THESIS

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Development plan of precision agricultural machinery in Mezőfalvai Zrt.

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Introduction and objectives

Implementation of more efficient agricultural systems is becoming a must in any agricultural enterprise due to increasing global temperatures which result in stagnating production levels. Through a combination of developing new precision machinery, adoption of sustainable strategies and the education of workers, the agricultural sector can find a way to create and sustain value for both the users and consumers in a way that will preserve the health of our environment for the future generations. (Campos, 2021)

The demand for worldwide crop production and food quality is increasing and put great pressure on the agricultural sector. The main reason behind these trends is the increase in global population and globalisation. Larger income, especially in developing countries leads to increased food consumption and an increase of demand for high value products. (EU Agricultural Markets Briefs, 2019) A major on-going problem for providing increasing demand is the pace at which farmers can produce goods. The average age of farmers is increasing, which means less and less workers can produce better results by putting in more working hours, leading them to look for innovative and automated systems to use for crop production which reduce physical stress for workers and can increase efficiency. (Becker, 2024)

The question the thesis aims to answer is the following: What are the current limitations and challenges faced by Mezőfalvai Zrt. in terms of precision agriculture, and how can these be addressed?

The objective of this research is to evaluate the technological relevance of machines of Mezőfalvai Zrt., an agricultural company and gather information on the strengths and weaknesses of how these machines are used. This research will consider elements connected to the correct and most efficient operation of these machines including strategy planning by management and human operators' capabilities.

The goal of the development plan is to provide the company with a list of improvements to make their operations more efficient which include upgrades to machinery, PA strategies and solutions to human resource constraints.

Literature Review

Introduction

The purpose of this literature review is to gain understanding of the current research and scientific literature published on precision agriculture, presenting debates and gaps in knowledge relevant to the modernization of a medium to large sized agricultural business in Hungary. The scope of this review will include several key areas which all need to be considered to make informed decisions regarding the topic of this thesis such as.

- Concepts and definitions in PA for example: Precision farming, variable rate technology, remote sensing
- Key areas of precision agriculture
- Benefits of precision agriculture
- Challenges and limitations
- Current trends
- Conclusion

The aim of precision agriculture (hereafter PA) is to reduce and minimize environmental impacts and damages while increasing agricultural productivity (Zhang, 2015). Using PA technology will enable farmers to increase their productions and contribute to a sustainable intensification of agricultural activities. PA technology is aiming to reach this goal through optimizing resource management using technologies like Geographical Positioning Systems, satellite navigation, sensors and machine learning (Abobatta, 2020). With the correct implementation and adaption of PA a future where global agricultural production is sustainable, is possible.

Global Positioning System

GPS originated in the Sputnik era, with the US Navy using satellite navigation to track submarines carrying nuclear missiles. In the 1970s, the Department of Defense (DoD) developed a stable satellite navigation system, using the "Doppler Effect" to track satellites. The first NAVSTAR satellite was launched in 1978, and the 24 satellite system was fully operational in 1993. The DoD's efforts contributed to the development of GPS. (Walker, 2023)

Global Navigation Satellite System or GNSS, such as GPS, allows for real-time monitoring of vehicles moving through land and is highly accurate for uses and applications in agriculture (Stombaugh, 2018), which is one of the most important qualities needed in precision agriculture. It is crucial for an enterprise to know accurately the geographical boundaries of the arable land they work on. It is usually the first step to measure and record this data when implementing any automated machinery. This proves to be the most crucial first step in implementing precision machinery as it lays the foundations for the use of any PA implements that distribute fertilizers, pesticides or irrigation water. This allows the farmers to create their field management practices specific to each site based on size, shape and other soil characteristics, Site specific management practices lead to the most efficient planting, fertilizing and irrigation strategies, resulting in higher efficiency and less input. Another example further supporting this point is the resulting reduction in overlapping and wastage where variable rate technology and vehicle path planning using GPS has been successfully used (Brown et al., 2008). GPS technology also works in Unmanned Aerial Vehicles (hereafter UAV) for monitoring uses, which allow for better spatial resolution of images, resistance to various weather conditions and operation costs are much lower. (Hu, 2023).

