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The assessment of soil and land degradation in Volgograd region, the case of agricultural farm Donskoe

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Abstract. This study is aimed at assessing soil and land degradation of agricultural farmlands of Kalachev district, Volgograd region. To identify the level of land degradation, soil properties of samples taken in summer 2019 in that area were compared with average values for the same area obtained by YUZHGIIPROZEM in 1982 [1]. The calculations to evaluate land degradation were based on “Methodology for determine the extent of damage of soil and land degradation” [2]. The conducted chemical and physical analysis of sampled soils demonstrated the highest level of land degradation in that area. The soils were proven to have an increase in exchangeable sodium percentage (ESP); 52% of the agricultural lands of Donskoe demonstrated these values. The assessment of the other land degradation parameters such as density, mobile phosphorus, exchange potassium, heavy metals concentration and arsenic content, toxic salts and pH (H₂O) revealed lower level of degradation and insignificant occurrence in the farmland territory.

1. Introduction
Nowadays, in anthropocene [3] land and soil degradation are intensive processes worldwide. According to the specialists’ assessment ¾ of lands are exposed to land degradation processes. The forecast has shown that the number of degraded lands might increase by 2050 and will have accounted for 90% of planet land resources [4]. The processes are especially intensive in dry and semi-dry climate, where land degradation is characterized by aridization, wind erosion, poor land quality, and high level of salinization [5].

The growing numbers of degraded lands in arid regions can be attributed to global warming and climate aridization [6] as well as to irrational use of land resources under precipitation deficit conditions. The ecological and economical assessment of land degradation in arid regions of Russian Federation is required at the moment as it will contribute to the evaluation of the damage currently done to soils and estimation of recultivation works, which should be planned wisely [7, 8].

1.1. A study problem
One of the most significant agricultural areas that seeks assessment of its land degradation processes is Volgograd region. Most part of the lands (80%) in that region is used for agricultural purposes. The climate of that region can be described as steppe climate. Volgograd region lays between two soil zones, Chernozem and Kastanozem, therefore soils are presented by Chernozem (31.5%) and Kastanozem (31.2%) [9]. The soils of the region are exposed to common land degradation processes for arid climate, such as alkalinization, salinization, wind erosion, loss of soil fertility. The main issues that region is
experiencing at the moment are salinization and alkalinization as a result of climate aridization and probably poor land management [10]. Based on the problems described above, the objective of the study is to assess land degradation level of farmland Donskoe of Volgograd region.

2. Research methods

Research was carried out in the fields of agricultural farmland «Donskoe» (48° 42’ 20.33” N 43° 39’ 56.81” E) in the Kalachev district of the Volgograd region. The studied area is 2,703 hectares. The territory belongs to the sub-zone of the Haplic Kastanozems (Chromic) and Haplic Kastanozems (Sodic) of the Don region [12], with loess as a soil-forming rock [12]. The dominant soils in the cover structure are Haplic Kastanozems (Chromic) and complexes of Haplic Kastanozems (Chromic) and Haplic Kastanozems (Sodic) [1]. The main cultivated crops are winter wheat, soy, corn. The field work was carried out in the summer of 2019. Surface mixed soil samples were collected in an evenly ordered grid with a pitch of 450 m [13, 5] from the test site 10 m x 10 m, depth of the sampling was 20 cm. In total 131 mixed samples were obtained. Soil density samples were obtained thrice from each sampling site by the Kachinsky Drill. Under laboratory conditions, the content of exchangeable potassium and mobile phosphorus was determined in the soil samples [14], as well as organic carbon, which was analyzed using the method of Tyurin in the Nikitin modification with a colorimetric ending according to Orlov and Grindel [15]. The exchangeable sodium percentage (ESP) in cation exchange capacity (CEC) [16] and pH of water extract were also determined [17]. The set of assigned parameters was chosen based on the available analytical data on the main sections in the materials of previous soil surveys. Laboratory studies were performed in the soil chemistry laboratory of the faculty of soil science of Lomonosov Moscow State University. Data interpolation was conducted by Inverse Distance Weighting (IDW) [18] using RStudio 1.2.5033 and SAGA 2.3.2. Data obtained in the course of field studies in 2019 was compared with data from 1982 [1]. The land degradation level was assessed using 5 level scale according to “Methodology for determination of the extent of soil damage and land degradation” [2] (table 1). Kastanozems (Chromic) and Kastanozems (Sodic) properties were chosen as a reference (table 2). The reference values were chosen in accordance with the analyzed soil type.

