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ABSTRACT
of the dissertation
for the degree of Doctor of Philosophy

ASSESSMENT THE AGROPHYSICAL STATE OF SOIL AT THE MOUNTAINOUS SHIRVAN CONDITIONS UNDER CEREAL CROPS

BAKU -2024

The dissertation research took place at the "Soil and Plant Analysis" laboratory whitin the Research Institute of Crop Husbandry of the Ministry of Agriculture of Azerbaijan Republic

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INTRODUCTION

Research issue rationale and development rate. In recent years special attention has been paid to the assessment of the physical condition of soil in both scientific research and agricultural practices[1]. Under the climate change condition the problem of degradation and the sustainable agriculture production require a scientifically based assessment of the physical condition of the soil. The assessment of soil physical condition under specific soil-climate conditions is an important scientific and practical issue, because it allows to give recommendations on the cultivation of agricultural crops, to determine the optimal and equilibrium values of the agrophysical parameters of soil fertility. In intensive agriculture conditions, productivity improvement can be achieved by optimizing agrophysical parameters which characterizing the physical condition of the soil through agrotechnical methods. Depending on the soil and climatic conditions, with the application of a specific agrotechnical method, it becomes necessary to determine the ranges of change in agrophysical properties in order to assess the physical condition of the soil during the vegetation a specific agroecosystem. Complex agrophysical studies have not been carried out in the area of Gobustan District of Mountainous Shirvan in the last 20-30 years to assess the physical condition of the soil under cereal crops taking into account agrotechnical methods and soil and climate conditions. Therefore, during the studies, it was planned to assess the physical condition of the light gray-brown (chestnut) soils during the vegetation period of cereal crops under the rainfed conditions in the Gobustan district of Mountainous Shirvan.

Aims and objectives of the research. Object and subject of research. The main purpose of the research is to determine the agrophysical properties, ranges of change in the structural-aggregate composition of the soil, optimal and equilibrium values in the arable

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[1]Ahmadova, A.M., Hummatov, N.G. Evaluation of the agrophysical state of the light-chestnut soil dry-land conditions of Mountain Shirvan // Materials of the scientific-practical conference on "Actual problems of modern biology and chemistry", part I, Ganja, May 5-6, 2015, p. 274-278

layer of light gray-brown (chestnut) soil under cereal crops in the Mountain Shirvan (Gobustan region) conditions and to assess the physical condition of the soil. It is considered appropriate to perform the following tasks to achieve the set goal:

- Study of soil and climate conditions of the area under cereal crops under rainfed the conditions of the Mountainous Shirvan during the research period;
- Determination of agrophysical properties of soil and structural-aggregate composition intra-vegetation variation range and evaluating the general physical condition of the soil and indicators of the structure-aggregate composition by mathematical-statistical methods;
- Study of rheological properties of soil;
- Determination of soil agrophysical quality index.

Research methods: Light gray-brown (chestnut) soils under cereal crops cultivated in production conditions was taken as the object of study. The studies were carried out in field and laboratory conditions on the scale of arable land by standard methods used in modern soil science. For agrophysical analysis, soil samples have been taken using auger or cylinder. Samples were taken from topsoil and subsoil layers with 3-5 times, 5-9 repetitions in different growth stages of crops in cereal crops agrocenosis, which distinguished in different years of tillage methods, fertilizer rate and predecessor.

Structural-aggregate composition of the soil has been determined by N.I.Savvinov method, soil bulk density by auger or cylinder method, soil perticle density by pycnometer method, soil moisture content by gravimetric method, porosity was determined by calculation. The granulometric composition of the soil was determined by the method of laser diffraction by treating the soil with sodium-pyrophosphate ($Na_4P_2O_7$) and ultrasound, the specific surface area of the soil was determined by the method of low-temperature sorption of nitrogen on the Sorbtometer-M device, rheological properties were determined on the MCR-302 modular rheometer. The soil agrophysical quality index was calculated as the geometric average value. The amount non-organic carbon in carbonates, amount of total and organic carbon is determined in the "AH-7529" automatic express Analyzer by the method of dry burning in the Gustavson-Peregil oxygen flow (1050-1150^{0}C), the pH indicator is determined in pH-meter. The mathematical-statistical analysis of the results was evaluated by the Minitab 14 software package at a probability level of 0.05 for all statistical parameters.

Basic theses for defence:

- The study of the general physical properties of the soil and the dynamics of the structural-aggregate composition of soil under the rainfed conditions in cereals agrocenosis allows to evaluate the direction of the change of the physical state of the soil and its fertility from an agrophysical point of view against the background of applied agrotechnics;
- A reliable assessment of the ranges and direction of changes in the parameters of the physical state of the soil can be a diagnostic indicator of physical degradation;
- Determination of agrophysical quality index of soils under cereals allows its effective use by controlling its quality;
- The study of the rheological properties of soils under rainfed conditions allows to evaluate structural-mechanical changes under the land use conditions

The research's scientific innovation. Over the past 20-30 years, almost no complex agrophysical studies have been carried out on the assessment of the physical condition of the soil under cereal crops, taking into account agrotechnical and soil-climatic conditions in the Gobustan district of Mountainous Shirvan. Under rainfed conditions of the Gobustan region under cereal crops at the arable land scale as a result of complex agrophysical studies, agrophysical indicators of soil fertility, taking into account their dynamic nature were evaluated by modern soil-physical and mathematical-statistical methods. The soil agrophysical quality index was determined, for the first time has been studied rheological properties of light gray-brown (chestnut) soil in Mountainous Shirvan conditions.

Theoretical and practical significance of the research. The results of the study can be used for obtaining information on the agrophysical state of soils under cereal crops under the Mountainous Shirvan conditions. This information also can be used for enriching the

Republic`s Soil Information System and for information support of the agrophysical block of soil fertility, for reading a special course on soil science and agrophysics in the educational process at universities. Determination of soil rheological parameters is a fundamental and operational approach to the study of soil microstructure. The results of the study can be used when assessing the soil resistance to mechanical impact and in the study of the influence of compaction of soils on rheological parameters under the influence of physico-chemical, anthropogenic factors of the soil structure, including agricultural machinery.

