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Study of natural-ecological conditions in agro-landscapes based on field surveys and remote sensing

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ABSTRACT

Problem definition. The number of undernourished people has dropped by almost half in the past two decades because of rapid economic growth and increased agricultural productivity. Under the conditions of climate change, natural and anthropogenic factors related to human activity lead to soil cover degradation, which leads to a decrease in soil fertility and ecosystem productivity, a deterioration in the socio-economic quality of human life, and generally creates serious problems in the country's food security. Failure to take into account the agrophysical, agrochemical, physicochemical and other properties of soils in land use, depending on agroecological conditions, leads to the degradation of agricultural lands and manifests itself in the form of soil salinization, mechanical deformation and compaction, erosion, desertification, decreased productivity of ecosystems, and other forms. Therefore, in conditions of intensive land use, the management of the productivity of agrocenoses depends to one degree or another on the assessment of the agrophysical and agrochemical state of soils, which plays a decisive role in detecting and controlling degradation and making proposals for solving this problem.

The purpose. The study was conducted in the cereal crops of the Lankaran-Astara (Jalilabad, Masalli, Lankaran) economic region of the Republic of Azerbaijan in the rainfed conditions with varying degrees of moisture. The study included cereal fields located in various rural areas of the administrative regions, as well as areas covering cereal crops of the Jalilabad Regional Experimental Station (RES) of the Research Institute of Crop Husbandry.

Research methodology. In accordance with the methodology, the studies were conducted in the relevant departments and laboratories of the Research Institute of Crop Husbandry using space (GIS technologies, Earth remote sensing) and terrestrial (soil agrophysical and agrochemical properties, grain yield and quality indicators) methods.

Conclusions. In terms of assessing the degree of erosion of soils, the structure vulnerability coefficient (K_Z) is often used. K_Z reflects the general structural quality of the soil in terms of its structural-aggregate composition. Structural degradation can lead to compaction and crusting of the soil surface, which reduces the rate of water infiltration, increases the risk of soil erosion and loss of the topsoil. The results show that the indicators characterizing the structural state of soils in all study regions (AVA, K_{str}, D_s) can be assessed as “very good” (AVA >60%) and “good” (AVA >50%) according to the existing gradations. The trend of NDVI changes indicates that cereal crops are already in the full ripening phase in the Jalilabad region at the end of May and harvesting has begun.

***Keywords**: zero hunger, remote sensing, sustainable agriculture, cereal crops, Landsat images, food security, crop yield assessment, climate-smart agriculture, NDVI.*

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Introduction. In order to obtain high-quality and high-quantity agricultural crops in a changing climate, objective information on the temporal and spatial variability of the state of soil and vegetation cover is required [11, 22, 24]. Modern soil monitoring is mainly based on GIS technologies and remote sensing data [23]. The use of data covering different periods allows us to assess ongoing processes based on the differences detected in the state of objects [2]. Agroecological conditions, which are becoming more complicated due to anthropogenic impact in the context of climate change, necessitate operational monitoring of the state of agricultural lands [14]. Regardless of the cause, the process of soil degradation begins with a change in vegetation cover, its main dynamic characteristic – biomass [18]. To assess this change, various vegetation indices calculated from remote sensing data of the Earth in a certain range of electromagnetic waves are used [8, 10]. For example, the MARS (Monitoring Agriculture by Remote Sensing) system, which serves the countries of the European Union, allows us to determine the state of cultivated areas and the productivity of agricultural crops on various scales.

In connection with the above, the relevance of the topic stems from the need to obtain objective information on the regularities of temporal and spatial variability of the state of soil and vegetation cover in the arable lands of some administrative regions of the republic and the factors determining it, and to effectively use soil, climate and plant resources in conditions of changing natural and anthropogenic influences.

The purpose of the study is to study, analyze and map the "inert" and dynamic parameters characterizing the state of soil and vegetation in the agricultural areas of the Lankaran-Astara (Jalilabad, Masalli, Lankaran) economic region of the Azerbaijan Republic using space (GIS technologies, Earth remote sensing) and terrestrial (field, laboratory) methods.

The object, methods and soil-climatic conditions of the study area. The climatic conditions of the study areas by economic regions can be characterized by the following indicators of perennial precipitation and temperature. The Jalilabad region has a mainly temperate-hot semi-desert and dry-steppe climate with a dry summer. The average temperature in January is 1-3 ^{0}C, in July 25-30 ^{0}C. The annual precipitation is 400-600 mm. The Masalli district has a semi-desert, dry-steppe and semi-humid subtropical climate with mild winters and dry summers. In summer, the temperature sometimes rises to 40 ^{0}C. In winter, the lowest temperature is -10 ^{0}C, and the highest temperature is 15 ^{0}C. The amount of annual precipitation varies between 450-650 mm. In the Lankaran district, a humid subtropical climate prevails. In such climatic conditions, the annual temperature reaches 14 ^{0}C, and the amount of precipitation reaches 650-1300 mm.

In accordance with the purpose of the study, the object of the study is the soil and vegetation used in agricultural use in various agro-ecological conditions. In the study areas, the agrophysical indicators of the top layer of soils (0-20 cm) – granulometric and structural-aggregate composition, moisture, density, porosity; agrochemical indicators – humus, carbonation, pH, electrical conductivity, mineral nutrients (NPK); grain yield and quality indicators of the plant – 1000-grain mass, vitreous, gluten, sedimentation and protein were determined using standard methods used in modern soil-plant analyses [3, 17, 19]. Landsat data are usually used for classification. Landsat data has several bands (blue, green, red, infrared, thermal, panchromatic) that differ in wavelength. The panchromatic band is used to increase the resolution of the data. Landsat 7 data has 8 bands, and Landsat 8 data has 11 bands [5].

NDVI (Normalized Difference Vegetation Index) is a simple and effective index widely used to determine the state of vegetation development [1, 4, 24]. This index is a normalized quantity that relates the absorption of red light (RED) by chlorophyll in green plants to the scattering of light in the near-infrared (NIR) range from the leaf surface [9, 16].

In general, healthy vegetation is highly sensitive to visible light [12, 20]. Chlorophyll in green plants absorbs blue (0.4-0.5 μm) and red (0.6-0.7 μm) light to a high degree, and reflects green (0.5-0.6 μm) light [17]. This is why we see healthy vegetation in green [7]. Healthy green plants highly reflect electromagnetic waves in the near-infrared (NIR) range of the spectrum, 0.7-1.3 μm [6, 15]. The calculation of NDVI is based on the absorption and reflection of electromagnetic radiation in the RED and NIR ranges, respectively [13].

NDVI is determined by the following formula:

$$NDVI = (NIR – RED) / (NIR + RED)$$

NDVI for Landsat 8 is calculated using Band 4 (RED) and Band 5 (NIR):

$$NDVI = (B05 – B04) / (B05 + B04)$$

Discussion and results. The SDGs aim to end all forms of hunger and malnutrition by 2030, making sure all people – especially children – have sufficient and nutritious food throughout the year. This involves promoting sustainable agricultural, supporting small-scale farmers and equal access to land, technology and markets. It also requires international cooperation to ensure investment in infrastructure and technology to improve agricultural productivity [21].

That is why the investigation of agriculture, agrolandscapes, and natural components is an essential issue. In the study areas of the regions, mainly gray-brown, chestnut, brown forest, alluvial meadow, pseudopodzolic yellow and pseudopodzolic gley yellow soils are distributed. The geographical coordinates and altitude above sea level of the places where soil and plant samples were collected in the study areas of all regions were determined using GPS, and satellite observations were conducted according to these coordinates (Table 1).

