

THE ANALYSIS OF INFLUENTIAL PARAMETERS ON OPTIMAL STRUCTURE OF THE MACHINERY POOL IN AGRICULTURE

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SUMMARY

Structure of machinery pool is influenced by following: seeding structure, soil condition, conception and category of tractors, plot length and size of estate. The analysis conducted within this investigation, gave following output: required number of tractors per hectare (tractors/ha), fuel consumption per hectare (l/ha), work-hours input per hectare (h/ha) and total exploitation costs per hectare (din/ha). The seeding structure has influence on the required number of tractors, fuel consumption, work-hours and exploitation costs of agricultural machinery. An increase in specific soil resistance and size of estate influence larger number of tractors, higher fuel consumption, higher work-hours input and higher total exploitation costs. However, the increase of plot length influences these very parameters to decrease.

Key words: machinery pool, influential parameters, tractors, optimization

INTRODUCTION

Serbian agriculture with the available acreage, technological know-how and qualified labour force has significant potential for eco food production, for both home market and export, (Nikolić, 1984). However, that potential is impossible to materialize, due to difficult economic situation which is to blame for the unfavourable structure and operating readiness of the machinery pool, (Savin, 2004). Production scale is low, while the unit production costs – per acre and per product - are increasing. This calls for substantial future investment into agricultural machinery. The parity between the structure of production and the work capacity of agricultural machinery – as a relatively stable parameter – is of special importance for crop production, (Novković, 1990). The objective of this paper is to investigate the factors of influence and to optimize the machinery pool structure. Among the factors of influence which were taken into consideration are: seeding structure, soil conditions, tractor categories, plot length and size of estate. The output parameters of such analysis are: number of tractors and machines, fuel consumption and exploitation costs.

MATERIAL AND METHODS

Soil conditions are defined by specific soil resistance, which ranges between 0.5 and 1.5 daN/cm² and the matching resistance of tractor aggregates. The seed structure encompasses basic field crops: mercantile wheat, seed wheat, spring barley, winter barley, oilseed rape, mercantile corn, seed corn, silage corn, soybean, sunflower, sugar beet, green peas, green beans, old and new alfalfa.

To determine the structure of the new machinery pool, grapho-analytic method was used on account of its general popularity. Tilling procedures were created using 4 tractor categories, namely: 8, 15, 30 and 50 kN. Plot length was varied from 400 to 1600 m, while

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each crop was allotted 100 ha of arable land for analysis of the seeding structure. In order to appreciate the real influence of specific soil resistance on the machinery pool structure, special mathematical model was formed which allows forming of a tractor system for ploughing. This model was programmed in Visual Basic, which allowed us to perform a simulation in order to obtain maximal work efficiency for each specific soil resistance.

RESULTS

In order to determine optimal machinery pool structure, the most up-to-date biotechnology production was adopted. This production technology encompasses the following agrotechnological measures: soil preparation, fertilizing, selection of crops for crop rotation, seeding, crop cultivation, picking and transport. Only mercantile wheat, sunflower, soybean, corn and sugar beet were considered in the analysis of influence of the seeding structure, for they are most popular crops in Serbian agriculture.

Tractors of the 8 kN category are used only for soybean, i.e. for cultivation between rows. The required number of tractors of the 15, 30 and 50 kN categories, was determined based on the critical period in October. In all considered crops, 15 kN tractors are least used for sunflower, where their number is 3.74 units, while that number is greatest for sugar beet where it is 13.88 units, Tab.1. This number of tractors is influenced by the production technology and the number of technological operations, where sugar beet is the most demanding. Also of influence is crop yield which directly determines the load size to be transported. Knowing the fact that transport requires 15 kN tractors, makes it obvious why sugar beet requires largest number of them. The same line of reasoning is applied to explain the minimal tractor requirements for sunflower. 30 kN tractors are used for seeding of wheat and soybean. Sugar beet also requires largest number of heavy tractors of the 50 kN category. Comparison of sugar beet with wheat reveals that sugar beet requires 2.18 times more tractors than wheat, due to higher ploughing depth which reduces the tractor speed. Although corn, sunflower and soybean require higher ploughing depths than wheat, the required number of tractors is smaller than that of wheat, due to double the agrotechnical period for ploughing operation. In October, beside ploughing, wheat requires 50kN tractors to be used for disc harrowing and seeding preparation, which increases the total number of tractors.

