Justification of the choice of potato harvesters by the method of expert assessment

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Abstract. In the context of the country's growing self-sufficiency in foodstuffs, including potatoes, commodity producers need to purchase potato harvesters and devices. The choice of potato harvesting equipment should meet the needs of agricultural producers (potatoes) while contributing to the improvement of agricultural performance. In this situation, enterprises are faced with the problem of choosing potato-harvesting equipment: cheap but low in productivity, or expensive but high-tech. To substantiate the choice of using machines for harvesting potatoes, it is possible to use the method of expert assessment, which allows choosing among a variety of alternatives, based on the preferences and justifications of experts. The use of the mathematical apparatus makes it possible to compare various physical characteristics by reducing them to a dimensionless scale. As a result of studying the most common trailed potato harvesters, the KKP-2M trailed harvester possesses the optimal ratios of the cost of the machine, productivity and quality of the resulting product. Trailed potato harvesters at a lower price have technical parameters that are not much inferior to self-propelled machines. This conclusion is confirmed by such methods as "Score table" and "Polygon for alternatives". The first method provides a mathematical justification and the second one allows visualizing the resulting solution.

1. Introduction

Potatoes play a special role in providing the population with food, remaining the most valuable and essential everyday food product in the country [1, 2]. The area under crops for potatoes in large-scale commercial farms has been decreasing everywhere recently, and it is increasing in personal subsidiary farms. The current situation creates certain problems for both large and small potato producers. Large ones have a fleet of potato-harvesting equipment, as a rule, outdated and in need of renovation. Small ones lack the necessary units for harvesting potatoes in increased volumes. In this regard, potato producers need to purchase potato harvesters and units.

The improvement of individual working bodies of potato harvesters is of great importance for increasing the agrotechnical indicators of their work [3]. The greatest interest is aroused by the following digging working bodies: the roller finder, discs and the shovel, since the performance of the machine as a whole directly depends on the quality of their work. The roller is of no small importance, since it provides a predetermined digging depth of the bed and effectively destroys the surface clods of soil, since it first enters the harvesting process. The existing designs of rollers do not consider...
peculiarities of their use in changing agrarian landscape conditions. They have a high level of unification. The disadvantages of the roller design include:

• existing methods of cleaning from soil adhesion, especially on waterlogged soils;
• significant metal intensity;
• using only mechanical action by static load;
• insufficient number of studies to substantiate the shape of the working surface of rollers.

2. Materials and methods
The following brands are in greatest demand at the Russian market of potato harvesters: potato digger KTN-2V, trailed combine KKP-2, trailed combine Grimme SE 150-60, trailed combine AVR 220BK Variant, modernized trailed combine KKP-2M with an improved roller [4], which will participate in choosing a potato harvester using a mathematical apparatus.

The modernized trailed combine KKP-2M has an improved roller, where rings made of D-rings are fixed on the cylindrical part in the form of a drum. Each roller is equipped with scrapers and is fixed on the sidewalls with bearing supports. Each roller is attached to the frame with brackets, and a screw mechanism equipped with a handle is installed between the bracket and the hinge frame.

To substantiate the choice of using machines for harvesting potatoes, the method of expert assessment is used. It assumes a certain sequence of a set of methods: diagnostics of the problem; formation of assessment criteria; solving the problem by Churchman-Akoff method; solution of the problem by the method of "table of estimates"; solving the problem using the "polygon of alternatives" method.

3. Results of mathematical modeling
In this situation, enterprises are faced with the problem of choosing potato-harvesting equipment: cheap, but low productive or expensive, but high-tech [5, 6].

The priority criteria for choosing equipment for enterprises include [5]:

• technological effectiveness as a complex characteristic of potato harvesting equipment, which determines the combination of optimal technical and quality characteristics;
• productivity, as an indicator of the volume of work performed (harvested area of potatoes) per unit of time, considering design features, technical characteristics and production qualifications of workers;
• cost - cheapness, as the lowest possible cost for the given characteristics of the equipment.