In GIS-technologies and Earth remote sensing, the processing of Landsat and Sentinel satellite images and the dynamics of several vegetation indices were determined using the ArcGIS software package. This allows us to monitor the development process of vegetation cover and determine the degree of soil moisture. To obtain the relevant information, NDVI (Normalized Difference Vegetation Index) was determined in the study areas. This will be discussed

Table 1

Vegetation cover, geographical coordinates and soil granulometry of the study areas

№	Plant	Geographic coordinates and altitude			Granulometric composition, %			Texture class (USDA)
		N (Y)	E (X)	Altitude (m)	Sand	Silt	Clay	
The Jalilabad district								
1	Wh	$39^0 14.059'$	$48^0 26.787'$	79	6.7	46.4	46.9	SC
2	Wh	$39^0 14.329'$	$48^0 27.578'$	66	7.6	45.7	46.7	SC
3	Ba	$39^0 13.847'$	$48^0 27.396'$	73	0.5	55.5	44.0	SC
4	Wh	$39^0 13.392'$	$48^0 27.775'$	65	3.4	41.7	54.9	SC
5	Wh	$39^0 13.481'$	$48^0 27.921'$	64	1.0	47.3	51.7	SC
6	Wh	$39^0 12.398'$	$48^0 25.507'$	131	1.0	47.2	51.8	SC
7	Wh	$39^0 15.547'$	$48^0 21.799'$	141	2.9	44.9	52.2	SC
8	Wh	$39^0 11.710'$	$48^0 17.070'$	326	5.3	36.6	58.1	C
9	Wh	$39^0 15.004'$	$48^0 19.259'$	165	0.0	48.0	52.0	SC
10	Wh	$39^0 19.025'$	$48^0 23.507'$	96	3.7	38.4	57.9	C
11	Wh	$39^0 19.444'$	$48^0 26.878'$	42	2.9	39.5	57.6	C
12	Wh	$39^0 06.198'$	$48^0 36.154'$	15	7.1	46.1	46.7	SC
13	Wh	$39^0 15.917'$	$48^0 32.609'$	0	1.9	29.8	68.3	C
14	Wh	$39^0 18.286'$	$48^0 32.802'$	5	6.6	41.4	52.0	SC
15	Wh	$39^0 19.413'$	$48^0 31.816'$	13	6.9	39.4	53.7	C
16	Wh	$39^0 23.037'$	$48^0 32.336'$	11	6.6	45.1	48.3	SC
17	Wh	$39^0 19.098'$	$48^0 30.292'$	24	1.3	31.1	67.6	C
18	Wh	$39^0 17.653'$	$48^0 31.033'$	16	2.9	44.3	52.8	SC
The Masalli district								
19	Wh	$39^0 00.647'$	$48^0 42.363'$	6	7.5	46.0	46.5	SC
20	Oa	$39^0 01.587'$	$48^0 43.982'$	27	21.1	40.5	38.4	CL
21	Wh	$39^0 02.103'$	$48^0 47.396'$	10	7.3	45.6	47.1	SC
22	Wh	$39^0 00.525'$	$48^0 37.558'$	58	5.5	40.7	53.8	SC
23	Wh	$38^0 58.117'$	$48^0 40.151'$	6	16.3	44.6	39.1	SCL
24	Wh	$38^0 56.808'$	$48^0 39.780'$	29	5.2	52.9	41.9	SC
The Lankaran district								
25	Wh	$38^0 43.974'$	$48^0 49.726'$	2	28.9	38.0	33.1	CL
26	Wh	$38^0 40.930'$	$48^0 48.296'$	11	13.1	47.5	39.4	SCL
27	Wh	$38^0 48.594'$	$48^0 46.705'$	12	33.0	30.1	36.9	CL
28	Oa	$38^0 48.694'$	$48^0 45.992'$	8	14.0	48.6	37.4	SCL

Note: Ba – *barley,* Wh – *wheat,* Oa – *oats, C – clay, SC – silty clay, CL – Clay loam, SCL – silty clay loam.*

in detail in the following sections of the report.

Results of the study and their discussion. According to the methodology, soil and plant samples were collected and analyzed from cereal fields in 28 villages and settlements within the Jalilabad, Masalli, and Lankaran districts, which are part of the Lankaran-Astara economic region.

Fundamental characteristics of soils – granulometry and texture class. The granulometric composition or texture of the soil expresses the relative percentage of sand (2-0.05 mm), silt (0.05-0.002 mm) and clay (<0.002 mm) particles in the soil. It is very important for understanding soil functions such as water retention and hydraulic conductivity, water and nutrient availability, accumulation and transport of pollutants, etc. Almost all physical, chemical and biological properties of the soil depend to one degree or another on the granulometric composition.

In essence, soil texture reflects the size distribution of particles – granulometric fractions (sand, silt, clay). There is no generally accepted universal classification of the boundaries of granulometric fractions in the world. Although the classification of the size distribution of granulometric particles is carried out according to different schemes in different countries, in most classifications the upper limit of the particle diameter for clay and sand fractions is taken as 0.002 mm and 2 mm, respectively. Currently, the most widely used is the International and the United States Department of Agriculture (USDA) classification scheme.

Accurate determination of the particle size distribution in the soil texture fraction smaller than 2 millimeters plays an important role in the application of many studies. Since it affects various processes occurring in the soil and numerous soil properties, including pore size distribution, water retention and water permeability. These properties are of great importance for soil functions and ecosystem services – aeration, regulation of water and nutrient cycling and habitat for microorganisms, carbon storage and suitability for agricultural production.

The results of granulometry show that the granulometric composition of the soils in the study areas, determined by the Bouyocos method, is clay and silty clay in more than 90% of cases according to the classification of the US Department of Agriculture (Table 1, Figure 1). This type of soil is found in all regions except Lankaran. In the Lankaran and in some cases in the Masalli region, it is observed that the soils have a clay loam and silty clay loam granulometric composition.

Structural-aggregate composition of soils. Another agronomically important soil property that affects the productivity of agricultural crops and the stability of the soil-ecological environment is its structure and water stability. Soil structure is one of the main physical properties that ensure the movement and retention of water, water-soluble substances, gases, microorganisms, etc. in natural and agroecosystems. Soil structure is often a limiting factor for productivity and has a strong impact on many processes occurring in the soil. It regulates the water capacity of the soil, infiltration, gas exchange, the dynamics of organic and nutrient substances, the spread of plant roots in the soil and the tendency to erosion.

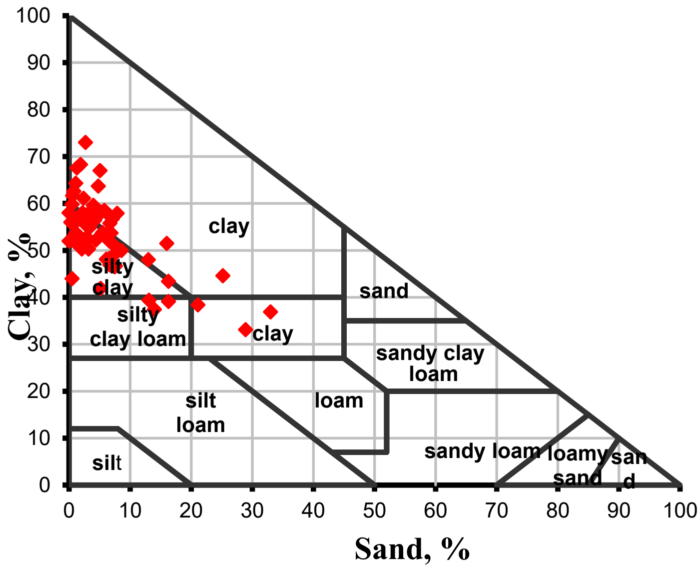

Fig. 1. Granulometric composition triangle

The concept of structure usually characterizes the spatial distribution or architecture of solid particles and voids or pores. Many soils have a hierarchical structure, that is, the initial mineral particles interact with organic matter to form small aggregates – microaggregates (<0.25 mm). Then, from the combination of these microaggregates, larger aggregates - macroaggregates (>0.25 mm) are formed. Organic matter plays the role of "cement" or "glue" in the formation of aggregates and structure. Without a structural hierarchy in loamy and clayey soils, they would be practically impermeable to liquids and gases. Thus, soil structure plays a decisive role in the transport of water, water-soluble substances and gases to the environment, and in transforming the soil into a favorable environment for the development of plants and other biological organisms.

There is no doubt that organic matter is one of the main components of soil structural stability. However, as a result of intensive cultivation of arable lands in agriculture, both soil structure and organic matter are gradually lost. Loss of structure and water stability in arable soil ecosystems is a widespread form of degradation. Soils with a high content of organic matter have relatively large aggregates that are more stable to mechanical action (compaction, deformation, etc.) and water action.

Improving soil aggregate stability has a number of positive effects for the agroecosystem (reducing the risk of erosion, etc.). The structural quality of the soil depends significantly on the amount of organic matter, especially its labile fraction. Labile organic matter also plays an important role in maintaining soil structure and providing the soil with nutrients. Soil aggregate stability is the cornerstone of its physical quality and can be improved by proper management of plant residues and organic amendments. In addition, precipitation also affects the structural state of the topsoil. Soil without vegetation cover (e.g., burning or removal of plant residues from the field) is in direct contact with raindrops, which leads to the disintegration of soil aggregates and an increased risk of soil erosion. Structural degradation can lead to compaction and crusting of the soil surface, which reduces the rate of water infiltration, increases the risk of soil erosion and loss of the topsoil.

Soil structure and its water stability are dynamic characteristics and are very sensitive to anthropogenic influences. As mentioned above, it directly affects the formation of a number of soil properties and plant productivity. The average values and ranges of variation (Lim) of structural and water stability indicators of soils in the study regions are given in Table 2.

