Properties of dark gray forest soil in the cultivation of cereals according to various basic processing systems

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Abstract. The purpose of the research is to establish the influence of various systems of basic dark gray forest soil processing with prolonged use on the transformation of the most important fertility elements. The results of prolonged (1988-2022) exposure to processing systems in the grain-steam crop rotation are presented: dead fallow, winter rye, spring wheat, spring barley, in the northern forest-steppe of the Tyumen region of the Russian Federation. The basic tillage systems were compared: dump, non-dump, combined, differentiated, flat-cut, surface. The peculiarities of the transformation of fertility elements under prolonged exposure to basic processing systems of varying intensification degrees are determined. It was found that the long-term use of basic treatment systems of varying minimization degrees in conditions of complex chemicalization ensured the formation of water-physical properties, nutritional conditions and phytosanitary conditions in their values slightly inferior or close to the control version of the dump processing system. Tillage systems with minimization elements reduced the energy efficiency coefficient in comparison with the dump system against the background of fertilizer application by 4.5-11.5%, against the background without fertilizers - by 7.7-18.4%. The lowest decrease in efficiency in comparison with the dump processing system for both nutrient backgrounds was for the combined processing system – 4.5-7.7 %.

1 Introduction

In modern grain cultivation technologies, there is a widespread focus on improving production efficiency by reducing production costs. The use of more productive agricultural machinery, reducing the timing of technological operations, the consumption of fuels and lubricants, the possibility of reducing manpower, and, consequently, wage costs [1,2,3]. One of the possible and most important components in this case is given a significant place to reducing the cost of tillage, the use of treatment systems with minimization elements. With these treatments, it is assumed that it is possible to replace the annual deep tillage in the main

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tillage system with the use of shallow or surface tillage. Now there are such technical possibilities. Producers can use modern productive wide-range tillage tools to perform resource-saving tillage [4, 5].

There are positive examples of increasing production efficiency and their beneficial effects on soil fertility elements. This occurs on soils with relatively high fertility, with an equilibrium density of the arable soil layer close to the optimal density for cereals (1.10-1.25 g/cm^3), as well as under the condition of preserving crop residues, observing crop rotation [6, 7]. Scientific evidence has also been obtained that there are limitations to the use of resource-saving soil treatment systems. This is typical for soils with unfavorable agrophysical properties in terms of density, a low level of nutrient availability and especially nitrogen [8, 9, 10]. The ambiguity of the influence of various processing systems is explained by the peculiarities of the conditions (soil type, climate), the duration of their application [11, 12].

The task of rationalizing the basic treatment system is also relevant for the dark gray forest soils of the Northern Trans-Urals. With zonal climatic features, they have some unfavorable properties that restrain the use of resource-saving processing systems: heavy mechanical composition, high equilibrium soil density, low nitrogen supply [13, 14]. Therefore, our studies of the influence of different intensity of cultivation systems are of scientific and practical importance for this climatic zone, since this type of soil is widespread in the northern forest-steppe of the Trans-Urals and occupies a third of the arable land [15, 16]. The purpose of the research is to establish the influence of various systems of basic dark gray forest soil processing with prolonged use on the transformation of the most important fertility elements.

2 Materials and Methods

The systems of basic treatment in stationary experiment on dark gray forest soil in the northern forest-steppe of the Tyumen region of the Russian Federation for 35 years (1988-2022) have been studied.

The research was carried out in crop rotation: dead fallow, winter rye, wheat, wheat, barley. Variants of basic tillage systems were studied:1) dump; 2) non-dump; 3) combined; 4) differentiated; 5) flat-cut; 6) surface.

Pre-sowing treatment is traditional for the zone, followed by sowing with a seeder with disc colters. Harvesting with a combine harvester with straw shredding.

Mineral fertilizers were applied for pre-sowing treatment at the rate of $N_{40}P_{40}K_{40}$ per 1 hectare of crop rotation area, the yield was considered on backgrounds without and with the use of fertilizers. The depth of the humus horizon is 25-27 cm, with a content of 4.2-5.0%, pH KCL – 6.0-6.4,

Agrophysical properties were determined according to N.A. Kachinsky [17], chemical analyses of soil according to E.V. Arinushkina [18], statistical processing by the method of variance analysis [19, 20], using specialized computer programs, bioenergetic and economic efficiency according to A.F. Neklyudov [21]. During the years of the final crop rotation, the growing periods of 2 years were insufficiently provided with precipitation with increased heat supply, and 3 years with conditions from close to the average annual to favorable in terms of precipitation and heat supply.

