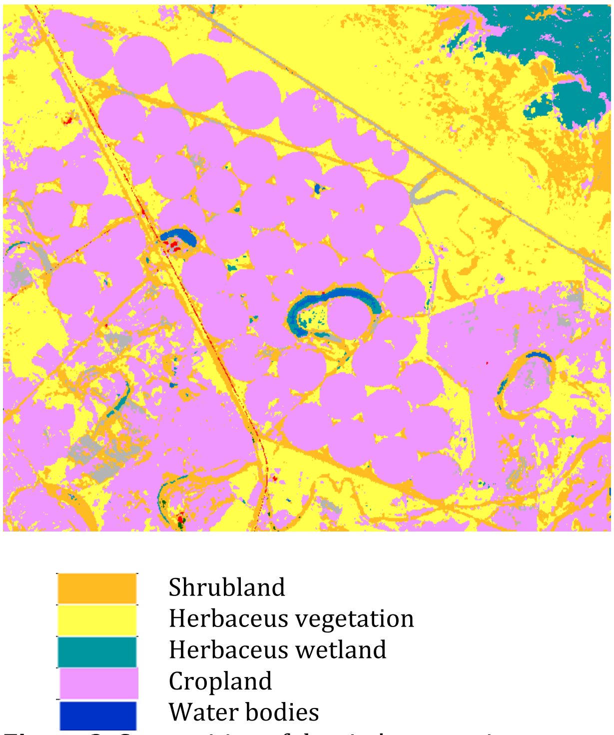


Figure 3. Composition of the site's vegetation cover

Satellite imagery is very effective in dynamically updating field boundaries to the farm level. Using fuzzy object-oriented image analysis (OBIA) we have carried out for the first time in our republic the delineation of agricultural fields at a specific site (Rasouli 2021, 2022).

2.2. Normalized Difference Vegetation Index

NDVI is calculated using the Equation 1

$$NDVI = (NIR-RED) / (NIR+RED) \quad (1)$$

where NIR is light reflected in the near-infrared spectrum, RED is light reflected in the red spectrum. NDVI is expressed as -1 to 1. Negative NDVI values mainly show clouds, water and snow, while values close to zero show rocks and bare ground. NDVI values between 0.2 and 0.3 represent shrubland and grassland and between 0.6 and 0.8 represent forest. NDVI can identify fields with dense, moderate or sparse vegetation at any time. If NDVI values are between 0.95 and 1.00 it is considered better to use NDRE "Table 1".

Table 1. NDVI values

Land cover	Values NDVI
Better to use NDRE	0,95 – 1,00
Dense vegetation	0.60 – 0.95
Moderate vegetation	0.40 – 0.60
Sparse vegetation	0.20 – 0.40
Open soil	-1.00 – 0.20

We compared the NDVI on 2 June and 15 September 2021 "Figure 4". Note the areas where the NDVI value is very different. For example, areas of a field with too low NDVI indicate pest or plant problems; areas with abnormally high NDVI indicate an admixture of weeds.

Figure 4. NDVI - June 2, and September 15, 2021

The values in the figures and in the graph are very different. While in early June the NDVI dense vegetation index was 2.58% within the study area, in the first half of September it was 36.70% "Figure 5".

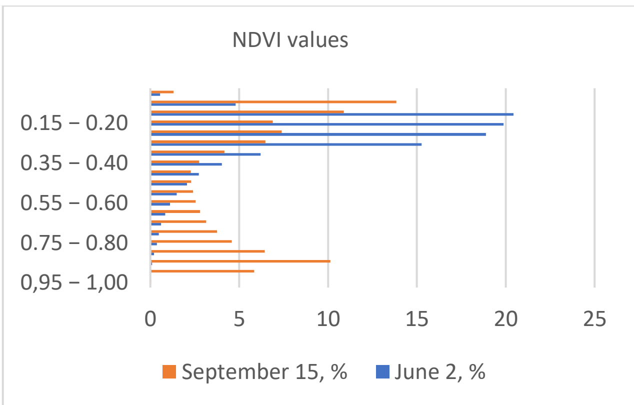
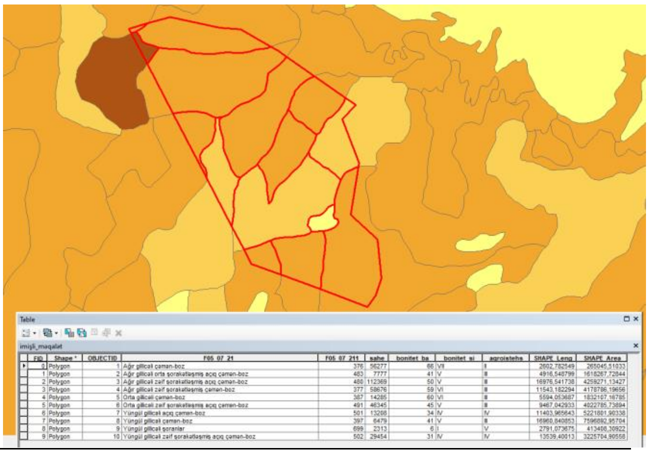