The ratio of the selected criteria determines key characteristics of the potato harvesting process: expensiveness, slowness, losses (Fig. 1).

Each criterion is revealed through a series of technical characteristics of potato harvesters:

• technological effectiveness is determined by the following indicators:
  • number of harvested rows, pcs.;
  • coverage, m;
  • digging depth, cm;
  • the number of service personnel;
  • capacity of the hopper, t;
  • loss of tubers, %;
  • damage to tubers, %, etc.
• performance is determined by the following indicators:
  • performance per hour of work, ha/hour;
  • working speed of the unit, km/h, etc.
• the cost is determined by the following indicators:
  • device cost, rubles;
  • costs per hectare, rubles/ha, etc.
Figure 1. Correlation of criteria for choosing potato harvesters

These technical characteristics are the most important ones when choosing a potato harvester [7]. However, the number of harvested rows and the depth of digging in the objects under consideration coincide and amount to 2 pieces and 22 cm, respectively. In this connection, they are dropped from further comparison. To compare parameters of potato harvesters, their averaged values were taken (Table 1).

Table 1. Comparative characteristics of technical parameters of potato harvesters

| Combination of technical characteristics | Types of potato harvesters |
|-----------------------------------------|----------------------------|
|                                        | Potato-digger KTN-2B | Trailed combine KKP-2 | Trailed combine Grimme SE 150-60 | Trailed combine AVR 220BK Variant | Trailed combine KKP-2M |
| Performance per hour of work, ha/hour   | 0.35 | 0.54 | 0.60 | 0.52 | 0.54 |
| Device working speed, km/h              | 2.3  | 4.7  | 4.9  | 4.7  | 4.7  |
| Number of harvested rows, pcs.          | 2    | 2    | 2    | 2    | 2    |
| Coverage, m                             | 1.4  | 1.5  | 1.5  | 1.5  | 1.5  |
| Digging depth, cm                       | 22   | 22   | 22   | 22   | 22   |
| Number of the operating staff, persons: | 5    | 3    | 3    | 3    | 3    |
| tractor driver, manual labour           | 1    | 1    | 1    | 1    | 1    |
| Hopper capacity, t                      | 4    | 2    | 2    | 2    | 2    |
| Device cost (new), million rubles       | -    | 2    | 6    | 5.5  | 2    |
| Cost per hectare, thousand rubles       | 0.31 | 2.71 | 13.40| 6.58 | 2.71 |
| Loss of tubers, %                       | 5.7  | 4.2  | 4.1  | 3.4  | 4.0  |
| Tuber damage, %                         | 2.83 | 5.4  | 2.1  | 4.0  | 5.2  |

To choose machines for harvesting potatoes, it is necessary to rank the criteria by preference, that is, the influence on the choice. Using the mathematical apparatus MS Excel allows assessing the relative position of the rank among all test results. The percentage rate is redefined to a normalized
value in fractions of a unit, thus a weight factor is formed for each criterion. Churchman-Akoff method allows one to assess the quality of estimates by comparing the preference for alternative variant \( a_1 \) and the sum of the remaining alternative variants (Table 2).

### Table 2. Comparison of estimates by Churchman-Akoff method

| Expression | Conclusion on satisfaction |
|------------|----------------------------|
| \( 1<0.889+0.778+0.667+0.556+0.445+0.334 \) | satisfied |
| \( 1<0.889+0.778+0.667+0.556+0.445 \) | satisfied |
| \( 1<0.889+0.778+0.667 \) | satisfied |
| \( 1<0.889 \) | satisfied |

By analogy, there is a comparison of assessment of alternative variants \( a_2, a_3, \) etc. with the sum of the remaining alternatives. All comparison expressions are fulfilled, which makes it possible to use the obtained estimates further when making a choice of potato harvesting equipment.

To compare the characteristics of different types of technology, a dimensionless scale of abstract units from 1 to 10 is used. As optimal, the largest sum of dimensionless units is taken. To obtain rounded-off values on a dimensionless scale, the ranges of table values are slightly expanded. The creation of a table of correspondence between dimensional and dimensionless characteristics allows unequal criteria to be brought to a single scale, the use of which makes it possible to evaluate alternatives (Table 3).