While GPS technology has many benefits, it comes with some disadvantages as well, like security risks, cost and adaptation problems. The data needed in the use of automated machines needs to be stored in digital system which no matter how well protected, always stand the risk of being compromised. Security risks are one of the bigger issues regarding PA. Passive and active attacks are both threats when working with a digital network (Wu & Liu, 2022). Large companies and corporations which have extreme amounts of sensitive data regarding their yields, field boundaries, types of fertilizers used on specific plants etc., face a constant threat of hackers attacking their systems which could lead to substantial losses in profit and data as well. Passive attacks however are a far larger threat as they involve scanning traffic, spying on activities and stealing data which do not alter any already existing data and are very difficult to detect. This could give competitors opportunities to unethical gain information on other organizations and improve or potentially outperform a company using the data gathered.

As sophisticated as they are, positioning systems, hardware and integration into agricultural usage aren’t as well developed as GPS systems for other uses such as military or civilian. Despite huge advancements made certain technological immaturity and high costs due to this make GPS fitted PA systems more difficult to obtain and efficiently implement in smaller or

even some midsize farms (Pandey et al., 2021). The difficulty to obtain this machinery requires owners to plan many steps ahead, making it a complicated task to begin modernization.

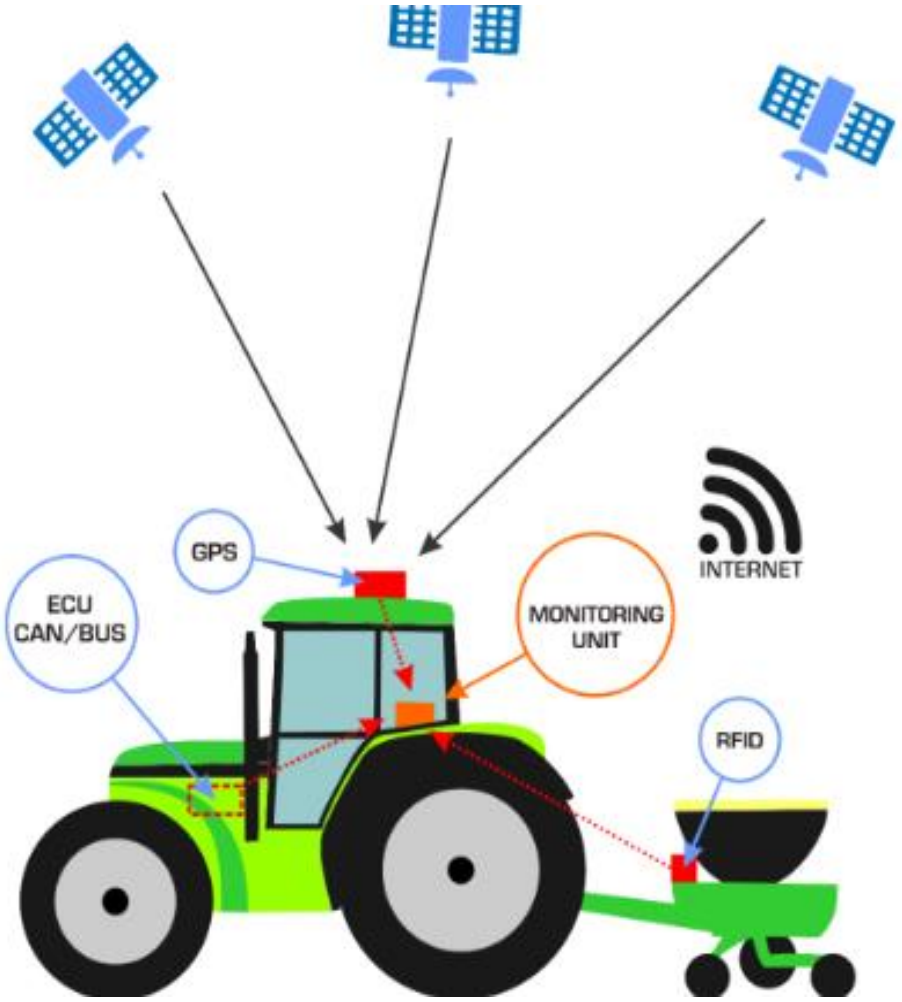

Figure 1 illustrating communication scheme of automated tractor. (Řezník et al., 2016)

