THESISES OF THE DOCTORAL (PhD) DISSERTATION

COMPARATIVE ECONOMIC ANALYSIS OF DIFFERENT HOLDING SIZES, FIELD PRODUCTION TECHNOLOGIES

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1. INTRODUCTION OF THE TOPICS, OBJECTIVES, RESEARCH HYPOTHESIS

Since graduating from college, I have spent two and a half decades working in various roles and at various managerial levels in different areas of the agricultural sector, and I have recognised the importance of planning processes, analysing production factors and evaluating the results in terms of risk mitigation, formulating production-action options and in terms of the expected results.

Agricultural production and the closely related food and feed production play a vital role in meeting the basic needs of humanity in terms of food and livestock production. An important factor of supply is the quantity of products produced, but the fulfilment of the economic expectations of producers is equally as relevant. The purpose of the production and the size of the activity may in many cases be limited to the needs of the producer and their family, whereas in the case of larger-scale activities, which specifically aim at the production of goods, the producer is expected to be able to earn a living and to generate income. This latter expectation itself can have several levels, depending on whether production is carried out as a main or a secondary activity. In the first case, the expected mass of income will depend partly on the number of dependants on the holding and partly on the amount of capital invested. In the case of the second (secondary) activity, production becomes meaningful, rather than necessary, through the possibility of exploiting available factors of production, since the farmer's main activity is already ensuring livelihood. In this case, agricultural production places extra demands on the part-time farmer, both in terms of time and in terms of invested and working capital. These farmers are the ones who do not necessarily expect the type of returns that would be expected from full-time production, as they consider agricultural production as a kind of activity to supplement their income by exploiting opportunities that exist from the onset.

It is important for all agricultural producers and all stakeholders in the production process to understand the expectations related to production, i.e. what is the level of yield and associated production value that will ensure the expected return on capital invested in production. The identification of these is a complex process, as there are two types of assets in production: fixed assets and current assets. Both groups are valued in the accounting statements each year: the balance sheet values them as of the balance sheet date for the year in which they are owned and managed by the enterprise, while the profit and loss account values them for the year in which they are used for the purposes of the activity (the latter

cost figures, depending on the form of the profit and loss accounting, do not necessarily include all operating costs if the change in own output is not taken into account). The entrepreneur decides on the level and value of both groups of assets at the start of the activity and during its operation, but while the value of current assets and their level of use can be varied flexibly from year to year, even from one production period to another, the value of fixed assets produces a longer-term effect, in addition to generating fixed costs independent of production volume, which are also expected to be recovered from the operating income. Use of current assets in the production process is linked to products, cost bearers, and since the products ensure the operating income needed to calculate income through their sale, it is worth knowing the value of the current assets that are directly consumed in their production (complemented by personnel costs and other expenses directly linked to the production of the products) in order to assess the product-related results of the activity.

Decision-makers have a direct influence on some factors affecting agricultural production, including arable crops (in the long term, these relate to the planned use of fixed assets, and in the short term, to the planned use of material and human resources inputs), while other factors are not affected or can only be influenced indirectly (climatic conditions, sourcing and selling opportunities and related prices, forms of support, etc.).

Based on the above, the analysis of the factors of production influenced by the decision-maker is of primary importance, as it provides (or can provide) an indication of future success as planned.

The inspiration for the design of my research was to see if there is any actual correlation between the much talked about economy of scale across accounting asset groups, asset utilisation indicators and performance indicators for enterprises of different sizes engaged in arable crop production in Hungary as their main activity. As a further academic curiosity of mine, partly for its own sake, I also need to know the characteristics of the production processes for which I am responsible, including whether the different input-intensive production technologies really produce the intended results, i.e. whether precision processes do differ from conventional production methods in terms of certain input elements, and whether their expected effects manifest themselves in actual yields.

In line with the foregoing, by comparing the input-output ratios of farmers using different technologies and farming on different area sizes, I can make generalised conclusions about the differences in working capital type inputs and their efficiency of use in Hungarian

agricultural production, especially in the case of arable crop production, thus contributing to the implementation of production processes that are approaching the economic optimum but are sustainable at the same time.

1.1. Main research objectives

As a business decision-maker, I have to constantly assess, among other things, the economic efficiency of crop production processes. Information obtained during the decision preparation processes is aggregated, which can be used to prioritise, select and eliminate certain production factors. Underlying this information, however, are the detailed, elementary factors of production with their actual effects and constituting the input-output correlations.

During decision preparation and decision making at a given sectoral level, senior experts are involved in the assessment of production technology and its controlling, with joint responsibility. While relying on their work and expertise, it is possible to make informed decisions with a high degree of certainty, I would like to make sure myself, through my studies and past and current workplace experience, that my assumptions regarding economies of scale based on literature and actual empirical data show the same results for both national and company level.

To this end, in my doctoral thesis, I formulated the following research questions for enterprises engaged in arable crop production in Hungary as their main activity:

1. Are there indeed size-dependent differences in sales, earnings and profitability for Hungarian enterprises with arable crop production as their main activity? Are there any statistically detectable differences between the size of farms engaged in arable production as their main activity and the value of their fixed assets, current assets, operating income, earnings and profitability, and the size of the farms of micro, small and medium-sized enterprises (SMEs), as defined on the basis of assets and turnover, pursuant to the Act on Small and Medium-Sized Enterprises and the Support Provided for Such Enterprises (Act XXXIV of 2004, hereinafter referred to as the SME Act)? That is, is there indeed a demonstrable correlation between the absolute values of the variables listed above and the size of the enterprise?
2. Taking the previous question further, the question arises whether, if size-related differences in absolute values of operating incomes and earnings can be demonstrated,

are they significantly different per unit of fixed asset value and per unit of working capital, and do they confirm superior efficiency of larger enterprises?