Approbation and implementation. Results of the research has been discussed in scientific report meetings and Scientific Council of the Research Institute of Crop Husbandry, at the international scientific conference on "Reflection of bio-, geo-, anthropospheric influences on soil and soil cover" (September 7-11, 2015, Tomsk, Russia), at the scientific-practical conference on "Actual problems of modern biology and chemistry" dedicated to the 93rd anniversary of national leader H.A.Aliyev's birth (May 12-13, 2016, Ganja), at the international scientific conference on "Sustainable development of soil and state" (March 1-4, 2017, St. Petersburg, Russia), at the conference of young scientists and students on "Innovations and global challenges in modern biology and agrarian sciences" dedicated to the 90th anniversary of Acad. J.A.Aliyev (October 31, 2018, Baku), at the international scientific conference "Key concepts of soil physics: development, current applications and prospects" (May 27-31, 2019, Moscow, Russia), at the scientific conference on the topic "Modern problems of soil science and agriculture" (October 16, 2019, Fergana, Uzbekistan). It has been discussed at the scientific-practical conference on "Ecology, land reclamation and energy" dedicated to the 110th anniversary of Akad. V.R.Volobuyev's birth, at the virtual international scientific-practical conference on "Actual problems of modern agrarian and biological sciences: global challenges and innovations" (December 17, 2020 Baku), At the international scientific-practical conference on "Current problems of modern agricultural and biological sciences: global challenges and innovations" (2022, Baku).

The name of the organization where the dissertation was conducted. The research was carried out on the scale of the arable area in production conditions in the territory of Gobustan Regional Experimental Station (RES) of the Research Institute of Crop Husbandry of the Ministry of Agriculture of the Republic of Azerbaijan.

The volume of the dissertation's structural sections separately and the general volume. Dissertation work consists of introduction, 5 chapters, conclusion, bibliography and appendices. The work has a total of 198 pages, including 41 tables, 31 graps, 2 images (186461 excluding images, tables, bibliography and appendices). So, the title part is 1 page and 393 symbols, the introduction is 6 pages and 10444 symbols, Chapter I is 37 pages and 73331 symbols, Chapter II is 15 pages and 24512 symbols, Chapter III is 16 pages and 27429 symbols, Chapter IV is 19 pages and 35716 symbols. Chapter V consists of 4 pages and 6043 symbols, the conclusion consists of 2 pages and 2547 symbols, farm Recommendations 1 pages and 758 symbols and the bibliography of 282 numbers consists of 30 pages and 48188 symbols. References to 282 literature sources were given using local and foreign literature, of which 46 are local, 6 Turkish, 116 Russian, and 116 English language publications.

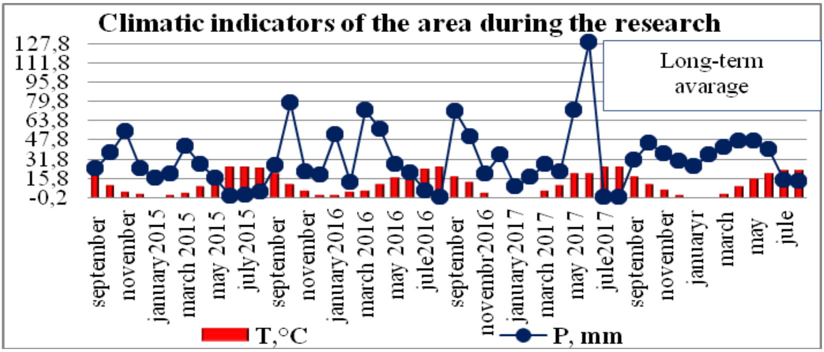
Abstract

In the introductory part of the thesis, a short description of the relevance of the work is given, and its scientific and practical significance is indicated.

Chapter I. Literature review on the topic

In this chapter, the factors affecting the main agrophysical properties of the soil, the variability of agrophysical properties during the vegetation, soil structure, its effect on soil fertility and plant growth, the stability of the soil structure, the granulometric composition, crop cover and the role of organic matter in soil structure formation, the influence of soil tillage methods, fertilizer rates and root system on soil structure, the importance of soil rheological properties, as well as the results of scientific research on the assessment of soil`s structural-mechanical condition through rheological properties were summarized.

Chapter II. Natural geographical conditions of the area. Research objectives and methodologies. In this chapter, the information about the natural-geographic conditions of the Mountanous Shirvan economic region, the object of the study, research methods and conducting conditions of the research, the main physical and physico-chemical properties of the soil and the climatic indicators of the area during the reseach period has been given. The research was carried out in 2014-2017 under cereal crops at the Gobustan RES of the Research Institute of Crop Husbandry in the Gobustan region of Mountanous Shirvan. The territory of RES is mainly composed of light gray-brown (chestnut) soil - ***Castanozems.***



Graph 1. Information of Gobustan Hidrometeorological Station

Undisturbed soil samples for agrophysical analysis, has been taken using a soil auger or a cylinder. Soil samples has been collected in different research years, in different growth phases of the plant, in the cereal agrosenosis, which differed according to the tillage method, fertilizer rates and predecessor, with 5-9 replicates of topsoil (0-25 cm soil layer or 10-15 cm average depth) and subsoil (25-50 cm soil layer or 35-40 cm average depth). Graph 1 and Table 1 provide information about the research conditions and research areas.

Table 1

Research conditions and areas

VY	GC, H	Crops	L, m	T_i	F_i	Predecessors	t_i
I	N40°31.456′ E48°53.488′ 734 m	Barley	40x40	T_1+T_c	F_1	Barley	11.11.14 27.03.15 01.05.15 27.05.15 22.06.15 21.08.15
	N40°31.370′ E48°53.801′ 831 m			$T_2+T_3+T_4$	F_1	Black fallow	
	N40°31.156′ E48°53.564′ 831 m			T_1+T_3	F_1	Barley	
II	N40°31.233′ E48°53.848′ 829 m	Wheat	15x12	T_c T_m T_0	F_0 F_3	Wheat	24.11.15 24.03.16 20.05.16 14.07.16
III	N40°31.193′ E48°53.738′ 837 m	Wheat	40x40	T_c+T_3	F_2	Wheat	13.04.17 07.06.17 15.07.17
	N40°31.343′ E48°53.904′ 823 m					Black fallow	
	N40°31.702′ E48°53.888′ 816 m					Pea	

Note. VY-vegetation year; GC, H–geographical coordinates, elevation (height above sea level); L – the size of the research area; T_0-no-tillage, T_1-5-8 cm disking, T_2-25-27 cm plowing, T_3-7-10 cm disking, T_4-7-10 cm cultivation, T_c-20-22 cm plowing, T_m – minimal cultivation (10-12 cm disking); F_0–$N_0P_0K_0$ (without fertilizer), F_1–$N_{85}P_{16}K_{16}$, F_2–$N_{90}P_{60}K_{60}$, F_3–$N_{120}P_{60}K_{60}$; t_i–sampling date.

Chapter III. Variation in general physical properties of light gray-brown (chesnut) soil under cereal crops depending on research years

Chapter III provides statistical assesment of soil`s general physical properties and their intra-vegetation dynamics.

3.1. Statistical parameters of general physical properties of soil. The results of statistical analyzes show that the distribution of agrophysical properties corresponds to the normal law in over 90% of cases. The coefficients of variation for the investigated agrophysical properties (except sometimes ε_a, K_{str}, >10 mm soil fraction) has been demonstrated weak (<15%) or moderate (15-50%) variability. Throughout the study years, the coefficients of variation have been observed in the topsoil -W: 2.1-23.1%, ρ_b: 3.5-18.5%, ε_t: 2.9-17.4%, ε_a: 6.2-49.5% and in the subsoil - W: 1.3-31.2%, ρ_b: 2.1-13.3%, ε_t: 2.1-12.0%, ε_a: 3.8-40.9%.

