ECONOMIC EFFICIENCY OF MECHANIZATION TECHNOLOGY OF MINIMUM WORKS IN MAIZE

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Abstract

Large-scale application in Romania of work systems that aim to preserve soil fertility is of primary importance given that increasing arable areas are cultivated without consulting a specialist and without a system in which to take account of the short-, medium- or long-term consequences on the soil. The purpose of soil preparation works performed after the ploughing consist of breaking and crushing the structural soil clods and soil structural macro-aggregates in order to sow. For the execution of mechanized soil scarification, the preparation of the germination bed and of the sowing of maize is important for the choice of the types of tractors according to the technological work process and the biological properties of crops depending on the following indicators: gauge, size, plot size, energy consumption of agricultural machinery, land condition, humidity, and manoeuvrability. This paper aims to highlight the usefulness and economic efficiency of conservative (unconventional) works because this cultivation technology contributes to: reducing soil works to a minimum by reducing the number of machines; reducing soil setting by reducing the number of passes and work operations; reducing water and wind erosion by leaving plant remains on the soil surface; maintaining soil humidity by reducing evaporative water losses because the layer of plant remains are left on the ground; increasing the soil water capacity due to the layer of plant remains that slows water drain on the soil surface thus increasing the infiltration time; improving the physical structure of the soil; increasing the content of humus; and developing biological activity in the soil. From an economic point of view, the method is less costly because it reduces fuel consumption and working time with machines. The use of modern mechanization technologies has a great economic efficiency due to the following: works are carried out in a short period of time, so that the optimal time of technological work is respected; the number of aggregates is reduced; the number of passes on the ground is reduced; the setting of soil is reduced; wage costs are reduced; fuel consumption is reduced.

Key words**:** *economic efficiency, mechanization, maize, soil*

INTRODUCTION

Soil works have been an integral part of agriculture since the beginning and they serve important purposes, such as: the preparation of the germination bed, reduction of soil compaction in order to increase aeration and enhance a better development of the root system of the plants, reduction of the weeding degree, incorporation of fertilizers and amendments, and plant remains management. [20].

The conventional system is characterized by strong annual soil aeration by furrow turning, which is then followed by other secondary works [7],[2]. Depending to the intensity and frequency of soil work, three major categories of methods are distinguished in this system, namely: aeration by ploughing with furrow turning, discing aeration, and low aeration. This soil-aeration system defines the type of conventional agriculture [17].

The need for unconventional system works is due to the existence of economic benefits:

-Soil works time is 2-4 times shorter;

-Fuel consumption per area unit is reduced by 30-50%;

-The need for agricultural machinery per area unit is reduced [3], [9].

-Soil structure is restored and soil compaction is reduced both at the surface and in the ground [6], [8].

-The content of organic matter in the soil is increased [11], [16].
-Soil water permeability is increased and global soil drainage is improved;
-Soil erosion is reduced;
-Plant remains on soil surface or incorporated at a depth of 10-15 cm (where biological activity is maximal) contributes to the growth of fauna and flora in the soil [1].
-The quality of ground and surface water is maintained (nutrients and pesticides applied are no longer washed by erosion, and more intense biological activity – associated with the organic matter in the soil – uses and decomposes these entrants) [10], [18].
-Air quality is maintained by reducing fossil fuel emissions (diesel) used in field traffic and by reducing carbon eliminated in the atmosphere (being fixed by increasing the organic matter in the soil) [14].

