Features of the granulometric composition and properties of weakly and low-humus agro-gray soils in the Vyatka strip of the forest-steppe zone

Lilia Gaffarova*, *Ragat* Minicaev, *Anastasia* Akhrarova, and *Lilia* Nikifirova

Kazan State Agrarian University, 65, K. Marx Str., Kazan, 420015, Republic of Tatarstan, Russian Federation

Abstract. Statistical parameters of agro-gray soil varieties obtained on the basis of generalization of information are the zero-monitoring cycle in the studied region and serve as reliable criteria for the diagnosis of these soils. Numerical indicators reflect the results of past and current soil processes. In agricultural production, the role of the arable layer with all the properties that determine the level of grain yield is especially important. Thus, in the studied varieties, there is a stable relationship between the amount of silt fraction, food elements, and humus. Thus, the clay variety is characterized by the highest fertility of the arable layer - an average content of mobile potassium (10.5 mg/100 g), an increased content of phosphorus (12.4 mg/100 g), low-concentration of humus (2.9%), close to neutral reaction of the medium (5.8 pH). Comparative analysis of soil formation products in the analyzed soil varieties shows their regular change in morphometric characteristics and properties of soils, reflects the result of soil formation processes, partly-economic activity.

* Corresponding author: gaffarovalylya@mail.ru

1 Introduction

The analyzed zonal soil varieties are at the equilibrium stage, with minor changes under the influence of natural factors of soil formation [1]. Current transformations mainly occur under the influence of economic activities, which include plowing the soil with a violation of natural composition, its annual processing for growing a whole set of crops – from grain to row crops, alienation of crops from the place of cultivation, application of organic and mineral fertilizers, protection of cultivated plants with modern means, etc. In modern conditions, intensive farming is carried out by agricultural machines, which also negatively affects the soil cover of arable land.

Despite the existing changes in the morphological structure and chemical composition of soils, the main patterns of distribution of properties are still preserved. At the same time, human economic activity and its intensity have a general tendency to increase over time. It is aimed at increasing soil fertility by improving their humus state, providing basic nutrients and neutralizing soil solution through liming and phosphorization of acidic soils.

For the purpose of directed regulation of soil changes under the influence of economic activity, it is necessary to take into account natural patterns of spatial changes in soil properties.

2 Materials and methods

We have considered the regularities of changes in soil parameters depending on the granulometric composition. For processing data of soil sections, clay (c), heavy loam (h), medium loam (m), light loam (l) and sandy loam (s) varieties of agro-gray soils of the Republic of Tatarstan in the North-Eastern part of the forest-steppe were selected [2, 3]. The region occupies the Northern strip of the forest-steppe zone, occupies one of the leading places in modern agricultural production, crop production and animal husbandry. The obtained samples of soil indicators of multiple sections of agro-gray soils were processed by the method of mathematical statistics [4].

3 Results and discussion

Each soil property and morphological indicators have their own significance in the formation of agricultural products. At the same time, statistical indicators of the morphological structure and properties of soils (arithmetic mean, average error of the arithmetic mean, standard deviation, coefficient of variation, sample size, limit values) are more informative than information obtained from typical soil sections. The significance of statistical characteristics increases at the regional level, and the uniqueness of these soil varieties is determined by the same set of soil formation factors.

The thickness of the arable horizon in the varieties under consideration varies in the following order (tables 1–5): 27(c) – 24.8 (h) – 24.7 (m) – 24.2 (l) – 23.8 cm (s). The Maximum difference between them is 3.2 cm, which confirms the anthropogenic nature of this soil layer and the depth of humus-accumulative and transition horizons in the varieties.

The transition horizon AEl lies below the arable layer, in many cases it is part of it, so information about its lower boundary is fragmentary.

The lower boundary of the BEL horizon has the following range: 32.7 (c) – 28.0 (m) – 34.2 (l) cm – 32.7 cm (s); the differences between them are also insignificant.

The lower boundary of the horizon B lies at a depth of 80.8 (c) – 96.7 (h) – 84.9 (m) – 99.6 cm (l) – 73.3 (s). Significant difference between them observed only is in the sandy loam variety. The formation of a powerful illuvial horizon should be explained by a periodically flushing type of water regime.

The distribution of the humus content in the arable horizon from the granulometric composition is more clearly reflected, it is as follows: 2.9 (c) – 2.8 (h) – 2.4 (m) – 2.0 (l) - 1.2 (s) %. The feature is a decrease in the humus content by 1.7% between clay and sandy loam varieties, at a depth of more than 30 cm, the differences are almost erased. All this is evidence of improved conditions for the accumulation of humus of clay and heavy loam varieties.

