



Scientific and Methodological Approaches for Assessing the Degree of Degradation of Leached Chernozem in Apple Orchards in Central Russia

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ABSTRACT

Background: In the monoculture of a low-growing apple tree, soil fatigue of leached chernozem manifests itself at the age of 20-24 years of trees.

Methods: A methodology for assessing the degree of soil degradation in apple orchards has been developed.

Result: Its approbation on the example of leached chernozem showed that the content of mobile phosphorus and exchangeable potassium in the upper 30-60 cm layer, cellulolytic activity in the 10-100 cm layer, the number of bacteria in the 0-40 cm layer and the provision of total nitrogen in the leaves of the bioindicator (barley) in the tillering phase degraded to the greatest extent. The weakest degree of degradation of leached chernozem is noted by the thickness of the humus horizon, total porosity in a layer of 10-70 cm, structural coefficient in a layer of 0-40 cm, hygroscopicity in a layer of 0-70 cm, maximum hygroscopic humidity in a layer of 0-30 cm, the lowest moisture capacity of a layer of 0-30 cm, capillary moisture capacity in a layer of 0-60 cm, hydrolytic acidity in a layer of 10-60 cm, the sum of the exchangeable bases in a layer of 0-60 cm, the content of nitrate nitrogen in a layer of 0-60 cm, calcium exchange in a layer of 20-60 cm, magnesium exchange in a layer of 10-70 cm, meaning of this sentence is not clear. The soil parameters that have changed to the least extent can be considered as composing components of the buffering of leached chernozem. The degree of degradation of leached chernozem in 24-year-old low-growing apple orchards on rootstock 62-396 with row spacing under black steam in the conditions of CJSC 15 years of October in the Lipetsk region in 2014-2023 was low. Based on the degradation structure in this farm, it is recommended to increase the amount of phosphorus-potassium, organic or green fertilizers applied under the apple tree.

Key words: Apple orchards, Soil degradation, Soil fertility assessment, Soil transformation.

INTRODUCTION

The study of aspects and mechanisms of soil degradation has always mainly concerned the crop industry (Bindraban, 2012) and little attention has been paid to horticulture. Meanwhile, in this branch of the agro-industrial complex, the anthropogenic load on the soil is many times greater than in field farming. In garden agroecosystems, the erosion vector often develops perpendicular to the rows of trees, therefore, inter-row water erosion may occur (Unnikrishnan *et al.*, 2023). Large-scale aerial photography is well adapted for water erosion of soils (Lafren *et al.*, 2020). The second most common form of degradation after erosion is chemical (Vinogradov *et al.*, 2022). It can be estimated by the rate of acidification (Kissel *et al.*, 2020), salinization (Krasilnikov *et al.*, 2016), heavy metal (Novo *et al.*, 2017) pollution (Methods, 2004) loss of nitrogen, phosphorus and potassium (Yahaya, 2023). Physical degradation of soils often consists in the destruction of the soil structure (Schlüter *et al.*, 2018) scattering of soil particles, clogging of pores and increasing density (Osman, 2013). The deterioration of the physico-chemical and morphological properties of the soils between rows of gardens leads to a decrease in cellulolytic activity (Zakharov *et al.*, 2018). Biological degradation of soils is most often assessed by a decrease in the biological activity of the soil, including the number of lignolytic fungi (Sekholola

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et al., 2013), bacteria (Young *et al.*, 2021) and mesofauna (Bedano *et al.*, 2011). Pathogenic fungi *Rhizoctonia solani*, *Pythium ultimum*, *Phytophthora cactorum*, *Fusarium oxysporum*, *Dematophora necatrix* were found in the soils of old dying gardens, which, along with bacteria and actinomycetes, are more numerous than in the soil of young gardens (Singh *et al.*, 2020). The assessment of the degree of soil fatigue in the apple monoculture is very significant primarily with the help of 7-week-old apple plants of the McIntosh and Delicious varieties (Kowalczyk *et al.*, 2017).