3. Capital supply is an important factor in determining the owners' return expectations for all businesses, also in agriculture. The productive operation of the assets and liabilities included in the statement of assets and liabilities and the indicators derived from them should also be a key objective, hence the next research question: do fixed assets, working capital and liabilities of Hungarian enterprises engaged in arable crop production as their main activity, falling into different size categories in terms of assets and sales, have a statistically verifiable impact on the company's operating income, various earnings categories and profitability indicators? That is, to what extent do asset and liability indicators affect operating income, earnings and profitability at different company sizes?
4. In Hungary, certain elements of precision farming technology are increasingly being adopted by agricultural enterprises, with the explicit aim of increasing production efficiency, as proven by both natural and financial indicators. The two enterprises belonging to my workplace also use precision technologies driven by similar expectations of increased efficiency. Are these expectations really met in the main crop production sectors? Is there a detectable difference between yields, different categories of input use, specific operating income and earnings between using conventional vs. precision technologies? Do these differences reflect the better values expected from precision technology?

1.2. Hypotheses of the research

- According to my first hypothesis **(H1)**, in the case of micro, small and medium sized Hungarian enterprises (as defined by the SME Act) engaged in arable crop production as their main activity, the larger size category also implies significantly different asset values (H1a), sales (H1b), earnings (EBIT, EBITDA, before and after tax; H1c) and profitability (ROA, ROE, ROS, EBITDA Margin; H1d). My sub-hypothesis H1e assumes an increase in profitability ratios with an increase in size.
- My second hypothesis **(H2)** makes the same assumption as the first one, but in specific terms, i.e. in Hungary, the specific operating income per unit of fixed asset value (H2a) and the specific income per unit of working capital (H2b) and different specific earnings figures (EBIT, EBITDA, pre-tax and after tax) for enterprises of varying size

with arable crop production as their main activity show significantly different and at the same time more favourable (H2c) specific values for enterprises belonging to the larger size category.

For the first two hypotheses, the results of the statistical calculations alone are not sufficient from a professional point of view, and it is therefore necessary to compare the average values of descriptive statistics by size class to ensure that the conclusions on economies of scale are correct.

- I believe that my third research question is of importance because, if confirmed, the management and planning of larger enterprises' fixed assets and working capital of higher value will become more reliable through the verification of regression correlations, thus reducing the risk of managing larger assets. Accordingly, in the case of Hungarian enterprises with arable crop production as their main activity, belonging to different size categories, my third hypothesis **(H3)** states that for enterprises of the larger size category, more elements of fixed assets, working capital and liabilities have a statistically verified impact on sales, earnings and profitability indicators of the enterprise in comparison to smaller enterprises.
- My fourth hypothesis **(H4)** suggests that precision farming technologies applied by agricultural enterprises selected for the analysis show significant differences compared to conventional farming technologies in terms of impact on specific yields (H4a), operating income per unit area (H4b) and per unit yield (H4c), operating earnings, and the use of specific direct inputs required for production, which also implies, in line with expectations, more favourable yields, sales, operating earnings (EBIT) and lower levels of input consumption.

I have formulated my hypotheses on the basis of the results of scientific research available in scientific literature and on the information needs of professional practice. The findings of these analyses are expected to be useful in the decision-making process and to increase the success of production processes.

2. MATERIAL AND METHODS

The findings derived in this thesis are from secondary and primary research. The first part of my analysis focuses on comparing the efficiency of agricultural production enterprises of different sizes that have arable crop production as their main activity, followed by an analysis of the capital requirement differences between precision and conventional production technologies using farm databases. In order to ensure that the findings of my analyses are based not solely on my own calculations, I have collected and analysed Hungarian and international literature on the general importance of agriculture, the main aspects of the recent history of Hungarian agriculture, the economic characteristics of arable crop production, the efficiency of arable crop production, its capital requirements and sources of financing, with special emphasis on the role of working capital and the characteristics of precision crop production.

I have compiled my research questions partly on the basis of information processed in scientific literature, partly on the basis of my own studies and practical experience - my expectations - or professional curiosity, so to say, and I have tried to confirm the results of previous research published in scientific literature also through my own research. Furthermore, I sought to explore the potential for new correlations not previously explored by the analyses, using a new comparison approach for the first time. The latter type of research carries the risk of not meeting the intended research objective, hypothesis, however, I would not call such a research unsuccessful, since the verified results, established by logical and correct analytical methods on a representative database, have explanatory power, even if no research has been done on them before and even if they do not show the expected – perhaps wrongly assumed – results.

2.1. Description of the secondary research

The scientific literature selected for presentation in my thesis was chosen from the results of keyword searches related to the topics listed above. The primary source was Google Scholar, but the Web of Science, Science Direct and ResearchGate online databases were also very useful.