Table 2

Average values of soil structural and water stability indicators*

district	Structural and water resistance indicators						
	AVA, %	K_{str}	D_S, mm	WSI, %	$C_{AFİ}$, %	D_{sw}, mm	K_Z
Jalilabad	80.3 (54.7-94.5)	4.5 (1.2-7.9)	4.9 (3.1-8.5)	54.7 (28.2-75.3)	336 (134-624)	0.6 (0.3-0.9)	8.9 (5.5-14.7)
Masalli	71.0 (65.0-85.2)	2.7 (1.8-5.8)	6.8 (5.0-8.0)	60.9 (51.9-73.7)	721 (476-1023)	1.2 (0.8-1.8)	6.2 (4.0-8.6)
Lankaran	79.0 (77.6-80.3)	3.4 (2.6-4.0)	3.4 (2.3-5.5)	51.0 (46.2-54.6)	170 (112-302)	0.8 (0.6-1.1)	4.4 (2.4-7.9)

Note: ** – in brackets Lim = min-max, AVA – the amount of agronomically valuable aggregates (10-0.25 mm), K_{str} – structural coefficient [Σ(10-0.25 mm) / Σ(>10 mm + <0.25 mm)], D_s and D_w – mean weighted diameter of structural and water-stable aggregates [Σ(amount of fraction x mean diameter of the fraction) / 100], WSI – water stability indicator (amount of water-stable aggregates >0.25 mm), C_{AFI} – AFI water resistance criterion [ratio of the amount of 1-0.25 mm water-stable aggregates to the amount of structural aggregates of the same size x 100], K_Z – structure vulnerability coefficient [D_s / D_w].*

The results show that the indicators characterizing the structural state of soils in all study regions (AVA, K_{str}, D_s) can be assessed as "very good" (AVA >60%) and "good" (AVA >50%) according to the existing gradations (Table 2). Approximately the same result is obtained for all structural indicators, which indicates a high correlation between them. The high structurality of soils is most likely due to their predominantly silty clay and clay granulometric composition. Such soils are usually more resistant to mechanical impact.

The water stability of the soil structure in the study regions has a wider range of variations (Table 2). Thus, the assessment of the amount of water-stable aggregates (WSI) larger than 0.25 millimeters according to the existing gradations in the regions gives the following results: Jalilabad – mainly medium water-stable (WSI 40-60%), in some places weak (WSI 20-40%) and good (WSI 60-80%); Masalli – medium and good water-stable; Lankaran – mainly medium water-stable is observed.

In terms of assessing the degree of erosion of soils, the structure vulnerability coefficient (K_Z) is often used. K_Z reflects the general structural quality of the soil in terms of its structural-aggregate composition. The assessment of the structural quality of soils in the study areas according to the existing gradation according to KZ allows us to draw the following conclusions. In total, the structural quality of soils in 28 study areas can be assessed as follows: "very good" (K_Z <4) – 1% (Lankaran district), "good" (K_Z 4-7) – 39%, "satisfactory" (K_Z 7-10) – 36%, "unsatisfactory" (K_Z >10) – 14% (mainly in the Jalilabad district).

Agrophysical indicators of soil fertility. The results of agrophysical analyses are shown in Table 3. Overall, the agrophysical fertility indicators of the studied grain and pasture soils vary in a very wide range (W: 11.1-26.1 %, ρs: 2.3-2.61 g/cm^3, ρ_b: 0.94-1.55 g/cm^3, ε_t: 35.1-34.4 %, ε_a: 2.6-48.1 %). Spatial variability of agrophysical properties on a regional scale can be determined by a number of natural and anthropogenic factors, along with soil-climatic conditions. Assessment of agrophysical indicators of soils according to various gradations shows that there is a need to improve the physical condition of some arable land areas of the regions. Thus, in 28 research areas in different regions, the indicators characterizing the physical quality of the soil's arable layer (compaction, water-air capacity, aeration) are at an "unsatisfactory" level in 25-54% of cases: ρ_b >1.30 g/cm^3 – 39%, ε_t<50% – 54%, ε_a<15% – 25%.

Agrochemical properties of soils. The results of the agrochemical analysis are given in Table 4. As can be seen from the table, in general, the agrochemical state of the studied soils in economic region can be characterized as follows: According to the pH index, the soils were weakly acidic (36%), normal (28%) and weakly alkaline (36%), carbonated (86%) and moderately carbonated (14%), mainly (>80%) moderately humus-rich, not saline (EC1:1 < 1.0 dS . m–1), mainly (85%) very poorly and poorly

Table 3

Average values of agrophysical indicators of fertility

District	Agrophysical indicators				
	W, %	ρ_b, q/sm^3	ρ_s, q/sm^3	ε_t, %	ε_a, %
Jalilabad	19.8 (11.1-26.0)	1.20 (0.94-1.52)	2.49 (2.31-2.60)	51.6 (41.6-63.4)	27.3 (11.1-48.1)
Masalli	23.8 (21.3-26.1)	1.38 (1.23-1.55)	2.51 (2.35-2.59)	45.1 (35.1-55.7)	12.5 (2.6-28.0)
Lankaran	15.5 (14.9-16.0)	1.29 (1.19-1.48)	2.48 (2.37-2.61)	48.0 (40.7-54.2)	29.3 (18.7-36.1)

Note: *W – moisture, ρ_b – dry bulk density, ρ_s – particle density, ε_t – total porosity [100 (1 – ρ_b/ρ_s)], εa – air filled porosity [ε_t – Wρ_b].*

supplied with easily absorbable phosphorus, and moderately and well (50%), high and very high (40%) with potassium.

Productivity and grain quality indicators. Grain productivity and quality indicators of cereal crops in the cultivated areas by region are given in Table 5. In general, it is observed that the productivity and quality of cereal crops in the study regions are significantly dependent on soil-climatic conditions, soil properties, nutritional conditions, soil cultivation, fertilization, etc. That is, the diversity of soil fertility and cultivation technology elements leads to the diversity of plant productivity and quality. In general, the grain productivity and quality of plants also vary in a very wide range, and the grain quality mainly corresponds to class III.

In the current agroecological conditions, which are becoming more complicated by climate change, preserving soil fertility, improving its agrophysical and agrochemical properties, and obtaining high-quality crops from cereal crops depend critically on the efficient use of arable land and the elements of applied cultivation technology.

Remote sensing of land cover: NDVI and its mapping. Remote sensing data are the main sources for the analysis of ecological processes on a regional or global scale. These data have been widely used in recent decades to detect variability. Remote sensing data (e.g. Landsat and Sentinel data, Spot imagery, etc.) are very useful for visualization, classification

Table 4

Average values of agrochemical indicators

District	Agrochemical indicators						
	pH	$CaCO_3$, %	OM, %	N, %	P, mg/kg	K, mg/kg	$EC_{1:1}$, dS/m
Jalilabad	7.3 (6.1-8.0)	3.5 (1.2-9.7)	2.0 (1.2-2.8)	0.16 (0.13-0.22)	11.4 (3.7-39.2)	473 (226-1181)	0.51 (0.35-0.69)
Masalli	6.7 (6.1-7.4)	2.5 (2.1-3.5)	2.2 (1.6-2.5)	0.17 (0.13-0.20)	18.6 (4.6-32.7)	357 (118-1014)	0.36 (0.17-0.50)
Lankaran	6.2 (6.0-6.5)	2.5 (1.7-3.2)	2.4 (1.7-3.0)	0.19 (0.13-0.25)	15.8 (10.4-19.9)	336 (324-357)	0.16 (0.12-0.20)

Note: *pH – acidity (alkalinity), $CaCO_3$ – carbonation, OM – humus, N – total nitrogen, P – mobile phosphorus, K – exchangeable potassium, $EC_{1:1}$ – electrical conductivity.*

Table 5

Average values and ranges of grain yield and quality indicators of wheat

district	Y, %	Quality indicators					
		M_{1000}, g	Vi, %	Gl, %	KDI, c.g.	Se, ml	Pr, %
Jalilabad	36.1[a] 6.5-58.8[b]	35.9 19.2-45.0	61.0 16.0-90.0	28.6 19.2-36.0	101.3 87.4-111.2	20.0 12.0-33.0	12.6 9.5-15.4
Masalli	27.1 13.6-39.5	29.6 24.6-32.8	43.2 23.5-65.5	27.8 22.4-32.8	97.9 91.6-104.9	30.3 25.5-37.5	12.4 10.7-15.0
Lankaran	30.6 15.8-59.6	35.3 22.8-46.4	30.0 15.0-46.0	22.1 16.0-32.8	89.2 86.4-92.0	21.5 12.0-33.0	11.0 9.3-14.0

Note: *Y – grain yield, M_{1000} – thousand grain mass, Vi – vitreousness, Gl – gluten, GDI – gluten deformation index, Se – sedimentation, Pr – protein, [a, b] – average value and range of variation.*

and analysis of the area. These data can be classified according to their resolution, electromagnetic wave spectrum, energy source, etc. The higher the resolution of satellite data (spatial, spectral, radiometric and temporal resolution), the higher the accuracy achieved during classification.

