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Dynamics of Light-Gray Forest Soils Agrochemical Properties in the Conditions of Agrogenesis

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Abstract. The paper presents a regional statistical characteristic of the analytical and morphometric properties of the prevailing light gray forest agrogenic soils and the dynamics of the yield of winter rye. It has been established that the balance is generally positive, with a phosphorus content of plus 15.4 kg, nitrogen - plus 4.7 kg, negative potassium - minus 16.5 kg. The example of background zonal light gray forest soils shows changes in the agrochemical state due to economic activity. The noted regularity affects the dynamics of the yield of the winter rye of the region. The actual yield of winter rye rises from the beginning of observation to the last years, with a maximum of 31.9 c / ha. At the same time, in recent years there has been a tendency to reduce the yield of all crops, including winter rye. The noted decrease in the yield of winter rye in the region is recorded by its moving averages over 11 and 22 years, which is due to the negative balance of macroelements in agriculture during this period.

1. Introduction

These guidelines, written in the style of a submission to J. Phys.: Conf. Ser., show the best layout for your paper using Microsoft Word. If you don't wish to use the Word template provided, please use the following page setup measurements. The provision of arable soils with accessible food elements depends on the factors of soil formation and genesis that determine the type of ownership and the classification position of soils. Fundamental and stable properties establish the availability of soils with mobile forms of nitrogen, phosphorus and potassium [1]. With the transition to intensive farming - the use of mineral and organic fertilizers, an important role in this process belongs to the economic activity of man.

In the forest-steppe zone, 3 kg of nitrogen, 1.2 kg of phosphorus oxide and 2.5 kg of potassium oxide [2, 3] are required to form 1 gram of winter rye grain with byproducts, which causes a close relationship between the content of mobile forms of phosphorus, potassium and the yield of cultivated plants [4, 5].

The purpose of this work is to study the parameters of the relationship between the yield of winter rye and the factors (agrochemical indicators of soils, the volume of application of mineral and organic fertilizers), the forecasting of winter rye based on the revealed regularities.

2. Materials and methods

The object of research is the right-bank part of the Privyatskaya strip of the Precamian Republic of the Republic of Tatarstan, represented by the Mamadysh Municipal Formation. The total area of the facility is 260.1 thousand hectares, including agricultural land - 150.0 thousand hectares. Intensively



used in agriculture land - arable land is 93.8 thousand hectares or 62.5%, in their composition is dominated by light gray forest soils - 52.2 thousand hectares. The remaining zonal soils-gray forest, dark gray forest, rock type sod-carbonate soils and extrazonal sod-podzolic soils occupy a subdominant position [6, 7, 3].

In the region, forms of erosion relief have developed, and the area of eroded soils is 81.5% of the arable land.

To characterize the soil properties of light-gray forest soils of the Privytskaya Strip, the accumulated morphological features and analytical properties of light gray forest soils were used during mass soil studies (scale 1: 10000), carried out in 1974-2008 by employees of the Rosgiprozem branch. Parameters of soil properties ensure the provision of soils with mobile elements of nutrition.

The following indicators are included in the sample: the lower boundaries of the genetic horizons, the humus content, the sum of the absorbed calcium and magnesium, mobile phosphorus, exchangeable potassium, hydrolytic acidity, and the pH of the aqueous and salt extracts.

Agrochemical characteristics of soils are based on the materials of the "Center of agrochemical service Tatar", where the supply of soils between cycles is obtained through interpolation of the parameters of the content of phosphorus and potassium. Information on the saturation of arable land with organic and mineral fertilizers was obtained from the materials of the statistical department of the republic.

Soil analyzes and statistical processing were carried out according to accepted methods and available programs [8].

3. Results and discussion

The arable horizon of the zonal soil of the object has an average thickness of the soil subtype - up to 24.8 cm. The combination and depth of the remaining genetic horizons are consistent with the zonal process of soil formation (Table 1).