As regards the results of keyword searches, I tried to select the most recent scientific literature possible, depending on the list of results, but I also tried to ensure that the literature

used was general and presented a comprehensive overview of recent international and national trends. I used the following keywords and their combinations:

- the global importance of agriculture;
- characteristics of Hungarian agriculture;
- economic efficiency of arable crop production;
- capital requirement of crop production; fixed assets current assets, working capital;
- financing of agriculture;
- precision crop production.

2.2. Presentation of the primary analysis based on a secondary database

In order to answer and verify my first two research questions and my first three hypotheses, which relate to the economies of scale of Hungarian agricultural enterprises with different size classes, involved in arable crop production as their main activity, I used company data from the EMIS database. In my research, I selected Hungarian companies engaged in arable crop production, and within this, in the cultivation of cereals and oilseeds as their main activity, from the EMIS database for the years 2018-2022. The objective of my research was to analyse, using a statistical correlation test, whether there is actually a detectable difference across enterprise sizes in terms of different asset categories, operating income, income categories and profitability of the enterprises. The statistical method used was the analysis of variance (ANOVA: ANalysis Of VAriance), carried out with the help of the SPSS software. Using analysis of standard deviation, I tested whether there is a significant difference between the means of three groups (micro, small and medium size as defined by the SME Act) regarding hypotheses H1, H2. The objective of the method is to determine whether the differences between these groups are due to random variability or whether there is actually some factor that affects the means of the groups. Using ANOVA I not only tested whether the means were different, but also how much variability there was within and between the groups. This helped in understanding how reliable were the differences observed. That made ANOVA a simple, yet effective method for multi-factor tests (for H1-H2 hypotheses), where the use of more complex models (e.g. multiple regression) was not necessary.

I conducted my analyses for a period of 5 years, running the ANOVA analysis separately for each year. What makes the annual analysis necessary? Basically, a curiosity of the

researcher as to whether there is a difference between years in terms of the existence and tightness of correlations, in search of explanations.

The ANOVA analysis included the number of enterprises shown in Table 1 from the EMIS database for each year, filtered by size categories on the basis of assets and operating income.

Table 1: Number of enterprises included in the ANOVA analysis, pcs

Size/Year	2018	2019	2020	2021	2022	Total
Micro	255	310	302	258	225	1350
Small	206	216	211	235	275	1143
Medium	10	8	7	9	46	80
Total	450	523	518	500	542	

Source: Based on EMIS data, own editing

No large enterprises were filtered from the EMIS database.

The ANOVA test was done using the so-called one-way method, because in my case the independent variable was only the size category (micro:1; small: 2; medium:3) and I related this to the monetary values of the following dependent variables: Value of Fixed Assets; Value of Inventories; Value of Trade Receivables; Value of Working Capital; Sales, EBIT, EBITDA, Profit before Tax, Profit after Tax, ROA%, ROE%, ROS% and EBITDA Margin%. When performing an ANOVA analysis, the decision whether the significance value obtained is meaningful or not depends on the standard deviation identity of the groups, i.e. the variance homogeneity. The standard deviation identity is fulfilled if the significance value (p) of the Levene test is greater than 0.05 (95% probability level) and in this case we can classify the correlations based on the significance value of ANOVA (if ANOVA $p>0.05$, the difference is attributable to chance, if ANOVA $p<0.05$, the difference between the two groups is not attributable to chance, there is a verifiable correlation in terms of the differences). Another possible p-value for the Levene test is that it is less than 0.05, in which case the p significance values calculated from the Welch test will indicate the existence of a correlation. The verification of hypothesis H1 and H2 is based on three groups, in which case not only the significance value for the three groups but also the correlations between the groups can be tested using the Post-Hoc window Tamhane test in SPSS within ANOVA.

Thus, for hypotheses H1 and H2, the presence or absence of correlations between the micro, small and medium size groups can be confirmed using comparisons in pairs. (SZÉKELYI – BARNA, 2004)

In order to prove my hypothesis 3, I analysed the working capital efficiency of Hungarian enterprises engaged in arable crop production as their main activity, looking at the balance sheet and profit and loss account and the economic indicators derived from these. The database is the same as used for hypotheses H1, H2. In the course of the regression analysis, I investigate which explanatory variables have an effect on the operating income, earnings and profitability indicators as dependent variables and if so, whether they can be considered significant?

The generic form of the multivariate linear regression equation is as follows:

$$y=\beta_0+\beta_1x_1+\beta_2x_2+\cdots+\beta_nx_n+\epsilon \text{ where}$$

- y is the dependent (target) variable
- $x_1,x_2,\ldots,x_n$ are the explanatory variables (independent variables),
- β_0 is the constant term of the equation (intercept),
- $\beta_1,\beta_2,\ldots,\beta_n$ are the coefficients of the explanatory variables,
- ϵ is the error term representing the variability not explained by the model.

For hypothesis H3, the following factors were selected for regression analysis:

Dependent variables (y) (in the regression analysis, the formula can only be applied to one dependent variable, therefore the following dependent (target) variables were treated separately in the regression calculation).