Mapping of soil degradation using remote sensing plays an important role in understanding the spatial scale and rate of spread of this problem (Shoshany *et al.*, 2013). The GASEMT database has been created to predict soil erosion (Bindraban *et al.*, 2021). The International Reference and Information (Rajalakshimi *et al.*, 2025). Centre on Soils have created the GLASOD information base (Global Assessment of Anthropogenic Soil Degradation), containing data on the global distribution and intensity of erosive, chemical and physical types of degradation (Bridges *et al.*, 1999). The purpose of our research was to test the previously developed and patented methodology for assessing the degree of soil degradation in apple orchards (Zakharov, 2020) (using the example of leached chernozem).

MATERIALS AND METHODS

The research was conducted from 2014 to 2023 in the apple orchard of CJSC “15 years of October” Lebedyansky district of the Lipetsk region. The apple orchard was laid out in 1998 according to the 5×3 m pattern on the rootstock 62-396. The row spacing system is black steam: spring tooth harrowing by 3-5 cm and 5-6-fold treatment by 10-12 cm during the summer, consisting in alternating cultivations and disc harrowing. Varieties: Northern Sinap, Lobo, Welsey, Spartan, Melba, Zhigulevskoye. The soil is leached medium loamy chernozem. 1 time in 4 years, autumn dump plowing was carried out to a depth of 30-40 cm. The average yield of apple fruits was 90.0 kg/ha with a production margin of 207%. Using the method, we compared the properties of the soil in the trunk strips and in the aisles, for which soil samples were taken at these points. There were 24 accounting trees (6 trees per block). The number of blocks (repetitions) is 4. The arrangement of blocks is randomized. The intensity of fiber destruction was determined by the application method, hygroscopicity - by the thermostatic-weight method, the lowest moisture capacity - by the method of gypsum casts and pad filling, capillary moisture capacity – using a cylinder with a mesh bottom, total porosity - by the calculation method (according to soil density and

solid phase density), soil density - by the method of cutting cylinders, solid phase density -by the pycnometric method, structural analysis by the dry sieving method. Agrochemical soil analyses were carried out according to the instructions of the Central Research Institute of Agrochemical Services of Agriculture. The number of microorganisms in the soil was determined by sowing on nutrient media The total nitrogen content in the leaves of the bioindicator plant (barley) was determined by wet salting. During the years of research, the GTC ranged from 0.9 to 1.3.

RESULTS AND DISCUSSION

Based on a detailed study of soil fatigue in apple orchards, we have developed and patented a method for assessing the degree of soil degradation (Sekhohola *et al.*, 2013). The novelty of the technique is that the degree of soil degradation is estimated by the difference in soil properties between two zones of the garden: No. 1 is the zone at a distance of 130 cm from the stem in the trunk strip, No. 2 is the zone of the middle of the aisles. The degree of degradation is estimated in points according to the deviation of zone No. 1 from zone No. 2. A very low degree of degradation corresponds to 0.8 points, low - 1.6 points, average - 2.4 points, elevated - 3.2 points, high - 4 points. This paper presents an approbation of this technique using the example of an assessment of leached chernozem from one of the advanced fruit farms in the Lipetsk region.

Comparing the properties of the soil in the center of the aisles with the properties in the trunk strips at a distance of 130 cm from the stem, you can see a mathematical difference in some parameters, which is reflected in the table. The greater this difference, the higher the degradation score, that is, it is more intense. It was found that by the age of 24 years of apple trees, as a result of the exploitation of leached chernozem, some of its physical parameters had degraded to varying degrees. A very low degree of degradation was revealed by the thickness of the humus horizon (planar erosion occurs due to the removal of soil with processing tools during previous treatments of physical ripeness of the soil), total porosity in the layer of 10-70 cm

Table 1: The degree of degradation of the physical parameters of leached chernozem.