Table 1. Average indices of signs and properties of light gray forest heavy loamy soils (n = 106-144).

Horizonts	Bottom	particle, %		Humus,	mg-eq /		pH	Movable,	
	Boundaries,%	<0.001	<0.01	%	100 g			mg / 100g	
					S	Hr		P ₂ O ₅	K ₂ O
A _n	24.8	16.5	44.1	2.8	19.8	3.1	5.5	10.1	9.1
A ₁ A ₂	28.5	16.7	43.0	1.7	16.4	2.8	5.3	9.6	7.5
A ₂ B	32.7	22.5	47.1	1.1	19.8	3.4	4.8	6.9	8.5
B ₁	48.3	34.2	53.1	0.7	22.8	3.1	4.9	10.6	9.0
B 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		32.8	54.7	-	-	-	6.3	-	-

The soil subtype analyzed has a heavy loam granulometric composition, and in the soil-forming rock it is light-clayey. The ratio of the particle content <0.001 and <0.01 mm in the plow horizon is 0.60, in the plow horizon this ratio is 37.4. Simultaneously, these indices confirm that the upper part of the soil profile is depleted by the finest dispersed fraction - silt, due to water erosion, soil deflation during the droughty periods of the season, as well as the manifestations of soil processes - leaching, podzalization and leaching.

The content of humus in soils serves as a criterion for assessing the potential fertility of soils. In the studied soils it has typical indices.

In the profile distribution of the sum of the absorbed bases, the leading role is played by the humus content and saturation by the finely dispersed fraction - silt. The absolute values of the sum of the

absorbed bases in the soil have an eluvial-illuvial type of distribution with a maximum in subhorizon B2 - 25.8 mg / 100 g.

The hydrolytic acidity value ranges from 2.8-3.4 mg / 100 g soil, the highest values of which tend to approach the illuvial horizon. The degree of saturation varies from 85 to 90%. The average saturation level is in the horizons A₁A₂ and A₂B, the lower part of the profile has a moderately high base saturation.

The profile distribution of pH indicates a decrease in the concentration of the hydrogen ion to the lower part of the profile. The change of the acid reaction to the neutral reaction is usually observed in the soil-forming rock. The pH of the arable horizon is maintained by periodic liming.

The content of biophilic elements corresponds to the average degree of availability. These indicators somewhat decrease to the podzolized horizon and, conversely, increase to the illuvial horizon.

A brief analysis of the average statistical soil properties indicates that, because of the heavy granulometric composition, soils may have higher levels of mobile potassium forms than phosphorus.

The information given in Table 2 confirms the use of fertilizers for the period under study.

At the same time, the agrochemical state of soils is corrected by using both mineral and organic fertilizers. The systematic introduction of mineral fertilizers began in the late 1950s and early 1960s. By the mid-1970s, the doses of mineral fertilizers had reached 30.5 kg / ha, and by 1993, 264 kg / ha of the active ingredient (highest rates). During this period and subsequent years there is a decrease in the saturation of organic fertilizers of arable land from 7.0 to 0.5 t / ha (Table 2).

Table 2. Time series of agrochemical state of soils, application of mineral (kg ai) and organic fertilizers, winter rye yield in the Mamadysh District.

Cycles and years	P ₂ O ₅	K ₂ O	pH	Fertilizers		Yield, c / hectare		
	mg / kg			min.kg	Org.t / ha	Y _f	Y ₁₁	Y ₂₂
I -1967	70.0	110.0	5.4		no information			
II – 1975	88.8	115.0	5.4	30.5	7.0	7.7	10.7	10.9
III -1983	116.0	129.0	5.4	42	4.8	15.9	14.8	16.1
IV -1988	125.0	126.0	5.3	177	6.7	19.3	19.3	18.8
V -1993	155.5	138.3	5.3	264	5.4	19.9	22.7	23.4
VI -2000	137.5	137.0	5.4	66	3.3	31.9	26.8	26.1
VII–2005	137.3	141.3	5.4	36.9	0.5	25.0	28.3	24.6
VII -2009	137.4	140.1	5.4	61.8	0.7	31.2	28.8	23.4
VIII-2014	141,2	142,2				17.3	21,6	229