Tab. 1 Number of tractors per crops, $A = 100ha$, $L = 800m$, $k_o = 0.8 daN/cm^2$

Crop	Category of tractors					
	8 kN	15 kN	Index	30 kN	50 kN	Index
Wheat	-	4.90	100.00	0.13	0.33	100.00
Maize	-	6.50	132.70	-	0.19	57.07
Sunflower	-	3.74	76.25	-	0.19	57.07
Soybean	0.55	3.88	79.19	0.35	0.19	57.07
Sugar beet	-	13.88	283.19	-	0.72	218.99

Of special importance in optimization is determination of the number of heavy tractors which are used for basic soil cultivation and which contribute to almost 50 % of the total costs of machinery exploitation. The increase in plot length causes a mild decline in the required number of 50 kN category tractors, due to the increase in shift efficiency, i.e. shift-time efficiency rate, Tab.2.

If the required number of tractors for 400m plot length is taken as base value, a series of indices is derived for each crop. For wheat, the series is: 94.19; 91.79 and 90.34. For corn, sunflower and soybean, we have: 94.19; 91.78 and 90.32, while for sugar beet the series is:

94.03; 91.63 and 90.14. Sugar beet requires highest ploughing depth, thus having lowest tractor speed, which diminishes the share of time for swiveling the aggregate.

Tab. 2 Needed number of tractor category 50 kN, $k_o = 0.80 \text{ daN/cm}^2$

Crop	Length of parcel (m)			
	400	800	1200	1600
Wheat	0.35	0.33	0.32	0.32
Maize	0.20	0.19	0.18	0.18
Sunflower	0.20	0.19	0.18	0.18
Soybean	0.20	0.19	0.18	0.18
Sugar beet	0.77	0.72	0.70	0.69

Considering plot lengths within the interval of 800-1200m and assuming the proportional increase of the number of tractors within the interval, one can calculate the decrease in the number of tractors for every 100 m of plot length over an area of 100 ha. Thus for wheat, the number of tractors decreases by 0.0012 for every 100m length. For corn, sunflower and soybean, the number of tractors decreases by 0.0012, while the decrease for sugar beet equals 0.0047 for every 100m length.

The analysis of the required number of tractors for a predefined plot length, Fig.1 reveals that sugar beet has the most pronounced relationship between the increase of specific soil resistance and the increase of the number of required tractors, while for the other crops that relationship is less pronounced. If the required number of tractors for specific soil resistance of 0.5 daN/cm^2 is taken as base value, then the indices of increase of the required number of tractors for specific soil resistance of 1.5 daN/cm^2 equal 176.67 for wheat; 209.76 for corn, sunflower and soybean; and 340.49 for sugar beet. Obviously, the increase of the required number of tractors is smallest for wheat, while it is largest for sugar beet, due to significant ploughing depth.

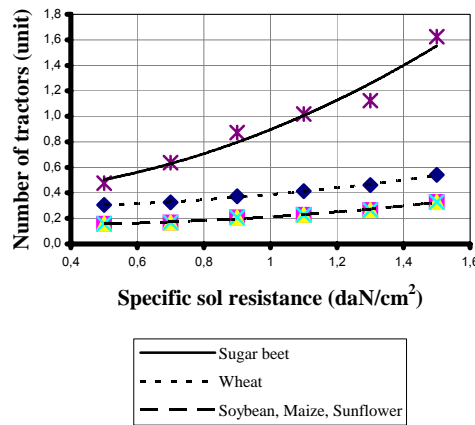


Fig. 1 Relationship between the required number of tractors (50 kN category) and specific soil resistance

Within the $0.7-0.9 \text{ daN/cm}^2$ interval of specific soil resistance, for wheat, corn, sunflower and soybean, the 0.1 daN/cm^2 increment of specific soil resistance increases the number required tractors for 0.02, while for sugar beet the increase equals 0.12. Specific soil

resistance exerts greater influence on the required number of tractors than the plot length, which is obvious from the indices shown.