- Operating income
- EBIT – Result from operating activities (Earning Before Interest and Taxes)
- EBITDA Result from operating activities excluding amortisation (Earning Before Interest Taxes, Depreciation and Amortization)
- Profit before tax
- ROA % (Return on Assets)
- ROE % (Return on Equity)
- ROS % (Return on Sales)
- EBITDA Margin (EBITDA / Sales)

Explanatory variables:

x_1: Value of fixed assets

x_2: Value of inventories

x_3: Value of trade receivables

x_4: Value of working capital

x_5: Equity

x_6: Long-term liabilities

x_7: Short-term liabilities

x_8: Liquidity ratio

x_9: Quick ratio

x_{10}: Working capital turnover rate

x_{11}: Assets turnover rate

x_{12}: Fixed assets turnover rate

x_{13}: Current assets turnover rate

The selection of dependent and explanatory variables was based on the scientific literature reviewed in this thesis (AZAM-HAIDER, 2011; AKOTO et al. 2013.; ABUZAYED, 2012.; HAJDU, 2017.; VÁRKONYINÉ, 2022) seeking to allow the fullest possible comparison in order to identify the correlations. Regression analysis was conducted using IBM SPSS software for the period 2018-2022.

2.3. Presentation of the primary analysis based on a primary database

In my primary research, I sought to investigate the differences between conventional and precision farming technologies in terms of capital expenditure, i.e. fixed asset supply and ongoing working capital expenditure, for different crops and three production periods (2020-2021, 2021-2022 and 2022-2023). The objective of my investigations was to verify whether the cost-effectiveness expected from precision farming technology can be substantiated, be it in terms of specific inputs per area or in terms of yields. The analysis of the scientific literature has highlighted the advantages of more modern cultivation technologies, but also their burdens (I will not describe them as disadvantages) resulting

from the availability of new and more expensive means of production (purchase, leasing, renting or use as a service).

I performed my research using detailed data on the arable crop production of three agricultural enterprises belonging to Talentis Agro Zrt. over three marketing years. The three crops I have analysed, winter wheat, maize and sunflower, represent more than 90% of the crop production area of the enterprises.

I extracted the technological inputs of production from the three selected holdings' table records, the controlling planning and analysis system based on them and the AgroVIR farm management program.

The analysis related to my fourth hypothesis (H4) reveals correlations between yields, input consumption, operating income and sectoral operating earnings based on data on conventional and precision technologies. For example, in the case of costs recorded under direct costs such as seed, fertiliser, pesticides cost and in the case of a proper accounting system, fuel consumption within machinery costs is not necessarily lower in a precision farming system if the projected yields are targeted at a higher level than in the conventional method. However, the specific input use expressed per yield instead of per unit area should show a more favourable trend and I assume a corresponding significant difference compared to the conventional method.

To demonstrate this, I use analysis of variance, because in this case, too, the correlation between categorical and numerical variables is investigated.

To verify hypothesis H4, I related the factors listed below to the farming practices (conventional and precision) as explanatory variables, looking for significant differences in the production of three different products (winter wheat, maize and sunflower) by pooling data from the three years of the research:

- Yield (t/ha);
- Herbicide (HUF/ha);
- Fungicide (HUF/ha);
- Insecticide (HUF/ha);
- Other plant protection products (HUF/ha);
- Seed (HUF/ha); Fertilizer (HUF/ha);

- Operating costs – costs of machine work (HUF/ha)
- Total direct costs (HUF/ha)

After looking at the specific direct costs per area unit, I also analysed the relationship between the input use per yield unit for the two types of technology. In my opinion, the HUF/t values are the true indication of the efficiency of input use, because if the direct cost per hectare is higher for precision technology compared to conventional technology, this is not a problem in itself as long as the yields increase at a higher rate compared to the cost increase. Accordingly, I also determined the differences between the two technologies for the following variables and qualified their significance:

- Herbicide (HUF/t);
- Fungicide (HUF/t);
- Insecticide (HUF/t);
- Other plant protection products (HUF/t);
- Seed (HUF/ha); Fertilizer (HUF/t);
- Operating costs – costs of machine work (HUF/t)
- Total direct costs (HUF/t)
- EBIT HUF/t

3. MAIN FINDINGS OF THE DISSERTATION

In the course of processing the scientific literature related to my research questions, I was in a relatively easy situation, I was in a sort of abundance problem, which is perhaps why it took me more time to collect and process the current and relevant scientific literature and compare it with other works of scientific literature. No literature has dealt with my research questions in the same approach, but the analyses, some of which were somewhat similar, were of great help in defining my own planned research aspects.

In the first phase of my own research, my aim was to analyse the differences in asset value, derivative asset value (=working capital), operating income, earnings and profitability indicators by size categories of companies, i.e. do the values of these indicators as variables really differ as much as the different size categories would suggest?

My related hypothesis **(H1)** was that in the case of micro, small and medium sized Hungarian enterprises engaged in arable crop production as their main activity, the larger size category also implies significantly different asset values (H1a), sales (H1b), earnings (EBIT, EBITDA, before and after tax; H1c) and profitability (ROA, ROE, ROS, EBITDA Margin; H1d). My sub-hypothesis H1e assumes an increase in profitability ratios with an increase in size.

I performed my calculations for 5 years using ANOVA analysis, the results of which are summarised in Table 2.