The equilibrium state of the pH of the soil suspension is in the acidic range, and the introduction of lime only temporarily changes it, confirming the fundamental nature of this soil property. The actual material also confirms a slight tendency to accelerate the acidification of the pH of the medium during the years of maximum application of fertilizers. According to the results of the first round, arable land had a weighted average pH of 5.4. The weakly acidic soils prevail - 48.8%, the groups of soils with close to neutral and neutral degrees of acidity occupy 33.8% of the total arable land. The share of soils with an average degree of acidity is significant (16.8%), with a strong - a small (0.6%). In the last rounds of research there is a slight tendency to expand the soil areas with acidity close to neutral, neutral medium (45.9%) and with a strong degree of acidity (8-6.6%). This was facilitated by the erosion processes taking place, the deepening of the arable horizon - on the one hand, and the application of physiologically acidic mineral fertilizers - on the other. Weighted average pH values from I to VIII rounds are in the same range - 5.3-5.4. The observed acidification of arable soils is hampered by the growth of land reclamation areas (on average 8,000 ha annually) with lime (Table 2).

According to the results of the first round of the agrochemical survey (1964-1970), the average weighted content of mobile phosphorus in the arable soil horizon of the district was 70.0 and in the

fifth round it reaches a maximum of 155.5 mg / kg (Table 2). According to the results of the first round, the arable soils of the region basically had a low (37.5%) and medium (28.1%) degree of supply with mobile phosphorus. By the VI round the picture has changed. Thus, in the sixth round, the average (25.4%) prevailed, the high and high (25.6 and 28.2%) degree of soil supply with this element. After 2000, the phosphorous regime is set at the level of increased security (137.4 mg / kg).

The content of potassium in the earth's crust is higher than that of phosphorus, however, under the conditions of the washing type of the water regime of soils, the content of mobile potassium varies over a wide range, which is confirmed by agrochemical data (Table 2).

The average weighted amount of exchangeable potassium in the observed years rises from 110 mg / kg to 141.3 mg / kg soil. In the first round, the average (44.6%) and the higher (29.5%) prevail, and in the V and VI rounds - the increased (41.4%) and average (31.8%) degree of provision with this mobile element.

The balance of batteries is usually carried out according to individual agrochemical properties-humus content, mobile nutrients-nitrogen, phosphorus and potassium, carbonates, etc [9, 10, 11, 12, 3, 13, 14].

A regular change in the degree of provision of arable soils with mobile macronutrients-phosphorus and potassium-was noted earlier [15, 16, 17, 18, 19, 20, 21], which finds full confirmation of the results of economic activity district and corresponding balance calculations. So, for 1974-2017 in the area was used 3469.7 kg doses of mineral fertilizers, including 1734.8 kg doses - nitrogen, 1040.9 kg doses - phosphoric and 693.8 kg doses - potash. Annually 1 hectare of arable land received 42.3 kg of nitrogen, 25.4 kg of phosphorus and 16.9 kg of potassium. For 48 years, each hectare of arable land yielded 958.8 centners of winter rye, and except for planting material - 862.8 centners. With an average of 3.1 kg of nitrogen, 1.37 kg of phosphorus and 2.6 kg of potassium in 2.6 kg per 1 centner of grain, 2674.7 kg of nitrogen, 1182.0 kg of phosphorus and 2243.3 kg of potassium or, respectively, 55.7% per annum have been alienated over the years. 24.6 and 46.7 kg doses these elements. With organic fertilizers (manure), the average dose of which was 4.0 t / ha over the years, 24 kg of nitrogen, 24 kg of potassium and 17 kg of phosphorus were added per hectare of nitrogen. Thus, for the considered period, the balance of the nutrient elements in nitrogen and phosphorus is generally positive. At the same time, it amounts to + 15.4 kg for phosphorus, +4.7 for nitrogen, and -16.5 kg for potassium. The calculations fix a more noticeable dynamics of the content of mobile phosphorus than the content of mobile potassium, which is confirmed by balance calculations.

