Resource potential of introducing links with row crops in the Central Ciscaucasia

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Abstract. The introduction of links with row crops in the Stavropol territory is associated with the assessment of the territory resource potential. The monitoring of changes in the area under row crops in various soil and climate zones of the region over the eleven period (2008-2018) showed that a significant increase was established in the arid zone, zones of unstable and sufficient moisture by 5.0, 6.3 and 5.4 thousand hectares, respectively. Accepted criteria for the survey areas of the region: humus content in the arable layer, %; presence of saline, %; the relative indicator of the hydrothermal coefficient of the spring-summer period and the energy availability of equipment, allow using certain mathematical operations to calculate a generalized indicator of the resource potential of the D_{fact} for each specific area of the region. Areas with favorable resource potential have been identified (D_{fact} > 0.889), which occupy 20 % of the territory's area, districts with D_{fact} within 0.78 – 0.889 have a satisfactory potential, their area is 51 %, the area with limited potential (D_{fact} <0.78) is 29% of the territory. The map with different resource potential zones, taking into account the contours of administrative districts, will allow specialists to navigate when making certain technological decisions when cultivating row crops.

1. Introduction

The issues of introduction of field links with row crops are directly related to the resource potential in one or another soil-climatic zone of the Stavropol territory [1-2]. At the same time, it is necessary to take into account the presence of salt-marsh and saline complexes, which are a negative factor in assessing the resource potential [3]. Dynamics analysis of the arable land expansion under these crops leads to the search for the main criteria for assessing the resource potential of territories where conditions correspond to favorable or limited opportunities for cultivating row crops [4-7]. There is a number of significant and less significant individual soil-climatic, technological and material-technical factors that characterize the resource potential of certain areas of the region territory and to a greater or lesser extent reflect the possibility of introducing, including resource-saving soil treatment systems, as an element of crop cultivation technology [8-10]. In addition, a significant factor in the assessment of resource potential is the relative power equipment of the proposed row crops cultivation zones with the appropriate set of tillage tools. However, these factors do not allow for a fully integrated assessment of the resource potential of the region's areas, which allows making certain practical decisions. The purpose of the study is to develop a generalized criterion for assessing the resource potential for determining zones that are more or less favorable for the introduction of field links with row crops based on a certain set of criteria indicators.
2. **Material and research methods**

The dynamics of change in the areas occupied by row crops from 2008 to 2018 in the Stavropol territory was analyzed using the method of nonlinear trends [11]. For this purpose, we used annual statistics on the availability of areas under row crops in various natural and climatic zones of the region: extremely arid (1), arid (2), unstable moisture (3) and sufficient moisture (4). The methodological basis for conducting research to determine the favorable, satisfactory or limited resource potential in the row crops cultivation by spike precursors in various region zones was a number of accepted indicators for the survey points: the content of humus in the arable layer \( y_1 \) (%), the presence of salt-marsh and saline complexes \( y_2 \) (%), the average hydrothermal coefficient of the spring-summer vegetation \( y_3 \) (units), the presence of tractors \( y_4 \) (pieces per 1000 ha of arable land), which differ in physical meaning and dimensions. Calculations of the generalized \( D_{\text{wor}} \) and \( D_{\text{act}} \) indicators were conducted according to the methodology developed by the Krasnodar Research Institute of Agriculture [12]. The integral criterion \( D \) was defined as the geometric value of desirability of individual indicators:

\[
D = n \sqrt[n]{d_1^{k_1} * d_2^{k_2} * d_3^{k_3} * d_4^{k_4}}
\]  

where:

\( d_1 \ldots d_4 \) – values of desirability of indicators 1 ... 4;
\( k_1 \ldots k_4 \) – weight (importance) of indicators 1 ... 4;
\( n = 4 \) – number of indicators.

3. **Research results**

Based on data on the area of arable land occupied by row crops in the region, the plotting of trends in the dynamics of changes in areas for the period from 2008 to 2018 is carried out (figure 1). It is noted that in an extremely arid zone, a significant increase in the area under row crops has not been established due to the low hydrothermal coefficient of 0.5 – 0.7 and the predominance of chestnut soils of light mechanical composition (humus 1,7 – 1,4) in this zone.