The parameter according to which there is a deviation between two zones of the garden	Degree of degradation, points				
	0.8	1.6	2.4	3.2	4.0
thickness of the humus horizon (A), cm	10.0				
the total porosity in the layer is 10-70 cm, %	4.0				
the structural coefficient in the layer is 0-40 cm	1.0				
the content of water-resistant aggregates is larger than 0.25 mm in a layer of 0-30 cm, %		10.0			
hygroscopicity in a layer of 0-70 cm, %	0.8				
the maximum hygroscopic humidity in the layer is 0-30 cm, %	1.6				
the lowest moisture content of the layer is 0-30 cm, %	4.4				
capillary moisture capacity in a layer of 0-60 cm, %	3.4				
the rate of capillary rise of water in aggregates is 0.25-5 mm in a layer of 0-10 cm, mm/min		30.0			

(due to compaction by machinery), structural coefficient in the layer of 0-40 cm (due to frequent treatments to the same depth), hygroscopicity in the layer 0-70 cm and maximum hygroscopicity in a layer of 0-30 cm (due to a decrease in the amount of calcium and organic matter), the lowest moisture capacity in the layer is 0-30 cm (due to a decrease in organic matter) and the capillary moisture capacity in the layer is 0-60 cm (due to the destruction of capillary bonds). It is by these parameters that the soil can be considered buffered (Table 1).

A low degree of degradation of leached chernozem is established by the content of water-bearing aggregates larger than 0.25 mm in a layer of 0-30 cm and by the rate of capillary rise of water in aggregates with a diameter of 0.25-5 mm in a layer of 0-10 cm (due to the spraying effect of frequent disk harrowing to the same depth during the growing season).

From the agrochemical indicators of leached chernozem, the content of mobile phosphorus and exchangeable potassium was degraded to an average degree, the content of easily hydrolyzed nitrogen in a layer of 10-60 cm and humus in a layer of 30-60 cm was degraded to a very low degree: hydrolytic acidity in a layer of 10-60 cm, the sum of exchange bases in a layer of 0-60 cm, nitrate nitrogen in a layer of 0-60 cm, calcium is exchangeable in a layer of 20-60 cm, magnesium is exchangeable in a layer of 10-70 cm and the pH of the salt extract in a strip is 30-60 cm. According to these parameters, the soil can be considered stable.

Of these indicators, the highest degree of degradation was noted for mobile phosphorus and exchangeable potassium, which is explained by the initial phosphorus limit in chernozem soils, as well as the absorption activity of roots in the root layer of 30-60 cm of apple trees as a potassium-loving crop. These parameters indicate the need to increase the application of phosphorus-potassium fertilizers for apple trees in this farm on leached chernozem (Table 2).

Of the biological parameters of leached chernozem, the bacterial content in the 0-40 cm layer underwent the greatest change (average degree of degradation), which signals the need to increase the amount of organic or green fertilizers applied to apple trees in this enterprise on leached chernozem.

The degree of destruction of fiber in the 10-100 cm layer also degraded to an average degree. This parameter is an additional indicator of the need to increase the biological activity of leached chernozem due to organic fertilizers. The average degree of soil degradation is also indicated by the level of total nitrogen in the leaves of a bioindicator plant (barley) in the tillering phase grown on this soil. The number of mold fungi in the 0-40 cm layer and the aboveground green mass of the bioindicator plant degraded to a low degree. The least change (very low degree of degradation) in this soil was the yeast content in a layer of 0-40 cm (Table 3).

According to physical parameters, the sum of degradation points was 8.8, according to agrochemical –

Table 2: Degree of degradation of agrochemical properties of leached chernozem.