3 Results and Discussion

Our data on changes in the structural and aggregate state of the arable soil layer showed that the content of agronomically valuable aggregates of 10.0-0.25 mm (69.8-77.8%) was good and stable.

During the 30-years period of application of various basic processing systems, the content of agronomically valuable aggregates, as a rule, was not inferior to the initial state. This was due to the fact that in the 0-10 cm soil layer, the content of agronomically valuable aggregates increased by 15.6-22.8% compared to the initial state, and in the 10-20 cm layer, the content of these aggregates remained unchanged for dump and flat-cut processing systems, for other treatments the decrease was insignificant.

The highest values of the aggregate content of 10.0-0.25 mm were for dump, flat-cut and differentiated processing systems of 77.8–72.8% and the structural coefficient of 2.67-3.51 (K is the structural coefficient, the value of the quantitative ratio of fractions of agronomically valuable aggregates (10.0–0.25 mm) to the sum of aggregates of more than 10.0 mm and less than 0.25 mm obtained during soil dry sifting). According to these processing systems, the content of agronomically valuable aggregates increased by 6.1-13.4%, the structural coefficient - by 22-60%. For the rest of the systems, the content of this fraction of aggregates continued to remain at the level of the initial values (Table 1).

Table 1. The structural state of the soil, 1988 -2019.

Option number	Soil layer, cm	Aggregate content (%), size (mm)			K pedality coefficient	Weighted average diameter of the aggregates (mm)	
		>10	10-0.25	<0.25		total aggregates	10-0.25
initial state, 1988							
	0-20	24.7	68.6	6.7	2.19	5.13	2.71
at the end of the 6th rotation, 2019							
1	0-20	15.4	77.8	6.8	3.51	4.26	2.70
2	0-20	29.2	67.5	3.3	2.07	6.22	3.29
3	0-20	27.0	68.5	4.5	2.17	5.63	2.92
4	0-20	22.4	72.8	4.8	2.67	5.38	3.13
5	0-20	18.6	74.9	6.5	2.99	4.88	3.00
6	0-20	25.8	69.8	4.4	2.31	5.70	3.10
LSD_{05}	0-20	6.9	5.1	1.8	0.62	1.10	0.58

According to the results of the study of soil moisture supply state, it was found that during the study period favorable conditions of moisture supply were formed for all processing systems, moisture reserves amounted to 82-98% of HB. Therefore, in the initial growing season, moisture reserves in the 0-100 cm layer were equal for various processing systems. By the tillering period, treatment systems based on minimization by reducing moisture loss to evaporation contributed to a better moisture retention by 4.4–6.9% compared to the control. At the same time, in the tillering phase, as well as in the sowing-germination phase, the treatment system options did not significantly affect the state of moisture availability of 0-30 cm of the soil layer (Table 2).

Table 2. Productive moisture reserves (mm), 2018-2022.

№ of option	Basic tillage system	Soil layer, cm	Sowing -shoots	Tillering	Full ripeness
1	dump	0-30	44.3	34.0	37.9
		0-100	141.4	122.6	102.4
2	beardless	0-30	42.2	34.1	35.5
		0-100	142.8	125.4	106.1
3	combined	0-30	44.8	32.1	36.4

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		0-100	142.1	121.2	103.9
4	differentiated	0-30	42.1	32.4	36.7
		0-100	147.2	131.1	108.0
5	surface	0-30	43.7	32.3	34.4
		0-100	141.5	128.0	106.3
6	flat-cut	0-30	41.4	36.1	37.1
		0-100	140.8	129.4	103.6
LSD_{05}		0-30	2.1	2.3	3.6
		0-100	4.9	5.1	6.0

Studies of the arable soil layer density have established that the studied tillering systems during the growing season provided a mode of addition close to the optimal value for grain crops. Under generally favorable conditions for the density of these combined soil layers, we noted that according to treatment systems with minimization elements in the soil layer of 10-20 and 20-30 cm, soil compaction is stronger than in the dump treatment system. Thus, during the sowing-germination period, the soil density in a layer of 10-30 cm for beardless, surface and flat-cut treatments was higher than for the dump treatment system by 0.06-0.11 g/cm^3, during the tillering period by 0.07-0.10 g/cm^3.

These data indicate a negative trend in the influence of minimizing the main treatment of dark gray forest soils on the addition - on the over-compaction of the soil layer of 10-30 cm, which can have a negative impact on the conditions of autumn-winter and summer precipitation absorption due to the deterioration of their penetration into deeper soil layers. (Figure 1).

