

To Ecological Monitoring of Self-Propelled Field Sprinklers

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Abstract. An improved method for making a decision on choosing the best self-propelled sprayer from alternative options is proposed. It refers to new developments in various fields of environmental monitoring and analysis of field self-propelled sprinklers, but which substantiate the studied factors characterizing each unit. The factors are taken with real values of calculated parameters, for which the desirability function and weighty coefficients are developed using the method of pairwise comparison of calculated parameters of absolute and relative rank places and the percentile function. The dependence of the transfer of calculated parameters of the unit from real values to dimensionless ones for the y' scale is clarified, according to which the desirability function is calculated, and then a generalized parameter characterizing the complex evaluation of the unit in respect to the weighting coefficient of each estimated parameter. The decision is made according to the maximum value of the parameters of integrated assessment of the sprinkler, in this task for the sprinkler TUMAN-1 (Russia), for which the value of the parameter of integrated assessment is obtained.

1 Introduction

Environmental monitoring and analysis are important in environmental protection. It is of particular relevance in the interaction of agricultural machinery on the soil and its contamination with fuel and lubricants, chemical protection agents, harmful exhaust gas emissions, destruction of the soil structure causing erosion processes. The successful solution of environmental problems in agriculture is determined by the precision fulfillment of environmental requirements [1] by the units used and their technical level.

The high technical reliability of the units, their low-capacity structural and technological features make it possible to adapt to natural and climatic zonal conditions, fulfill the ecological and agrotechnical requirements of cultivated crops qualitatively, ensure a sparing effect on the soil of the working bodies of units and running systems and provide favorable conditions for growth and development in cultivated plants to obtain high yields. Even when developing the technical specification for the unit, its relationship with the

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environment and the expected consequences for the preservation of soil fertility, its compaction by the running systems of units, and the destruction of the soil structure should be taken into account. When using self-propelled sprinklers, it is also necessary to take into account the energy intensity of the workflow and economic parameters (operational and labor costs) to the listed negative trends when working units in the field.

The problem of making a decision to choose the best unit from alternative options is complex and multifaceted. Each feature of specialized machines is characterized by its own determining factors, environmental and technological features of cultivated crops. Previously, papers have been published that reflect the results of research on the theory of decision-making [2,3] using the Harrington function [4].

Our domestic technologies require a reduction in energy intensity, operational and labor costs to increase the competitiveness of crop production [5]. And this can be achieved by selecting the best equipment from a wide variety of machines industrially produced.

The purpose of the present article is to propose a new methodological approach to the modernization of the Harrington function to justify the best design of a self-propelled field sprinkler from alternative options.

2 Materials and Methods

The paper reveals the method of analysis and synthesis, various design and technological schemes of self-propelled sprinklers, as well as new methodological additions to the improved Harrington function.

The theory of substantiating the best design of a field self-propelled sprinkler has its own distinctive features in terms of determining factors and environmental effects. The sprinkler requires high reliability of the design, since downtime of equipment during field work will cause crop losses. A sealed cabin, a strong rod with a rigid fixation in operation, good lighting for round-the-clock operation, modern automation systems of the unit are needed. The presence of these factors forms the first evaluation parameter of the sprinkler - its technical level, which varies in the range 0 ...1 depending on the design. We took the energy intensity of the working process (MJ/ha) as the second evaluation parameter of the design. The third and fourth estimated parameters operating costs (rubles/ha) for sprinkling and labor costs (people-h/ha) are taken. It is clear from the proposed information that the higher the value of the first parameter (reliability) and the lower the other ones (energy intensity, operating costs and labor costs), the higher the value of the generalized parameter of a comprehensive assessment, the more preferable the design of the unit.

The environmental impact factors of the sprinkler are shown in Figure 1.

The three groups of factors presented in Figure 1 characterize the interaction of sprinklers with the environment and their comprehensive assessment to choose the best design.