3.1.1. Moisture content of soil. Under rainfed conditions soil moisture content is usually unstable and depends on the amount of precipitation[2]. Throughout the vegetation period, soil moisture changes with a certain regularity (graph 2). If we pay attention to the distribution graph of precipitation and temperature (graph 1), we will see that soil moisture content depends on climatic conditions. There was little difference in soil moisture content according to tillage methods, but sharp dynamics of soil moisture content has been observed during the vegetation. Variability in moisture content is discernible among cultivation methods, with distinct patterns observed during the growing season. Decreasing of moisture content in the topsoil from the beginning to the end of the vegetation is related to the low rainfall according to the season and the water demand of the plant[3]. At the beginning of the research, the values of moisture content in the arable layer of the respective variants are 23.5%, 25.1% and 25.0%. Although the dynamics of moisture change in all 3 options were similar, its high values were in the black fallow predecessor (T_2+T_3+T_4), but its low values were 5.0%, 5.3% and 5.1% in the arable layer after harvest, according to the respective

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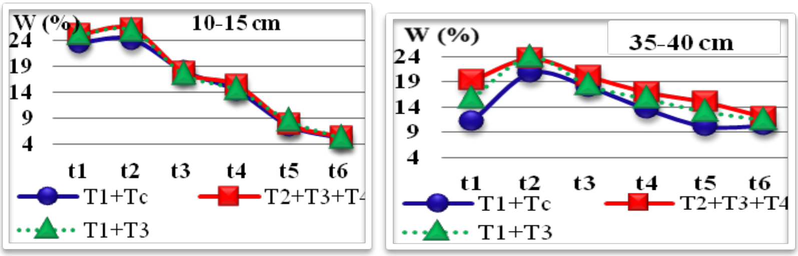
[2] Ahmadova, A.M., Hummatov, N.Q. Influence of basic tillage practices on agrophysical properties of the soil under the winter wheat in rainfed condions of Mountain Shirvan. -Baku: "Muallim" publishing house, Collection of scientific works of RICH, XXVIII volume, 2016, p. 352-362.

[3] Hummatov, N.G., Ahmadova, A.M. Dynamics of the physical properties of light-brown soils in dry-land conditions // Materials of the scientific-practical conference dedicated to the 80th anniversary of the birth of Academician M.I. Jafarov, - Ganja, ASAU publishing house - July 8, 2016, - p.122-125.

options. In the 2nd research year, soil moisture content in the topsoil layer have been varied between 10.1-28.4% and 16.0-25.8% in the subsoil. At the beginning of the study, the soil moisture content in the topsoil was 25.3, 24.4, and 23.6% in the conventional, minimal, and no-tillage without fertilizer, and 25.2, 25.0, and 26.4% in the options with fertilizer, respectively. The high value of soil moisture content has been observed under the no-tillage with fertilizer (T_0F_3), and the low value was observed in the topsoil at the end of vegetation. At the end of the vegetation, soil moisture content has been observed respectively, 10.1, 10.2, 10.7% and 10.0, 10.0, 10.4% in the topsoil under conventional, minimal and no-tillage methods without fertilizer and with fertilizer options. In the third year of the study, a comprehensive examination of soil moisture content reveals notable fluctuations in both the topsoil and subsoil. Soil moisture content in the topsoil has ranged from 13.6% to 27.8%, while the subsoil exhibited variations between 16.1% and 24.2%. Particularly high moisture levels have been observed during the stem elongation phase. These findings underscore the influence of favorable climatic conditions in the 3rd year, resulting in higher overall soil moisture levels in comparison to the preceding years. Minimal values of soil moisture content have been recorded in the topsoil at the end of the vegetation period (16.7%, 15.3%, and 13.5%). In all three research years, high moisture levels have been observed in the topsoil at the beginning and in the subsoil at the end of vegetation. The influence of seasonal rainfall on soil moisture level has been observed. The presence of substantial rainfall during autumn and spring lead to heightened moisture content in the topsoil at the beginning of the vegetation period, conversely, decreasing rainfall towards the end of the vegetation period led to decline soil moisture content in the topsoil. Despite the reduced rainfall towards the end of the vegetation period, the subsoil maintains relatively high soil moisture content. This divergence in moisture dynamics between the topsoil and subsoil layers underscores the complex interplay of soil characteristics, climatic factors and other factors.



Note. t_1-post sowing, t_2–tillering, t_3–stem elongation, t_4-flowering, t_5-ripening phaase, t_6-post harvest

Graph 2. Dynamics of soil moisture content (I year)

3.1.2. Soil bulk density. In the 1st year of the study, the soil bulk density has changed in the range of 0.97-1.43 in the topsoil and 1.32-1.49 g/cm^3 in the subsoil layer, high values of bulk density in the soil have been observed under T_1+T_c, and low values have been observed under T_1+T_3 option (table 2). The lowest density (0.97 g/cm^3) in the topsoil has been under T_1+T_3, the highest density (1.43 g/cm^3) has been under the T_1+Tc. In the 2nd research year the bulk density changed in the range of 0.97-1.53 g/cm^3, the smallest bulk density in the topsoil (0.97 g/cm^3) has been observed under the conventional option without fertilizer, high soil bulk density (1.53 g/cm^3) has been observed under no-tillage option with fertilizer. The smallest value of the soil bulk density in the subsoil (1.24 g/cm^3) has been under conventional tillage method, but high value of soil bulk density has been observed under minimal tillage method without (1.49 g/cm^3) fertilizer. In the third year, the soil bulk density changed in the range of 1.14-1.36 in the topsoil, 1.30-1.42 g/cm^3 in the subsoil, and the high bulk density has been observed under the black fallow predecessor. The low value of the bulk density (1.14 g/cm^3) has been observed in the topsoil, and the high value (1.42 g/cm^3) has been observed in the wheat predecessor in the subsoil layer.

In all three research years, soil bulk density values close to the optimum have been observed at the beginning of vegetation period and in the period of intensive growth of plants and rainfall. The soil bulk density has been relatively high in the subsoil, and varied in a wide range in the topsoil and relatively narrow in the subsoil layer.