The sum of absorbed bases represents a positive function of the humus content and fine fraction of the granulometric composition and has the following series for these representatives of the arable horizon soils: 25.7 (c) – 19.8 (h) – 17.7 (m) – 16.1 (l) – 14.5 (s) mmol/100 g. In this series, the difference in extreme values is 11.2 mmol/100 g of soil. The hydrolytic acidity of the arable layer has the following values: 2.2 (c)–3.1(h)–2.6 (m)–2.3 (l)-2.0 (s) mmol/100 g of soil. The maximum difference between them is 1.1 mmol/100 g of soil, which indicates a uniform distribution. The profile distribution of the sum of absorbed bases and hydrolytic acidity is consistent with changes in both the humus content and the fine fraction, as well as with a local increase in the podzolic process in the upper part of the profile.

The pH value of the salt suspension of soils in the arable layer has the following range: 5.8 (c)–5.5 (h) – 5.6 (m) – 5.8 (l) – 5.4 (s).

According to the pH value of the illuvial horizon, the group of soils has the following range: 5.3 (c) – 4.9 (h) – 5.0 (m) – 5.4 (l) - 5.6 (s). It reflects the gradual neutralization of pH as it moves from the upper horizons to the soil-forming rock. In this direction, there is an improvement in the conditions for the absorption of trace elements for the root system, along with better migration in light soils.

Mobile elements of nutrition-phosphorus and potassium are mainly inherited by the breed in the form of gross forms. In the process of weathering rocks and minerals, they pass into water-soluble forms and become available to the root system of plants. In extensive

* Corresponding author: gaffarovalylya@mail.ru

agriculture, the main source of phosphorus and potassium is their gross forms, and in intensive agriculture, a new source appears in the form of mineral and organic fertilizers. Accordingly, the phosphate and potash regimes of the arable horizon are the result of reflecting the influence of these two components.

The content of mobile phosphorus of the studied soils in the arable horizon has the following range in the direction from average to high security: 12.4 (c)–10.1 (h)–11.1 (m)–11.9 (l)–8.0 (s) mg/kg of soil. Of course, such a change in the phosphorus content in arable soils is the result of the use of phosphorus-containing mineral fertilizers and the possibilities of its accumulation. The criterion for effective use of fertilizers is a positive balance of phosphorus, which is confirmed by calculations in recent years [5, 6].

A similar trend is also observed with respect to mobile potassium. The studied soils in the arable horizon have a corresponding range: 10.5 (c)–9.1 (h)–7.6 (m)–9.7 (l)–3.6 (s) mg/kg of soil. The content of mobile potassium gradually increases from a very low degree of security in sandy loam varieties to an average security in others. Such a relatively high level of potassium supply is an integral process of the following phenomena: decomposition of rock containing potassium in the composition, alienation of potassium from the soil with the crop yield, loss of mobile potassium by water flows during intense precipitation, negative potassium balance in recent years [7, 8].

The profile distribution of granulometric particles < 0.01 and < 0.001 mm of the studied soils has an eluvial-illuvial type according to B. G. Rozanov (2004), which is the result of elementary soil processes, primarily due to the movement of a fine soil fraction [9]. This requires a wash or periodically wash type of water regime and an acid reaction of the soil solution to disperse soil particles. These conditions are most optimal in the sandy loam variety.

The fundamental components of soils - particles of physical clay (<0.01 mm) and silt fraction (<0.001 mm) are less subject to change over time. As is known, the granulometric composition and the ratio of granulometric particles in the soil is inherited from the soil-forming (parent) rock and changes slightly in the process of soil formation [10]. The silty fraction of the granulometric composition in the middle part of the soil is more mobile and variable than the fraction of physical clay, this is evident from the corresponding series: 23.2 (c) – 16.5 (h) – 13.8 (m) – 7.2 (l) - 5.1 (s) % of the soil. Thus, the arable layer of agro-gray forest soils contains 16.5 % silt, in the horizon B-34.2-37.2 %, in the soil-forming rock-32.8 %. This difference in the values of this fraction occurred in the process of soil formation. Thus, the upper part of the agro-gray soil undergoes acid hydrolysis as a result of the podzolic process. Therefore, the upper horizons are impoverished by the silty fraction, and the products of destruction are moved by the soil solution to the illuvial horizon, where they accumulate. Some of the silty particles migrate without significant destruction and these two processes go together.

Table 1. Statistical averages of indicators of signs and properties of light gray clay arable soils in the Vyatka strip of the pre-Kama region of the Republic of Tatarstan.