Real Time Kinematics

RTK signals, an abbreviation for Real-Time Kinematic signals, represent a sophisticated satellite navigation technology that enhances GNSS positioning. It encompasses prominent systems such as GLONASS, which deliver locational data via a satellite network. (Agrárágazat Szerkesztőség, 2020)

RTK signals surpass conventional GNSS by delivering real-time corrections to positioning

data, guaranteeing centimetre-level precision. This improvement is essential in fields where accuracy is critical, including agriculture, surveying, and autonomous navigation.

The fundamental principle of RTK technology is differential positioning. In a conventional GNSS configuration, accuracy is constrained by elements such as atmospheric disturbances and satellite clock inaccuracies. RTK addresses these limitations by concurrently comparing the position of a stationary reference station with that of a mobile rover station. A fixed reference station with a high-accuracy GNSS receiver acquires satellite signals to determine its location. It computes the discrepancy between its position and the signals and sends correction data in real-time to a mobile rover station. This enables centimetre-level precision in real-time, mitigating inaccuracies caused by atmospheric conditions and other variables, thereby ensuring accurate location determination. (Emms, n.d.)

This technology proves to be very useful in certain situation where geographical conditions make it difficult for drivers to navigate precisely while sowing or harvesting. Hilly areas are usually not sown in straight lines but rather in curves following the contour of the hill to avoid soil erosion from any rainwater running down the hillside and to improve water retention.

Remote sensing

Remote sensing has become a fundamental part of modern agriculture since its introduction in the 1970s. It is a technique where the physical characteristics of a target area are measured and monitored through the radiation emitted by it. The main target of remote sensing in agriculture is the monitoring of vegetation in crop fields through Normalized Difference Vegetation Index (hereafter NDVI).

NDVI is calculated through a simple equation: $NDVI = \frac{NIR-Red}{NIR+Red}$

NIR: Near Infrared

Chlorophyll in green vegetation reflects a large amount of near infrared and green light in comparison to other wavelengths. Using this formula a result between -1 and +1 will be obtained, the closer the result is to 1, the higher the reflectance is in the measured area. Low NDVI figures mean there is low to no vegetation. (GISGeography, 2024)