3.1.3. Total (ε_t) and air porosity (ε_a). During the research period, the total porosity in the topsoil and subsoil layer has been varied 42.3-63.5%, and the air porosity has been varied in the range of 12.5-43.1% (table 3). The high porosity has been observed in the topsoil and low porosity in the subsoil. In all cases, soil air porosity values greater than the critical value (10%) indicates that there is no aeration problem in the research area[4]. In the first year, high values of porosity have been observed mainly under T_1+T_3, air porosity has been increased relatively towards the end of vegetation and its highest value was under T_1+T_c. This can be explained by the drying of the soil due to the lack of precipitation at the end of the vegetation, the decrease of soil moisture content in the pores and the increase of air. In the second year, low air porosity values have been observed under no-tillage method due to the decrease of porosity depending on the soil bulk density. Under conventional tillage with and without fertilizers, the porosity has been slightly different, and under other options, it has been characterized by similar values. High porosity has been recorded in the topsoil of conventional tillage at the end of vegetation. In the third year, high porosity has been observed under the wheat predecessor in the topsoil and black fallow in the sub-plough layer. The small values of ε_a have been observed under black fallow predecessor in the topsoil and under the wheat predecessor in the subsoil layer. In all cases during the research period, the soil porosity can be evaluated as satisfactory, only under no-tillage method as unsatisfactory.

Agrophysical parameters follow the normal distribution law with weak and moderate variability. Differentiation of these properties is observed according to the depth of the soil layer. Since the topsoil is more sensitive to the tillage cultivation, climate condition and other factors, the agrophysical properties in the subsoil layer vary in a relatively narrow range.

Table 3

[4] Shein, E.V. Course of soil physics /E.V.Shein. -Moscow:MSU Publishing House,-2005, -432 p.

Mean values of soil porosity (year I)

Parameter	Depth (cm)	Total (ε_t) və air (ε_a) porosity (%)					
		t_1	t_2	t_3	t_4	t_5	t_6
T_1+T_c							
ε_t	10-15	55.3	49.2	46.1	48.8	49.5	49.7
	35-40	45.1	46.8	43.8	45.5	50.3	47.4
ε_a	10-15	27.7	16.8*	20.7	29.5	39.5	43.1
	35-40	28.7	17.6	17.2	25.8	36.7	32.9
T_2+T_3+T_4							
ε_t	10-15	55.3	52.6	47.9*	48.4	49.6	46.6
	35-40	48.0	49.6	46.6	48.1	47.2	46.2
ε_a	10-15	26.4	20.1	23.4	27.5	39.4	39.1
	35-40	21.5	18.2	18.3	24.8	26.3	29.0
T_1 + T_3							
ε_t	10-15	63.5	57.8	55.4	53.7	49.2	48.5
	35-40	48.2	47.6	48.5*	47.9	45.9	48.1
ε_a	10-15	39.2	26.5	34.9	36.0	37.9	41.5
	35-40	26.7	16.3	23.5*	26.4	27.1	36.8

Satisfactory values of agrophysical properties coincide with the plants intensive growth period in the topsoil layer, and the effect of fertilizer on them is weak compared to tillage methods and the predecessor. Although the conventional method is more suitable in terms of agrophysical properties in the cereal agrosenosis under the rainfed conditions of Mountanous Shirvan, it may be appropriate to expand the conservation tillage methods applications to ensure ecologically and economically sustainable agriculture.

Chapter IV. Variability of light gray-brown (chestnut) soil structure and water-stability parameters under cereal crops

In this chapter, statistical parameters of dry and water-stable aggregates have been evaluated. Agronomically valuable aggregates (AVA), coefficient of soil structure (K_{str}), mean weight diameter of dry aggregates (D_d), >0.25 mm water-stable aggregates and dynamics of water-stable aggregates mean weight diameter (D_w) within vegetation period have been studied.

4.1. Statistical parameters of soil dry aggregate size ditribution. The results of the statistical analysis show that the soil dry aggregate size distribution follows the normal law. During the research period, the coefficient of variation of dry aggregates in the topsoil layer - >10 mm: 11.6-97.9%, AVA: 1.3-27.6%, D_q: 6.7-33.9%; in the subsoil layer - >10 mm:15.9-106.4%, AVA:1.2-12.7%, D_d:8.5-29.9%, indicate that the structural composition of the soil is weak and moderately variable, except for the >10 mm fraction.

4.1.1. Agronomic valueable aggregate fraction and coefficient of soil structure. During the research period mean values of >10 mm aggregates, AVA and K_{str} in the topsoil layer varies in the range of - >10 mm:4.9-28.1%, AVA:68.8-88.1%, K_{str}:2.3-8.3, in the subsoil layer in the range of - >10 mm:0.7-25.7%, AQA:70.1-88.3%, K_{str}:2.5-7.9 (table 4). In first year differentiation of the soil structural composition according to the depth is weak under T_1+T_c, relatively strong under T_2+T_3+T_4 and T_1+T_3. At the beginning of the vegetation period, AVA and K_{str} differed according to the options, but at the end, they have been characterized by close values due to the equilibrium state of the soil, high AVA values have been observed under T_1+T_3 in the topsoil layer (table 4). In 2nd research year the AVA change trendency under no-tillage, especially in the subsoil layer is different from others. The differentiation of dry aggregate size distribution by depth is weak under conventional tillage, relatively strong under minimal and no-tillage methods. High AVA values have been observed under the wheat and under the fodder (forage) pea predecessor in 3rd year, its change trend in the topsoil layer was different under the fodder pea predecessor, and at the end of the vegetation period, the highest values have been in the topsoil (88.2%) and subsoil layer (81.3%) under the fodder pea predecessor. As a nitrogen-fixing legume plant, forage pea had a positive effect on soil structure and led to an increase of AVA values. In general, based on the existing gradations in all three research years the soil structure can be assesed very well (AVA>60%, K_{str}>1.5). During the plants intensive growth period, the differentiation of the soil structure in the topsoil and subsoil layer can be related to the climate conditions, tillage methods and the growth of the root system. Fertilizer, tillage methods and the predecessor had a relatively weak effect on the soil structural composition.

4.1.2. Mean weight diameter of dry aggregates size (D_d). The mean weight diameter, which characterizes the distribution and stability of aggregates, has been widely used in recent years for assessment the soil structure-aggregate composition. During the research period, D_d varies between 2.8-6.6 mm in the topsoil and 2.8-6.4 mm in the subsoil layer. 1st research year (graph 3, table 4) in the topsoil layer at the beginning of vegetation D_d has been characterized by relatively high values under T_1+T_c and T_2+T_3+T_4, and close values in all options starting from the flowering phase (t_4).

