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ECONOMICAL ANALYSIS OF THE MACHINE TECHNOLOGY OF THE CULTIVATION OF DROUGHT-TOLERANT PLANTS FOR RENEWABLE ENERGY PRODUCTION

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Abstract: This study analyses the management of machinery on farms growing sorghum as a drought-tolerant crop, and feedstock for renewable energy production, in addition to the cereals and oilseeds in the classical crop rotation, considering not only field operations but also logistical tasks and machinery usage costs. Furthermore, the machine operation characteristics specific to different farm-level production technologies have also been taken into account.
It can be concluded that the difference between the costs of the small and the large-scale farm size is significant. This all can be explained with the efficiency of the machine exploitation.
In the field of costs there is also a difference between the use of modern and less modern machines. In case of small-scale farm size, with using less modern power-machines a more advantageous cost level can be reached, although the quality of the work and the circumstances of the working must be considered. In case of large-scale farm size, the difference between the operational costs of the less modern and more modern machines decrease significantly, because the operation of the less modern machines is more expensive at larger strain and the high-level constant costs of the modern machines decrease significantly, according to their better exploitation, considering one unit of work.

Key words: *Renewable plant production, farm size, machine fleet management, logistical tasks, machinery cost*

INTRODUCTION

The goal of the research is the technical-economic analysis of the production-technology system of the sweet sorghum that is known as drought tolerant energy plant and nowadays as a promising base material of biotechnological industries [1].

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Work done *by an efficiently developed machine system* is a significant condition of the fruitfulness of farming [2]. The machine prices and the cost of their utilization are extremely high and all these result in extraordinarily high production costs. *Rational machine utilization* is a definitive factor of the efficiency of farming [3].

We have accomplished the examinations by taking power-machines from different quality and cost levels as base.

Through this we have showed that not only the size of the farms effects the amount of the operational costs, but the standard of mechanization too [4].

MATERIAL AND METHODS

The crop plan

The surveys can be conducted by *modelling* the machine working processes of agricultural production. On the base of field crop production, a crop plan including cereal plants for human consumption and for *energy* production purposes, *sweet sorghum* for animal breeding and for *energy* production purposes and oil seeds – as sunflower and the nowadays very popular oilseed rape - appropriate for human consumption and energy production as well and reflecting the special features of production in Hungary has been applied. Depending on farm size the proportion of the crop area of the individual plants has been stipulated in view of the agronomical and production technological conditions. In the sowing plan the ratio of the plants is the following: wheat 40%, sunflower 25%, sweet sorghum 25%, rape 10%.

The sweet sorghum is one of Hungary's plants that is capable to produce the greatest amount of biomass and it's production can be fitted in the conventional alternation of the cereals and industrial plants and the outstanding yields can be ensured at lower costs than other cultures. From the point of view of energetic use, the component of the sweet sorghum that is classed as secondary product, the high sugar content solution that can be pressed from the spears, that is a suitable base material for bioconversion methods. The amount of the productable sugar reaches or exceeds the amount of the glucose that can be produced from cereals grown on a land with the same size. The complex use of the components that can be obtained from the sweet sorghum can significantly increase the reachable profitableness of agriculture [5].

The plant is subtropical, needs hot weather and drought tolerant. It is also called durra or sweet-cane. It was grown in a higher amount between the two world wars. After the II. World War, until the start of the sugar production, the sugar containing syrup pressed and condensed from the plant was used instead of sugar. Nowadays it is mainly used to produce silage fodder, planted with silage corn.

The growing conditions are very advantageous, because the sweet sorghum gives a stable yield even in case of poor water supply (60-70 tons/hectare) [6].

The significance of machine utilization, the machine categories applied, the parameters of model calculations

In the utilization costs of the more and more up-to-date and expensive power machines the proportion of *fixed costs*, especially amortization and maintenance is very high [7]. This expense can be decreased by increasing *utilization*. If the applied means are coupled to the individual field work operations at their effective operation cost – i.e., taking the rate of utilization into account – the effect of *working-hour performance* on costs will become measurable [8].

Basically, the cheapest power machine families used in Hungary on the one hand, and the ones with the highest possible investment cost demand available on the market of agricultural machinery on the other have been the subject of the survey [9, 10].