Table 2: Results of the significance (Sig(p)) test for size-dependent variance of assets, earnings and profitability indicators (2018-2022)

	Sig (p) 2018	Sig (p) 2019	Sig (p) 2020	Sig (p) 2021	Sig (p) 2022	Hypothesis
Fixed assets	<.001	<.001	<.001	<.001	<.001	H1a
Inventories	<.001	<.001	<.001	<.001	<.001	H1a
Accounts receivables	<.001	<.001	<.001	<.001	<.001	H1a
Working capital	<.001	<.001	<.001	<.001	<.001	H1a
Operating income	<.001	<.001	<.001	<.001	<.001	H1b
EBIT	<.001	<.001	<.001	<.001	<.001	H1c
EBITDA	<.001	<.001	<.001	<.001	<.001	H1c
AEE	<.001	<.001	<.001	<.001	<.001	H1c
AE	<.001	<.001	<.001	<.001	<.001	H1c
ROA%	.175	.257	<.001	<.001	<.001	H1d
ROE%	.097	.422	<.001	<.001	<.001	H1d
ROS%	.650	0.798	.882	.015	.030	H1d
EBITDA Margin%	.656	0.936	.066	.209	.067	H1d

Source: Own calculation (2024)

The table shows that there is a significant difference by size category for all assets, sales and earnings variables (green background), for ROA% and ROE% there is a partial correlation (yellow background), for ROS% and EBITDA Margin % there is no significant correlation (red background).

In order to validate my hypothesis H1e, I compared the average values of the factors analysed in my research. For each of the variables showing significant differences in each year of the 2018-2022 period, I found that larger size was not associated with better profitability, and this was particularly the case for the medium size category, i.e. micro and small farms exhibited better profitability. Against this background, I consider it particularly important to plan the use of resources of holdings with higher asset values in order to increase efficiency. In many cases, higher levels of assets do not imply higher asset values, as unused assets are also shown on the balance sheet, but their capacity utilisation is likely to be sub-optimal, thus reducing the profitability calculated from the accounting statements. To determine capacity utilisation, the "active" assets, more detailed information is needed, something that accounting does not provide.

Accordingly, I consider

- my hypotheses H1a, H1b and H1c to be confirmed,
- my hypothesis H1d for the variables ROA% and ROE% partially confirmed, for ROS% and EBITDA Margin % not confirmed, i.e. profitability is not significantly correlated with the size of the enterprises with arable crop production as their main activity,
- my hypothesis H1e not confirmed, because the results of my tests show that larger holding size does not imply better profitability.

My next hypothesis **(H2)** also refers to Hungarian enterprises engaged in arable crop production as their main activity, but I was looking for significant differences in the variables of different sizes in terms of the specific value of the variables, i.e. per unit of fixed assets (FA) and per unit of working capital (WC). The results obtained by ANOVA are illustrated in Table 3.

Table 3: Results of the significance (Sig(p)) test for size-dependent variance of sales and earnings indicators per fixed assets (FA) and working capital (WC) (2018-2022)

	Sig (p) 2018	Sig (p) 2019	Sig (p) 2020	Sig (p) 2021	Sig (p) 2022	Hypothesis
Sales/FA	.002	.001	.002	.007	<.001	H2a
EBIT/BE	.006	.012	.003	.289	<.001	H2a
EBITDA/FA	.003	.004	<.001	.207	<.001	H2a
AEE/FA	.007	.013	.009	<.001	<.001	H2a
AE/FA	.008	.019	.010	<.001	<.001	H2a
Sales/WC	.094	.812	.903	.120	.238	H2b
EBIT/WC	.039	.919	.902	.222	.431	H2b
EBITDA/WC	.059	.970	.886	.085	.098	H2b
AEE/WC	.148	.920	.788	.234	.600	H2b
AE/WC	.143	.912	.770	.252	.595	H2b

Source: Own calculation (2024)

On the basis of these 5 years, I consider the size-related differences in the fixed asset ratio and earnings categories to be significant, as there is only one case in the 5 years where the assumption was not confirmed, whereas the difference in the working capital ratio variables is not statistically confirmed.

In this context, it was examined whether the specific operating income and earnings indicators evolve in a more favourable way with the increase in size. Where there was a significant difference, the average values did not show more favourable values with increasing size, but for operating income and earnings per working capital, where there was no significant correlation with size, larger size gave more favourable average values. This confirmed the assumption that statistical correlation analyses are not sufficient to assess size-dependent variations, and that a more detailed, but often simpler, analysis based on averages is needed.

Accordingly,

- I consider the hypothesis H2a to be confirmed,
- hypothesis H2b is rejected, i.e. the working capital to sales and profitability ratios are not significantly related to the size of the enterprises engaged in arable crop production as their main activity,
- my hypothesis H2c is only confirmed for statistically unconfirmed differences, so I reject this hypothesis, since in this case there is no real explanatory power of the descriptive statistical averages.

According to my third hypothesis **(H3)**, in the case of Hungarian enterprises with arable crop production as their main activity, belonging to various size categories, several of the values of fixed assets, working capital and liabilities of the larger size categories provide significant relationships with the indicators of sales, earnings and profitability of the enterprise. I performed regression analysis on data for 5 survey years aggregated for micro, small and medium size of enterprises.

To confirm my hypothesis, I conducted an analysis of the explanatory and dependent variables showing a significant effect, looking for explanations of the correlations. It has become clear that working capital and liabilities have an impact on the earnings, the return on assets, the return on equities in the case of micro and small enterprise size, as indicated by the significance values of the differences (Table 4).