Table 1. The soil land degradation assessment based on chosen parameters.

| Parameter                                                                 | Level of degradation |
|---------------------------------------------------------------------------|----------------------|
| Increase in soil density of arable layer, % of initial value              | < 10  11–20  21–30  31–40  > 40 |
| Reduction of humus stock in soil profile, % of initial value              | < 10  11–20  21–40  41–80  > 80 |
| Reduction in potassium exchange, % of CEC                                | < 10  11–20  21–40  41–80  > 80 |
| Increase of exchange sodium, % of CEC (alkalinization)                     | < 5   5–10  10–15  15–20  > 20 |
| Acidity variation, % of average acidity                                  | < 10  11–15  16–20  21–25  > 25 |
| Reduction of mobile phosphorus, % of average stock                       | < 10  11–20  21–40  41–80  > 80 |

Table 2. Reference values [1].

| Soil                      | Bulk density, g/cm³ | Humus, % | Potassium level, mg/kg | Phosphorus level, mg/kg | pH | ESP, % |
|---------------------------|---------------------|----------|------------------------|-------------------------|----|--------|
| Kastanozems (Chromic)     | 1.26                | 1.4      | 306                    | 15                      | 7.55 | 0.97   |
| Kastanozems (Sodic)       | 1.31                | 1.89     | 446                    | 13                      | 7.28 | 1.54   |
3. Results and discussion

The results of the statistical processing of the results are shown in table 3.

**Table 3. Basic soil properties for agricultural farmland.**

| Description          | Mobile phosphorus, mg/kg | Exchangeable potassium, mg/kg | ESP, % | Humus, % | pH (H₂O) | Bulk density, g/cm³ |
|----------------------|--------------------------|-------------------------------|--------|----------|----------|--------------------|
| Sample size          | 131                      | 131                           | 71     | 131      | 131      | 131                |
| Mean                 | 40.0                     | 275.6                         | 1.4    | 1.5      | 7.24     | 1.1                |
| Mode                 | 28.55                    | 237.87                        | 3.10   | 1.43     | 7.27     | 1.04               |
| Dispersion           | 579.02                   | 4530.37                       | 0.94   | 0.11     | 0.12     | 0.01               |
| Scope                | 236.5                    | 315.0                         | 3.8    | 1.9      | 2.0      | 0.7                |
| Variation coefficient | 59.96                    | 24.33                         | 66.31  | 22.57    | 4.73     | 9.20               |
| Minimum              | 7.5                      | 158.1                         | 0.2    | 0.8      | 6.3      | 0.8                |
| Lower quartile       | 27.22                    | 225.82                        | 0.77   | 1.29     | 7.05     | 1.04               |
| Median               | 38.0                     | 264.6                         | 1.1    | 1.5      | 7.2      | 1.1                |
| Upper quartile       | 49.28                    | 327.40                        | 1.81   | 1.68     | 7.39     | 1.19               |
| Maximum              | 244.0                    | 473.1                         | 4.0    | 2.7      | 8.3      | 1.4                |

3.1. Overall results of the lab analysis

Average values of humus and pH as well as maximum and minimal ones are typical and common for Kastanozems (Sodic) of that region [19, 11]. Based on dispersion and scope the greatest value variation is observed in mobile phosphorus and exchangeable potassium. Variation coefficient showed the largest variation in exchangeable sodium and mobile phosphorus. Minimal scope was seen for soil density property (table 3).

3.2. Assessment based on soil bulk density

The calculation of land degradation parameters allowed to draw maps of parameters distribution for the studied area. On the basis of the map of density distribution, areas with insignificant (1st level) degradation were identified. Areas with higher density are spread randomly, in small groups, with the total coverage 0.33% of all studied area.