If we consider the total seeding structure, largest requirement is for tractors of the 15kN category. This is logical, considering the fact that they are included in the majority of agro technical operations and transport, Fig. 2, and less required category are 50 kN tractors, followed by 8 kN and, finally, 30 kN tractors. The increase of the required number of tractors in the 15 kN category is defined by polynomial functions, while linear functions are used for other tractor categories.

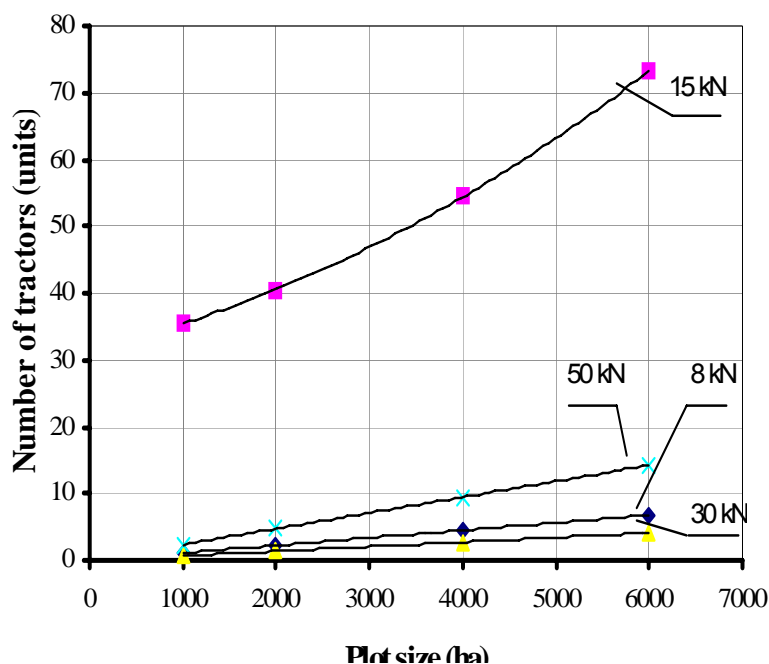


Fig. 2 Relationship between the required number of tractors and te size of estate

Specific soil resistance has much larger impact on fuel consumption for the 50 kN category tractors, then plot length, Fig. 3. Within the 0,7-0,9 daN/cm² interval of specific soil resistance, the 0,1daN/cm² increment of specific resistance on a 400m plot length, causes fuel consumption to increase for 4,72 l/ha. For 800 m plot length the increase is 4,43 l/ha; for 1200 m plot length the increase is 4,32 l/ha, while for 1600 plot length the fuel consumption increases by 4,25 l/ha.

The increase of specific soil resistance causes steep rise of resistance on tractor drawbars, which requires a shift-down, i.e. speed reduction, thus affecting the total efficiency. Low tractor efficiency leads to increased fuel consumption per area unit.

Fuel consumption decreases with the increase of plot length. The highest fuel consumption is recorded at 400 m, while the lowest consumption is at 1600 m, fig. 4. If the fuel consumption at 0.5 daN/cm² specific soil resistance is taken as base value, a series of indices are derived for various plot lengths. Thus for 400 m, the series of base indices are: 102.90; 111.56; 117.23; 125.80 and 139.41. For 800 m, the indices are: 102.88; 111.47; 117.10; 125.60 and 139.12. For 1200 m, the indices are: 102.87; 111.45; 117.07; 125.55 and 139,04. Finally, for plot length of 1600 m, the following series is derived: 102,87; 111.46; 117.08; 125.58 and 139.08. Judging by the shown series, there follows that the 200%

increase of specific soil resistance leads to the 40% increase of fuel consumption per unit area.