Table 4: Significance values of assets and liabilities of different holding sizes on the sales, earnings and profitability indicators (2018-2022)

	Operating income			EBIT			EBITDA			AEE			ROA%			ROE%			ROS%			EBITDA M%		
	Micro	Small	Medium	Micro	Small	Medium	Micro	Small	Medium	Micro	Small	Medium	Micro	Small	Medium	Micro	Small	Medium	Micro	Small	Medium	Micro	Small	Medium
Fixed assets	0.45	0.035	0.463	0.002	<.001	0.585	0.02	<.001	0.485	0.002	<.001	0.541	0.011	<.001	0.665	0.016	0.012	0.989	0.078	<.001	0.478	0.093	0.004	0.216
Inventories	0.003	<.001	0.066	0.162	0.55	0.92	0.339	0.078	0.765	0.081	0.765	0.313	0.166	0.699	0.223	0.573	0.131	0.486	0.154	0.062	0.469	0.209	0.192	0.996
Accounts receivables	0.705	0.114	0.171	0.752	0.227	0.403	0.31	0.59	0.253	0.9	0.11	0.696	0.658	0.518	0.826	0.196	0.935	0.546	0.507	0.005	0.978	0.695	0.013	0.699
Working capital	0.523	0.025	0.328	<.001	<.001	0.724	0.02	<.001	0.968	<.001	<.001	0.263	0.007	<.001	0.401	0.012	0.013	0.449	0.046	<.001	0.396	0.075	0.003	0.62
Equity	0.955	0.16	<.001	0.003	<.001	0.688	0.009	<.001	0.276	0.003	<.001	0.292	0.01	<.001	0.726	0.012	0.012	0.612	0.079	<.001	0.831	0.111	0.004	0.618
Long-term liabilities	0.943	0.15	0.5	0.002	<.001	0.664	0.007	<.001	0.354	0.001	<.001	0.953	0.007	<.001	0.653	0.016	0.012	0.861	0.067	<.001	0.48	0.108	0.003	0.387
Short-term liabilities	<.001	<.001	0.713	0.049	0.005	0.451	0.049	0.003	0.535	0.048	0.076	0.213	0.003	0.05	0.507	0.109	0.006	0.387	0.474	0.328	0.528	0.677	0.141	0.794
Liquidity ratio	0.424	0.04	0.544	0.132	0.063	0.803	0.205	0.067	0.683	0.127	0.162	0.949	0.245	0.096	0.853	0.742	0.729	0.916	0.129	0.186	0.941	0.117	0.018	0.538
Quick ratio	0.887	0.059	0.486	0.137	0.026	0.798	0.204	0.013	0.686	0.136	0.05	0.92	0.291	0.004	0.835	0.688	0.1	0.916	0.186	<.001	0.991	0.186	<.001	0.535
Working capital turnover rate	0.554	0.616	<.001	0.707	0.222	0.612	0.512	0.334	0.643	0.749	0.266	0.747	0.689	0.415	0.673	0.711	0.009	0.094	0.941	0.443	0.963	0.728	0.339	0.651
Inventories turnover rate	<.001	<.001	0.094	0.033	0.407	0.456	0.047	0.201	0.316	0.032	0.576	0.353	<.001	0.886	0.145	<.001	0.919	0.152	0.171	<.001	0.672	<.001	<.001	0.021
Fixed assets turnover rate	0.681	0.049	<.001	0.01	0.796	0.282	0.018	0.215	0.128	0.009	0.516	0.338	<.001	0.035	0.342	0.021	<.001	0.178	0.126	0.136	0.983	0.187	0.599	0.503
Current assets turnover rate	<.001	0.115	0.132	0.347	0.926	0.859	0.475	0.691	0.608	0.343	0.985	0.96	<.001	0.586	0.736	<.001	0.981	0.99	0.252	0.758	0.81	0.037	0.57	0.04

Source: Own calculation (2024)

Working capital is a more flexible asset element of an enterprise that can be changed in the short term, since based on the correlation between current assets and short-term liabilities, a well-designed current asset management (= optimal inventory levels, low accounts receivable, proportionate accounts payable to suppliers) can result in better profitability. There are, of course, several limiting factors to working capital management, which I have presented through the literature, since in the case of accounts receivable we may be exposed to the ability and willingness of the customer to pay, and in the case of accounts payable we may not be in a good bargaining position. I had expected the analysis to find significant

correlations between the turnover rate and liquidity explanatory variables, which correlations would affect several outcomes, as the literature suggests, but these were not observed to the extent I had anticipated. Only the turnover rate of assets and fixed assets was found to have a more significant effect on the dependent variables, with several significant effects, as shown in Table 4.

The assessment of the effects for dependent variables is also facilitated by the green highlights, showing that the different levels of earnings categories and ROA%, ROE% profitability are the most affected by the explanatory variables examined in the relevant literature. Comparing the findings of the above-mentioned scientific literature with my own research, there is agreement on the effects on EBIT-EBITDA and ROA%. In addition, my regression analysis on earnings before tax (AEE) and return on equity (ROE%) also showed a large number of assets and liabilities to be influencing the outcome. In the case of profit before tax, this was to be expected in the case of smaller companies, because the result of operating activities is often the same as the profit before tax, so in principle and in practice a similar result should be obtained. The main reason for this is that micro and small enterprises try to avoid indebtedness, so their liabilities do not include interest-bearing liabilities, whether long or short-term, and therefore interest payments do not appear in their profit and loss accounts. Nor have they interest income, as these sizes of business are not yet characterised by holdings of financial investments and trading securities, and thus the absence of interest received means that the operating result is very close to or equal to the profit before tax. The same reasoning can be applied to the emergence of a provable effect on ROE%, since if there are no or only minimal financing liabilities in the economic sense (long-term liabilities - LTL – and short-term interest-bearing liabilities – STL), the value of assets approaches the value of equity, so that ROA% and ROE% are similar.