Thus, the example of background zonal light-gray forest soils shows a change in the agrochemical state of arable soils due to economic activity. The noted regularity affects the dynamics of the yield of the winter rye of the region.

The actual yield of winter rye rises from the beginning of observation to the last years, with a maximum of 31.9 c / ha. At the same time, in recent years there has been a tendency to reduce the yield of all crops, including winter rye. The noted decrease in the yield of winter rye in the region is recorded by its moving averages over 11 and 22 years, which is due to the negative balance of macroelements in agriculture during this period. Usually the moving averages eliminate the influence of the weather factor, obscuring the linkage of yields from the agrochemical state of the soils.

The long-term yield data of winter rye have a positive and reliable correlation with the content of mobile forms of phosphorus and potassium ($r = 0.64-0.66$, with significance levels of 0.05 and 0.01, the correlation coefficient is 0.41 and 0.53). A closer connection, $r = (0.86-0.96)$, is observed when using moving averages with 11 and 22-year steps, since smoothing in this case occurs because of the cyclicity of agroclimatic conditions. The parameters of the agrochemical state of soils - the content of mobile forms of phosphorus and potassium - are also closely interrelated ($r = 0.93$).

The parameters of multiple correlation, where the correlation coefficients vary in the range of 0.66-0.97, with the coefficients of determination 0.44-0.94 (Table 3). In this case, the average deviation is 33.1% between the actual and predicted yield of winter rye. For sliding yields, they are 5.2-12.1%. The actual yield of winter rye has a relationship with the contents of P_2O_5 and K_2O with coefficients of 0.66. For the time series of the moving average yield, the relationship becomes close.

Table 3. Parameters of multiple correlation between factors and yield of winter rye, n = 48.

Y _f	Factors	Coefficients		t- Students	Mean Deviation Y _f from Y _{rated} , %
		Correlation	determination		
	Actual productivity of winter rye				
Y _f	1, 2	0,66	0,44	5,91	33,1
Y _f	1	0,66	0,44	5,94	33,1
	Moving Average Yield of Spring Wheat - Y ₁₁				
Y ₁₁	1, 2	0,89	0,79	12,88	12,1
	Moving Average Yield of Spring Wheat - Y ₂₂				
Y ₂₂	1,2	0,97	0,94	27,19	5,2

The regression equations make it possible to predict the yield of winter rye depending on the agrochemical state of the arable soils of the region (Table 4).

Table 4. Multiple regression equations for calculating the yield of winter rye (n = 48).

	r	Equations
Actual productivity of winter rye		
Y_f	0,665 (2 factors)	$Y_{11} = -18,0 + 0,1889 \times P_2O_5 + 0,111 \times K_2O$
Y_f	0,66 (1 factor)	$Y_f = -8,9 + 0,233 \times P_2O_5$
Moving Average Yield - Y_{11}		
Y_{11}	0,89 2 factors	$Y_{11} = -22,2 + 0,155 \times P_2O_5 - 0,176 \times K_2O$
Moving Average Yield of Spring Wheat - Y_{22}		
Y_{22}	0,670 2 factors	$Y_{22} = -24,3 + 0,149 \times P_2O_5 + 0,196 \times K_2O$

Note. Y - productivity of winter rye, P_2O_5 and K_2O - content of mobile forms of phosphorus and potassium, mg / kg.

Thus, the revealed functional character of the relationship between the content of mobile forms of phosphorus, potassium and yields simultaneously indicates that agrochemical indicators relative to winter rye are below optimal values. Reserves to increase the yield of this crop due to the introduction of mineral fertilizers have not yet been exhausted.