MATERIALS AND METHODS

Experiments were made at S.C. Ineu S.R.L., on the territory of the Commune of Orţişoara, Timiş County, Romania. For the execution of mechanized scarification, the preparation of the germination bed and the sowing of maize, John Deere 6190R and John Deere 8285R tractors were used.
The choice of aggregates was made according to direct operating costs. If two aggregates, according to work costs, require the same production costs, the one that satisfies the requirements of the machine system is selected.
When performing works with different agricultural aggregates, always choose the optimal variant that is appreciated by the minimum number of aggregates taking part in the execution of the work or the minimum amount of time or depending on fuel consumption.
Agricultural aggregates, moving in the field, consume a large amount of energy, which is the question of determining the scientific basis of constructive and exploitation parameters to which energy consumption is minimal.
The energy source in the construction of an aggregate is the tractor entering all agricultural aggregates, as the essential element in a mechanization technology [19], [21].
Low-work technologies, those with minimal works, and generally soil conservation technologies applied on large areas because this increases economic efficiency. The working organs of machines used in minimal soil technology are of the chisel aeration type [4], [5]. By applying these working methods, an average energy consumption and labour force is achieved in relation to the classic system [12].
Taking these considerations into account, the technology of minimal soil works for cereal culture includes the following mechanized works: scarification, soil preparation, and sowing [13], [15].
Agricultural aggregates used for minimal soil works were:
-***The scarification aggregate***: John Deere 8285R tractor + Maschio Gaspardo Artiglio Magnum 500 scarifier;
-***The soil preparation aggregate***: John Deere 8285R tractor + Vogel & Noot Disc Terra Disc 600 disc harrow;
-***The sowing aggregate***: John Deere 6190R tractor + Gaspardo MT 12 sower [1].

RESULTS AND DISCUSSIONS

An optimal mechanization technology consists in a judicious correlation of agricultural works and aggregates within the technological process to achieve production yields with as low as possible labour and fuel consumption.
Artiglio Magnum 500/11 scarifier from Maschio Gaspardo is intended for deep soil aeration up to a depth of 40 cm. It works in aggregate with the John Deere 8285R tractor. The scarification work was performed by moving the aggregate according to the shuttle method. Economic indices require both knowledge of consumption per area unit and cost per ha, per cost elements. Production costs for carrying out a mechanized agricultural work consist of indirect costs and direct costs.
Direct costs C_d are calculated with the relationship:

$C_d = C_S + C_c + C_A + C_{dt}$

in which:

C_S - costs for salary (retributions);

C_c - fuel costs;

C_A - depreciation costs;

C_{dt} -costs of technical service of the aggregate.

Costs on of salary are expressed according to the hourly tariff salary S_h and the coefficient C_m.

The salary of a mechanizer is about RON 9,680 per month. Twenty-two working days/month, i.e., 176 h/month, correspond to an hourly tariff salary of RON 55 per hour. Costs of salaries per ha will be:

$C_S = C_m \cdot S$ = 0.34 · 55 = **18.7** RON/ha

Fuel costs C_c are established according to fuel consumption G_{ha} (l/work unit) and fuel price p_1 (RON/l), i.e.:

$C_c = G_{ha} \cdot p_i$ = 15 · 6.5 = **97.5** RON/ha

Costs of depreciation of the aggregate C_A are calculated for both tractor and scarifier taking into account the initial value of the aggregate V_i and the residual value of the aggregate V_r, the exchange capacity W^r_{sch}, the number of exchanges n_s, the number of days worked in a year n_z and service life D expressed in years, i.e.:

$C_{A\ tractor} = V_i - V_r / W^r_{sch} \cdot n_s \cdot n_z \cdot D$ = 500,000/ 23.68 · 250 · 10 = 8.44 RON/ha;

$C_{A\ plough} = V_i - V_r / W^r_{sch} \cdot n_s \cdot n_z\ D$ = 200,000 / 23.68 · 250 · 8 = 4.22 RON/ha;

C_A = 8.44 + 4.22 = **12.66** RON/ha.

Costs of technical service of the aggregate C_{dt} are: technical maintenance costs, technical review costs, and repair costs. These costs are determined for the entire duration of service for the tractors and machinery in the aggregate.

For the tractor, technical service costs are calculated with the relationship:

$C_{dt\ tractor} = V_i \cdot C_{ha} / C_n$ = 500,000 · 10/ 90,000 = 5.55 RON/ha

in which:

V_i - the inventory value in RON;

C_n - normal fuel consumption during service in l;

C_{ha} - fuel consumption per ha in l.

For the plough, technical service costs are calculated with the relationship:

$C_{dt\ scarifier} = V_i / W_n$ = 200,000/70,000 = 2.85 RON/ha

in which:

V_i - the inventory value in RON;

W_n - the volume of works during service, in ha.