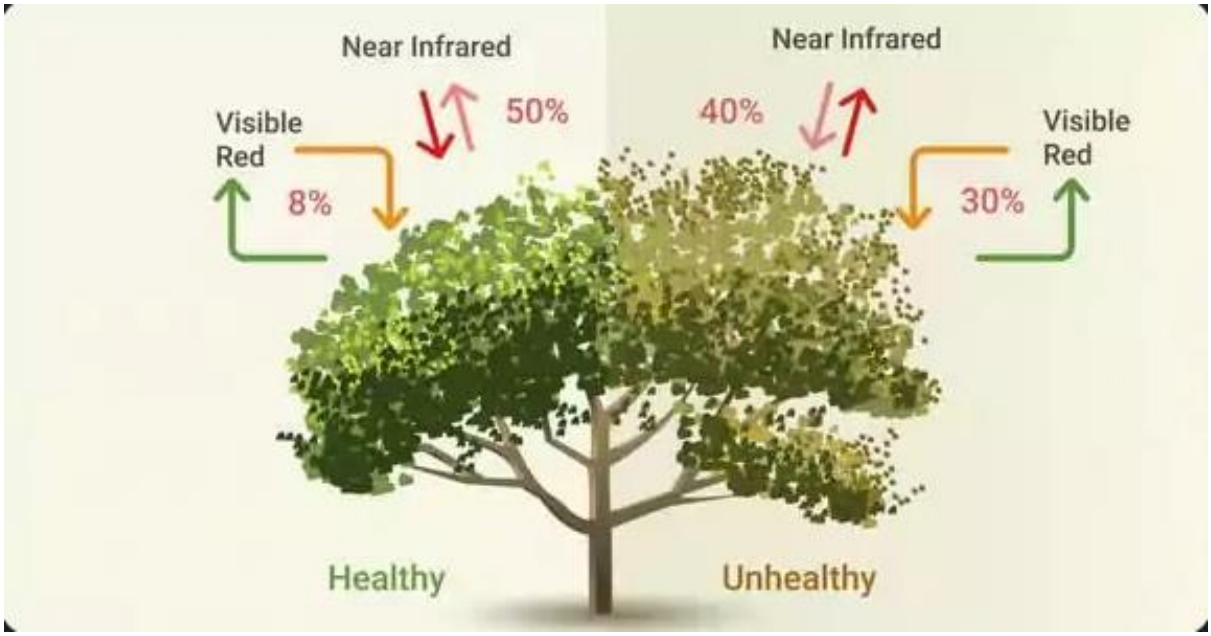

Figure 2 Illustrating light waves reflecting from vegetation. (Cherlinka, 1970)

Remote sensing has limitations in mapping certain areas that might be used for various agricultural activities such as urban areas, wetlands and deciduous needleleaf forests (Zhang et al., 2006). Even though such areas might not be used for agricultural purposes, similar conditions may arise in various crop sites that hinder the use of remote sensing or show incorrect results. This could cause challenges in areas where flooding or heavy rain fall is to be expected near or on the crop site such as rice fields where flood irrigation is the conventional system of irrigation. Or in areas where the topsoil is compacted, and rainwater might stagnate on the surface.

Atmospheric conditions are another obstacle faced by remote sensing technology. Cloudy weather could decrease the accuracy of the measurements (Nagol et al., 2009) or in extreme cases change them so much that they will not be usable at all. In precision agriculture this is especially important as the main idea of this farming practice is to fine tune every component of operations such as fertilizers supplied to the soil based on NDVI figures.

As with any piece of technology, integration and standardization can be an issue. Sensors can't capture all the necessary data so multiple ones need to work together. Each remote sensing platform like Satellites, drones and ground-based units have their own software and systems which they run on, to collect all the data and represent it in one software is challenging.

Variable Rate Technology

Variable rate technology (hereafter VRT) is the process of applying inputs such as seeds, water or fertilizers are applied to the soil at varying rates across the crop field. This technology works hand in hand with map based (GPS and NDVI) information or sensors built into the machines themselves. New advancements include variable depth tillage (hereafter VDT) which require a three-dimensional map of the crop field and takes into consideration every hill and valley, being able to adjust the depth of the blades for soil tillage on the go, to provide the same tillage depth relative to the surface all over the crop field.

Variable rate technology comes with higher initial costs but can make up for this in terms of overall higher efficiency (Kempenaar et al., 2017). High initial costs can often put off farmers from investing into new, state of the art technology however as shown by a study "Advances in variable rate technology application in potato in the Netherlands" the correct implementation of this technology can save 25% on pesticides and fertilizers compared to regular practices. This point is further supported by (Robertson et al., 2007) who noted that all farms taken part in the case study spent medium to high amounts to invest into precision technology relative to Australian standards but in the end grain growers managed to recover the amount invested within a few years.

This technology requires modern machinery and highly skilled work force (Späti et al., n.d.) which ads further obstacles in the way of implementing such systems into a business that does not already deal with precision agriculture. In many work environments, employees tend to over value their abilities and knowledge of using modern technology (Kőmíves et al., 2019) which may lead to unwanted complications at times of modernization. Educating the employees and constantly increasing their skills will make integration of modern techniques easier and more efficient.