Table 4 allows a comparison by size category. Whilst we should not assess the effects primarily on the basis of their numerical magnitude, but on the basis of their direction and strength, I would still like to begin with this as a first step, since I also assume this in my related hypothesis. Accordingly, I have summarised the number of significant correlations for each size, highlighting the dependent variables showing the most correlations:

- Micro-sized enterprise: 43 cases have a significance (p) value below 0.05 (EBIT, EBITDA, AEE, ROA%, ROE% in similar proportions)

- Small-sized enterprises: 53 cases have a significance (p) value below 0.05 (Operating income, EBITDA, AEE, ROA%, ROE% in similar proportions)
- Medium-sized enterprises: 5 cases with a significance (p) value below 0.05 (Only for Operating income and EBITDA Margin%)

The correlation test figures show a closer correlation between the explanatory and dependent variables of the two smaller size categories, i.e. basically a higher proportion of the proven impact of each asset and resource group on the different dependent variables, most notably on the earnings categories.

In correlation analyses, it is also necessary to analyse the direction of correlations, since it is not irrelevant what the magnitude and direction of an effect is in the case of a statistically significant correlation.

During the regression analysis I analysed Pearson's correlation values for significant correlations. Regardless of size categories, the correlation coefficients show that current assets and equity have a positive Pearson correlation for the operating income and profit categories, while long-term and short-term liabilities have a negative Pearson correlation.

For profitability indicators, fixed assets have a negative effect in the micro and small size categories. This is logical in the case of ROA%, since fixed assets are a divisor of asset value, but in the case of ROE% and ROS% there is no direct correlation with fixed assets, so in principle a significant regression correlation is not justified. Accordingly, the assumption of my hypothesis H3 is not confirmed, i.e., significant correlations between the individual asset items and derivatives of firms (e.g., turnover rate, liquidity ratios) and sales, earnings, profitability as dependent variables are more likely to be found in the case of micro and small enterprise sizes. Accordingly,

• I reject my hypothesis H3 because the number and proportion of significant correlations of each asset item with the turnover, earnings and profitability indicators of the activity are lower when compared to those calculated for smaller enterprise sizes. The higher overheads associated with larger enterprise size, as mentioned above, also explain the findings, since in these enterprises an increasing share of the assets is not used for production and direct value creation, but for management and other processes that are not directly productive, and thus not closely related to operating income, earnings and profitability.

My last complex test was an analysis of the difference between the conventional and the precision farming production systems based on actual data, where I used a statistical method (ANOVA) to verify the differences between the specific (HUF/ha, HUF/t) input uses and the differences between the sales and the sectoral operating result (EBIT) for three years and three crops. My hypothesis **(H4)** suggests that precision farming technologies applied by agricultural enterprises selected for the analysis show significant differences compared to conventional farming technologies in terms of impact on specific yields (H4a), operating income per unit area (H4b) and per unit yield (H4c), operating earnings, and the use of specific direct inputs required for production, which also implies, in line with expectations, more favourable yields, sales, operating earnings (EBIT) and lower levels of input consumption.

The results of my calculations are summarized in Table 5.

Table 5: Significance values (Sig (p)) of tests of variance of yields, direct inputs, operating income and earnings per unit area and per unit yield per crop

Variables	Sig (p)						Hypothesis
	Winter wheat		Maize		Sunflower		
	HUF/ha	HUF/t	HUF/ha	HUF/t	HUF/ha	HUF/t	
Yield (t/ha!)	.739	–	.955	–	.209	–	H4a
Herbicide	.302	.223	.080	0.751	.201	.199	H4b
Fungicide	<.001	<.001	–	–	<.001	<.001	H4b
Insecticide	<.001	<.001	<.001	.553	<.001	<.001	H4b
Seeds	.042	.010	.352	.933	<.001	.879	H4b
Fertilizers	<.001	<.001	.134	.878	.993	.259	H4b
Operating costs	0.116	0.05	0.973	.570	.994	.522	H4b
Total direct costs	<.001	<.001	0.057	.870	.391	.642	H4b
Sales	.260	–	.788	–	.821	–	H4b
EBIT	<.001	<.001	.602	0.873	.399	.449	H4b

Source: Own calculation (2024)

The results combined in a single table are of course diverse, since the difference tests between the two technologies are based on the cultivation of three different crops. My hypothesis is that there is a significant deviation between yield and each input element and production mode and that this deviation is due to the more favourable values of the indicators in the case of precision technology. Only in the case of the specific indicators for winter wheat production per tonne of production were the largest number of significant differences found. Is precision farming delivering the better values we expect? Unfortunately, in the majority of cases not, as the descriptive statistical tables in the annex show more favourable specific input values than the average input values with significant

differences. Thus, differences can be confirmed, but the expected result of precision farming has not yet been achieved in the case of the farms studied on the basis of the database received.