Values G_n and W_n have been experimentally determined and can be found in maintenance technologies, revisions, and repairs of tractors and agricultural machinery.

The costs for the technical service of the aggregate are:

C_{dt}= 5.55 + 2.85 = 8.40 RON/ha.

Direct costs for a scarified ha are:

$C_d = C_s + C_c + C_A + C_{dt}$ **= 18.7 + 97.5 + 12.66 + 8.40 = 137.26 RON/ha**

Auxiliary costs C_{ac} are costs for main and auxiliary materials, costs for storing and preserving tractors and agricultural machinery. They are calculated by a percentage (15-20%) of the direct costs:

C_{ac}= 0.2 · 137.26 = **27.45 RON/ha.**

The total cost of a scarified ha will be:

$C_T = C_d + C_{ac}$ **=137.26+ 27.45 = 164.71RON/ha.**

Germination bed preparation works aim at: land levelling, weed control, and creating a layer of ground, loose soil along the sowing depth, ready to receive the seed.

Vogel & Noot Terra Disc 600 disc harrow

The Vogel & Noot Terra Disc 600 disc harrow is intended for the preparation of the germination bed. It works in aggregate with the John Deere 8285R tractor.

The main *mandatory agrotechnical requirements to be achieved* through the works system for winter crops are.

-The soil should be mobilized at a minimum of 18 cm, optimally 20-22 cm;

-Until winter sowing, soil works should ensure the accumulation of sufficient humidity for seed germination;

-The soil for winter sowing should not be too shredded because it may be too slightly shattered by the wind; a too shredded soil at the surface forms a crust and frost-thawing favours plants uprooting; clods up to 5 cm prevent snow shattering from the wind, favour the accumulation of water in the soil on slope land, and prevent crust formation in spring;

-Through the work system, soil should be cleaned of weeds so that it can be seen under normal conditions and prevent, after the plants sprout, competition by other plant species.

When preparing the germination bed, in addition to land levelling and soil shredding, an essential objective to be pursued is the preservation of water in the soil, which is achieved by its superficial mobilization and, as low as possible, by works to reduce the losses of water by evaporation. Correct adjustment and use at optimal time of machine aggregates prevent the risk of situations in which the work is repeated for the correction of the germination bed. By reducing the number of passes on the ground, fuel savings are achieved and the danger of soil compaction is reduced (it affects the aero hydric regime and the development of the root system).

Calculus and formation of aggregates for germination bed preparation

The traction resistance force of the disc harrow is:

$R_M = K \cdot B_l = 750 \cdot = 4.500$ *daN*

in which:

K - the specific resistance in DAN/M;

B_1 - the working width of the combiner in m.

Speed work

Comparing the resistance of the aggregate to soil preparation R_m with the traction force Ft that the John Deere 8285R tractor can develop, choose the speed with which the work will be done. Work speed will be:

$$v_l = v_t(1-\delta) = 3.2 \cdot (1-0.1) = 2.9\ m/s = 10.4\ km/h$$

h.

Aggregate working capacity for land preparation

The actual hourly working capacity is calculated with the relationship:

$$W_h^r = 0.1 \cdot B_l \cdot v_l \cdot K_s = 0.1 \cdot 6 \cdot 10.4 \cdot 0.8 = 5\ ha/h$$

Real work capacity per shift is calculated with the relationship:

$$W_{sch}^r = W_h^r \cdot T_s = 5 \cdot 8 = 40\ ha/sch\ .$$

For a three-day work, an aggregate for land preparation is used.

The method of work movement is that of circular paths with turns to 90^0.

The duration of a work cycle is:

$T_c = L_l \cdot n_l / v_l = 1{,}000 \cdot 2 / 2.9 = 689$ sec.