4. References

- [1] Davlyatshin I D and Bakirov N B 1999 *Dynamics of the yield of spring wheat* *Scientific Tatarstan* **2** pp 50-56
- [2] Ilyin B V 1985 *Elemental chemical composition of plants* (Novosibirsk: Science) p 129
- [3] Davlyatshin I D 2013 *Agricultural chemist handbook*, ed I D Davlyatshin (Kazan: Publishing House of MeDDok) p 300
- [4] Aliev Sh A, Gaffarova L G and Davlyatshin I D 2000 Forecasting the harvest of winter rye *Agrochemical bulletin* **5** pp 8-10
- [5] Davlyatshin I D, Minikaev R V and Saifieva G S 2012 The relationship between nutrients and yields of spring wheat *Bulletin of the Russian Academy of Agricultural Sciences* **3** pp 8-11
- [6] Tyurin I V 1939 Soil of the forest-steppe *Soils of the USSR* (M.-L. : Publishing House of the Academy of Sciences of the USSR) **1**pp 187-223
- [7] Vinokurov M A 1962 *Soil of Tataria* (Kazan: Publishing house of KSU) p 420
- [8] Dmitriev E A 1995 *Mathematical Statistics in Soil Science* (Moscow: Moscow State University) p 320
- [9] Peterburgskii A V 1979 The cycle and balance of nutrients in agriculture (Moscow:) p 168
- [10] Mineev V G 1999 *Agrochemistry and ecological functions of potassium* (Moscow: Moscow State University) p 332
- [11] Mineev V G 2006 *Agrochemistry* (Moscow: Science) p 720
- [12] Lomako E I and Bakirov N B 2007 *Reproduction of soil fertility of the Republic of Tatarstan* (Kazan: Publishing house KFU) p 318
- [13] Chekmarev P A 2015 *Directory of the agrochemical of the Republic of Tatarstan* P A Chekmarev, A A Lukmanov, I D Davlyatshin [and others]; under the editorship of Academician of the Russian Academy of Agricultural Sciences P A Chekmarev (Kazan: s.n.) p 324
- [14] Ivoylov A V 2015 *Efficiency of fertilization and liming of leached chernozems* (Saransk: Mordov Publishing House University) p 264
- [15] Dospekhov B A, Kiryushin B D and A N Braterska 1975 Changes in the agrochemical properties of sod-podzolic soils along the profile under the influence of 62 years of fertilizer application and periodic liming *News of the Russian State Agrarian University MAAA named after K A Timiryazev* **6** pp 30-40
- [16] Davlyatshin I D 2007 Moving average yields of spring wheat in the forest-steppe zone and aspects of their application *Bulletin of the Russian Academy of Agricultural Sciences* **3** pp 9-11
- [17] Davlyatshin I D 2013 Potassium in arable soils of forest-steppe *Fertility* **2** pp 27-28
- [18] Davlyatshin I D, Badikov A M, Lukmanov A A and Avakumov O V 2014 Supply with macronutrients of nutrition and forecasting the yield of spring wheat in the Republic of Tatarstan *Bulletin of the Kazan GAU* **4 (34)** pp 120-125
- [19] Davlyatshin I D, Avakumov O V, Lukmanov A A and Badikov A M 2014 Macroelements of nutrition and forecasting of spring wheat yield in the northern part of the forest-steppe *Resource-saving environmentally safe technologies of production and processing of agricultural products* – (Saransk: publishing house of the Mordovian University). - pp 51-55
- [20] Davlyatshin I D 2016 b Time series of the yield of spring wheat and its prediction on agrochemical factors in the forest-steppe of the Middle Volga region I D Davlyashin and A A Lukmanov *Problems of Agrochemistry and Ecology* **1** pp 29-37
- [21] Dmitriev N N and Gamzikov G P 2015 Systematic application of fertilizers as a factor of stabilization of fertility of gray forest soils and productivity of grain crops in the grain-crop rotation *Agrochemistry* **2** pp 3-12