Adaptation of soils of the Ciscaucasia to processing systems

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Abstract. The intense technological and natural anthropogenic load on the soils of the Stavropol Territory, leading to a violation of its ecological and production functions and a decrease in fertility, requires a differentiated approach when introducing a particular soil cultivation system for a specific type or subtype of soil. It is proposed to develop a generalized indicator D for assessing the implementation of various systems of basic tillage for different types of soils based on criterion factors: humus content (%), soil density (d, g/cm³), soil resistivity (T, kg/cm²) and soil ped content >10 mm (C, %). As a result of calculations of the indicator D for a specific soil and comparing its values with the range of D, it was found that for ordinary chernozem and solonetze chernozem with D equal to 0.889 and 0.932, moldboard plowing is acceptable for certain crops in the crop rotation, dark chestnut and chestnut soils with D equal to 0.828 and 0.778, respectively, it is preferable to cultivate without moldboard with a combination of different methods and depth of soil cultivation, on light chestnut soils (D=0.749), minimization with shallow mulching is recommended.

1. Introduction
Agricultural lands of the Stavropol Territory, which occupy 92.6% of agricultural land, are characterized by a high degree of plowing (69.5%). This indicator not only limits the increase in arable areas, but also requires a differentiated approach when introducing resource-saving systems and minimizing the main tillage to stabilize the fundamental strength of the agrolandscape frame [1-2]. Negative changes in soil properties, under the influence of long-term repetitive dump mechanical treatments, contribute to a decrease in soil fertility indicators, disruption of its ecological and production functions [3-5]. The presence of a variety of different types and subtypes of soils in the region, with an ambiguous technological and natural anthropogenic load on them, leads to an understanding of the development of a certain generalizing criterion, on the basis of which a decision to introduce a particular cultivation system on a certain type of soil is made. Theoretical insights have shown that in order to assess the possibility of introducing a particular soil cultivation system, a set of criterion indicators is required that have a certain value for a specific type of soil [6-7]. The main concept of this study is the statement that soils with a high degree of humus content, and, consequently, a high content of water-resistant aggregates, are less susceptible to the destructive effect of dump treatments, while light chestnut soils with a light loamy texture, having a high equilibrium density and low percentage of humus, to a large extent, are subject to degradation processes under the influence of deep cultivation. The purpose of the research is to develop a generalizing indicator of the possibility of introducing resource-saving soil cultivation systems on various types of soils of the region.
2. Materials and methods

The proposed technique for calculating to determine the generalizing indicator $D$ of the possibility of introducing various systems of basic cultivation on various types of soils of the region is based on the development of Krasnodar Research Institute of Agriculture [8]. Calculations of $D$ are carried out according to the agrophysical indicators of the arable soil layer 10 - 15 days before harvesting: $Y_1$ is a humus content (%), $Y_2$ is soil density ($d$, g/cm$^3$), $Y_3$ is soil resistivity ($T$, kg/cm$^2$) and $Y_4$ is a content of soil aggregates $>10$ mm, (C, %). The generalized indicator $D_{act}$ by comparing it with the calculated test indicator $D_{est}$ will allow assessing the possibility of introducing one or another system of basic tillage on a certain type of soil in order to reduce its intensity. Integral criterion $D$ was defined as the geometric mean of the desirability of individual indicators:

$$D = n \sqrt[d_1]{d_1^{k_1} \cdot d_2^{k_2} \cdot d_3^{k_3} \cdot d_4^{k_4}}$$  \hspace{1cm} (1)

Where

$d_1$ ... $d_4$ is a desirability value 1 ... 4 of the indicator;

$k_1$ ... $k_4$ is weight (importance) 1 ... 4 of the indicator;

$n = 4$ is a number of indicators.

3. Results and discussion

The weight of the indicators $k_1$ ... $k_4$ was determined by the method of expert assessment based on a survey of experts in the field of agriculture and crop production technologies (table 1) and checking the degree of consistency of experts’ opinions was assessed by the $\chi^2$ criterion. The assessment of the significance of the indicators, carried out on the basis of a survey of experts, showed the following results: $k_1 = 0.351$; $k_2 = 0.310$; $k_3 = 0.188$; $k_4 = 0.146$. The degree of consistency of experts’ opinions was checked by the $\chi^2$ coefficient. The obtained value $\chi^2 = 8.8$ is more than the tabular value $\chi^2 = 7.815$ at a 5% significance level, i.e. there is a non-random consensus among experts. Consequently, the determining factors in assessing the possibility of optimizing processing systems are the humus content ($y_1$) and density ($y_2$) in the tilth-top soil of a certain type of soil.