The theoretical surface worked after a cycle is determined with the relationship:

$W_c = L_l \cdot n_l \cdot B_l / 10^4 = 1{,}000 \cdot 2 \cdot 6 / 10{,}000 = 1.2$ *ha/cycle*

The theoretical working capacity will be:

$W_h = 3{,}600 \cdot W_c / T_c = 3{,}600 \cdot 1.2 / 689 = 6.26$ *ha/h*

Fuel consumption per ha will be:

$C_{ha} = C_h / W_h$ = 45l/ha / 6.26 ha/h = 7.18 l/ha

Calculus of economic indices

Consumption of h/aggregate:

$$C_a = \frac{T_s}{W_{sch}^r} = \frac{8}{40} = 0.20 \text{ h-aggregate/ha}$$

The coefficient C_m for servicing the aggregate:

$$C_m = C_a \cdot m = 0.20 \text{ h-man/ha}$$

Costs of salary per ha will be:

$$C_S = C_m \cdot S = 0.2 \cdot 15 = 3.0 \text{ RON/ha.}$$

Fuel costs are:

$C_c = C_{ha} \cdot p_i = 9 \cdot 6.5 = 58.5$ RON/ha

Costs of aggregate depreciation is:

$C_{A\ tractor} = V_i - V_r / W^r_{sch} \cdot n_s \cdot n_z \cdot D = 500{,}000 / 40 \cdot 250 \cdot 10 = 5$ RON/ha;

$C_{A\ grower} = V_i - V_r / W^r_{sch} \cdot n_s \cdot n_z \cdot D = 250{,}000 / 40 \cdot 250 \cdot 8 = 3.12$ RON/ha;

$C_A = 5 + 3.12 = 8.12$ RON/ha.

Costs of technical service of the aggregate are:

$C_{dt\ tractor} = V_i \cdot G_{ha} / C_n = 500{,}000 \cdot 9 / 900{,}000 = 5$ RON/ha;

$C_{dt\ grower} = V_i \cdot W_n = 250{,}000 / 62{,}500 = 4$ RON/ha;

The costs for the technical service of the aggregate are:

$$C_{dt} = 5 + 4 = 9 \text{ RON/ha.}$$

Direct costs per ha worked with the combiner are:

$C_d = C_s + C_c + C_A + C_{dt} = 3.0 + 58.5 + 8.12 + 9.0 = 78.62$ RON/ha.

Auxiliary costs are:

$C_{ac} = 0.2 \cdot 78.62 =$ **15.72 RON/ha.**

Total costs per ha prepared with the combiner will be:

$C_T = C_d + C_{ac} = 78.62 + 15.72 = 94.34$ RON/ha.

The Gaspardo MT 12 seed drill is designed for precision sowing (grain by grain) of the seeds of tillage crops. Simultaneously with the sowing work in the nests, the machine also performs fertilization by incorporating solid chemical fertilizers. It is a machine pulled and operated from the John Deere 6190R tractor power tree with which it works in aggregate.

Calculus and formation of sowing aggregates

The traction resistance force of the sowing machine is:

$R_M = K \cdot n = 80 \cdot 24 = 1.920$ *daN*

in which:

K - the specific resistance on the coulter in daN/m;

n – number of patina coulters (for sowing + embedding fertilizers).

Speed work

By comparing the traction resistance of the sower R_m with the traction force F_t that the John Deere 6190R tractor can develop, select the rapid speed gear with which the work will be done. Work speed will be:

$$v_l = v_t(1-\delta) = 2.7 \cdot (1-0.15) = 2.3\, m/s = 8.3\, km/h$$

h.

The working capacity of the sowing aggregate

The actual hourly working capacity is calculated with the relationship:

$$W_h^r = 0.1 \cdot B_l \cdot v_l \cdot K_s = 0.1 \cdot 8.4 \cdot 8.3 \cdot 0.65 = 4.5\, ha/h$$

Real work capacity per shift is calculated with the relationship:

$$W_{sch}^r = W_h^r \cdot T_s = 4.5 \cdot 8 = 36\, ha/sch\,.$$

For a three-day work, a sowing aggregate will be used.

The method of work movement is the method of shuttle traveling.

