JUSTIFICATION OF THE ECONOMIC EFFICIENCY OF THE APPLICATION OF COMBINED FRONT PLOUGH FOR SMOOTH PLOWING

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Introduction. In modern agriculture, new technologies are rapidly developing through intensive methods. Technical complexes for the mechanization of agriculture are being implemented. Designers are striving to make aggregators more modern, introducing proposals aimed at optimizing structures, increasing productivity, and improving the quality of technological processes. The active investment in intensive technologies contributes to the widespread use of combined aggregators. Against this backdrop, new technologies for minimum tillage are being developed, where the inclusion of plowing is considered mandatory. The rationale behind this is that plowing enables the utilization of the relatively deeper soil layers for the growth and development of plants.

Methodology. The foundation of this work lies in the economic analysis of the proposed combined plough for smooth plowing, offered by our team. The proposed aggregator operates following the scheme "plowshare-disc-roller." This scheme ensures, in a single pass, initial plowing up to a depth of 25 cm, where part of the soil layer is turned over. This is followed by disc harrowing up to a depth of 15 cm, which breaks up the clods formed by the plowshare and cultivates the surface, cutting remaining weeds and leveling the field. Subsequent rolling compacts and smoothen the soil surface up to a depth of 5 cm. To assess the economic value of the proposed machine, it was virtually divided into three separate machines: plough, disc harrow, and roller. The economic indicators of each were determined individually, followed by a comparative analysis of their cumulative indicator versus the corresponding indicator of the proposed combined machine. As a result, the feasibility of using the proposed machine was substantiated.

Literature Review. The efficiency of the application of the proposed combined machine for basic and surface soil tillage depends on the correct selection of its place and role in the agricultural system [Yerzamaev, Pavlovich, 2012]. It should be noted that every rational agricultural method has a dual significance: on one hand, it contributes to the improvement of the quality of the performed process, and on the other hand, it requires certain expenses. The suitability of the application should be determined by the combination of these two factors [Trubilin, et al., 2008, 654-672]. The new method of soil cultivation and the technical means should contribute to increasing the productivity of crops with minimal labor expenses [Pavlushin, 2010, 5; Brusentsov, 2016, 75]. It is accepted to evaluate the efficiency of the new machine by comparing it with the base machine actually used in production [Afonin, 2007]. The suitability of creating and investing in new technology is determined by the performance indicator of the expenses incurred in the work done [Zazulya, et al., 2015, 117-126.]. The annual economic efficiency based on the incurred expenses represents the total economic management of all production resources, including labor, materials, primary investments, and other expenses that arise during the production and utilization of the new machine [Shmonin, et al., 2014, 120-122]. It is calculated using the following formula.

$Э_a = (З_b - З_n) A_a,$ (1)

Where $З_b$ and $З_n$ are the expenses incurred on the unit of work for the base and new machines respectively. A_a is the annual volume of work.

Scientific novelty. A combined plough for smooth plowing has been proposed, which consists of a frontal plough without turner plow, a shaped disc harrow, and a roller (see Fig.1) [Yesoyan, et al., 2023].

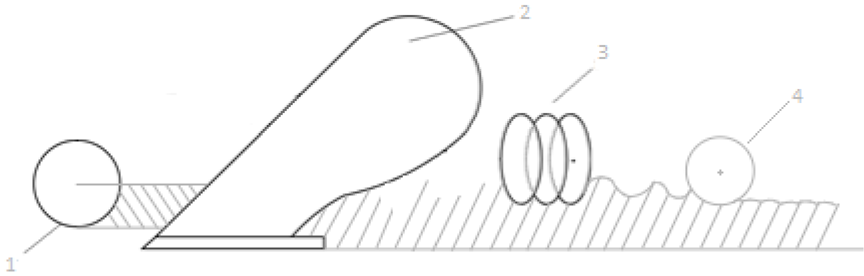

Figure 1. Schema of the combined plough for smooth plowing 1 - Shaped disc blade, 2 - frontal plough without turner plow, 3 - Shaped disc harrow, 4 - Roller.

The proposed machine has compact dimensions, which ensures its maneuverability in areas with uneven terrain. With this machine, the aggregator can maintain efficiency without reducing maneuverability in such challenging fields. The machine, in a single pass, ensures the necessary surface preparation for seeding. This reduces the number of passes required in the field, consequently decreasing operational costs.

Analysis. The main parameters determining the efficiency of agricultural machinery are considered to be the productivity and the price of the machine [Turusov, et al., 2016, 78-80]. The calculation of these parameters has been performed for the proposed combined plough for smooth plowing (aggregated with the T-150K tractor) and for the base machine. Calculation of the productivity of the aggregate: The productivity of the aggregate is determined by the following formula [Tseddies, et al., 2000, 400].