The basic figures of machine utilization have been determined with the help of the data base of the Hungarian Institute of Agricultural Engineering [11].

The machine cost calculations on which the study is based were made in 2022-2023, and were based on the mechanisation cost data for Hungary in 2021 [12]. In this way, the effects of the significant input material-, and agricultural product price fluctuations in the production year 2022-2023 have not been incorporated into the model.

The *model-calculations* have affected the farm size points of machine stock development in a farm size of 30 and 1000 ha. On this basis we can come to statements affecting a wider segment of the agricultural property structure, resp. to conclusions concerning mechanization and machine utilization [13].

RESULTS AND DISCUSION

The constitution of the machine system in case of the examined farm sizes

The power-machine system that can be ordered to serve the examined farm size of 30 hectares to finish the soil preparation in a good quality consists of the minimal 40 kW output power machine and the attachable soil tilling, nutritive spreading and plant protection working machines.

In case of the 1000 hectares farm size, that is the base of the large-scale examination, the minimum is the tractors with 60-120 kW of output that can be the base of the machine works. The different output-categories are represented by two power-machines in each case. The easier nutritive supply and plant protection tasks are done by the machines with smaller output and the heavier tasks are done by the machines with higher output. The *materials handling to the depot* can also be done by these tractors by using tow-cars to increase the exploitage of the machines.

In case of farm size of 30 hectares, the finishing of the harvesting works as wage work is the most efficient. According to the calculations, on a 1000 hectare sized farm, to reach the acceptable capacity-utilization, one *cereal combine-harvester* can be operated as the property of the farm. The appliance of the self-propelled silage harvester that does the gathering of the sorghum as a property, highly increases the machine costs of the farm, therefore it can be seen in the chapter *results* in details that it is more advantage out to use a self-propelled silage harvester for commission work.

The number of the executed working-hours in function of the power-machine category, the mechanical level and the farm size

The number of the executable working-hours of the power-machines in case of different farm sizes determines the composition to each category of the power-machine system.

In case of the examined *smaller sized farm* (30 hectares) based on our calculations *low exploit age* can be reached to the tractors: maximum 435 working-hours/year.

In case of large farm sizes (1000 hectares) the executed machine working-hours of the farms power-machine fleet, based on our model calculations is 6650 working-hours, from which the tractors represent a major (1100 working-hours/year (power-machine with 60 kW output) and 1700 working-hours/year (power-machine with 120 kW output)) part.

With a clever-chosen cereal harvesting machine at *one thousand hectare* farm size executing about 450-500 working-hours it reaches *significant* exploit age, that results in *acceptable* operational cost. The annual capacity exploitage of the self-propelled silo combine in case of own property is only 150 working-hours, that makes the idea of purchasing the machine as property to think it over.

In case of a 30 hectare sized farm the machine work demand of sweet sorghum that's production is fitted in the rotation of crops is 120 working-hours, that is 14,8 working-hours/hectare. This value is slightly higher than the economic average. In case of a 1000 hectare sized farm the machine work demand of sweet sorghum that's production is fitted in the rotation of crops is 1675 working-hours, that is 6,7 working-hours/hectare. This marks well that the production of sweet sorghum is a labour-intensive activity, because this value is also higher than the value that is specific to the whole farm. By using *modern machines*, the shown working-hour execution parameters will decrease with 4-5 % [14, 15].

In case of small-scale production, the significant number of shift-hours increases the living work outlay, thereby *increases the employment*. In the farms with this size the use of small output machines is reasonable. However, the proper usage of the small capacity machines is not ensured either, so the significant constant costs induce *higher operational costs* [16].

The analysis of the machine work costs

Applying *low-level* power-machine fleet, the annual machine use cost of a 30 hectare farm that produces sweet sorghum too is 11.785 EUR, that is 393 EUR per hectare.

Applying *modern power-machines* the annual machine use cost is 14.645 EUR, that is 491 EUR per hectare.

Those who work on small sized farm can count with low power-machine utilization, that also has effects on the use costs per working-hour of the tractors.