The duration of a work cycle will be:

$$T_c = \frac{L_l \cdot n_l}{v_l} + \frac{L_g \cdot n_g}{v_g} = \frac{(930+42)\cdot 2}{2.3} = 845\,\text{sec}.$$

The theoretical area worked after a cycle is determined with the relationship:

$W_c = L_l \cdot n_l \cdot B_l / 10^4 = 930 \cdot 2 \cdot 8.4 / 10{,}000 =$ 1.56 ha/ cycle.

Theoretical working capacity will be:

$W_h = 3.600 \cdot W_c / T_c = 3{,}600 \cdot 1.56 / 845 =$ 6.64 ha/h

Fuel consumption per ha will be:

$C_{ha} = C_h / W_h$ = 27.3 l/h / 6.64 ha/h = 4.11 *l/ha*

Calculus of economic indices

Consumption of h/aggregate:

$$C_a = \frac{T_s}{W_{sch}^r} = \frac{8}{36} = 0.22 \text{ h-aggregate/ha}$$

The coefficient C_m for servicing the aggregate:

$C_m = C_a \cdot m$ = 0.22 h-man/ha

Costs of salary per ha will be:

$C_S = C_m \cdot S = 0.22 \cdot 15 = 3.33$ RON/ha.

Fuel costs are:

$C_c = C_h \cdot p_i = 6 \cdot 6.6 = 39$ RON/ha

Costs of aggregate depreciation C_A is:

$C_{A\ tractor} = V_i - V_r / W^r_{sch} \cdot n_s \cdot n_z \cdot D$ = 300,000 / 28 · 250 · 10 = 4. 29 RON/ha;

$C_{A\ sem} = V_i - V_r / W^r_{sch} \cdot n_s \cdot n_z \cdot D$ = 150,000 / 28 · 250 · 8 = 2.68 RON/ha;

C_A = 4.29 + 2.68 = 6.97 RON/ha.

Costs of technical service of the aggregate C_{dt} are:

$C_{dt\ tractor} = V_i \cdot G_{ha} / C_n$ = 300,000 · 6 /450,000 = 4 RON/ha;

$C_{dt\ sem} = V_i / W_n$ = 150,000 / 55,000 = 2.73 RON/ha;

The costs of technical service of the aggregate are:

C_{dt} = 4 + 2.73 = 6.73 RON/ha.

Direct costs per sowed ha are:

$C_d = C_S + C_c + C_A + Cdt$ = 3.3 + 39 + 6.97 + 6.73 = 56 RON/ha.

Auxiliary costs C_{ac} are:

$C_{ac} = 0.2 \cdot 56$ = **11.20 RON/ha**.

The total cost per ha prepared with the combiner will be:

$C_T = C_d + C_{ac}$ = 56.00 +11.20 = 67.20 RON/ha.

CONCLUSIONS

Based on the experiments in the field of maize and of economic calculus, the following can be concluded:

Fuel consumption for scarified works, soi preparation, and sowing is 30 l/ha, corresponding to ploughing consumption in classical technology.

Taking into account that the price of diesel is 6.5 RON/l, the fuel costs are 195 RON/ha, i.e., 71.72% of the direct costs, i.e., 58.77% of the total costs.

The use of modern mechanization technologies has an increased economic efficiency due to the following aspects:

-Works are carried out within a short term, so that the optimal time of technological work is respected;

-The number of aggregates is reduced;

-The number of passes on the ground is reduced;
-Soil setting is reduced;
-Salary costs are reduced;
-Fuel consumption is reduced.

The use of modern technologies for mechanization, chemical treatment, fertilization, the use of high-productivity hybrids suitable for these technologies has a great economic efficiency in the sense that production is higher even if costs per ha in the current stage are high. Also, the use of herbicides reduces fuel consumption by reducing the number of passes per ha.

The use of complex aggregates when preparing the germination bed and even sowing or maintenance favours soil texture improvement and low soil setting. But perhaps the most important thing is that fuel consumption is reduced per ha that: because of its high price, it increases the costs per area unit; from an environmental perspective, soil processing technology in the conservative (unconventional) system contributes to reducing pollution and greenhouse gases (GHG) in the context of sustainable development.

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