Soil sampling and mapping

Apparent soil electrical conductivity, also called EC is a widely recognized method in agriculture for determining the spatial variability of soil physico-chemical properties. It was initially used to measure soil salinity in arid regions but has since been used to determine anthropogenic characteristics such as leaching fraction, irrigation patterns, and compaction

patterns from agricultural machinery. EC measurements help in understanding the complexities of soil properties. (Corwin & Lesch, 2005)

Efficient and precise evaluation of variation within a field is crucial for identifying overall differences and aiding in the enhancement of agricultural land management (Heil & Schmidhalter, 2017). It is the method of collecting soil samples from many different points within a crop field, the results be analysed and used to make maps to determine soil properties. In the lab the soil samples show the nutrient composition of the crop field and based on the results, fertilization maps can be made. When working with large crop fields, it is crucial to keep note of the soil properties of each region of land.

The ability to visualize variability gave rise to site specific management (SSM) decision making, which optimizes input use efficiency and profitability while reducing environmental contamination. (Shaheb et al., 2022)

Waste reduction and environmental consciousness is an increasingly important topic in our daily lives and more importantly in agriculture. Soil sampling provides an in-depth monitoring to the health of the crop field which is very important for the owner of the land because the soil used will need to provide future crops with chemical and biological support to produce food for the future generations.

Internet of Things

Perhaps one of the most important parts of precision agriculture and our everyday lives, is the internet of things or IoT, which refers to the ability to send and receive data between computing devices found in agricultural machinery through the internet.

Modern technology is of great importance in agriculture, control units, data collection devices and various sensors. Data can be collected periodically or continuously based on various requirements, usually about the state of the machines systems, crops or the environment. The information collected serves as feedback on how previously integrated techniques affected the crops and their development. These data need to be communicated towards the farmers and professionals to make informed decisions. For example, KITE Zrt. a Hungarian agricultural company, also dealing with precision agriculture, have developed their own computer and mobile phone application which connects the end user to the machinery provided by the company called precision agricultural system or PGR (Precíziós Gazdálkodási Rendszer). The

necessary requirements for the implementation of this precision system are machines specifically developed for it. Tractors for example, can communicate with various other precision tools through an ISOBUS connection. (*Mi a PGR? | PGR - KITE Zrt.*, n.d.)