This value is 19 EUR/working-hours in case of the 40 kW tractors that are usually used in small works. At this production size, the calculated cost of the borrowed used cereal harvester and self-propelled silo combine is 52,5 EUR/working-hours and 72,7 EUR/working-hours. In case of *modern machines*, the specific cost of the mentioned tractor to a time unit is 24 EUR. The cost of the cereal combine is 73,6 EUR/working-hours. In case of an ensilage cutter, we can also count with the given values, because in the database that we used for the calculations we haven't found two different technical levels from the harvesting machines with these functions.

Considering a 1000 hectare sized farm in case of *low-level* mechanization, taking the above mentioned sowing plan ratios the annual use cost of the machines is 303,5 thousand EUR, that is 303,5 EUR/hectare.

If the use of the self-propelled ensilage cutter machine is not as an own property, then it is *leased work*, the machine use cost of the whole farm is 267,8 thousand EUR. The specific value for a hectare is 267,8 EUR.

With the appliance of *high-level* power-machines the annual machine use cost projected to the whole farm is 339 thousand EUR, specifically 339 EUR/hectare.

It can be observed that the machine cost of sweet sorghum is the highest in every case, compared to the other plant cultures. This is mostly because great volume of the harvesting and crop transporting tasks: at least 60-80 t/hectare of crop has to be harvested and transported to the processing plant.

If the ensilage cutter does it's tasks as *leased work*, the costs decrease. As a result of the calculations, the total machine use cost of the whole farm is 303,5 thousand EUR. Specifically it is 303,5 EUR/hectare.

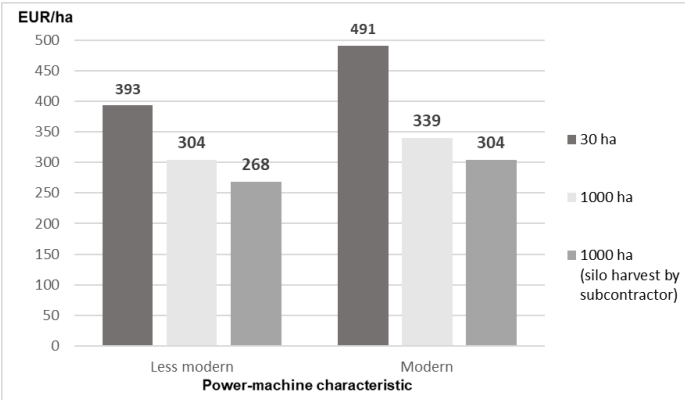

Fig. 1. The specific machine utilisation costs in case of different mechanization levels at farms with the investigated sizes (own editing)

The Figure 1 also shows the previously introduced results, where the upper and lower limit of the machine usage costs are shown in function of the farm size, that are determined considering the use of low-level power-machines and implements and the expensive power-machines that represent the modern machine technologies.

In large-scale production the exploitage of the power-machines is more advantageous. The tractor with 60 kW output works 1100 working-hours and the medium sized universal power-machine with 120 kW output works 1750 working-hours annually. The usage cost of them to one working-hour is 15,7 EUR, and 27,3 EUR. According to our calculations the use cost of the cereal harvester and self-propelled silo combine as own property is 83 EUR/working-hour, and 243,2 EUR/working-hour. If we borrow the ensilage cutter for work, the cost reduces significantly to 97,4 EUR/working-hour. In case of *modern power-machines* the specific cost of the mentioned tractors to a time unit are 19,7 EUR and 31,4 EUR. The cost of the cereal combine is 93,4 EUR/working-hours. In case of an ensilage cutter as we have mentioned, we can calculate with the above given values.

The operational costs of the work processes of the sweet sorghum production calculated after the computer modelling can be seen on Table 1.