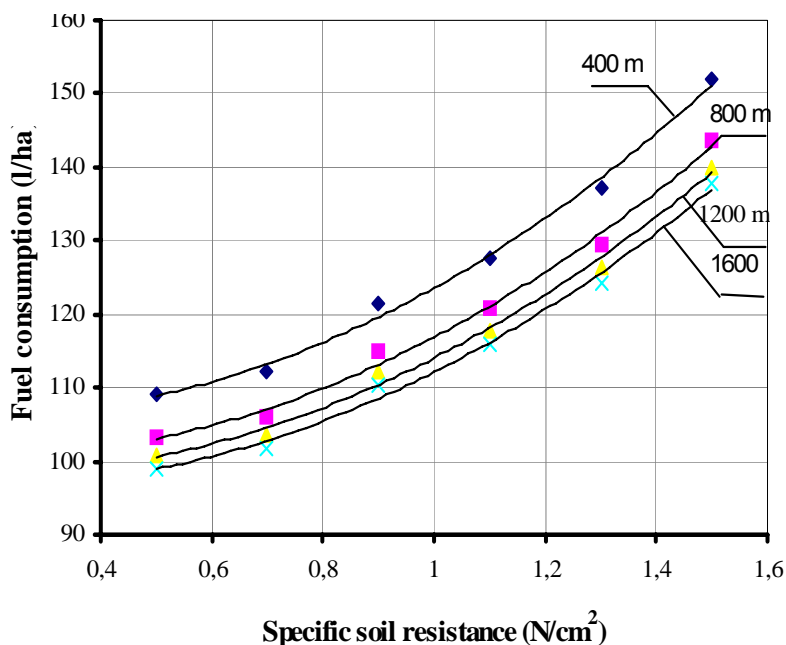


Fig. 3 Relationship between specific soil resistance, plot length and fuel consumption

The input of work-hours represents labour which is spent on agricultural production. Labour productivity is equivalent to work efficiency, which can be expressed as the physical volume of production realized by a worker in a unit of work-time (ha/h) or as the quantity of work-time which is spent on unit production (h/ha). To reduce labour input in agricultural production, agricultural machinery is employed to perform agro technical operations. In order to minimize labour input for tractor drivers and drivers of other mobile systems, high-power engines are mounted, which allow use of aggregates with large working widths. Production of each crop has its own specific features which reflect in the number of technological operations, production technology, working widths and speed of aggregates. The work-hours input increases with the increase of specific soil resistance, Fig. 4.

Within the 0,7-0,9 daN/cm² interval of specific soil resistance, the 0.1daN/cm² increment of specific resistance on a 400m plot length, increments the tractor work-hours input for 0.121 h/ha. For 800 m plot length the increase is 0.113 h/ha; for 1200 m plot length the increase is 0.110 h/ha, while for 1600 plot length the increase equals 0.109 h/ha.

If the tractor work-hours input for specific soil resistance of 0,5 daN/cm² is taken as base value, then one derives a series of indices for various plot lengths. Thus for 400m plot length the series is: 101.02; 104.06; 106.05; 109.06 and 113.84; for 800 m plot length the series is: 100.99; 103.95; 105.89; 108.82 and 113.48. For 1200m plot length the series is composed of the following values: 100.98; 103.91; 105.83; 108.73 and 113.34, while for 1600m plot length, base indices are: 100.98; 103.89; 105.80; 108.68 and 113.26. Based on the presented series of base indices, it is obvious that the largest increase is recorded for 400m plot length, while the smallest increase was recorded for 1600m plot length, which was influenced by the shift-time efficiency rate.

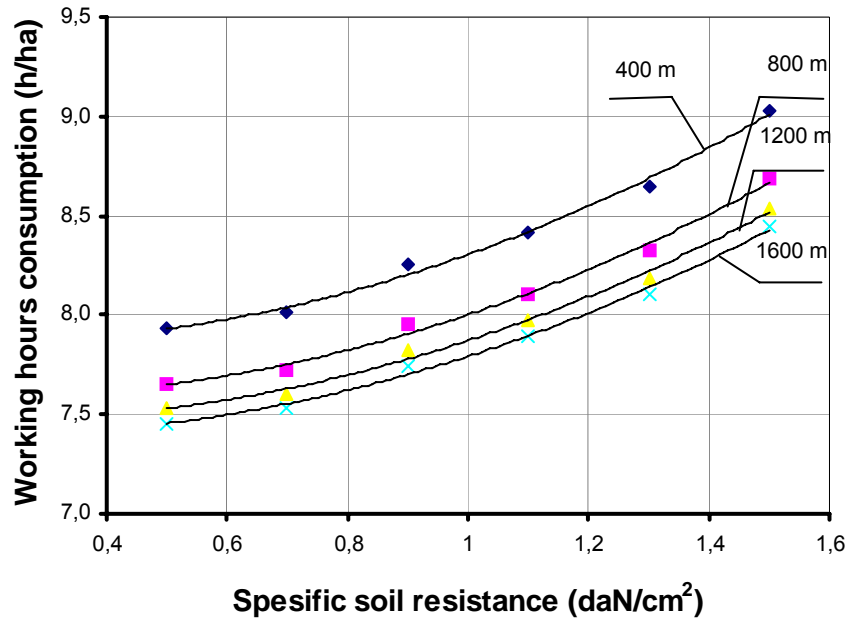


Fig. 4 Relationship between tractor work-hours input for the entire seeding structure and specific soil resistance/plot length