As mentioned above, the study was conducted in the cereal fields of 28 villages and settlements covering a total of 28 coordinate points in the Lankaran-Astara area. In accordance with the field study, NDVI indices were determined and analyzed comparatively in 28 study points selected from the areas where cereal agrocenoses are located in all administrative districts (Jalilabad, Masalli, Lankaran) in April, May 2024 based on satellite images. Tables and maps showing changes in NDVI values were compiled in accordance with the results of the study. Below, the values and maps of the NDVI indices reflecting the state of cereal fields in the study area in different periods are sequentially described. For this, data from the Landsat 8 and 9 satellites covering the relevant periods were downloaded and analyzed (Figure 2-9).

Let's follow the dynamics of NDVI based on the results obtained in the Lankaran-Astara economic region. The trend of NDVI changes indicates that cereal crops are already in the full ripening phase in the Jalilabad region at the end of May and harvesting has begun. The change in the index values within 0.1-0.2 indicates that the development of vegetation has almost stopped. However, in the Lankaran and Masalli regions, harvesting is usually carried out a few days later. Thus, the difference in NDVI in April and May is very low. This indicates that the development of plants is weak. This pattern can be applied to all villages of Masalli and Lankaran regions. The results show that cereal crops are weak in the Masalli and Lankaran regions compared to Jalilabad region (Table 6).

Conclusions. Many developing countries that used to suffer from famine and hunger can now meet their nutritional needs. In accordance with the purpose of the study, in the cereal fields of 28 villages and settlements of the Jalilabad, Masalli and Lankaran administrative districts, which are included in the Lankaran-Astara economic region of the republic, in a total of 28 coordinate points, the granulometric composition of the soil layer, structural quality, agrophysical and agrochemical indicators of fertility, grain yield and quality indicators of cereal

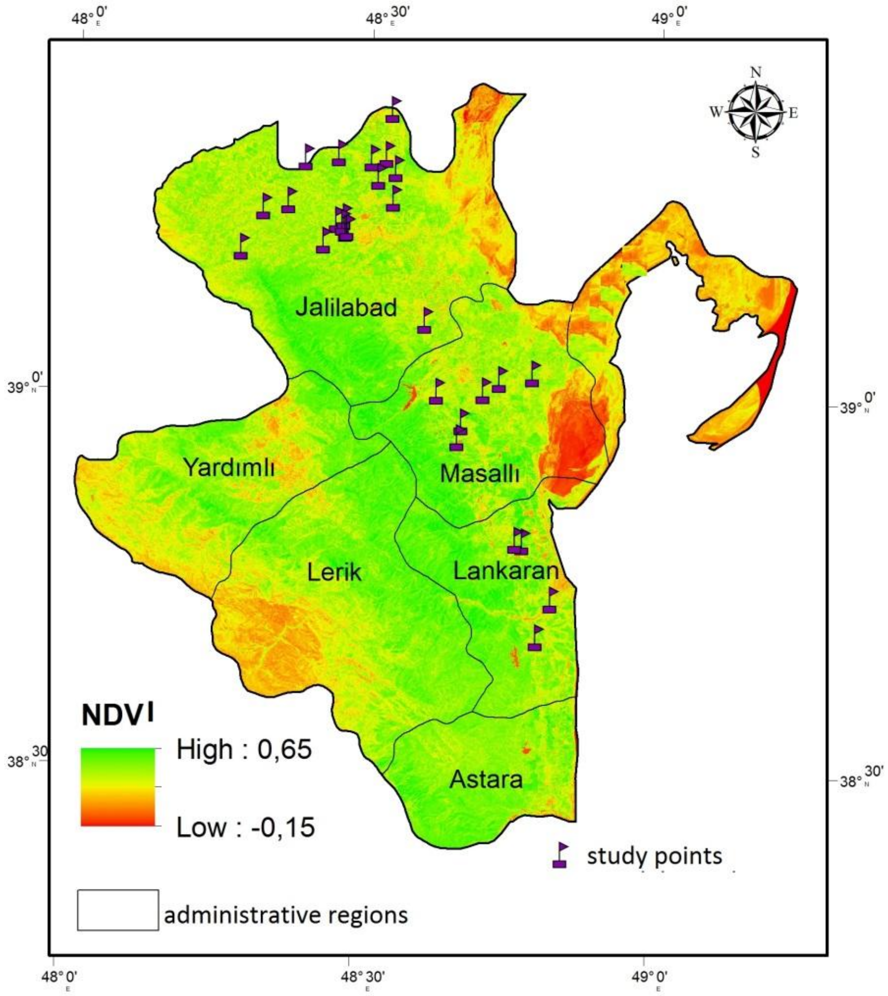

Fig. 2. Map of NDVI in the Lankaran-Astara economic region (28.04.2024)

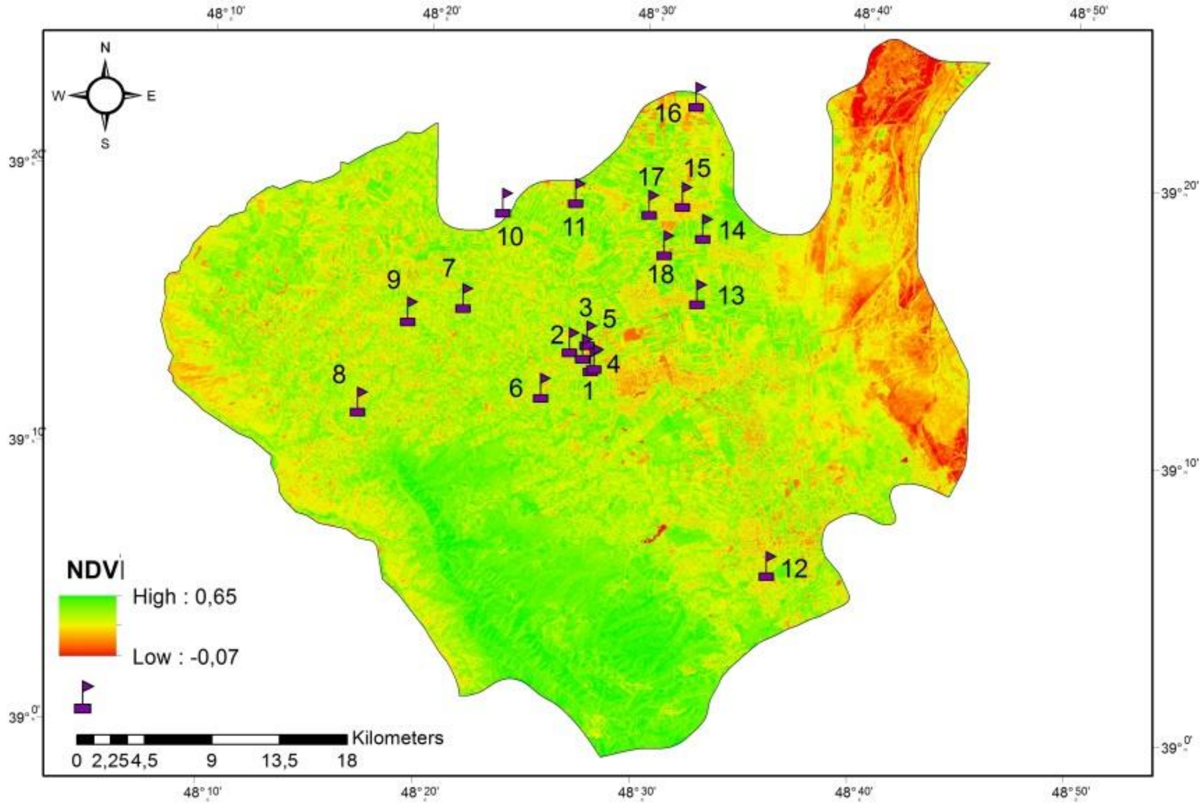

Fig. 3. Map of NDVI in the Jalilabad district (28.04.2024)