3.3. Assessment based on acidity

The studied area has more lots with insignificant degradation levels (1st level) in terms of acidity variation parameters which were compared to average values. According to database record [1], areas with higher acidity are located in the contours exposed to water erosion and feature slightly washed-off soils. Alkalization processes were proven for soil contours with solonetzic complexes. It is known that alkali soils (Sodic) are characterized by high values of exchangeable sodium in CEC, which results in alkaline conditions. The total percentage of land degradation in terms of this parameter is 1.5%.

3.4. Assessment based on the level of exchangeable potassium

The calculation of exchangeable potassium and its percentage in the cation exchange capacity and comparison with average values proved 1st and 2nd level of land degradation for the region (figure 1), low levels of it were found. Areas exposed to that kind of degradation are randomly situated, most part of them belongs to slopes. That parameter presumably depends on the slope angle as well as on light soil fractions which are characterized by low values of exchangeable forms in comparison to heavier
ones [20]. That area covers 2% of total area under study, which shows that degradation of this type is not widely spread and common for this region.

Figure 1. Land degradation level based on exchange potassium.

3.5. Assessment based on mobile phosphorus
The area under study has lots of 1st, 2nd, and 3rd level of degradation in terms of mobile phosphorus parameter (figure 2). The parameter is much lower than average values. Some lots that demonstrated these results are also exposed to degradation in terms of exchangeable potassium criteria. It conceivably demonstrates that the reasons for both types of land degradation for that part of the area are the same.

3.6. Assessment based on humus values
The soil in the agricultural area under study is affected by degradation processes of the 1st, 2nd and 3rd degrees in terms of humus loss. The contours of the degraded areas are widely distributed except for two fields (figure 3). In addition, the most advanced degradation processes are found in the field that is susceptible to water erosion of the soil [1]. The total area of degraded soils was 18% of the total area of the plot, with 67% of the degraded soils having the first degree of degradation. The parts with 32% and 1% belong to the first and the third level of degradation respectively. This distribution of process intensity indicates that the degradation processes are not yet irreversible. In the future, if no action is taken against water erosion, the proportion of soils with the 2nd and 3rd levels of degradation will continue to increase.

3.7. Assessment based on cationic exchange capacity (CEC)
The maximum development of degradation processes is recorded in terms of the increase of the exchangeable sodium percentage in cationic exchange capacity (CEC). All four levels of degradation have been identified for that parameter in the agricultural survey area (figure 4).
Figure 2. Land degradation levels based on mobile phosphorus.

Figure 3. Land degradation levels based on humus content.
The soil contour affected by degradation covers a significant area of the studied region. This pervasive development of degradation processes under this parameter is presumably related to the increasing soil alkalization, due primarily to aridity of the climate [6]. Compared with Giprozem results obtained in 1987 and presented in Agricultural Soil Survey [1], at the present alkalization processes in that area has become widespread. Moreover, despite the fact that the exchangeable sodium percentage is the diagnostic feature of alkalization processes in B horizon, we have recorded increased values of exchangeable sodium in the arable horizon, which is specific for weakly-solonetzic soils (more than 3% of CEC) [1]. Although we have detected the 4th degree of degradation, which is described as «soil destruction» [5], these lands are involved in crop rotation. The total area of degraded soils in terms of the increase in the exchangeable sodium percentage accounts for 62% of the studied area.

4. Conclusion
The soils of the agricultural farmland Donskoe of Kalachev district of the Volgograd region are exposed to various degradation processes, among which the highest degree (4) and the most widespread is the alkalization, manifested in the increase of the exchangeable sodium percentage in the cation exchange capacity (CEC). This process is most likely caused by decades of aridization of the climate which makes alkalization processes more intensive in the region.

Soil degradation indicators (increase in density, change in acidity and decrease in humus, potassium exchange and mobile phosphorus compared to the average values) indicate the lower level of damage of agricultural farmland (2nd level of degradation), which shows wise land management of the studied area at the moment.

The environmental-economic studies carried out on the territory of the agricultural farmland Donskoe of the Kalachev District of the Volgograd region made it possible not only to assess the degradation of the soil, but also to identify the main trends in modern soil processes, climate change (aridization) and the quality of agricultural activities.
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