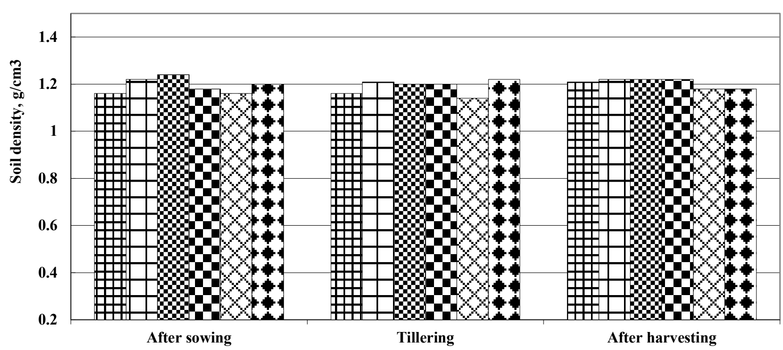

Fig. 1. Density of 0-20 cm of soil (g/cm^3) depending on tillage, 2018-2022.

- dump; - beardless; - combined;
- differentiated; - flat-cut; - surface

Determination of the state of soil nutrient availability showed that minor differences in the content of $N\text{-}NO_3$ and P_2O_5 in the arable soil layer according to various processing systems were in quantitative gradation of very low and low availability and processing systems did not significantly affect plant nutrition conditions. The application of mineral fertilizers contributed to an increase in nitrate nitrogen content in the arable horizon before sowing and during the period of full ripeness by 12-39, mobile phosphorus by 33-53% (Figure 2).

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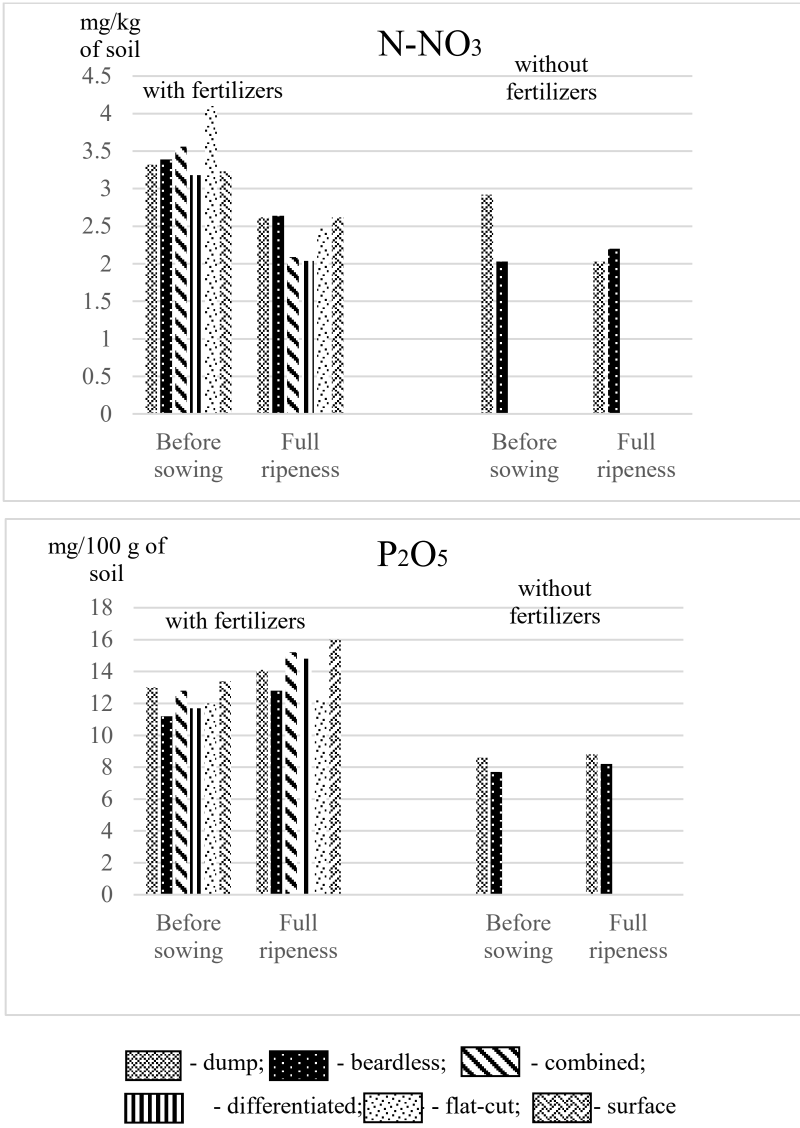

Fig. 2. The content of N-NO_3, P_2O_5 in a layer of 0-20 cm, depending on tillage, 2018-2022.