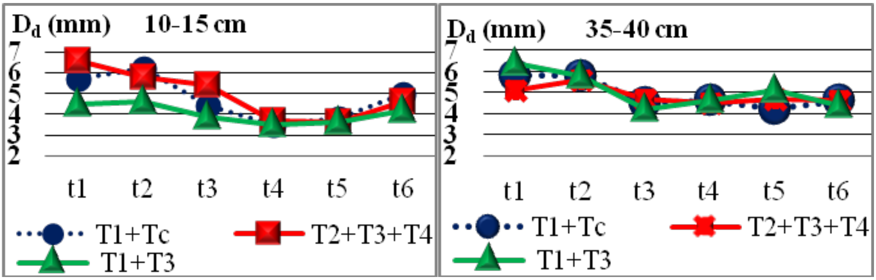
Table 4

Mean values of structural indicators (1st year)

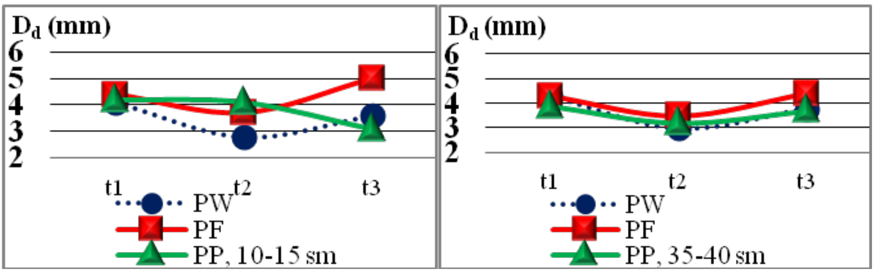
Struc. indic.	Depth (sm)	Mean values of structural indicators					
		t_1	t_2	t_3	t_4	t_5	t_6
T_1+T_c							
AVA (%)	10-15	76.6	76.5	80.3*	83.0	82.4	78.5
	35-40	73.6	79.2	81.5	80.6	80.0	76.2
K_{str}	10-15	3.6	3.5	4.3	5.1	4.8	3.9
	35-40	2.9	4.8*	4.7	4.3	4.3	3.3
D_d (mm)	10-15	5.7	6.2	4.4	4.1	3.9	5.1
	35-40	5.8	5.8	4.5	4.1	4.2	4.6
T_2+T_3+T_4							
AVA (%)	10-15	68.8	75.1	75.8	78.6*	81.3	73.9
	35-40	79.5	76.9	78.1	79.6	77.9	76.4
K_{str}	10-15	2.5	3.2	3.6	4.1	4.5	3.0
	35-40	4.1	3.6	3.9	4.0	4.7	3.3
D_d (mm)	10-15	6.6	5.8	4.6	3.7	3.6	4.6
	35-40	5.1	5.6	4.7	4.5	4.7	4.6
T_1+T_3							
AVA (%)	10-15	82.6	82.6	80.8	82.5	82.7	76.3
	35-40	70.1	75.4	80.5	76.9	76.3	75.9
K_{str}	10-15	4.8	5.8	4.5	4.9	5.0	3.3
	35-40	2.5	3.4	4.5	3.5	3.4	3.3
D_d (mm)	10-15	4.6	4.6	3.9	3.5	3.6	4.3
	35-40	6.4	5.8	4.2	4.6	5.1	4.4

In the 2nd year, D_d decreases from the beginning of vegetation to the tillering phase, then this changes depending on the depth and options. The highest values have been observed under no-till. One of the reasons for the change of D_d depending on time is the soil moisture level. In the 3rd year, the high values D_d have been recorded under the black fallow predecessor and increase towards the end of the vegetation (graph 4). When the soil moisture level is sufficient (t_2) and at the intensive root growth period D_d is characterized by a low values.

Research shows that the root system is one of the active factors of aggregates re-formation in the soil during the vegetation period, changes in quantity and quality.[5]



Graph 3. Dynamics of mean weight diameter (D_d) (1st year)



Graph 4. Dynamics of mean weight diameter (D_d) (3rd year)

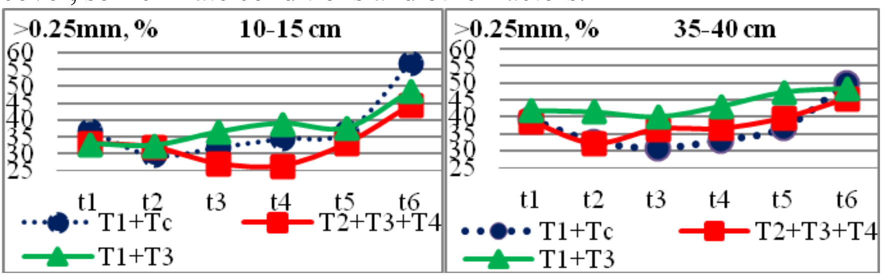
Differentiation of dry aggregates according to depth is weak under the wheat predecessor and relatively strong under the black fallow and forage pea predecessor. The reason for the differentiation of the dry aggregate size distribution by depth in all three research years may be the tillage methods, predecessor and root system. In terms of D_d the soil

[5] Hummatov, N.G., Pachepsky, Ya.A. Modern ideas about soil structure and structure formation: mechanisms and models, dynamics and factors (2nd ed.) / N.G. Hummatov, Ya.A. Pachepsky. -Baku: Muallim Publishing House, - 2016, - 100 p.

structural condition can be assessed very well (<9 mm) on the existing gradations.

4.2. Assessment of statistical parameters of water-stable aggregates. The results of the statistical analysis show that the distribution of water-stable aggregates follows the normal law. The values of coefficient of variation in topsoil (>0.25mm: 7.6-38.6%, D_w: 6.0-46.0%) and in the subsoil indicating that (>0.25mm: 4.2-29.7%, D_w: 5.9-36.5%) the soil waterstability parameters are weak or moderately variable.

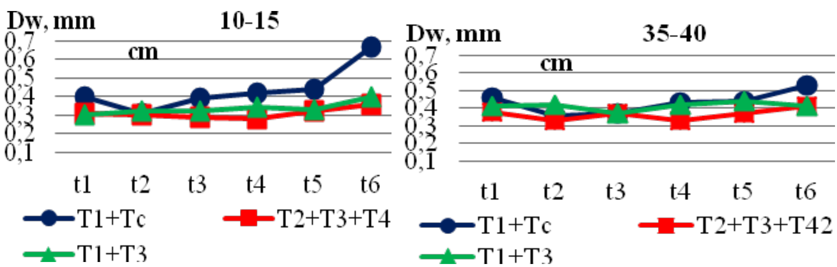
4.2.1. Waterstability indicator of soil aggregates. In the research years, >0.25 mm water-stable aggregates has been varied in the range of 26.5-57.0 in the topsoil layer and 30.0-62.4% in the subsoil layer. The 1st year changes of soil water-stable aggregates under different options is similar (graph 5) and it begins to increas starting from the stem elongation phase and the highest value has been observed after harvest under T_1+T_c. The differentiation of the aggregate composition by layers is weak under T_1+T_c, and relatively strong under T_2+T_3+T_4 and T_1+T_3. In the 2nd research year, in most cases, the tendency of this indicator under no-till with fertilizer in the subsoil layer is different. The relatively high values of water-stable aggregates in both layers was under conventional tillage method. The researches shows that values water-stable aggregates depend on tillage methods, crop cover, soil-climate conditions and other factors.