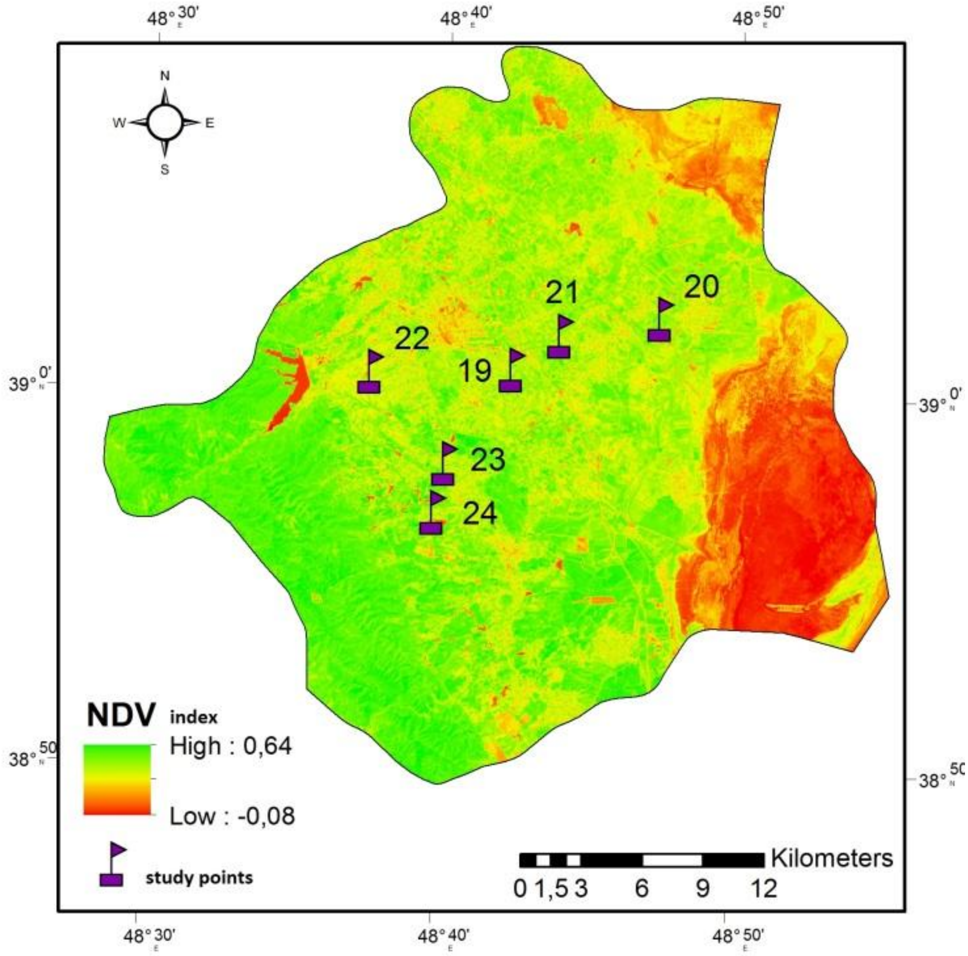

Fig. 4. Map of NDVI in the Masalli district (28.04.2024)

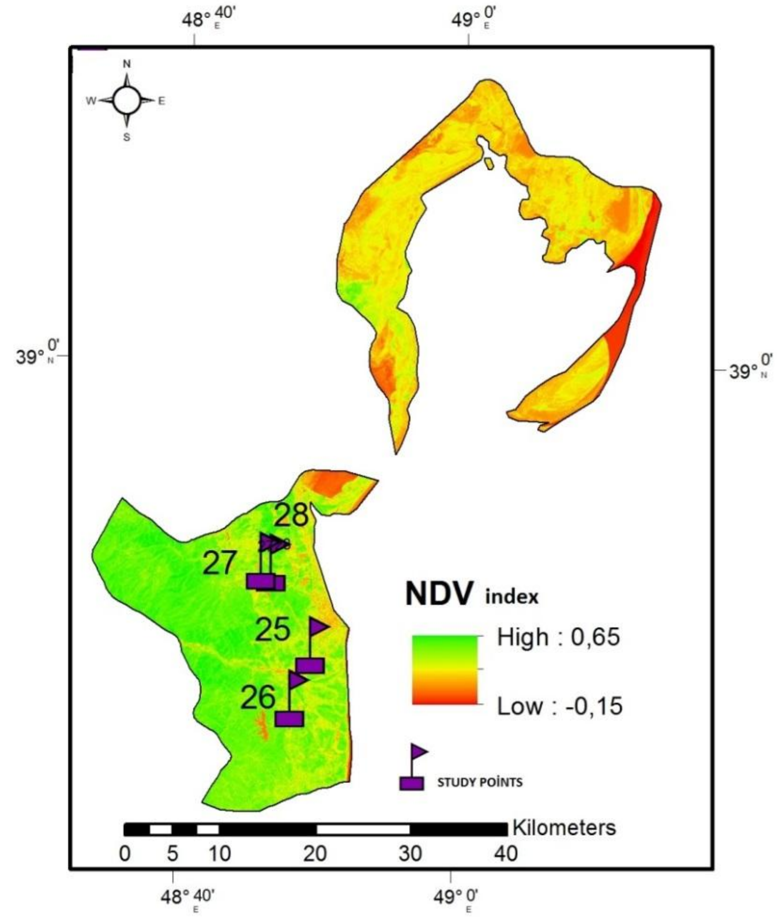

Fig. 5. Map of NDVI in the Lankaran region (28.04.2024)

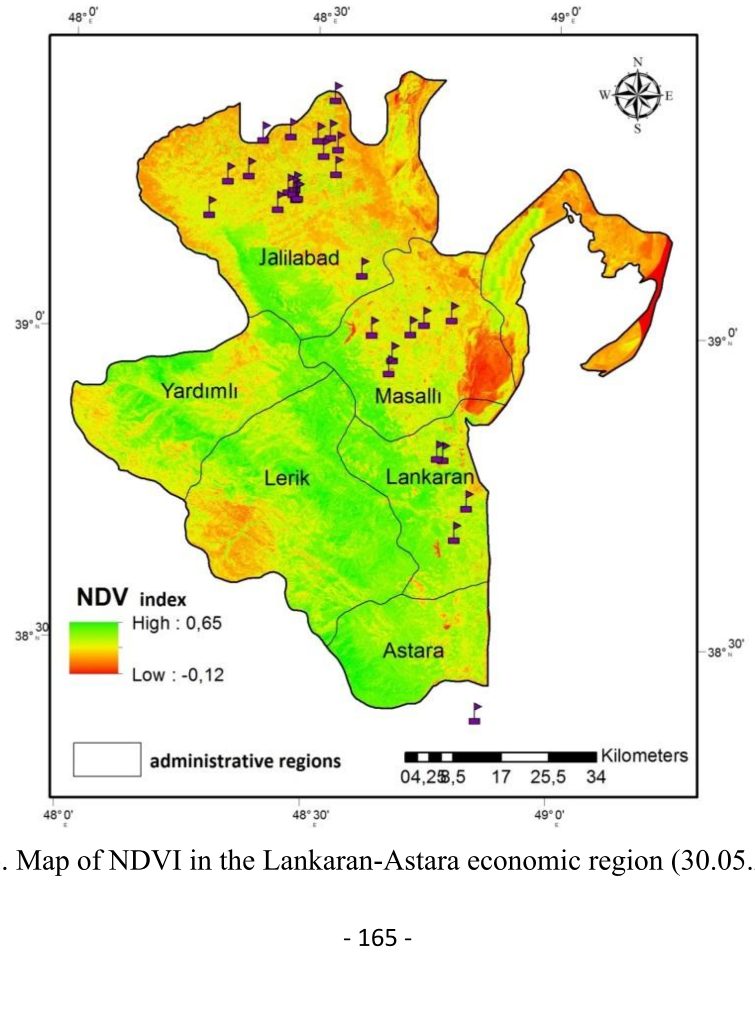

Fig. 6. Map of NDVI in the Lankaran-Astara economic region (30.05.2024)