Resource-saving processing systems increased the contamination of crops with predominant clogging by annual weeds. The most severe blockage was due to the non-waste treatment system in the spring. The number of weeds was 86%, in autumn by 228% and by weight by 192% higher than in the dump processing system. Significant clogging occurred with perennial weeds.

The remaining systems occupied an intermediate position in terms of clogging between the control and the waste-free tillage system. As a result of the use of herbicides, increasing the competitiveness of cultivated plants, in general, the harmfulness of weeds weakened. The mass of weeds as a percentage of the sheaf biomass was 1.18-4.47%. The greatest harmfulness in this regard was in the non-dump – 4.47% and in the flat-cut - 3.76% processing system [22].

The presented effect of processing systems on fertility elements had an impact on crop yields and crop rotation productivity, largely due to the use of fertilizers. Against the background of no fertilizers, the negative effect of using resource-saving processing systems increased in comparison with the control with the removal of the crop from fallow, with a decrease in yield from 0.08-0.54 t/ha on winter rye -1st crop by fallow to 0.17-0.73 t/ha of barley – 4th crop after fallow. Against the background of the use of fertilizers, they mainly ensured the yield of winter rye and barley close to control. Wheat yield was reduced by 0.09-0.73 t/ha [23].

Therefore, resource-saving processing systems, in comparison with the control, reduced grain yield on the background without and with the use of fertilizers, respectively, by 4.4-30.8% and by 11.8-22.6%.

The variants of combined, flat-cut processing systems were the closest in grain yield to the dump processing system without fertilizers and with their use (Figure 3).

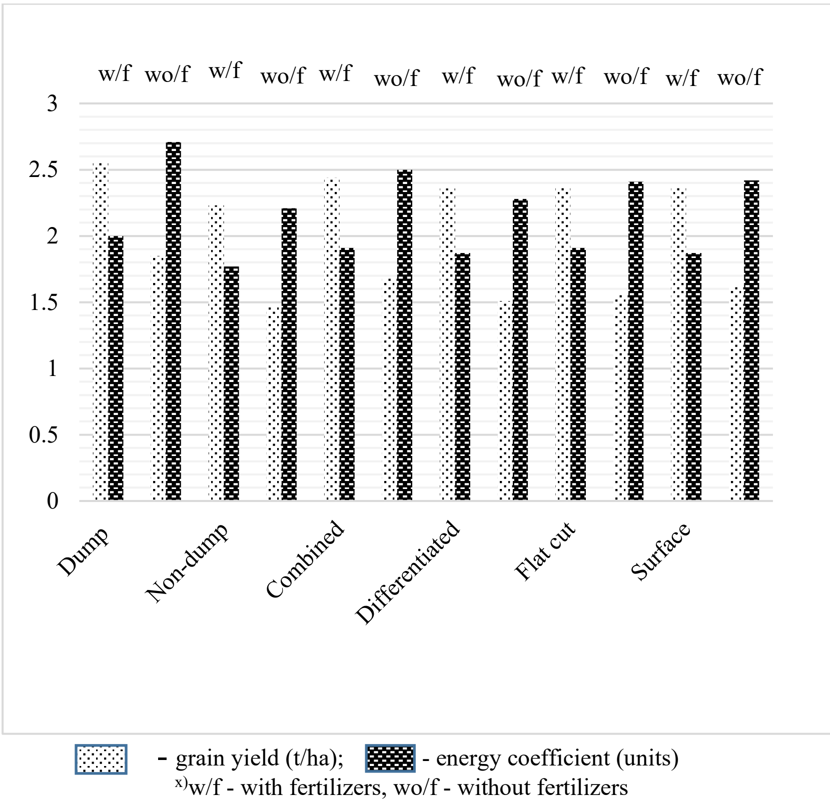

Fig. 3. Grain yield and energy efficiency coefficient depending on tillage, 2018-2022.

The highest results in crop rotation productivity for the dump processing system also explain the advantage of the control option in the energy efficiency of grain production. Resource-saving processing systems reduced the energy efficiency coefficient on a fertilized background by 4.5-11.5%, on a background without fertilizers by 7.7-18.4%. At the same time, the lowest decrease in efficiency in comparison with the dump treatment system on a background without fertilizers – by 7.7-10.7% was for surface and combined systems, against the background with fertilizers by 4.5% for flat-cut and combined processing systems.