$W_h = 0{,}1 \cdot B_o \cdot V_o \cdot \tau$,ha/hour (2)

Where:

B_o is the machine's operational coverage width

V_o is the aggregate's operational speed
τ is the time utilization factor
0,1 is the hectare conversion factor

For a more effective comparison of the new and base machines, the operational parameters of the combined machine are taken at their minimum values as per the assignment, while for the base machine, at their maximum values. The proposed parameters for the combined machine are as follows: B=2.1m, V=5.2 km/h, τ=0.85.

Therefore $W_h = 0.928\ ha/hour$.

The base machine includes three aggregates, each of which performs one technological process:

1.Plowing with a ПФН-2А plow, aggregated with a Т-150К tractor, B=2.1m, V=5.5 km/h, τ=0.89. Therefore, W_h=1.03 ha/hour.

2.Harrowing with a БДН-3 harrow, aggregated with a МТЗ-80.1 tractor: Bo= B·β=3·0.95=2.85m (B=3m is the constructive coverage width of the harrow, β=0.95 is its utilization factor), V=8 km/h, τ= 0.91. Therefore, W_h=2.07 ha/hour.

3. Rolling with a 3-ККШ-6 roller, aggregated with a МТЗ-80.1 tractor: Bo= B·β=6·0.95=5.7m, (B=6m is the constructive coverage width of the roller, β=0.95 is its utilization factor), V=7.8 km/h, τ=0.85. Therefore, W_h=4.09 ha/hour.

Calculation of the Branch Cost. The data for the base machine have been taken from the corresponding sources [Pavlushin, 2010]. The calculation was made only for the proposed combined plough for smooth plowing, which is divided into three rings (frontal plough without turner plow, shaped disk coulters, and roller), and the branch cost has been calculated separately for each. The branch cost is calculated by the formula:

$C_o = G(\lambda HK + M) + d,$ (3) *where.*

G is the net weight of the machine without wear parts, in kg,
λ is the construction complexity coefficient,
H is the cost of one kilogram of weight produced, in drams,
K is the variation coefficient, depending on the volume of production,
M is the cost of raw materials per one kilogram of net weight, in drams,
d is the cost of wear parts, including added transportation costs, in drams.

For the frontal plough without turner ploughs: G=950 kg, H=900 drams, K=1.1, M=600 drams, d=6000 drams, λ=1.0.

For the shaped disk coulters: G=65 kg, H=900 drams, K=1.4, M=1600 drams, d=36600 drams, λ=1.2.

For the roller: G=50 kg, H=900 drams, K=1.1, M=1600 drams, d=16000 drams, λ=1.0.

By substituting the corresponding values, we obtain: For the frontal plough without turner plows: C_{01}=1516500 drams, For the shaped disk coulters: C_{02}=238280 drams, For the roller: C_{02}=145000 drams. Thus, the branch self-cost for the combined flat varied facade plow will be: $C_0= C_{01}+ C_{02}+ C_{03}$=1900280 drams.

Calculation of the Machine's Balance Value. The balance value of the machine is determined in the following way.

$B = C_0.K_b$ where K_b is the coefficient for design of average balance value, K_b =1.148.

By substituting the values, we will obtain B=2181521 drams

Calculation of Operational Expenses. The operational expenses for the compared options are determined by the following formula.

$U=A+P+X+C_f+W$ drams/hour (4) where:

A is the sum of amortization allowances, in drams,

P is the allowances for current, major repairs and technical maintenance, in drams,

X is the sum of allowances for the storage of machinery, in drams,

C_f is the cost of fuel and lubricants, in drams,

W is the wage of the tractor-driver/machine operator, including bonuses, in drams.

The sum of amortization allowances is calculated using the following formula

$A = \frac{B \cdot a}{T \cdot 100}$, drams/hour, (5) where:

a is the annual norm of amortization allowances, in percentages. It is set at 14.2%.

T is the annual workload of agricultural machinery, in hours. Let's assume 325 hours. By substituting the corresponding values, for the combined plough for smooth plo-wing, we will obtain A=953 drams/hour.

From professional literature, we have for the ПФН-2А plow A=980 drams/hour, for the БДН-3 harrow 103 drams/hour, and for the 3-ККШ-6 roller 97 drams/hour. Therefore, for the base machine, the operational expenses are A_b =1153 drams/hour.

Assuming the annual norm for main, current repairs, and technical maintenance is 9.0%, and the norm for the preservation of machinery is 0.3%, we have calculated:

-The allowances for repairs and technical maintenance for the combined plough for smooth plowing: P_m =324 drams/hour, and for the base: P_b =390 drams/hour.

- The costs of machinery preservation for the combined plough for smooth plowing: X_m =20 drams/hour, and for the base: X_b =45 drams/hour.