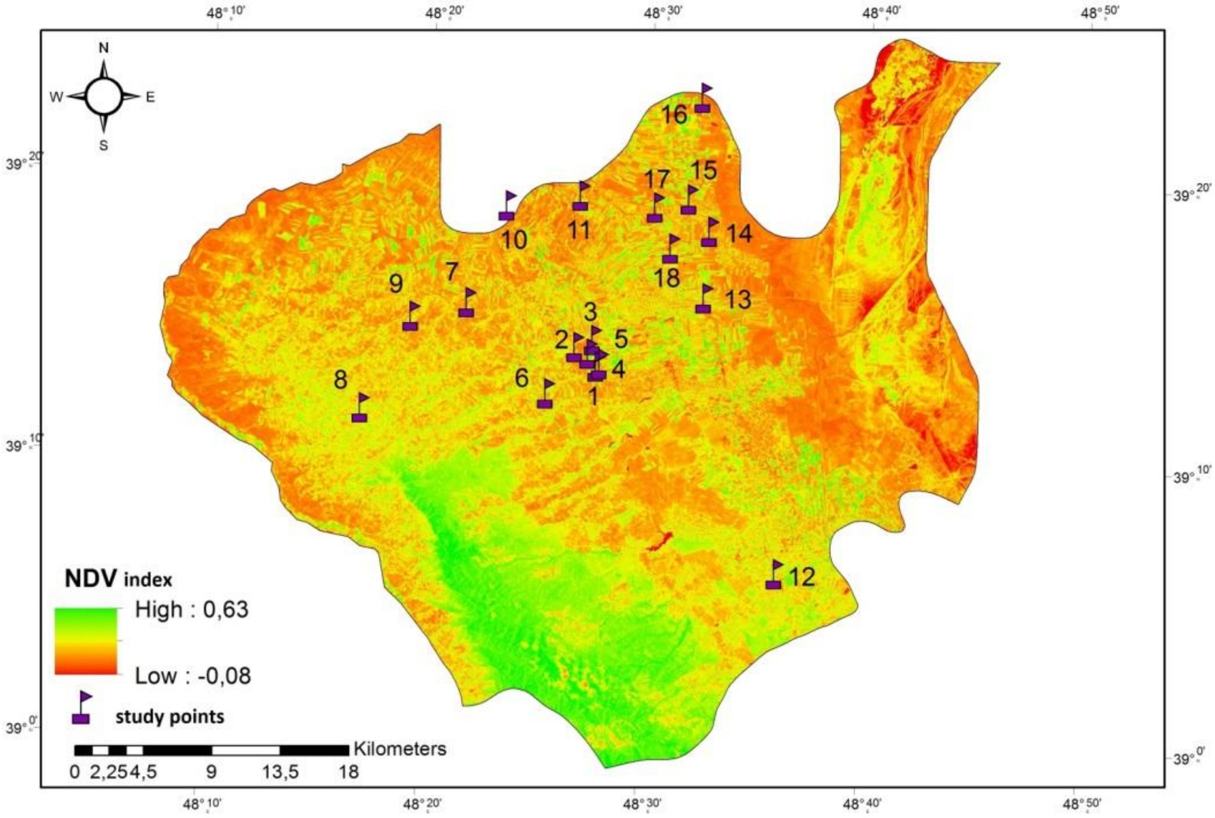

Fig. 7. Map of NDVI in the Jalilabad district (30.05.2024)

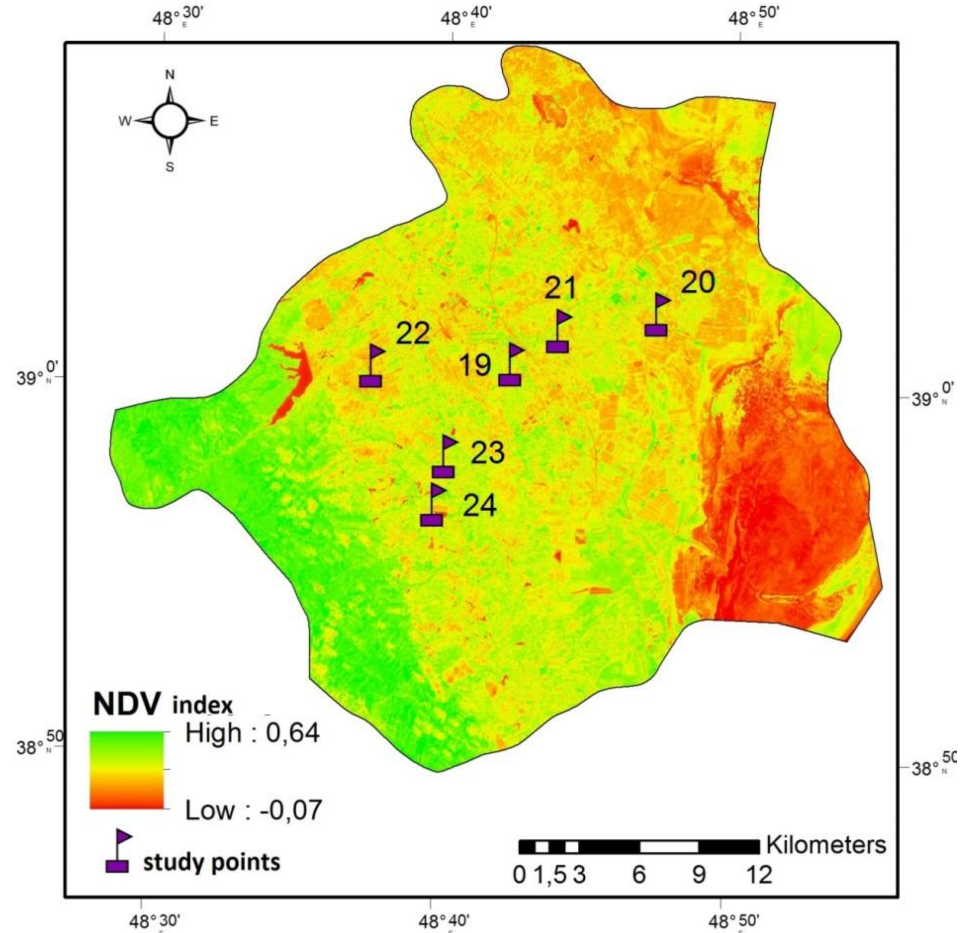

Fig. 8. Map of NDVI in the Masalli district (30.05.2024)

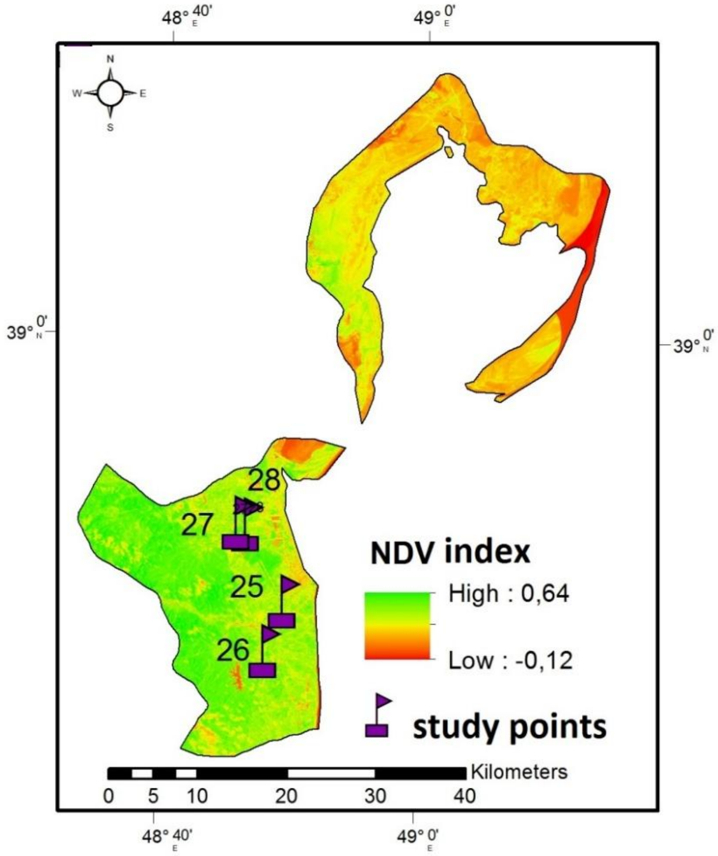

Fig. 9. Map of NDVI in the Lankaran district (30.05.2024)

Table 6

Dynamics of NDVI at survey points in the Lankaran-Astara economic region

№	Study points (village, town)	Administrative districts	NDVI values	
			April 28, 2024	May 30, 2024
1	RES 1	Jalilabad	0,3829	0,1829
2	RES 2		0,4454	0,2118
3	RES 3		0,4167	0,169
4	RES 4		0,3572	0,1767
5	RES 5		0,4581	0,2443
6	Astanli		0,4451	0,2274
7	Tekla		0,469	0,1809
8	Khanegah		0,4037	0,2838
9	Shorbachi		0,4506	0,2317
10	Babakhanli		0,4414	0,2414
11	Uchtepe		0,419	0,1891
12	Goytepe		0,447	0,2454
13	Sabirabad		0,3624	0,3107
14	Guneshli		0,4691	0,1668
15	Alar		0,4279	0,1536
16	Tazakend		0,3477	0,1416
17	Ojagli		0,4078	0,1604
18	Qarazenjir		0,3435	0,2218

Continuation of Table 6

19	Musakuche	Masalli	0,3575	0,2804
20	Huseynhajili		0,3887	0,3756
21	Gizilaghaj		0,4725	0,4175
22	Erkivan		0,3429	0,2414
23	Gizilavar		0,2341	0,211
24	Badalan		0,3713	0,2852
25	Darquba	Lankaran	0,3967	0,331
26	Mogonojoba		0,3747	0,2888
27	Girdeni		0,3764	0,2943
28	Viravul		0,463	0,3925

crops were determined. Remote sensing was carried out in the area covering different periods using the Landsat 8 satellite according to the geographical coordinates corresponding to the study, and the dynamics of vegetation indices characterizing the development of soil and plant cover were determined and mapped. In conclusion, the following can be noted:

The soils in the study areas are mainly of heavy granulometric composition, and according to the USDA classification, they are clay, silty clay, cleay loam, and silty clay loam.