4 Conclusion

The peculiarities of the transformation of fertility elements under prolonged exposure to basic processing systems of varying intensification degrees are determined. It was found that the

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long-term use of basic treatment systems of varying degrees of minimization in conditions of complex chemicalization ensured the formation of water-physical properties, nutritional conditions and phytosanitary conditions in their values slightly inferior or close to the control version of the dump treatment system. Tillage systems with minimization elements reduced the energy efficiency coefficient in comparison with the dump system against the background of fertilizer application by 4.5-11.5%, against the background without fertilizers - by 7.7-18.4%. The lowest decrease in efficiency in comparison with the dump processing system for both nutrient backgrounds was for the combined processing system – 4.5-7.7%.

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References

1. Ya.Z. Kaipov, R.L. Akchurin, Z.R. Sultangazin, A.H. Shakirzyanov, Agriculture, **1**, 40-43 (2020). doi:10.24411/0044-3913-2020-10111.
2. V.I. Kiryushin, Achievements of science and technology of the agro-industrial complex, **33(3)**, 5-10 (2019) doi:10.24411/0235-2451-2019-10301.
3. A.N. Vlasenko, N.G. Vlasenko, P.I. Kudashkin, Achievements of science and technology of the agro-industrial complex, **33(6)**, 5-9 (2019) doi:10.24411/0235-2451-2019-10601.
4. N.V. Abramov, S.A. Semizorov, A.M. Oksukbayeva, Agriculture, **3**, 32-35 (2022) doI:10.24412/0044-3913-2022-3-32-36.
5. V.L. Andreev, S.L. Demshin, V.V. Ilyichev, Bulletin of the NSEEI, **11(90)**, 87-102 (2018).
6. L.V. Yushkevich, A.G. Shields, D.N. Yushchenko, Perm Agrarian Bulletin, **2(38)**, 99-105 (2022) doi:10.47737/2307-2873_2022_38_99.
7. Yuan Li, Zhou Li, Song Cui et al, Soil and Tillage Research **194**, 104292 (2019) https://doi.org/10.1016/j.still.2019.06.009.
8. Tangyuan Ning, Zhen Liu, Hengyu Hu, et al, Soil and Tillage Research, **223**, 105490 (2022) https://doi.org/10.1016/j.still.2022.105490.
9. V.I. Kiryushin, Agriculture, **3**, 3-7 (2019) doi: 10.24411/0044-3913-2019-10301.
10. Pittelkow C, Liang X, Linquist B et al, Nature, **517**, 365-368 (2015) https://doi.org/10.1038/nature13809.
11. Ligang L, Zhoubing Gao, Kaihua Liao et al, Soil and Tillage Research **225**, 105527 (2023) https://doi.org/10.1016/j.still.2022.105527.
12. Humberto Blanco-Canqui, Sabrina J Ruis, Geoderma **326(15)**, 164-200 (2018) https://doi.org/10.1016/j.geoderma.03.011.
13. L.N. Karetin, Novosibirsk: Science. Siberian Branch, 258 (1990).
14. D.I. Eremin, S.M. Kayugina, Bulletin of the Kurgan State Agricultural Academy, **2(42)**, 3-10, 2022. DOI: 10.52463/22274227_2022_42_3.
15. N.V. Perfiliev, O.A. Vyushina, Siberian Bulletin of Agricultural Science, **50(1)**, 5-12 (2020). DOI: 10.26898/0370-8799-2020-1-1.
16. N.V. Perfiliev, O.A. Vyushina, Agriculture, **5**, 36-38 (2017).

17. N.A. Kachynski, M.: Higher School. 324 (1965).
18. E.V. Arinushkina, M.: Publishing House of Moscow State University, 478 (1970).
19. B.A. Dospekhov, M.: Kolos, 416 (1979).
20. O.D. Sorokin, Krasnoobsk, 162 (2004).
21. A.F. Neklyudov, Novosibirsk, 36 (1993).
22. N.V. Perfiliev, O.A. Vyushina, Siberian Bulletin of Agricultural Science, **49(1)** 19-26 (2019) DOI: 10.26898/0370-8799-2019-1-3.
23. N.V. Perfiliev, O.A. Vyushina, In the collection: Problems of agroecology of the agro-industrial complex of Siberia. Proceedings of the All-Russian Scientific and Practical Conference with international participation dedicated to the 50th anniversary of the scientific activity of Doctor of Agricultural Sciences, Professor A.S. Motorin and the 25th anniversary of the Department of Ecology and Environmental Management. Tyumen, 127-137 (2023).