Graph 5. Dynamics of water-stable aggregates (1st year)

The effect of tillage methods and fertilizer on the aggregate waterstability is not uniform. The change tendency of water-stable aggregates in the topsoil layer of the 3rd year is similar under black fallow and wheat predecessor (table 5). Under the wheat predecessor, the high values of waterstability in both layers have been observed under the tillering phase (t_1–37.5% and 44.2%), and decreased towards the end of vegetation (t_3–33.9% and 34.4%). The high values of waterstability under fodder pea predecessor have been observed in the topsoil layer during milk ripening (37.6%), in the subsoil layer in the stem elongation phase (39.2%), and the small value of waterstability in the topsoil (31.1%) and subsoil layer (30.0%) has been recorded at the end of vegetation.Watersability has been remained relatively stable under the black fallow predecessor, and high values was at the end of vegetation period, as well as in the subsoil layer. During the research period, the soil waterstability can be estimated as weak (20-40%) and moderate (40-60%)[6].

4.2.2. Mean weight diameter (D_w) of water-stable aggregates. The results showed that D_w varies in the range of 0.26-0.67 in the topsoil and 0.32-0.59 mm in the subsoil layer. In the 1st year T_1+T_c variant, D_w increased from the beginning to the end of the vegetation, it got the highest value in the topsoil layer after harvest (graph 6:t_6-0.67 mm). It was characterized by close values under



Graph 6. Dynamics of the D_w (1st year)

T_2+T_3+T_4 and T_1+T_3. In the 2nd year the change of D_w in the topsoil layer is similar under T_0 and T_m, and higher values are observed under T_c. The change of the aggregate composition depending on the

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[6] Mamedov, R.H. Agrophysical properties of soils of the Azerbaijan SSR / R.H. Mamedov. - Baku: Elm Publishing House, - 1989, - 244 p.

depth is weak under the non-fertilized and fertilized version of conventional tillage, and relatively strong in the others. In most cases, the variation of D_w in the subsoil layer of the fertilized no-till is different from the others. Apparently, D_w varies in one way or another depending on the tillage method.

Table 5

Dynamics of soil aggregate composition (III year)

Parameter	Depth (cm)	t_1	t_2	t_3
Wheat predecessor (PW)				
>0.25mm (%)	10-15	37.5	30.2	33.9
	35-40	44.2	33.0	34.4
D_w (mm)	10-15	0.33	0.31	0.34
	35-40	0.49	0.36	0.39
Black fallow predecessor (PF)				
>0.25mm (%)	10-15	34.4	33.5	34.5
	35-40	43.4	43.3	42.3
D_w (mm)	10-15	0.29	0.30	0.35
	35-40	0.42	0.40	0.44
Fodder pea predecessor (PP)				
>0.25mm (%)	10-15	31.6	37.6	31.1
	35-40	39.2	36.9	30.0
D_w (mm)	10-15	0.29*	0.35	0.35
	35-40	0.36	0.39	0.35

The higher the D_w (>2 mm), the more waterstable the soil is considered to be[7]. Although there is a difference between the variants in III year (table 5), a relative balance is observed at the end of the vegetation (PW-0.34, PF-0.35, PP-0.35 mm). During the study period, the soil can be evaluated as weak and moderate according to water-stable aggregate, and very weak (<0.4 mm) and weak (0.4-0.8 mm) according to D_w[7]. No sharp differences were found in the effect of fertilizer on aggregate composition. The relative influence of

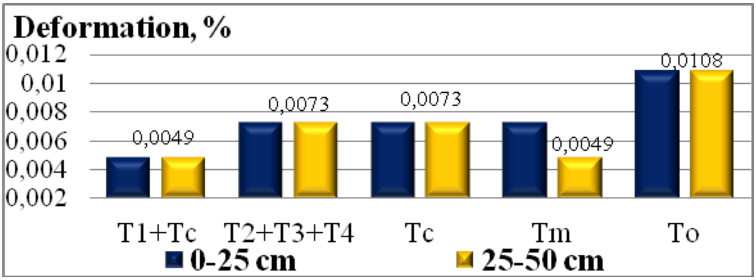
[7] Paluszek, J. Air-dry and water-stable soil aggregate distribution of polish chernozems classified in various complexes of agricultural suitability // Pol.J. Environ. Stud., -2014, v. 23(3), -p. 813-821

predecessor, tillage methods, climate, root system and other factors was observed.

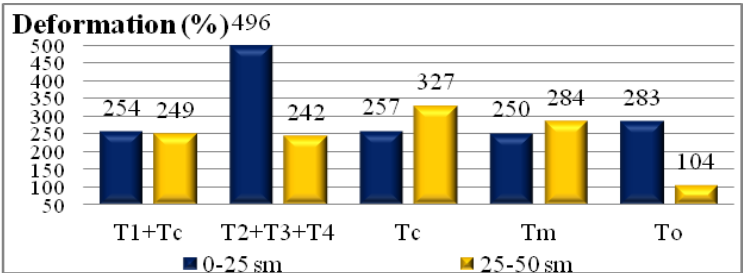
4.3. Rheological properties of light gray-brown (chestnut) soil. The study of rheological properties allows to assess the structural relations of the soil and their quality, resistance to mechanical impact, strength and plasticity. The rheological approach to structure assessment is considered an important diagnostic method for assessment of degraded, including deformed soils. Granulometric composition analysis shows that the fraction of coarse (0.05-0.01 mm), medium (0.01-0.005 mm) and fine dust (0.005-0.001 mm) prevails in the 0-50 cm soil layer. According to the classification of N.A. Kachinsky and R.H. Mamedov, the granulometric composition (texture) of light grey-brown (chestnut) soil in the research area is mainly light and medium clayey. The specific surface area of soil varied in the range of 27-56 m^2/g. Soil with a high degree of swelling and high organic matter requires a lot of force to compact. As the soil bulk density increases, the interparticle interaction force and modulus of elasticity (G') increase. During the rheological analyses, the linear visco-elasticity range (LVE-range), the modulus of elasticity in this range, the point of intersection of the modulus of elasticity and viscoelasticity (G'') (G'=G'') -the deformation value of the point of destruction of the structure were studied. LVE-range is the region where the soil behaves as an elastic body, it shows the parallelism of the curves of viscosity and modulus of elasticity.Its high values indicate the continuity of the interparticle connection and structure[8]. The equality of the modulus of elasticity and viscoelasticity indicates the transition of the soil from visco-elastic body to viscoelastic state during deformation or the value of the deformation at this moment. Rheological properties depend on climatic conditions, tillage

[8] Khaidapova, D.D. Rheological properties of typical chernozems (Kursk region) under different land uses / D.D. Khaidapova, V.V. Chestnova, E.V. Shein [etc.] // Pochvovedenie, - 2016, No. 8, - p. 955-963.

methods, depth of soil layer, amount of organic matter, maximum swelling moisture[9].