Horizons	lower bound, cm	Particles, %		Humus, %	mg-EQ/100g		PH, pH*	Mobile, mg/100g	
		<0.001	<0.01		Ca+Mg	Hr		P_2O_5	K_2O
P	27.0	23.2	52.1	2.9	25.7	2.2	5.8	12.4	10.5
Bt_1	44.4	37.8	59.3	0.7	26.7	2.0	5.3	7.3	8.8
Bt_2	80.8	41.2	58.9	0.6	28.9	–	5.0	–	–
BC	107.5	37.9	61.6	–	–	–	7.0	–	–
C	136.2	34.1	58.9	–	–	–	7.0	–	–

Table 2. Statistical average indicators of characteristics and properties of light gray forest heavy loam arable soils (n = 111–144).

Horizon	lower bound	Particles, %		Humus, %	mmol/100 g		pH_{KCl}	Mobile forms, mg / kg	
		<0.001 mm	<0.01 mm		Ca+Mg	H_r		P_2O_5	K_2O
P	24.8	16.5	44.1	2.8	19.8	3.1	5.5	101	91
AEl	28.5	16.7	43.0	1.7	16.4	2.8	5.3	96	75
BEL	32.7	22.6	47.1	1.1	19.8	3.4	4.8	69	85
Bt_1	48.3	34.2	53.1	0.7	22.8	3.1	4.9	106	90
Bt_2	96.7	37.2	56.1	0.5	25.8	2.8	4.7	–	–
BC	122.7	34.3	55.5	–	–	–	5.9	–	–
C	160.0	32.8	54.7	–	–	–	6.3	–	–

Table 3. The statistical average of the indicators characteristics and properties light grey medium loam arable soil Privatsky strip of pre-Kama region of the Republic of Tatarstan.

Horizons	lower bound, cm	Particles, %		Humus, %	mg-EQ/100g		PH, pH*	Mobile, mg/100g	
		<0.001	<0.01		Ca+Mg	Hr		P_2O_5	K_2O
P	24.7	13.8	36.6	2.4	17.7	2.6	5.6	11.1	7.6
AEl	31.3	11.3	35.8	1.4	14.5	2.2	5.3	11.1	4.5
BEL	28.0	17.4	41.0	0.7	16.0	2.8	5.2	14.0	7.8
Bt_1	45.0	28.0	44.8	0.7	20.4	2.3	5.0	15.2	9.2
Bt_2	84.9	32.4	47.4	0.4	23.4	2.6	4.8	–	–
BC	120.1	30.6	44.2	–	–	–	5.6	–	–
C	149.2	28.0	45.0	–	–	–	5.5	–	–

Table 4. The statistical average of the indicators characteristics and properties of light-gray, light loamy arable soils Privatsky strip of pre-Kama region of the Republic of Tatarstan.

Horizons	lower bound, cm	Particles, %		Humus, %	mg-EQ/100g		PH, pH*	Mobile, mg/100g	
		<0.001	<0.01		Ca+Mg	Hr		P_2O_5	K_2O
P	24.2	7.2	25.2	2.0	16.1	2.3	5.8	11.9	9.7
AEl	39.5	-	-	1.5	14.3	2.3	5.4	8.3	7.9
BEL	34.2	11.8	26.3	-	15.3	1.8	6.1	16.7	4.0
Bt_1	51.1	19.4	30.8	0.6	19.5	1.9	5.4	21.1	10.0
Bt_2	99.6	21.9	33.6	0.4	21.3	-	4.8	-	-
BC	125.0	28.6	40.4	-	-	-	3.4	-	-
C	155.6	18.8	28.5	-	-	-	5.0	-	-

Table 5. Statistical averages of indicators of signs and properties of light gray sandy loam arable soils in the Vyatka strip of the pre-Kama region of the Republic of Tatarstan.

Horizons	lower bound, cm	Particles, %		Humus, %	mg-EQ/100g		PH, pH*	Mobile, mg/100g	
		<0.001	<0.01		Ca+Mg	Hr		P_2O_5	K_2O
P	23.8	5.1	17.9	1.2	14.5	2.0	5.4	8.0	3.6
BEL	31.0	–	–	0.5	10.0	0.9	5.8	15.0	2.7
Bt_1	43.8	–	–	0.3	11.3	0.9	5.6	17.5	–
Bt_2	73.3	–	–	–	–	–	5.2	–	–

Table 6. Parameters of correlation of particle content <0.01 (x) and <0.001 (y) m, % of light gray heavy loam arable soil.

Properties		τ	Regression equation	
<0.01(x)	0.001(y)		x = a × y + b	y = a × x + b
P	P	0.429	x = 0.3577 × y + 38.20	y = 0.5133 × x − 6.15
AEl	AEl	0.846	x = 1.0342 × y + 25.70	y = 0.6914 × x −13.01
BEL	BEL	0.584	x = 0.5648 × y + 34.36	y = 0.6039 × x – 5.89
Bt_1	Bt_1	0.637	x = 0.7622 × y + 27.03	y = 0.5325 × x + 5.95
Bt_2	Bt_2	0.740	x = 0.7548 × y + 28.00	y = 0.7264 × x − 3.5389
BC	BC	0.525	x = 0.903 × y + 24.48	y = 0.30551 × x + 17.37
C	C	0.592	x = 0.7713 × y + 29.47	y = 0.454 × x + 7.96

Table 7. Parameters of particle content <0.01(x) and <0.001 (y) mm, % of light gray clay arable soils.