![Figure 1. Trends in the change of areas under row crops in various soil and climate zones of the region.](image)
There was a significant increase in the area occupied by row crops in the 2nd, 3rd and 4th zones with an annual increase of 5.0, 6.3 and 5.4 thousand hectares, respectively. Based on the sign criterion of Cox and Stewart [11], the confidence of increasing trends in areas under row crops is significant at \( z = 1.75 \) and \( \Delta t = 1.64 \). These data serve as the basis for predictive assessment of the resource potential for the survey areas in the territory of the region and, in cartographic form, by interpolation, to determine favorable zones for the introduction of links with row crops.

The weight of the indicators \( k_1 \ldots k_4 \) was determined by an expert assessment method based on a survey of specialists in the field of agriculture and crop production technologies (table 1), and the verification of the consistency degree of experts’ opinions was evaluated by the criterion \( \chi^2 \). The assessment of the weight of indicators, based on a survey of experts, showed the following results: \( k_1 = 0.293; k_2 = 0.314; k_3 = 0.226; k_4 = 0.167 \). The degree of consistency of experts’ opinions was checked by the coefficient \( \chi^2 \). The resulting value \( \chi^2 = 13.38 \) is greater than the table value \( \chi^2 = 10.62 \) at a five percent significance level, i.e. there is a non-random consistency of experts. Therefore, the determining factors in assessing the resource potential, according to experts, are the presence of salt-marsh and saline complexes (\( y_2 \)) and the content of humus in the arable layer (\( y_1 \)).

**Table 1.** The results of expert assessment.

| Experts | Indicators | \( y_1 \) | \( y_2 \) | \( y_3 \) | \( y_4 \) |
|---------|------------|-----------|-----------|-----------|-----------|
| 1       | 3/0.2      | 2/0.2     | 1/0.4     | 4/0.2     |
| 2       | 3/0.2      | 1/0.4     | 2/0.3     | 4/0.1     |
| 3       | 1/0.3      | 3.5/0.2   | 3.5/0.2   | 2/0.3     |
| 4       | 1/0.4      | 2/0.25    | 4/0.15    | 3/0.2     |
| 5       | 2/0.3      | 1/0.4     | 3.5/0.15  | 3.5/0.15  |
| 6       | 2/0.35     | 1/0.35    | 3/0.18    | 4/0.12    |
| 7       | 2/0.3      | 1/0.4     | 3/0.2     | 4/0.1     |
| Sum of ranks | 14/0.293 | 11.5/0.314 | 20/0.226 | 24.5/0.167 |
| Deviation from the average sum of ranks | – 3.5 | – 6 | 2.5 | 7 |
| Deviation squares | 12.25 | 36 | 6.25 | 48 |

The assessment scale that characterizes the indicators of the resource potential of the region territory was developed on the basis of an array of statistical indicators for an eleven-year period using the method of grouping data, while assuming that the lower limit of desirability of a satisfactory value of indicators is \( d = 0.37 \) (table 2).

**Table 2.** The value of indicators at different levels of desirability.

| Indicators                              | Level of desirability (d) | Mark | Range of indicators |
|-----------------------------------------|---------------------------|------|--------------------|
| Humus content, %                        | \( y_1 \)                 | 7.1 – 5.52 | 5.51 – 3.93 | 3.92 – 2.34 |
| Salt-marsh and saline complexes, %      | \( y_2 \)                 | 0.6 – 15.2 | 15.3 – 29.9 | 30 – 44.6 |
| Hydrothermal coefficient of the spring-summer growing season | \( y_3 \)               | 1.8 – 1.39 | 1.38 – 0.97 | 0.96 – 0.55 |
| Tractors, pcs/1000 ha                   | \( y_4 \)                 | 9.2 – 7.0  | 6.9 – 4.7  | 4.6 – 2.4  |
| \( D_{test} \)                          |                           | 0.944 | 0.889 | 0.78 |
Generalized test indicator $D_{\text{test}}$ was calculated using equation (1) based on three levels of desirability (0.8; 0.63 and 0.37), taking into account the calculated weight of $k_1$...$k_4$ indicators. As a result, the ranges of the test generalized indicator $D_{\text{test}}$ are obtained corresponding to: favorable resource potential at $D_{\text{test}} = 0.944 – 0.889$; satisfactory at $D_{\text{test}} = 0.889 – 0.78$; restricted at $D_{\text{test}} < 0.78$.