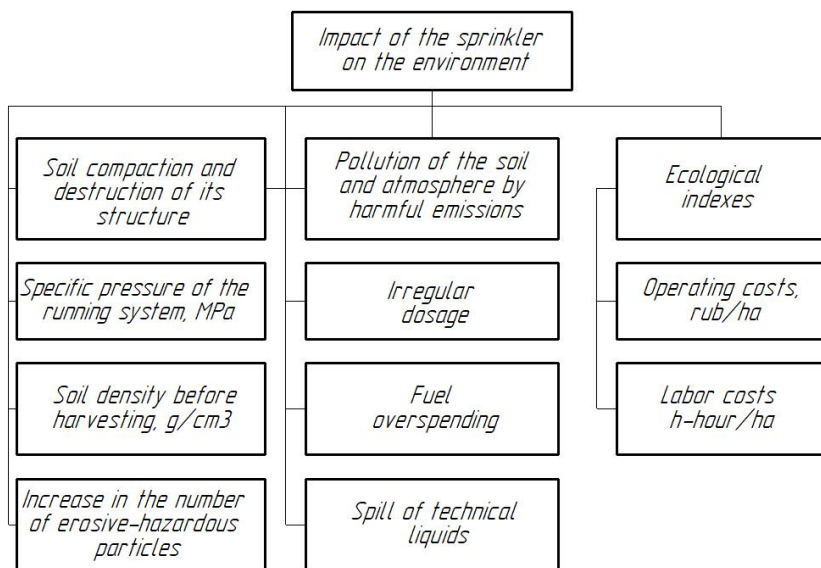


Fig. 1. Environmental and economic impact factors of the sprinkler

Special attention should be paid to the first group of factors (Figure 1) - this is the compaction of the soil and the destruction of its structure by the equipment used. These factors determine the preservation of soil fertility, which decreases from year to year even in Kuban. Annually, the fertility of the Kuban soil decreases by 0.03% in terms of humus content, soil compaction affects the yield reduction. The paper notes that even with sufficient moisture and nutrients in the soil, the crop yield is sharply reduced at optimal soil density. All this suggests that the sprinklers with narrow wheels and insufficient support area have fallen heavily and do not allow obtaining the high yields, therefore they will have low desirability according to the Fifth evaluation index "Specific pressure of the unit on the soil".

To make a decision about the best design of the sprinkler, we analyzed the *i*- brands of various units according to five *j*-th evaluation parameters.

Table 1. Technical characteristics of sprinklers of *j*-th estimated parameters.

№	Brands of <i>i</i> -th units	<i>j</i> - th estimated parameters of sprinklers				
		technical level of the unit	Energy intensity of the process <i>Z</i> , MJ/ha	operating costs <i>U</i> , rub/ha	labor costs <i>Z</i> , person-h/ha	specific pressure on the soil <i>q</i> , MPa
1	TUMAN-1	0,7	8,4	70,6	0,03	0,01
2	Versatile XS 275	1,0	26,9	116,6	0,031	0,6
3	John Deere 543	0,97	13,2	233,1	0,023	0,4
4	Rubin	0,95	5,8	88,4	0,027	0,5
5	GAZ-66	0,6	6,5	30,7	0,037	0,3
Weighting coefficients of <i>j</i> -th parameters		0,195	0,215	0,175	0,17	0,275

In Table 1, the pressure of the TUMAN - 1 unit on the soil is the 5th estimated parameter, which is more than 10 times less than other units. Its design relies on six wheels (Figure 2) with shell tires with a ground pressure of only 0.01 MPa. This advantage will affect not only the value of the integrated assessment parameter mainly but also the creation of favorable conditions for the soil and the normal development of plants. According to the TUMAN-1 sprinkler, the first three evaluation parameters (2-4) are preferred (Table 1), and only the first one is inferior to other sprinkler designs. For example, the RUBIN sprinkler (Figure 2b) has a more successful rod design, its suspension on shock absorbers, tightness of the cabin, illumination, etc. []

The technical characteristics (Table 1) of the studied units are used to construct scales of evaluation parameters and a desirability scale (Figure 3).