Graph 7. The linear viscoelastic deformation range(LVE-range)



Graph 8. The modulus elasticity

Changes observed in LVE-range and G' in topsoil layer were observed according to physical clay, organic matter and specific surface area (graph 7 and 8). LVE-range varied in the range of 0.0049-0.0108%, the smallest deformation was observed in T_1+T_c (0.0049%), the largest - in T_0 (0.0108%). Under T_0 LVE-range is ~2 times larger than others. G', which reflects the strength of the structure in the process of mechanical impact, changed in the range of 104–496 kPa. The deformation value of the point of destruction of the structure changed in the range of 1.27-3.05%, the smallest value is T_1+T_c (1.27%) in the subsoil layer, the highest values are in the

9 Hummatov, N.Q., Ahmadova, A.M. Rheological properties of Azerbaijan soils // Collection of scientific works of EITI, -2019, volume 1(30), No. 2, - p. 9-20.

subsoil and topsoil layer under $T_2+T_3+T_4$ (3.05%, 2.93%) and T_0 (2.97%, 2.62%) were recorded. As it can be seen, under the T_1+T_c, the destruction of the structure occurs at small deformations, that is, the structure is more resistant to mechanical impact under conventional cultivation.

For the first time in Azerbaijan, the rheological properties of Mountanous Shirvan were studied in a modern MCR-302 rheometer depending on the granulometric and structure-aggregate composition, soil bulk density, and organic matter. Soil organic matter and physical clay provide stability as a structural factor. Samples with a high content of organic matter and physical clay are distinguished by their plasticity and resistance to deformation.

Chapter V. Agrophysical quality index of light gray-brown (chestnut) soil under cereal crops

Soil quality index (SQI) is widely used to evaluate soil quality. SQI is calculated based on statistical methods through parameters characterizing physical, chemical and biological properties[10]. The assessment of the physical condition of the soil is determined based on the generalized "Agrophysical quality index" (AQI). AQI → 1 in soils with high agrophysical quality, and AQI → 0 in soils with poor agrophysical quality[11]. In the research areas, AQI was calculated based on the general physical properties of the soil (ρ_b, ε_t) and structure-aggregate composition indicators (AVA, D_d, >0.25mm, D_w). For this purpose, the statistical characteristics of various agrophysical parameters have been determined in ~1500 soil

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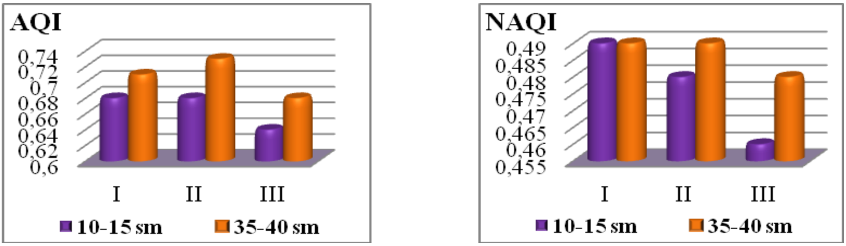
[10] Nabiollahi, K. Heshmat, E. Mosavi, A. Kerry, R. Zeraatpisheh, M. Taghizadeh Mehrjardi, R. Assessing the Influence of Soil Quality on Rainfed Wheat Yield / K. Nabiollahi, E.Heshmat, A.Mosavi [et al.] Agriculture, - 2020, vol. 10, 469. https://doi.org/10.3390/agriculture10100469

[11] Mukherjee, A., Lal R. Comparison of soil quality index using three methods // PLoS ONE, - 2014, E9(8):e105981. https://doi.org/10.1371/journal.pone.01059811

samples, six have been selected as the main physical condition indicators and used in AQI determination. During the research period, the agrophysical quality indicators - AQI 0.64-0.73, NAQI (normalized AQI) have beeen varied in the interval 0.46-0.49 (graph 9). The values of AQI indicate that the physical quality of the soil is weak and moderate. Studies show that the results of the assessment of general physical properties and structure-aggregate composition correspond to the results obtained from the assessment of generalized agriphysical quality indices (AQI, NAQI). Thus, in the conditions of Mountain Shirvan, and the physical condition of the light gray-brown (chestnut) soil, including the structural-water resistance characteristics, can be assessed as "moderate" and "weak".



Graph 9. Soil agrophysical quality index

Conclusion

1. During the research period, high values of soil moisture content were observed for topsoil at the beginning and for subsoil at the end of the vegetation and the moisture content differed reliably between the layers. Due to the fall of precipitation mainly in autumn and spring, the moisture content for topsoil layer was high at the beginning of vegetation and low towards the end of vegetation, and the moisture content was characterized by relatively high values for subsoil layer.
2. The values of the bulk density of soil close to the optimum were observed at the beginning of the vegetation, during the

intensive growth of the root system and the rainfall period, and the highest values were observed at the end of the vegetation in the subsoil. The bulk density had been varied from 0.97 to 1.49 g/cm^3 for topsoil, from 1.24 to 1.49 g/cm^3 for subsoil, respectively.

3. The results of the statistical analysis show that agrophysical parameters are mainly weak and moderate variables. The physical condition indicators of the soil undergo differentiation based on depth and very in a narrower range in the subsoil layer. Satisfactory values of agrophysical properties in the topsoil coincide within the period of intensive growth of the cereal crops, and the impact of fertilizer on these properties is relatively weaker than tillage methods and predecessor.
4. During the research period, in the plough layer of the soil the values of structural indicators (AVA, K_{str}) can be evaluated as "very good" according to the existing gradations. Structural composition of soil undergo differentiation according to depth. The effect of fertilizer rates on the structural composition of soil is weaker than cultivation methods and the predecessors.
5. In the topsoil, the content of water-stable aggregates of soil and mean weight diameter (D_w) vary in the range of 26.5-57.0% and 0.26-0.67 mm, respectively, and in the subsoil, in the range of 30.0-62.4% and 0.32-0.59 mm. Based on the existing gradations, the soil can be assessed as weak and moderate in terms of the content of water-stable aggregates, and very weak and weak in terms of $D_{w.}$ In terms of the effect of fertilizer, no sharp differences were found in aggregate composition, but it was observed that the predecessor, tillage methods, climate condition, depth of the soil layer, and the growth of the root system have relative effect on the water stability of aggregates.
6. For the first time, the rheological properties of arable light gray-brown (chesnut) soil under rainfed conditions of

Mountain Shirvan have been studied using a modern MCR-302 rheometer. Depending on the amount of physical clay and organic matter, the mechanical resistance and rheological properties of the soil have changed. The range of linear viscoelastic deformation range (LVE-range) is 0.0049-0.0108%, the storage modulus elasticity is 104-496 kPa, the deformation value of the point of destruction of the structure has changed in the range of 1.27-3.05%.