Figure 5. NDVI values on June 2, September 15, 2021

These NDVI properties enable you to predict crop yields and monitor crop condition throughout the growing season, as well as properly organize the rates and timing of irrigation, fertilization and other agronomic measures.

2.3. Soil evaluation

Soil fertility was assessed based on 100-point diagnostic indicators in a closed scale and taking into account coefficients on salinity, granulometric composition, irrigation, etc. in an open scale. A soil fertility assessment map has been drawn up. “Fig. 6”.



№	Soil names	Area, ha
1	Heavy loamy meadow-gray soils	56277
2	Heavy loamy medium saline light meadow-gray soils	7777
3	Heavy loamy slightly saline light meadow-gray soils	112369
4	Heavy loamy slightly saline meadow-gray soils	58676
5	Medium loamy meadow-gray soils	14285
6	Medium loamy slightly saline light meadow-gray soils	46345
7	Light loamy light meadow-gray soils	13208
8	Light loamy meadow-gray soils	6479
9	Light loamy salt pans	2313
10	Light loamy slightly saline light meadow-gray soils	29454
	Sum:	**347183**

Figure 6. Soils assessment cartogram

Each soil contour of the cartogram has attribute information - name, area, perimeter, coordinates, bonitet point, also each immet additional information (i) agrochemical, agrophysical and environmental data "Figure 7".

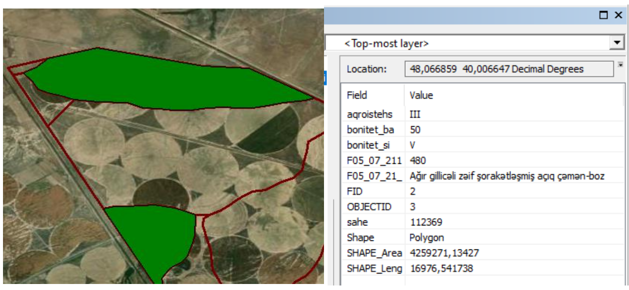


Figure 7. Information on the soil contours

3. Results

While in early June the NDVI dense vegetation index was 2.58% within the study area, in the first half of September it was 36.70%

Varieties of irrigated meadow-gray and light meadow-gray soils are common in the area. 32% of the site is occupied by heavy loamy light saline light meadow-gray soils, which scored 50, 17% by heavy loamy light saline meadow-gray soils, which scored 59, and 13% by medium loamy light saline light meadow-gray soils, which scored 60. Heavy loamy meadow-gray soils received the highest score of 66, with an area of 16%.

4. Discussion

NDVI has the advantage of identifying problematic fields and improving the accuracy of fertiliser and irrigation applications. Crop indices are tools for remote monitoring of crop health. Crop indices can be used to monitor crop rotation patterns, current vegetation intensity, temperature, precipitation, growth stage and much more.

Based on NDVI measurements, zoning can be carried out. This allows the creation of special maps for the application of seed rates and fertilisers. NDVI makes it possible to identify weak and strong zones of productivity throughout the field, measured over a long period of time. Based on NDVI, time and resources can be saved by providing farmers with accurate geolocation of problem fields. Farmers can get information about field conditions via mobile phones and mobile platforms. Based on each new satellite image, optimal and prompt decisions can be made.

5. Conclusion

Spatial analysis of soil data helps in agricultural planning and helps to make quick and right decisions for land cover and management. Within the limits of agricultural fields, GIS technology is used for the application of soil fertilizers with certain norms according to the condition of the site, as well as the correct organization of irrigation.

The use of NDVI makes it possible to identify fields with dense, moderate or rare vegetation at any time, so this index is very relevant for the assessment and management of soil fertility.

Environmental factors may affect the accuracy and reliability of vegetation index measurements. These factors should be taken into account when analyzing data to ensure that measurements are meaningful. Sizing is also an important factor, as vegetation indices should be calibrated to take account of differences in sensor characteristics, atmospheric conditions and other factors that may affect the accuracy of measurements. The lack of proper calibration of vegetation indices may lead to the use of multiple vegetation indices for proper interpretation and decision-making in the assessment and management of soil fertility.

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