Table 1. The direct machine operation costs of the work processes of the sweet sorghum production

30 ha		Farm size	1000 ha	
Low technical level power-machines	Modern power-machines	Machine features	Low technical level power-machines	Modern power-machines
EUR/ha	EUR /ha	Specific cost	EUR /ha	EUR /ha
23	28,6	Stubble ploughing	15,4	17,6
11,8	14,8	Fertilizer distribution + transport	8	8,3
		Manure spreading + transport	34,9	39,8
23	28,6	Stubble care	15,4	17,6
69,4	78,9	Deep ploughing	33,8	37,5
23	28,6	Plough levelling	15,4	17,6
10,9	13,4	Herbicide spraying	7	7,8
15,5	19,2	Chemical pouring + transport	10,6	12,1
15,5	19,2	Preparation of seedbed	10,6	12,1
22,3	25,9	Sowing + transport	18	19,8
10,9	13,4	Chemical plant protection	7,0	7,8
19,6	23,8	Row cultivation	7,7	9
(65,2)	(65,2)	Harvesting	171 (64,1)	171 (64,1)
(57,1)	(65,3)	Crop transportation to depot	32,9	38,5

The values in brackets show the first-cost of the leased work.

The marked costs in the chart show the direct costs of the machine operation, plus the accessory costs (farm level costs) that increase the discussed values with almost 20%.

The difference between the costs of the small and the large-scale farm size is well-marked. This all can be explained with the efficiency of the machine exploitage. In the field of costs there is also a difference between the use of modern and less modern machines. In case of small-scale farm size, with using less modern power-machines a more advantageous cost level can be reached, although the quality of the work and the circumstances of the working must be considered.

In case of large-scale farm size, the difference between the operational costs of the less modern and modern machines decreases significantly, because the operation of the less modern machines is more expensive at larger strain and the high level constant costs of the modern machines significantly decrease, according to their better exploitage, considering one unit of work.

CONCLUSIONS

Besides the introduced machine costs, we must count with the prices of the input materials of the sweet sorghum production to know the whole cost of the production of the plant. Adding all the cost of the nutrient supply, the seeds and the cost of the pesticide, we face that a minimal input material cost is 600 EUR/hectare. Beside this we must not forget about the cost of the insurance and other supplemental expenses that is connected to the production.

Adding everything, the total production cost of the studied plant per hectare in case of small-scale farm size is minimum 1065 EUR. Examining the large-scale industrial production the costs reduce, but they can not be reduced under the 960 EUR/hectare level.

The introduced operational costs can slightly modificated with the spatial distribution, because for example in a more undeveloped region the lower wages have decreasing effects on the operational costs, compared to the regions where the wages are higher and the job market is more efficient. Furthermore, the feature of the ground, the soil and other factors can slightly have influence on the costs.

The aim of our research work and the exposition of its results is the professional support of the machine investment decisions and the machine utilization practice of the different size farms promoting hereby the creation of the conditions of fruitful farming and rational machine investment decisions.

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EKONOMSKA ANALIZA MAŠINSKE TEHNOLOGIJE GAJENJA BILJAKA OTPORNIH NA SUŠU ZA PROIZVODNJU OBNOVLJIVE ENERGIJE

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Apstrakt: Ova studija analizira upravljanje mehanizacijom na farmama koje uzgajaju sirak kao usev otporan na efekat pojave suše, kao i sirovinu za proizvodnju obnovljive energije, pored žitarica i uljarica u klasičnom plodoredu, uzimajući u obzir ne samo terenske tehničke operacije već i logističke zadatke i troškove korišćenja mašina.
Osim toga, uzete su u obzir i karakteristike rada mašine specifične za različite tehnologije proizvodnje na nivou farme.

Može se zaključiti da je razlika između troškova malih i velikih farmi značajna.
Ovo se sve može objasniti efikasnošću eksploatacije mašine.
U oblasti troškova takođe postoji razlika između upotrebe savremenih i manje savremenih mašina.
U slučaju male farme, korišćenjem manje modernih mašina za pogon može se postići povoljniji nivo troškova, iako se mora uzeti u obzir kvalitet rada i okolnosti rada.
U slučaju velike farme, razlika između operativnih troškova manje modernih i modernijih mašina značajno se smanjuje, jer je rad manje modernih mašina skuplji pri većem opterećenju i visokim konstantnim troškovima modernih mašina. Troškovi mašine se značajno smanjuju, po njihovoj efikasnijoj eksploataciji, obzirom na usvojenu jedinicu rada.

Ključne reči: *Proizvodnja obnovljivih izvora, veličina farme, upravljanje mašinskim parkom, logistički zadaci, troškovi mašina.*

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