The assessment of the structure vulnerability coefficient (K_Z), which is a complex indicator of the resistance of soils to mechanical impact and water impact, in the study areas shows that the structural quality of the soils is highly heterogeneous. Thus, 1% of the soils in all 28 study areas have a structural quality of "very good" (Lankaran region), 39% have "good", 36% have "satisfactory", and 14% have "unsatisfactory" (mainly in the Jalilabad region).

In general, the agrophysical quality indicators of the studied soils vary in a very wide range (W: 11.1-26.1 %, ρ_s: 2.3-2.61 g/cm^3, ρ_b: 0.94-1.55 g/cm^3, ε_t: 35.1-63.4 %, εa: 2.6-48.1 %). The high spatial variability of agrophysical properties, along with soil-climatic conditions and natural soil heterogeneity, can be caused by various anthropogenic influences in the process of land use, vegetation cover, etc. Thus, the indicators characterizing the agrophysical quality of soils (compaction, water and air capacity, aeration) in 25-50% of cases in 28 research areas in different regions are at an "unsatisfactory" level. This is manifested by ρ_b >1.30 g/cm^3 in 39% of cases, ε_t < 50 % in 54% of cases, and ε_a < 15 % in 25% of cases.

Bibliography

1. *Amanova, Sh.S., Hajiyeva, G.N. (2023). Investigation of Natural Condition in Urban Landscapes of Plain Areas Based on GIS. C. R. Acad. Bulg. Sci., 76(11), 1679-1689. https://doi.org/10.7546/CRABS.2023.11.05*
2. *Beeson, P.C., Daughtry, C.S.T., Wallander, S.A. (2020). Estimates of Conservation Tillage Practices Using Landsat Archive. Remote Sens., 12, 2665. https://doi.org/10.3390/rs12162665*
3. *Carter M.R., Gregorich E.G. Soil Sampling and Methods of Analysis (2008) / (eds). 2nd ed. CRC Press, Boca Raton, 1234.*
4. *Hajiyeva, A., Hajiyeva, G., Dadashova, K. K. (2023). Landscape-ecological carcass model of urban landscape and methods of optimize urban landscapes (on the patterns of Ganja and Mingachevir cities). Visnyk of V. N. Karazin Kharkiv National University, Series Geology. Geography. Ecology, (59), 277-283. https://doi.org/10.26565/2410-7360-2023-59-20*
5. *Гелевера, О., Мостіпан, М., Топольний, С. (2023). Зимова та весняна багаторічна динаміка температури повітря в Центральній Україні. Вісник Харківського національного університету імені В. Н. Каразіна. Серія: Геологія. Географія. Екологія, (59), 83–94. https://doi.org/10.26565/2410-7360-2023-59-07*
6. *Hirzel, J., Paredes, M., Becerra, V., and Donoso, G. (2020). Response of direct seeded rice to increasing rates of nitrogen, phosphorus, and potassium in two paddy rice soils. Chilean Journal of Agricultural Research, 80, 263-273. https://doi.org/10.4067/S0718-58392020000200263*
7. *Hümmətov, N. Q. (2020). Torpaq-ekoloji mühitin fiziki xüsusiyyətlərinin tənzimlənməsinin torpaq sağlamlığının və bitki məhsuldarlığının yaxşılaşdırılmasında rolu. Torpaqşünaslıq və Aqrokimya İnstitutunun elmi əsərləri toplusu, 2(31), 9–38.*
8. *Ибрагимова, Л. П., Наджафов, Д. С., Асадов, Х. Б. (2020). Деградация почв и пути её оптимизации в Нахчыванской АР. Известия Тульского государственного университета. Науки о Земле, (4), 3–11.*
9. *Jafarova, F.M., Hajiyeva, A.Z. (2024). Modern situation and prospects of the use of biotechnologies in the development of Azerbaijan's agriculture. Revista Universidad Y Sociedad, (4), 303-310.*

10. Jiménez-Lao, R., Aguilar, F.J., Nemmaoui, A., Aguilar, M.A. (2020). Remote Sensing of Agricultural Greenhouses and Plastic-Mulched Farmland: An Analysis of Worldwide Research. Remote Sens., 12, 2649. https://doi.org/10.3390/rs12162649
11. Крайнюк, О., Буц, Ю., Барбашин, В., Нікітченко, О., & Сухов, В. (2024). Деградація екосистем у Харківській області під час війни: супутниковий аналіз. Вісник Харківського національного університету імені В. Н. Каразіна. Серія «Геологія. Географія. Екологія», (61), 329-343. https://doi.org/10.26565/2410-7360-2024-61-26
12. Lee, K., Sung, H.C., Seo, J.-Y., Yoo, Y., Kim, Y., Kook, J.H., Jeon, S.W. (2020). The Integration of Remote Sensing and Field Surveys to Detect Ecologically Damaged Areas for Restoration in South Korea. Remote Sens., 12, 3687. https://doi.org/10.3390/rs12223687
13. Li, D., Zhang, P., Chen, T., Qin, W. (2020). Recent Development and Challenges in Spectroscopy and Machine Vision Technologies for Crop Nitrogen Diagnosis: A Review. Remote Sens., 12, 2578. https://doi.org/10.3390/rs12162578
14. Lu, B., Dao, P.D., Liu, J., He, Y., Shang, J. (2020). Recent Advances of Hyperspectral Imaging Technology and Applications in Agriculture. Remote Sens., 12, 2659. https://doi.org/10.3390/rs12162659
15. Mo, N., Yan, L. (2020). Improved Faster RCNN Based on Feature Amplification and Oversampling Data Augmentation for Oriented Vehicle Detection in Aerial Images. Remote Sens., 12, 2558. https://doi.org/10.3390/rs12162558
16. Nedd R, Light K, Owens M, James N, Johnson E, Anandhi A. A (2021). Synthesis of Land Use/Land Cover Studies: Definitions, Classification Systems, Meta-Studies, Challenges and Knowledge Gaps on a Global Landscape. Land., 10(9), 994. https://doi.org/10.3390/land10090994
17. Petrenko L.R., Berezhnyak Ye.M. (2008). Soil Science: Practical Methods Manual. NAU Publishing house, Kyiv, 239.
18. Segarra, J., Buchaillot, M.L., Araus, J.L., Kefauver, S.C. (2020). Remote Sensing for Precision Agriculture: Sentinel-2 Improved Features and Applications. Agronomy, 10, 641. https://doi.org/10.3390/agronomy1005064
19. Sewa R., Sunil K., Gupta O.P. (Laboratory Manual on Protocols for Evaluation of Wheat Quality (2023). ICAR-Indian IW&B Research, Karnal 132001, Haryana (India), 36.
20. Sishodia, R.P., Ray, R.L., Singh, S.K. (2020). Applications of Remote Sensing in Precision Agriculture: A Review. Remote Sens., 12, 3136. https://doi.org/10.3390/rs12193136
21. Sustainable Development Goals by the United Nations. https://www.undp.org/ukraine/sustainable-development-goals/zero-hunger
22. Vlachopoulos, O., Leblon, B., Wang, J., Haddadi, A., LaRocque, A., Patterson, G. (2020). Delineation of Crop Field Areas and Boundaries from UAS Imagery Using PBIA and GEOBIA with Random Forest Classification. Remote Sens., 12, 2640. https://doi.org/10.3390/rs12162640
23. Wang Q., Li J., Jin T., Chang X., Zhu Y., Li Y., Sun J., Li D. (2020). Comparative analysis of Landsat-8, Sentinel-2 and GF-1 data for retrieving soil moisture over wheat farmlands. Remote Sensing, 12, 2708.
24. Zhou, X., Zhang, J., Chen, D., Huang, Y., Kong, W., Yuan, L., Ye, H., Huang, W. (2020). Assessment of Leaf Chlorophyll Content Models for Winter Wheat Using Landsat-8 Multispectral Remote Sensing Data. Remote Sens., 12, 2574. https://doi.org/10.3390/rs12162574