The wage for the tractor-driver/machine operator, including bonuses, is set at 2000 drams/hour for operating the combined plough for smooth plowing, 1500 drams/hour for operating the ПФН-2А plow, and approximately 1000 drams/hour for harrowing and rol-ling. Consequently, the labor cost for the base is 3500 drams/hour. To determine the cost of fuel and lubricants, first, we calculate the hectare consumption of fuel according to technological processes, which is determined by the following expression.

$Q_{ha}=G_h/W_h$ (6) where:

G_h is the hourly fuel consumption under normal load conditions. For the T-150K tractor aggregated with the combined plough for smooth plowing, according to our experimental research, the average hectare fuel consumption is 38.9 liters/ha. The productivity of the mentioned aggregate is 0.928 ha/hour. Therefore, the hourly fuel consumption is 36.1 liters/hour. According to the technical characteristics of the base machines, the fuel consumption is as follows:

- For operating with the ПФН-2А plow: 31.5 liters/ha or 26.2 liters/hour [Yesoyan, 2006, 180].
- For harrowing with the БДН-3 harrow: 7.56 liters/ha or 6.28 liters/hour.
- For rolling with the 3-ККШ-6 roller: 3.67 liters/ha, or 3.05 liters/hour.

Thus, the total fuel consumption for the base machine is 42.73 liters/ha or 35.53 liters/hour.

Considering the cost of one liter of diesel fuel is approximately 500 drams, the hourly fuel cost in monetary terms will be: for the new machine - 18050 drams/hour, for the base - 17765 drams/hour. Therefore, the direct operational expenses for the compared options will respectively be:

U_m = 953 + 324 + 20 + 18050 + 2000 = 21347 drams/hour,

U_b = 1151 + 390 + 45 + 17765 + 3500 = 22851 drams/hour.

Knowing the total operational expenses, we can also determine the incurred expenses.

$I_i=U+EK$ (7) where

E is the coefficient of capital investment efficiency for agricultural machinery, E=0.15.

K represents the specific costs of capital investments per unit of technology or per unit of cultivated land area, and is calculated using the following formula.

$K=B/W_h$□T drams/hour (8)

By substituting the corresponding values for the compared options, we will obtain. K_m=7233 drams/hour, K_b=8420 drams/hour:

By substituting the values, we will obtain the incurred expenses for the studied options.

I_m = 21347 + 0.15 × 7253 = 22434 drams,

I_b = 22851 + 0.15 × 8420 = 24114 drams.

Knowing the sum of the incurred expenses, we can determine the annual economic efficiency of the proposed machine.

$Э_a=[(U_b+E_bK_b)-(U_m+E_mK_m)]Q_s$=[(22851+0,15□8420)-(21347+0,15□7233)]180=302949 drams (9) where Q_a is the annual volume of work. Q_a = 180 ha.

Thus, by combining three technological processes, we achieve a cost saving of 1683 drams per hectare. It's important to note that this saving is calculated solely based on the reduction of operational costs. The use of the proposed combined machine also contributes to environmental sustainability from the perspective of soil conservation and erosion reduction, among other benefits, which we will consider separately.

Conclusions.

1. One of the direct ways to reduce operational expenses in soil cultivation processes is the creation of combined machines, which allow completing two or more consecutive technological processes in one pass.
2. A new technology of minimum tillage has been proposed, which differs from similar technologies by integrating three technological processes, including mandatory inclusion of plowing.
3. A combined plough for smooth plowing has been proposed, which performs both primary and surface soil cultivation in one pass. The annual economic efficiency of the proposed machine is 302,949 drams.
4. The use of the proposed machine will reduce the hectare fuel consumption by 3.83 liters, or 8.9%.
5. The application of the new machine will reduce fuel consumption and the number of passes, thereby decreasing operational expenses and contributing to the reduction of harmful effects on the soil and the environment.

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Justification of the Economic Efficiency of the Application of Combined Front Plough for Smooth Plowing

Key words: combined plough, incurred expenses, productivity, branch cost, fuel consumption, operating costs, economic efficiency

The main directions of the development of modern agriculture have been outlined. Emphasis has been placed on technologies for minimum tillage, considered mandatory processes. This is justified by the need to involve the relatively deeper layers of the soil in cultivation. The economic efficiency of applying new technical means in the agricultural sector has been presented, along with the peculiarities of assessing the economic efficiency of using machines and the methodology for their economic purpose. A technological scheme for a new combined plough for smooth plowing, capable of performing three technological operations in one pass, has been introduced, including its principle of operation. It consists of a frontal plow, disc-shaped cutting organs, and a roller. The machine performs plowing up to a depth of 25 cm, surface soil cultivation at a depth of 10-15 cm, harrowing, cutting of weeds, and rolling in one pass.The annual economic efficiency of the proposed technology has been determined based on the cost indicators of the work performed. All production resources have been taken into account: labor, materials, major investments, and other expenses incurred during the production and use of the machine. The productivity of the proposed machine, its branch self-cost, balance value, and operational expenses have been determined.