Table 1. The results of the expert assessment.

| Experts | Indicators $Y_1$ | $Y_2$ | $Y_3$ | $Y_4$ |
|---------|----------------|-------|-------|-------|
| 1       | 2/0.26         | 1/0.4 | 4/0.14| 3/0.2 |
| 2       | 3.5/0.3        | 1/0.3 | 3.5/0.2| 2/0.2 |
| 3       | 1/0.4          | 3/0.3 | 2/0.2 | 4/0.1 |
| 4       | 2/0.3          | 3/0.3 | 1/0.2 | 4/0.2 |
| 5       | 1/0.4          | 2/0.3 | 3/0.2 | 4/0.1 |
| 6       | 1/0.4          | 2/0.3 | 3/0.18| 4/0.12|
| 7       | 1/0.4          | 2/0.3 | 3.5/0.2| 3.5/0.1|
| Sum of ranks | 11/0.351       | 14/0.31| 20/0.188| 24/0.146|
| Deviation from the average sum of ranks | $-6.25$ | $-3.25$ | 2.75 | 6.75 |
| Squared deviations | 39.0 | 10.5 | 7.56 | 45.6 |

The rating scale characterizing the favorable level of desirability of indicators $d$ was developed on the basis of many years of research by soil scientists in the Central Ciscaucasia zone [9-10], while it is assumed that the lower desirability limit of a satisfactory value of indicators $d = 0.37$ (table 2).
Table 2. The value of indicators at different levels of desirability.

| Indicators                        | Designation | Desirability level d |
|-----------------------------------|-------------|----------------------|
|                                   |             | 0.8      | 0.63      | 0.37      |
| Humus level, %                   | y₁          | 6.3 – 4.18 | 3.63 – 2.32 | 2.25 – 1.61 |
| Soil density, g/cm³              | y₂          | 1.15 – 1.25 | 1.21 – 1.23 | 1.30 – 1.34 |
| Soil resistivity, kg/cm²         | y₃          | 0.499 – 0.480 | 0.370 – 0.361 | 0.252 – 0.217 |
| Aggregate content > 10 mm, %     | y₄          | 10 – 20 | 21 – 40 | 41 – 60 |
| Dₜₚₑₜ                           |             | 0.94     | 0.88     | 0.77     |

Generalized test indicator Dₜₚₑₜ was calculated according to equation (1) based on three levels of desirability (0.8; 0.63 and 0.37), taking into account the calculated weight of the indicators k₁ ... k₄. As a result, the ranges of Dₜₚₑₜ = 0.94 - 0.88 were obtained, allowing the use of moldboard plowing; with Dₜₚₑₜ = 0.88 - 0.77 it is recommended to use a non-moldboard or combined mid-depth tillage; with Dₜₚₑₜ <0.77 it is recommended to use a minimum tillage with fine mulch tillage.

Based on the data of the averaged test values of natural indicators y₁ ... y₄ (table 2), taking into account their desirability (d₀.8, d₀.63 and d₀.37), equations of second-order polynomials

\[ d_i = a_0 + a_1 y_i + a_2 y_i^2 \]

were obtained, allowing the use of moldboard plowing; with Dₜₚₑₜ = 0.88 - 0.77 it is recommended to use a non-moldboard or combined mid-depth tillage; with Dₜₚₑₜ <0.77 it is recommended to use a minimum tillage with fine mulch tillage.

Table 3. Coefficients of equations for calculating the desirability dᵢ.

| Desirability | Coefficients |
|--------------|--------------|
| d₁           | a₀ = -2.12  |
| d₂           | a₀ = 14.33   |
| d₃           | a₀ = -1.36  |
| d₄           | a₀ = 2.1    |

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Table 4. Generalized criterion indicator of soils Dₜₚₑₜ.

| Soil type             | y₁/d₁ | y₂/d₂ | y₃/d₃ | y₄/d₄ | Dₜₚₑₜ | Recommended processing systems       |
|-----------------------|-------|-------|-------|-------|-------|--------------------------------------|
| Ordinary chernozem    | 4.76/0.63 | 1.17/0.82 | 0.485/0.53 | 15/0.49 | 0.889 | Differentiated dumping for crop rotation |
| Solonetzic chernozem  | 5.51/0.88 | 1.20/0.84 | 0.490/0.54 | 17/0.42 | 0.932 | Dump-free or combined mid-depth tillage |
| Dark chestnut soils   | 3.29/0.49 | 1.22/0.85 | 0.375/0.43 | 25/0.41 | 0.828 | Fine mulch tillage                   |
| Chestnut soils        | 2.68/0.28 | 1.32/0.64 | 0.360/0.22 | 30/0.48 | 0.778 |                                      |
| Light-chestnut soils  | 1.93/0.22 | 1.32/0.65 | 0.255/0.21 | 43/0.24 | 0.749 |                                      |
Comparison of the values of each generalized soil indicator $D_{\text{fact}}$ with ranges of $D_{\text{test}}$ values, with highlighting on the map the edges of zones with moldboard, combined mid-depth and minimum mulch processing, taking into account the contours of administrative districts, allows specialists to make certain organizational and technological decisions (figure 1).

Figure 1. Zones of implementation of various tillage systems.

4. Conclusion
The values of the generalized indicator $D_{\text{fact}} = 0.899$ for ordinary chernozem and $D_{\text{fact}} = 0.932$ for solonetzic chernozem are included in the range $D_{\text{test}} = 0.94 - 0.88$, therefore, for these soils, moldboard plowing for certain crops in crop rotation is acceptable; dark chestnut and chestnut soils with $D_{\text{fact}}$ equal to 0.828 and 0.778, respectively, are preferable to cultivate without moldboard with a combination of different methods and depth of soil cultivation; for light chestnut soils ($D_{\text{fact}}=0.749$), it is recommended to use a minimum tillage with fine mulch tillage.

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