Total costs of exploitation of agricultural machinery include fixed and variable costs. The amount of costs does not depend on the volume of employment of agricultural machinery and in this group of costs belong costs of amortization, interest costs, insurance costs and storage, Andrić (1983). Due to the method which is used for calculation of salaries and maintenance costs, these two are also categorized as fixed, i.e. permanent costs. Variable costs include costs for engine fuel and lubricants. At the time of this investigation, 1EUR sold for 65 Dinars.

Over the entire seeding structure, the increase in specific soil resistance also increases exploitation costs for tractor systems and mobile systems, Fig.5, as was the case with individual crops. Within the 0.7-0.9 daN/cm² interval of specific soil resistance, the 0.1daN/cm² increment of specific resistance on a 400m plot length, causes exploitation costs to rise by 238.83 din/ha, on the 800 m plot length that number is 224.42 din/ha, on the 1200 m plot length, 218.55 din/ha, and, finally, on the 1600m plot length, the exploitation costs rise by 215.09 din/ha.

Exploitation costs are largest for short plots, while they tend to decrease as plot length increases. By taking the exploitation costs - which occur at 0,5 daN/cm² specific soil resistance - as base value, one derives series of indices for each plot length. Thus for 400m plot length, the series of indices is: 102.90; 111.56; 117.23; 125.80 and 139.41, while for 800m plot length, the series is: 102.88; 111.47; 117,10; 125.60 and 139.12. If plot length is 1200m, the following series applies: 102.87; 111.45; 117.07; 125.55 and 139.04. Finally, for 1600m plot length, the series is: 102.87; 111.46; 117.08; 125.58 and 139.08.

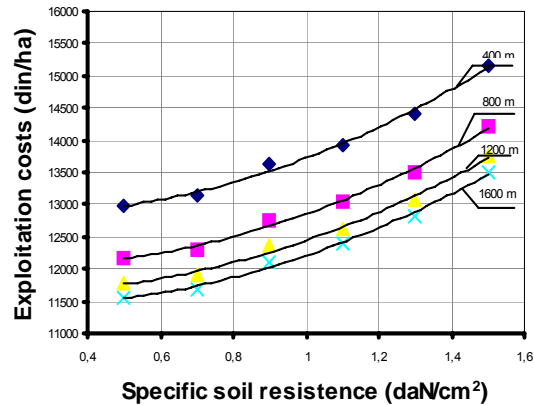


Fig. 5 Relationship between the specific soil resistance, plot length and employment costs of tractor- and mobile systems

CONCLUSIONS

Based on the presented investigation, following conclusions can be drawn:

The required number of tractors is a function of seeding structure, production technology, number of required technological operations and crop yield. The largest number of tractors is required by the sugar beet production technology (0.721 units of 50 kN tractors), while corn, sunflower and soybean production technologies requirements are smallest (0.188 units of 50 kN tractors).

The increase of specific soil resistance also increases following: the required number of tractors, fuel consumption, labour work-hour input and exploitation costs. Specific soil resistance has a much larger impact on the exploitation costs of the tractor system then the plot length.

The increase of plot length causes a mild decline in the required number of tractors of the 8, 30 and 50 kN categories, while the required number of the 15 kN category tractors increases with the increase of plot length. Increase of plot length also decreases fuel consumption, number of tractor work-hours, and costs of exploitation of tractor- and mobile systems.

The size of estate directly affects the number of required tractors, whereby for the 8.30 and 50 kN tractor categories that increase is linear, while the 15 kN category has degressive increase. The size of estate has no effect on the fuel consumption, tractor work-hours input and costs of exploitation per area unit.

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