Based on the data of the average test values of natural indicators $y_1$...$y_4$ (table 2) taking into account their desirability ($d_{0.8}$, $d_{0.63}$ and $d_{0.37}$), the equations of second order polynomials of the form $d_i = a_0 + a_1 y_i + a_2 y_i^2$ are derived to evaluate the desirability of natural values $d_i$ of each indicator for the survey areas $y_i$. Table 3 shows the coefficients of the calculation equations of second order polynomials for calculating the desirability of the natural indicators $y_1$, $y_3$ and $y_4$ and the linear equation for the indicator $y_2$ (table 3).

| Desirability | Coefficients |
|--------------|--------------|
|              | $a_0$        | $a_1$        | $a_2$        |
| $d_1$        | -0.4         | 0.3          | -0.017       |
| $d_2$        | 0.854        | -0.005       |              |
| $d_3$        | -0.32        | 1.1          | -0.255       |
| $d_4$        | -0.198       | 0.192        | -0.008       |

Substituting the obtained values of the desirability of each indicator for the survey points $d_i$, taking into account their weight ($k_1$...$k_4$) in equation (1) we get a generalized criterion indicator $D_{\text{fact}}$ (table 4).

| № survey areas | $y_1/d_1$ | $y_2/d_2$ | $y_3/d_3$ | $y_4/d_4$ | $D_{\text{fact}}$ |
|----------------|-----------|-----------|-----------|-----------|-------------------|
| 1              | 2.60/0.27 | 44.4/0.63 | 0.55/0.21 | 4.4/0.49  | 0.7775           |
| 2              | 2.34/0.21 | 36.8/0.67 | 0.6/0.25  | 2.4/0.22  | 0.7492           |
| 3              | 4.56/0.61 | 7.4/0.82  | 0.89/0.46 | 4.8/0.54  | 0.8855           |
| 4              | 2.98/0.34 | 14.2/0.78 | 0.82/0.41 | 2.8/0.28  | 0.8175           |
| 5              | 2.56/0.26 | 6.1/0.82  | 0.65/0.29 | 4.3/0.48  | 0.8057           |
| 6              | 2.97/0.34 | 9.4/0.81  | 0.68/0.31 | 3.0/0.31  | 0.8095           |
| 7              | 2.6/0.27  | 1.5/0.85  | 0.62/0.36 | 4.1/0.45  | 0.8037           |
| 8              | 3.99/0.53 | 10.6/0.80 | 0.8/0.40  | 3.5/0.38  | 0.8543           |
| 9              | 3.14/0.37 | 14.7/0.78 | 0.73/0.33 | 4.5/0.50  | 0.8323           |
| 10             | 4.74/0.64 | 3.6/0.84  | 1.04/0.55 | 5.0/0.56  | 0.9005           |
| 11             | 5.68/0.76 | 21.8/0.75 | 1.1/0.58  | 7.0/0.75  | 0.9157           |
| 12             | 3.73/0.48 | 2.9/0.84  | 0.84/0.42 | 3.7/0.40  | 0.8577           |
| 13             | 4.82/0.65 | 0.6/0.85  | 0.94/0.49 | 9.0/0.88  | 0.9141           |
| 14             | 5.93/0.78 | 20.4/0.75 | 1.0/0.53  | 3.2/0.33  | 0.8846           |
| 15             | 4.58/0.62 | 5.0/0.83  | 0.99/0.52 | 4.3/0.48  | 0.8889           |
| 16             | 5.55/0.74 | 7.1/0.82  | 1.0/0.53  | 2.7/0.26  | 0.8781           |
| 17             | 7.07/0.87 | 5.20/0.83 | 1.79/0.83 | 3.9/0.43  | 0.9318           |

Comparing the values of each $D_{\text{fact}}$ indicator by survey points with the ranges of $D_{\text{test}}$ values, highlighting the edges of zones with favorable, satisfactory and limited resource potential on the map, and taking into account the contours of administrative districts, allows making certain organizational and technological decisions (figure 2).
4. Conclusion
The reliability of changes in the trends of areas under row crops for a ten-year period with an increase in the area under row crops in the 2nd, 3rd and 4th zones with an annual increase in the average of 5.0, 6.3 and 5.4 thousand hectares was established.

The area of zones with favorable resource potential is 20 % of the Stavropol territory, with satisfactory resource potential is 51 %, with limited resource potential is 29 %. This will allow making appropriate technological decisions.

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Figure 2. Zones of resource potential for implementing links with row crops.
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