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References

1. Amanova, Sh.S., Hajiyeva, G.N. (2023). Investigation of Natural Condition in Urban Landscapes of Plain Areas Based on GIS. C. R. Acad. Bulg. Sci., 76(11), 1679-1689. https://doi.org/10.7546/CRABS.2023.11.05
2. Beeson, P.C., Daughtry, C.S.T., Wallander, S.A. (2020). Estimates of Conservation Tillage Practices Using Landsat Archive. Remote Sens., 12, 2665. https://doi.org/10.3390/rs12162665
3. Carter M.R., Gregorich E.G. Soil Sampling and Methods of Analysis (2008) (eds). 2nd ed. CRC Press, Boca Raton, 1234.
4. Hajiyeva, A., Hajiyeva, G., Dadashova, K. K. (2023). Landscape-ecological carcass model of urban landscape and methods of optimize urban landscapes (on the patterns of Ganja and Mingachevir cities). Visnyk of V. N. Karazin Kharkiv National University, Series Geology. Geography. Ecology, (59), 277-283. https://doi.org/10.26565/2410-7360-2023-59-20
5. Helevera, O., Mostipan, M., Topolnyi, S. (2023). Winter and spring long-term dynamic of air temperature in Central Ukraine. Visnyk of V. N. Karazin Kharkiv National University, Series Geology. Geography. Ecology, (59), 83-94. [in Ukrainian] https://doi.org/10.26565/2410-7360-2023-59-07 [in Ukrainian]
6. Hirzel, J., Paredes, M., Becerra, V., and Donoso, G. (2020). Response of direct seeded rice to increasing rates of nitrogen, phosphorus, and potassium in two paddy rice soils. Chilean Journal of Agricultural Research, 80, 263-273. https://doi.org/10.4067/S0718-58392020000200263
7. Hummatov, N.G. (2020). The role of regulating the physical properties of the soil-ecological environment in improving soil health and plant productivity. Collection of scientific works of the Institute of Soil Science and Technology, 2 (31), 9-38. [in Azerbaijani]

8. *Ibrahimova, L.P., Najafov, J.S., Asadov, H.B. (2020). Soil degradation and its optimization in Nakhchivan AR. Proceedings of Tula State University, Earth Sciences, (4), 3-11.*
9. *Jafarova, F.M., Hajiyeva, A.Z. (2024). Modern situation and prospects of the use of biotechnologies in the development of Azerbaijan's agriculture. Revista Universidad Y Sociedad, (4), 303-310.*
10. *Jiménez-Lao, R., Aguilar, F.J., Nemmaoui, A., Aguilar, M.A. (2020). Remote Sensing of Agricultural Greenhouses and Plastic-Mulched Farmland: An Analysis of Worldwide Research. Remote Sens., 12, 2649. https://doi.org/10.3390/rs12162649*
11. *Krainiuk, O., Buts, Y., Barbashyn, V., Nikitchenko, O., Sukhov, V. (2024). Ecosystem degradation in Kharkiv region during the war: satellite analysis. Visnyk of V. N. Karazin Kharkiv National University, Series Geology. Geography. Ecology, (61), 329-343. [in Ukrainian] https://doi.org/10.26565/2410-7360-2024-61-26 [in Ukrainian]*
12. *Lee, K., Sung, H.C., Seo, J.-Y., Yoo, Y., Kim, Y., Kook, J.H., Jeon, S.W. (2020). The Integration of Remote Sensing and Field Surveys to Detect Ecologically Damaged Areas for Restoration in South Korea. Remote Sens., 12, 3687. https://doi.org/10.3390/rs12223687*
13. *Li, D., Zhang, P., Chen, T., Qin, W. (2020). Recent Development and Challenges in Spectroscopy and Machine Vision Technologies for Crop Nitrogen Diagnosis: A Review. Remote Sens., 12, 2578. https://doi.org/10.3390/rs12162578*
14. *Lu, B., Dao, P.D., Liu, J., He, Y., Shang, J. (2020). Recent Advances of Hyperspectral Imaging Technology and Applications in Agriculture. Remote Sens., 12, 2659. https://doi.org/10.3390/rs12162659*
15. *Mo, N., Yan, L. (2020). Improved Faster RCNN Based on Feature Amplification and Oversampling Data Augmentation for Oriented Vehicle Detection in Aerial Images. Remote Sens., 12, 2558. https://doi.org/10.3390/rs12162558*
16. *Nedd R, Light K, Owens M, James N, Johnson E, Anandhi A. A (2021). Synthesis of Land Use/Land Cover Studies: Definitions, Classification Systems, Meta-Studies, Challenges and Knowledge Gaps on a Global Landscape. Land., 10(9), 994. https://doi.org/10.3390/land10090994*
17. *Petrenko L.R., Berezhnyak Ye.M. (2008). Soil Science: Practical Methods Manual. NAU Publishing house, Kyiv, 239.*
18. *Segarra, J., Buchaillot, M.L., Araus, J.L., Kefauver, S.C. (2020). Remote Sensing for Precision Agriculture: Sentinel-2 Improved Features and Applications. Agronomy, 10, 641. https://doi.org/10.3390/agronomy1005064*
19. *Sewa R., Sunil K., Gupta O.P. (Laboratory Manual on Protocols for Evaluation of Wheat Quality (2023). ICAR-Indian IW&B Research, Karnal 132001, Haryana (India), 36.*
20. *Sishodia, R.P., Ray, R.L., Singh, S.K. (2020). Applications of Remote Sensing in Precision Agriculture: A Review. Remote Sens., 12, 3136. https://doi.org/10.3390/rs12193136*
21. *Sustainable Development Goals by the United Nations. https://www.undp.org/ukraine/sustainable-development-goals/zero-hunger*
22. *Vlachopoulos, O., Leblon, B., Wang, J., Haddadi, A., LaRocque, A., Patterson, G. (2020). Delineation of Crop Field Areas and Boundaries from UAS Imagery Using PBIA and GEOBIA with Random Forest Classification. Remote Sens., 12, 2640. https://doi.org/10.3390/rs12162640*
23. *Wang Q., Li J., Jin T., Chang X., Zhu Y., Li Y., Sun J., Li D. (2020). Comparative analysis of Landsat-8, Sentinel-2 and GF-1 data for retrieving soil moisture over wheat farmlands. Remote Sensing, 12, 2708.*
24. *Zhou, X., Zhang, J., Chen, D., Huang, Y., Kong, W., Yuan, L., Ye, H., Huang, W. (2020). Assessment of Leaf Chlorophyll Content Models for Winter Wheat Using Landsat-8 Multispectral Remote Sensing Data. Remote Sens., 12, 2574. https://doi.org/10.3390/rs12162574*

Вивчення природно-екологічних умов в агроландшафтах на основі польових досліджень та дистанційного зондування

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В умовах зміни клімату природні та антропогенні фактори, пов'язані з діяльністю людини, призводять до деградації ґрунтового покриву, що призводить до зниження родючості ґрунту та продуктивності екосистем, погіршення соціально-економічної якості життя людини та загалом створює серйозні проблеми в продовольчій безпеці країни. Неврахування агрофізичних, агрохімічних, фізико-хімічних та інших властивостей ґрунтів у землекористуванні, залежно від агроекологічних умов, призводить до деградації сільськогосподарських угідь та проявляється у вигляді засолення ґрунту, механічної деформації та ущільнення, ерозії, опустелювання, зниження продуктивності екосистем та інших форм. Тому в умовах інтенсивного землекористування управління продуктивністю агроценозів тією чи іншою мірою залежить від оцінки агрофізичного та агрохімічного стану ґрунтів, що відіграє вирішальну роль у виявленні та контролі деградації та внесенні пропозицій щодо вирішення цієї проблеми. Дослідження проводилося на зернових культурах Ленкоран-Астарського (Джалілабадського, Масаллинського, Ленкоранського) економічного району Азербайджанської Республіки в умовах богарного зрошення з різним ступенем зволоження. Дослідження охоплювало зернові поля, розташовані в різних сільських районах адміністративних областей, а також ділянки, що охоплюють зернові посіви Джалілабадської регіональної дослідної станції (РДС) Науково-дослідного інституту рослинництва. Відповідно до методики, дослідження проводилися у відповідних відділах та лабораторіях Науково-дослідного інституту рослинництва з використанням космічних (ГІС-технології, дистанційне зондування Землі) та наземних (агрофізичні та агрохімічні властивості ґрунту, показники врожайності та якості зерна) методів. З точки зору оцінки ступеня ерозії ґрунтів часто використовується коефіцієнт структурної вразливості (КВ). КВ відображає загальну структурну якість ґрунту з точки зору його структурно-агрегатного складу. Структурна деградація може призвести до ущільнення та утворення кірки на поверхні ґрунту, що знижує швидкість інфільтрації води, збільшує ризик ерозії ґрунту та втрати верхнього шару ґрунту. Результати показують, що показники, що характеризують структурний стан ґрунтів у всіх досліджуваних регіонах (AVA, Kstr, Ds), можна оцінити як «дуже добрий» (AVA >60%) та «добрий» (AVA >50%) відповідно до існуючих градацій.

***Ключові слова**: нульовий голод, дистанційне зондування, стале сільське господарство, зернові культури, знімки Landsat, продовольча безпека, оцінка врожайності сільськогосподарських культур, кліматично розумне сільське господарство, NDVI.*

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