Properties		τ	Regression equation	
x	y		x = a × y + b	y = a × x + b
P	P	0.165	x = 0.3036455 × y + 45.09	y = 1.247229 × x – 41.81
Bt_1	Bt_1	0.098	x = 0.04300493 × y + 57.71	y = 0.2244788 × x + 24.50
Bt_2	Bt_2	0.474	x = 0.2597691 × y + 48.19	y = 0.8633741 × x – 9.65
BC	BC	0.744	x = 0.6039882 × y + 38.68	y = 0.9162761 × x – 18.49
C	C	0.986	x = 1.14195 × y + 19.98	y = 0.8514854 × x – 16.07

Table 8. Parameters of particle content <0.01 (x) and <0.001 (y) m, % of light gray medium loamy arable soils.

Properties		τ	Regression equation	
x	y		x = a × y + b	y = a × x + b
P	P	0.382	x = 0.4007527 × y + 31.08	y = 0.3648497 × x + 0.46
AEl	AEl	0.495	x = 0.9151309 × y + 25.51	y = 0.2677929 × x + 1.67
BEL	BEL	0.957	x = 0.910478 × y + 25.17	y = 1.004879 × x − 23.82
Bt_1	Bt_1	0.836	x = 0.8492653 × y + 21.01	y = 0.8235409 × x − 8.87
Bt_2	Bt_2	0.966	x = 1.315886 × y + 4.74	y = 0.7092959 × x − 1.20
BC	BC	0.960	x = 1.434731 × y + 0.25	y = 0.6429685 × x + 2.22
C	C	0.834	x = 0.9862598 × y + 17.43	y = 0.7056744 × x − 3.80

Table 9. Parameters of particle content <0.01 (x) and <0.001 (y) m, % of light gray light loamy arable soils.

Properties		τ	Regression equation	
x	y		x = a × y + b	y = a × x + b
P	P	0.731	x = 1.120957 y + 17.18	y = 0.4762433 x – 4.83
BEL	BEL	0.946	x = 1.3541 y + 10.25	y = 0.6602341 x – 5.51
Bt_1	Bt_1	0.977	x = 1.351128 y + 4.60	y = 0.7059461 x – 2.35
BC	BC	0.704	x = 0.9199553 y + 13.38	y = 0.5387522 x + 3.85
C	C	0.979	x = 1.444575 y + 1.38	y = 0.6632491 x – 0.13

Table 10. Correlation parameters of particle content <0.01(x) and <0.001 (y) mm, % of light gray sandy loam arable soil.

Properties		τ	Regression equation	
<0.01(x)	<0.001(y)		x = a × y + b	y = a × x + b
P	P	0.806	x = 0.7497177 × y + 14.13	y = 0.8666015 × x − 10.47

The content of physical clay in the profile confirms the eluvial-illuvial type [9]. The content of physical clay in the studied varieties corresponds to the following series: 52.1 (c) – 44.1 (h) – 36.6 (m) – 25.2 (l) - 17.9 (s) % of the soil. The data obtained correspond to the granulometric composition of the upper horizon of the varieties.

The silty fraction (particles <0.001 mm) is part of the physical clay (particles <0.01 mm), which allows us to consider the correlation between them by genetic horizons (tables 6-10). At the same time, the compared indicators characterize different soil sections laid down throughout the territory of the studied region, that is, these coefficients are obtained in a spatial series of soils, even soil horizons.

The obtained coefficients are reliable at a significance level of 0.05, and they characterize a tendency to strengthen the connection in the upper part of the soil profile than in the lower part. Exceptions are indicators of the clay variety and between the content of particles in the arable horizon. Apparently, the decrease in the tightness of communication is due to the processes of water erosion of soils and maximum migration of silt particles.

4 Conclusion

The genetic profile and location of horizons are fundamental soil features that carry information about past and current processes that form the main soil taxa. The obtained morphometric data can be used to diagnose aggressive soil types in this region.

The soil is a natural body formed as a result of a combination of natural factors, properties of the soil itself, and indicators of the profile structure. This relationship is more pronounced between soil indicators. The coefficients of pair correlation between the content of physical clay and silt fraction within the same genetic horizon and the sample are carriers of quantitative information about the intensity of their movement and the formation of genetic horizons.

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