A new approach in the method of choosing the best sprinkler design is the method of calculating the dependencies of the coefficients of the estimated parameters when translating them from actual to dimensionless to determine the desirability function.



Fig. 2. Compared parameters of TUMAN-1 2a and RUBIN 2b units

In Figure 3, the arrows show the transition from the actual values of the estimated parameters x_{ij} of the compared sprinklers to transitional scales, then to dimensionless y_{ij}^* , and then to the Harrington curve to calculate the desirability d_{ij} of each j -th estimated parameter for the i -th brand of the sprinkler.

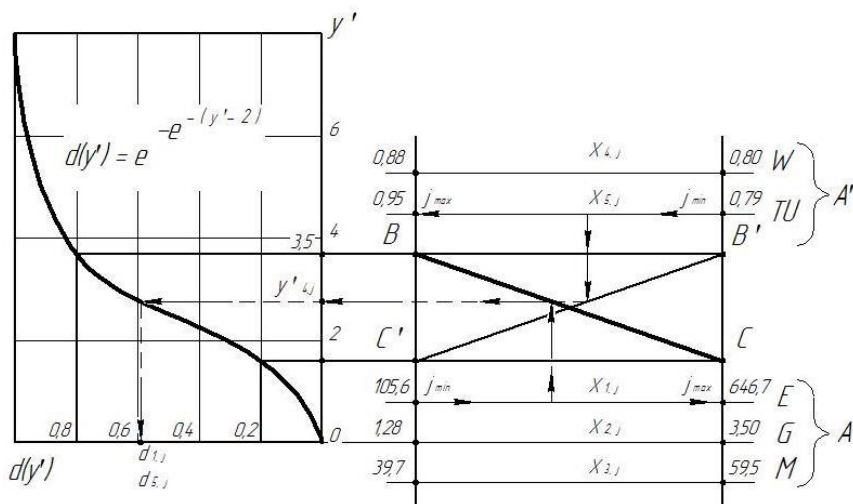


Fig. 3. Nomogram of the actual values of the estimated parameters

We have obtained the values for each i-th brand of sprinkler for conversion from the five actual values of the j-th estimated to dimensionless values for conversion to the y' scale. The transition is performed according to the following dependencies (1-5).

$$y'_1 = -3.349x_1 + 3.523, \tag{1}$$

$$y'_2 = -0.094x_2 + 4.043, \tag{2}$$

$$y'_3 = 4.94x_3 - 1.44, \tag{3}$$

$$y'_4 = -0.0098x_4 + 3.799, \tag{4}$$

$$y'_5 = -131,73x_5 + 6.53 \tag{5}$$

$y'_1, y'_2, y'_3, y'_4, y'_5$ - , dimensionless values of the estimated parameters, respectively, the pressure of the wheels on the soil P, the energy intensity Ab of the sprinkler operation process, the technical level of the machine T_Rub of operating costs I, labor costs Ya.

3 Results and discussion

The calculation of the desirability function d for each j-th evaluation parameter for each i-th machine is calculated according to the well-known formula (6):

$$d_{ij} = e^{[-e]^{-(x+2)}}$$

The desirability of j-th parameters for sprinklers are shown in Table 2.

In Table 2, the numerator shows the actual value of the estimated parameters, and the denominator shows its desirability for each unit without taking into account the weighting factor. The value of the pressure pa- P (Table 2) is determined by the design of the running wheels and varies in the range of 0.01-6 MPa, energy intensity E - engine power and unit performance, technical level T_u design features of the sprinkler, operating costs I - the price and performance of units, labor costs 3 - the performance of the sprinkler and the number of maintenance personnel.

According to the calculations, Table 2 clearly shows the advantage of one or another brand of the i-th sprinkler in terms of the desirability of each estimated parameter (in the

denominator). For example, for the TUMAN-1 sprinkler, the desirability of the first parameter - the pressure of the unit on the soil P is estimated by the desirability value $d_1=0.8$ (Table 1) energy intensity $E d_2=0.75$, operating costs $d_4=0.7$, and the lowest desirability takes place in terms of labor costs $d_5=0.24$.