The parameter according to which there is a deviation between two zones of the garden	Degree of degradation, points				
	0.8	1.6	2.4	3.2	4.0
hydrolytic acidity in a layer of 10-60 cm, mg-eq/100 g of soil	2.6				
the sum of the exchange bases in a layer of 0-60 cm, mg-eq/100 g of soil	2.8				
easily hydrolyzable nitrogen in a layer of 10-60 cm, mg/100 g of soil		1.1			
NO ₃ in a layer of 0-60 cm, mg/100 g	2.8				
phosphorus is mobile (P ₂ O ₅) in a layer of 30-60 cm, mg/100 g of soil			6.0		
exchangeable potassium (K ₂ O) in a layer of 30-60 cm, mg/100 g of soil			8.0		
exchange calcium in a layer of 20-60 cm, mg-eq/100 g of soil	1.3				
exchangeable magnesium in a layer of 10-70 cm, mg-eq/100 g of soil	0.5				
humus in a layer of 30-60 cm, %		1.0			
PH _{KCl} in a layer of 30-60 cm	0.3				

Table 3: Degree of degradation of biological parameters of leached chernozem.

The parameter according to which there is a deviation between two zones of the garden	Degree of degradation, points				
	0.8	1.6	2.4	3.2	4.0
the rate of decomposition of cellulose in a layer of 10-100 cm, %			25.0		
the number of bacteria in the 0-40 cm layer, thousand CFU/g of soil			9.0		
the amount of yeast in a layer of 0-40 cm, mln. CFU/g of soil	5.2				
the number of mold fungi in a layer of 0-40 cm, thousand CFU/g of soil		412.0			
aboveground green mass of winter triticale grown on soils of 2 zones, g/vessel		2.0			
total nitrogen in barley leaves in the tillering phase grown on soils of two zones, %			0.8		

12.8, according to biological - 15.6. In our methodology, we propose a 5-level scale for assessing the degree of soil degradation in apple orchards: 0-20 points – very low degree of degradation, 20-40 – low, 40-60 – medium, 60-80 – increased, 80-100 – high. Summing up the degradation scores for each of the 25 indicators, we obtain the final score of the degree of degradation of leached chernozem, which is 37.2 points, which corresponds to a low degree of degradation.

Thus, the degree of degradation of leached chernozem in 24-year-old low-growing apple orchards of CJSC 15 Let Oktyabrya on rootstock 62-396 with row spacing under black steam is low or medium. This assessment of the degree of soil degradation can be used not only as an indicator of sustainability, but also as a characteristic of the level of agricultural technology on a given farm.

CONCLUSION

1. With the content of leached chernozem under black steam, by the age of 24, apple trees were most degraded: The content of mobile phosphorus and exchangeable potassium in a layer of 30-60 cm, cellulolytic activity in a layer of 10-100 cm, the number of bacteria in a layer of 0-40 cm, the provision of total nitrogen in the leaves of the bioindicator (barley) in the tillering phase.
2. The weakest degree of degradation of leached chernozem is noted by the thickness of the humus horizon, total porosity in a layer of 10-70 cm, structural coefficient in a layer of 0-40 cm, hygroscopicity in a layer of 0-70 cm, maximum hygroscopic humidity in a layer of 0-30 cm, the lowest moisture capacity of a layer of 0-30 cm, capillary moisture capacity in a layer of 0-60 cm, hydrolytic acidity in a layer of 10-60 cm, the sum of the exchange bases in a layer of 0-60 cm, the content of nitrate nitrogen in a layer of 0-60 cm, calcium exchange in a layer of 20-60 cm, magnesium exchange in a layer of 10-70 cm, The pH of the salt extract in the layer is 30-60 cm and the number of yeast in the layer is 0-40 cm.
3. The soil parameters that have changed to the least extent can be considered as composing components of the buffering of leached chernozem.
4. The degree of degradation of leached chernozem in 24-year-old low-growing apple orchards on rootstock 62-396 with row spacing under black steam in the conditions of CJSC "15 years of October" of the Lipetsk region in 2014-2022 was low.
5. Based on the structure of degradation in this farm, it is recommended to increase the amount of phosphorus-potassium, organic or green fertilizers.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent

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Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript. Informed consent.

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