This is due in part to shortcomings in the design and implementation of precision technology:

- possible inaccuracy of design input data,
- continuing to make decisions based on traditions,
- inaccurate implementation of precision technology operations,
- failure to adapt to changing conditions (e.g. weather changes, infections) after the planning period,
- under-utilisation of the capacity of more modern and higher-cost precision equipment,
- lack of technical knowledge of machine operators,
- inaccurate recording of output data in the company management system.

Without a good practice regarding above factors, precision farming cannot improve its efficiency.

Based on the results of my research:

- my hypotheses H4a, H4b and H4c are not confirmed, i.e. there is no significant difference in favour of precision farming in terms of specific yields, input use, sales and sectoral operating result and the indicators of precision farming do not show a consistent advantage over conventional farming.

I do not, however, consider the results related to hypothesis H4 to be insignificant, despite the fact that they do not prove the logical assumption, since such a correlation-difference study supports the decision preparation of practitioners, i.e. it points out that in the case of precision technologies, greater attention should be paid to the specific inputs and expected returns.

The differences between size classes and cultivation technologies resulting from the research, and the understanding of the economic correlations identified, will help in planning future processes, focusing attention on the most important production and input factors.

4. NEW AND NOVEL RESULTS OF THE DISSERTATION

I conducted my research on Hungarian agricultural enterprises producing arable crops, including cereals and oilseeds as their main activity, investigating the correlations between the factors affecting specific operating income by farm size, different levels of earnings and profitability, and the existence of differences between conventional and precision technologies and their causes, based on empirical data.

1. In my thesis, I demonstrated that the values of current assets, working capital and different levels of earnings categories change significantly with changes in the size of agricultural enterprises producing arable crops, including cereals and oilseeds, as their main activity.
2. In the case of Hungarian agricultural enterprises producing arable crops, including cereals and oilseeds as their main activity, the increase in size is not accompanied by a proportional increase in profitability in terms of total assets, equity and sales.
3. In my thesis, in a gap analysis of fixed asset and working capital based efficiency ratios for enterprises of different size categories included in the analysis, I show that fixed asset based profitability ratios show a significant correlation with enterprise size, while working capital based profitability ratios do not show such a statistically proven correlation.
4. In line with the earlier finding, the proportional profitability of fixed assets decreased with the increase in size, which draws attention to the optimal capacity utilisation of fixed assets.
5. In my thesis, I used regression analysis to show that for Hungarian agricultural enterprises producing domestic arable crops, including cereals and oilseeds, as their main activity, working capital and resources have a pronounced effect operating income, output variation and profitability in the case of small enterprise size.
6. With my thesis, I have demonstrated that the actual application of precision technologies does not in itself mean a reduction in specific input consumption and an improvement in results compared to conventional production methods.

5. PRACTICAL APPLICABILITY OF THE RESULTS

Tests carried out in the framework of my thesis have demonstrated that as the size of agricultural enterprises has changed, not only the fixed assets that significantly determine their size, but also the current assets, working capital and the different levels of profit categories have changed significantly. For fixed asset and working capital based efficiency ratios calculated for enterprises of different size classes included in the analysis the fixed asset based profitability ratios show a significant correlation with enterprise size, while working capital based profitability ratios do not show such a statistically proven correlation. *This suggests that decision makers should not only think in terms of the value of fixed assets, but also in terms of the value of working capital, which is likely to increase with the planned growth of the enterprise size. Management of these can be achieved through a well-planned working capital management, with particular attention to ensuring continued liquidity.*

Using regression analysis, I demonstrated that, contrary to the preliminary hypothesis, there are more significant correlations between individual asset items and operating income/profitability for micro and small enterprise sizes. *This information provides micro and small-scale crop production farmers with a more reliable set of criteria for earnings and profitability planning, which of course requires accurate historical information and reasonably calculated future information.*

In my practice-based analysis, I have shown differences in specific input usage, sales revenue and sectoral earnings between conventional and precision production. *The findings demonstrated that the actual application of precision technologies does not in itself mean a reduction in specific input consumption and an improvement in results compared to conventional production methods. The theory and planned implementation of precision production should be implemented in practice in a precision way to ensure the expected results.*

As a final thought of my thesis, I would like to note that there is a continuous need for economic analysis in any field of agriculture, but in this case specifically in arable crop production, due to changing environmental conditions and changing ownership structures and management interests. I sought to contribute to this through the work I did in my dissertation.

6. LIST OF PUBLICATIONS RELATED TO THE DISSERTATION

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Registry number: DEENK/531/2024.PL
Subject: PhD Publication List

Candidate: Szabolcs Makai
Doctoral School: Doctoral School of Management and Business
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List of publications related to the dissertation

Articles, studies (6)

1. **Makai, S.**, Lakatos, V.: A működő tőke hatékonyságának változása a vállalati méret függvényében.
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2. **Makai, S.**, Lakatos, V.: Analysis of working capital efficiency for arable crop farms in Hungary.
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3. **Makai, S.**: A klímaváltozás alighanem a jelenkor egyik legnagyobb kihívását jelenti.
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   Controller Info. 10 (1), 30-34, 2022. ISSN: 2063-9309.
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Literature used in the thesis booklet

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