Table 2. Desirability of evaluation indexes for the sprinklers under study.

№	Unit brand	d desirability of evaluation parameters				
		technical level of units, T_u	energy intensity E, MJ/ha	operating costs I rub/ha	labor costs Z person-h/ha	pressure on the soil, P MPa
1	TUMAN-1	0,7/0,38	8,4/0,75	70,6/0,7	0,037/0,25	0,01/0,8
2	Versatile XS 275	1,0/0,8	26,9/0,2	116,6/0,6	0,031/0,53	0,6/0,20
3	John Deere 543	0,97/0,77	13,2/0,64	233/0,2	0,023/0,8	0,4/0,44
4	Rubin	0,95/0,75	5,8/0,8	88,4/0,68	0,027/0,69	0,5/0,32
5	GAZ-66	0,6/0,2	6,5/7,9	30,7/0,8	0,038/0,2	0,3/0,56

Already according to these parameters, it is possible to work on the design of the unit, improving its technical level and performance. The John Deere sprinkler has the lowest desirability in terms of operating costs (0.2 Table 2) due to the high price and the highest desirability (0.8) in terms of labor costs due to high productivity.

Parameters of a comprehensive assessment of the i-th brands of the sprinkler are presented in Table 3.

The calculations of the generalized index of the integrated assessment are carried out in two versions: taking into account the weighting coefficient of each of the five evaluation indexes j and without them (Table 3). In the first variant, the best spraying unit turned out to be TUMAN-1, in the second - Rubin. The advantage of Rubin was provided by the parameter of low energy intensity of the process (Table 2).

Table 3. Summary of the comprehensive assessment of self-propelled sprinklers

№	Unit brand	Generalized index of integrated assessment	
		with the weighting factor	without the weighting factor
1	TUMAN-1	0,903	0,590
2	Versatile XS 275	0,814	0,399
3	John Deere 543	0,871	0,511
4	Rubin	0,895	0,615
5	GAZ-66	0,845	0,426

When analyzing the data in Table 3, it suggests that all the sprinklers considered are practically equivalent in terms of the value of the generalized index of the integrated assessment, if you round the value of this parameter to the first decimal place. The value of the generalized integrated assessment parameter when calculated without the weight of the estimated parameters when rounded to the first decimal place (Table 3) differs by 0.2, which is more significant than in the first variant, and then TUMAN-1 and Rubin would be equivalent. In this case, the decision is made based on the results of the analysis of other private evaluation indexes. For example, TUMAN-1 $T_u = 0.38$. and at Rubin $T_u = 0.75$, which is much better. But TUMAN-1 has the best desirability of 0.8 according to the most

important agrotechnical parameter - the pressure on the soil of the running systems of the unit, which affects the fertility of the soil [11] and the harvest is the result of all labor.

Therefore, the decision should be unambiguous in favor of TUMAN-1. As can be seen, the evaluation of the compared units without taking into account the weighting factor of the estimated parameters can lead to erroneous results and will not provide the full effect of the purchased unit. In this regard, it is important to pay attention to the competent justification of the estimated parameters of the unit and the weight of each parameter in the comprehensive assessment of the unit according to the generalized index.

4 Conclusions

To choose the best design of a self-propelled field sprinkler, the factors of their impact on the environment and estimated indexes for a comprehensive assessment, taking into account their weight, are formulated. Among the evaluation indexes, technical, economic and technological parameters that determine the quality of the compared machines are accepted. One of the main evaluation parameters is the value of the specific pressure of units on the soil, which determines the yield of cultivated crops. A method has been developed and proposed for transferring the actual values of the estimated parameters of sprinklers into dimensionless ones for calculating the desirability function and the generalized index of the comprehensive assessment, which determined the best design of the TUMAN-1 sprinkler. The value of its comprehensive assessment index was 0.903, taking into account the weight of all evaluation indexes, and 0.615 – without weight.

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