### Table 3. The table of assessment of alternatives by the sum of dimensionless units with unequal criteria

| Criteria | Weight factor |
|----------|---------------|
| symbol \( V_k \) | \( P \) \( V_k^*P \) \( P \) \( V_k^*P \) \( P \) \( V_k^*P \) \( P \) \( V_k^*P \) |
| Performance per hour of work, ha/hour | 0.11 \( 1.33 \) 0.15 0.76 0.84 9.67 1.06 7.00 0.77 7.67 0.84 |
| Device working speed, km/h | 0.04 \( 1.33 \) 0.05 9.00 0.36 9.67 0.39 9.00 0.36 9.00 0.36 |
| Coverage, m | 0.07 \( 1 \) 0.07 9.33 0.65 9.33 0.65 9.33 0.65 9.33 0.65 |
| Number of the operating staff (manual labour), persons | 0.09 \( 2 \) 0.18 6 0.54 6 0.54 6 0.54 6 0.54 |
| Hopper capacity, t | 0.02 \( 1.00 \) 0.02 3.99 0.08 9.95 0.20 9.21 0.18 3.99 0.08 |
| Device cost (new), million rubles | 0.20 \( 9.67 \) 1.93 8.38 1.68 1.25 0.25 5.8 1.16 8.38 1.68 |
| Cost per hectare, thousand rubles | 0.18 9.81 1.77 8.13 1.46 3.41 0.61 6.34 1.14 8.12 1.46 |
| Loss of tubers, % | 0.16 1.67 0.27 6.67 1.07 7.00 1.12 9.33 1.49 7.33 1.17 |
| Tuber damage, % | 0.13 7.68 1.00 1.25 0.16 9.5 1.24 4.75 0.62 1.75 0.23 |
| Sum | 5.43 6.85 6.06 6.92 7.01 |

The maximum sum of products corresponds to the fifth alternative, that is, when choosing an alternative using the “score table” method, the KKP-2M trailed combine is the optimal type of potato harvesters. On the basis of the accepted criteria and the established dimensionless estimates within the
criterion, each of the proposed alternatives can be represented graphically in the form of a diagram built in polar coordinates - “polygon of alternatives”. The axes on which the values of the criteria are directed along the radii from the centre of the circle to the periphery. The number of axes corresponds to the number of selected criteria. The best dimensionless values are located further from the centre of the circle. Therefore, the optimal variant is considered, which corresponds to the polygon that outlines the largest area.

![Diagram of alternative types of potato harvesters](image)

**Figure 2. The range of alternative types of potato harvesters**

The figure allows assessing visually that the largest area corresponds to the fifth alternative. Since the values of the criteria are comparable, the axes are scaled, it is possible to calculate the area of each alternative through the area of the polygons using the following formula: 

\[ S_{total} = S_1 + S_2 + S_3 + S_4 + S_5 + S_6 + S_7 + S_8 + S_9, \]

where \( S_n = \frac{1}{2} \times A \times B \times \sin 40^\circ \) (40° = 360°/9 is the angle between axes).

4. Conclusion

The impossibility of mathematical formalization of the process of justifying the choice of using potato harvesters required the use of the method of expert assessment, which allowed choosing among a variety of alternatives, each of which has different advantages [1, 4, 5]. The assessment of the problem of choosing potato-harvesting equipment was based on the opinion of specialists (experts) with a view to further decision-making. The use of the mathematical apparatus made it possible to carry out a comparison according to criteria that were incomparable in physical units, due to their reduction to a dimensionless scale.

As a result of the study of the most common trailed potato harvesters, the KKP-2M trailed combine has the optimal ratios of the cost of the machine, productivity and quality of the resulting product. The good technical characteristics of the Grimme SE 150-60 trailed combine are covered by its high price, which does not make it possible to take a leading position in comparison with domestic combines. Trailed potato harvesters at a lower price have technical parameters that are not much inferior to self-propelled machines.
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