7. Soil agrophysical quality index (AQI) and normalized agrophysical quality index (NAQI) changes in the range of 0.64-0.73 and 0.46-0.49, respectively, indicates that light gray-brown (chestnut) soil has "weak" and "moderate" agrophysical quality.
8. Although the conventional tillage method is more appropriate in terms of agrophysical properties of light gray-brown (chestnut) soil in the cereal crop agrosenosis and under rainfed conditions, it can be considered appropriate to expand the application of conservation tillage methods for the sustainable agriculture from both ecological and economic aspects.

Farm recommendations

To maintain soil fertility and achieve satisfactory agrophysical indicators of fertility for farmers involved in cereal-growing activities in the mountain gray-brown (chestnut) soils of Mountainous Shirvan region, the following recommendations are considered appropriate for continuous high-quality crop production:

1. Conventional (20-22 cm deep plowing) or minimal (10-12 cm deep disking) tillage of the soil with timely use of rates of fertilizers ensure the mineral nutrition regime of cereal crops.
2. To enhance water and food supply in the soil, it is advisable to use fallow and one-year leguminous plants (such as fodder or food peas) as predecessors and to implement a three-field crop rotation in farms.

List of published scientific publications related to the dissertation topic

1. Ahmadova, A.M., Hummatov, N.G. Evaluation of the agrophysical state of the light-chestnut soil dry-land conditions of Mountain Shirvan // Materials of the scientific-practical conference on "Actual problems of modern biology and chemistry", part I, Ganja, May 5-6, 2015, p. 274-278
2. Ahmadova, A.M., Hummatov, N.G.Estimation of agrophysical state of light-chesnut soil in dry land condition of Mountain Shirvan // Materials of the V international scientific conference dedicated to the 85th anniversary of the Department of Soil Science and Soil Ecology of TSU, Tomsk, September 7-11, 2015, p. 157-160.
3. Ahmadova, A.M., Hummatov, N.G. Dynamics of the agrophysical properties under the barley // -Baku: "Muallim" publishing house, Collection of scientific works of RICH, XXVII volume, 2016, p. 356-362.
4. Hummatov, N.G., Ahmadova, A.M. The dynamics of the structure-aggregate composition of the light-chestnut soil under the barley plant in dry-land conditions of Mountain Shirvan // Proceedings of the international scientific conference on "Actual problems of modern chemistry and biology", Part IV, Ganja, 2016, p. 251-256.
5. Hummatov, N.G., Ahmadova, A.M. Dynamics of the physical properties of light-brown soils in dry-land conditions // Materials of the scientific-practical conference dedicated to the 80th anniversary of the birth of Academician M.I. Jafarov, - Ganja: - July 8, 2016, - p.122-125.
6. Ahmadova, A.M., Hummatov, N.Q. Influence of basic tillage practices on agrophysical properties of the soil under the winter wheat in rainfed condions of Mountain Shirvan. - Baku: "Muallim" publishing house, Collection of scientific works of RICH, XXVIII volume, 2016, p. 356-362.

7. Ahmadova, A.M. The influence of tillage methods on the agrophysical properties and yield of winter wheat in rainfed conditions of Azerbaijan // Materials of the international scientific conference of the XX Dokuchaev youth readings “Soil and sustainable development of the state”, St. Petersburg, March 1-4, 2017, p. 115-117.
8. Ahmadova, A.M., Hummetov, N.G. Investigation of agrophysical properties of the light-chestnut soil depending on the predecessor in the rain-fed conditions of the Mountain Shirvan Shirvan // Collection of scientific works of the Research Institute of Cropp and Husbandry, Volume XXIX - Baku: "Muallim" publishing house, -2018, p.434-443.
9. Ahmadova A.M. The study of physical status indicators of arable light-chestnut soils in rainfed condition of Mountain Shirvan // Conference of young scientist and students “İnnovations in biology and agriculture to solve global challanges” dedicated to the 90th anniversary of academician J.A.Aliyev, Baku, 31 oktyabr, 2018, p.35.
10. Hummatov, N.G., Ahmadova, A.M. Assesment of agrophysical properties of arable soils in rainfed conditions of Mountain Shirvan // Collection of works of the Society of Soil Scientists of Azerbaijan, volume XV, -Baku: "Elm" publishing house, -2019, -p. 347-353.
11. Hummatov, N.G., Ahmadova, A.M. Rheological properties of the soils of Azerbaijan // Collection of scientific works of RICH, volume 1 (30), No., 2, - Baku: "Elm" publishing house, -2019, p. 9-20.
12. Ahmadova, A.M., Hummetov, N.G. Evaluation some agrophysical properties of light-chestnut soil in rainfed condition // Proceedings of the international scientific conference on "Actual problems of modern natural and economic sciences", part III, Ganja, 2019, p. 145-147.
13. Ahmadova, A.M., Gummatov, N.G. Estimation of indicators of the agrophysical state of light chestnut soil in rainfed conditions of Mountainous Shirvan // Coll. scientific material

International scientific conference dedicated to the 90th anniversary of the birth of A.D. Voronin “Fundamental concepts of soil physics: development, modern applications and prospects”, Moscow: “KDU”, “Dobrosvet”, May 27-31, 2019, p. 380-384.
14. Akhmedova, A.M., Gummatov, N.G. The influence of fertilizers and soil tillage methods on the agrophysical properties and yield of winter wheat // materials of scientific conference young scientific conference IV Williams readings – “Genetic and agronomic assessment of soils”, Moscow: RGAU-MSHA, -2019, - p.115-117.
15. Gummatov, N.G., Akhmedova, A.M. Ecological assessment of the physical state of arable soils under agricultural use and rainfed conditions of Azerbaijan // Collection of articles. mat. republic scientific conference “Modern problems of soil science and agriculture”, Fargana: FarSU, - 2019, - p. 173-176.
16. Hummatov, N.G., Ahmadova, A.M. Rheological properties of irrigated and rainfed soils of Azerbaijan // Scientific-practical conference dedicated to the 110th anniversary of the birth of Academician V.R. Volobuyev on "Soil ecology, melioration and energetics". materials, Baku: - 2020, -p. 27-28.
17. Ahmadova, A.M. Variability of structural indicators of light-chestnut soil depending on tillage methods and fertilization // International scientific-practical conference on "Current problems of modern agricultural and biological sciences: Global challenges and innovations". materials. Baku:-2022, -p. 243-249.
18. Akhmedova, A.M. Evaluation of waterstability indicators of light gray-brown (chestnut) soils in the condition of Mountain Shirvan // Bulletin of Science and Practice, T.9., No. 7, Publishing Center “Science and Practice”, Nizhnevartovsk, Russia, - 2023, p. 168-178.
19. Akhmedova A.M. Assessment of soil bulk density and moisture content of light-gray-brown arable soils at the

rainfed condition // Бюллетен науки и практики, Т.9., №9, Издательский центр «Наука и практика», Нижневартовск, Россия, - 2023, с. 115-122.

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