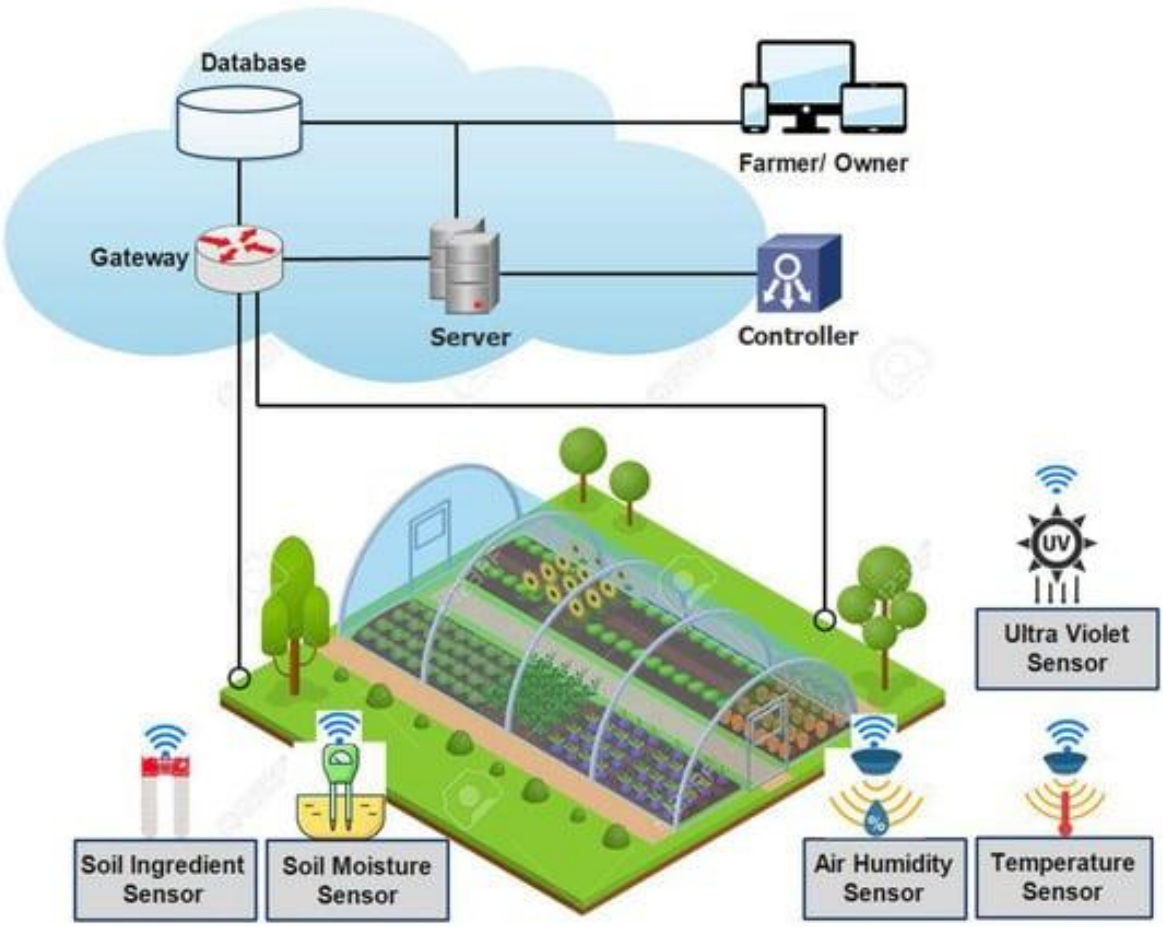

Figure 3: Illustrating IoT application for monitoring farming conditions in greenhouse (Quy, Van Hau, et al., 2022)

Devices created for such IoT tasks like sensors are anticipated to be deployed for a long time and therefore are built to last. These devices are unfortunately hard to upgrade since the key to longevity is simplicity and a lack of complicated parts, both software and hardware. Therefore, a limiting factor of its security can be the fact that the software used by the devices is not upgraded often, which will leave it vulnerable to cyber attacks such as Spear-Phishing. (Joshi & Kulkarni, 2016)

Social and environmental impacts

Agriculture is the largest industry in the world, employing approximately 1 billion people and generating food worth over 1.3 trillion USD a year. It is responsible for the production of food, fibre and other essential and includes crop cultivation, livestock raising, forestry and aquaculture. Agricultural production relies on the environment and can affect it too, meaning there is a balance between environment and industry. There are farms and agricultural businesses of different sizes, operating through different philosophies.

- Industrial agricultural businesses are responsible for large scale, intensive and highly mechanized operations with high yield crops which are given chemical fertilizers and pesticides for maximized productivity.
- Subsistence farming is a small size farm often referred to as a “family farm” which produces enough crops to provide the consumption needs of a family who often work on the farm themselves and use minimal inputs like fertilizers or pesticides.
- Organic farming refers to a method of farming where synthetic chemical fertilizers and pesticides are avoided and sustainability, biodiversity and environmental protection is emphasised.

The primary environmental consequences linked to agriculture in the U.K. stem from pesticides, nitrogen compounds, pollution from livestock waste, and soil erosion. Despite addressing the primary issue areas in isolation, they are generally interconnected, frequently resulting in several cascading consequences, some of which are "unseen," such as the degradation of aquatic ecosystems and the expenses linked to water purification.
(Skinner et al., 1997)

Although Nitrogen fertilizers can help increase the yield of our crops in agriculture, which has positive economic and some health benefits to human society, it has a downside when used in a careless manner. If humans consume polluted water, it will reduce nitrates in our body to nitrites and may reduce the oxygen carrying capacity of haemoglobin, resulting in methaemoglobin. (Camargo & Alonso, 2006)

“In addition to reduced swimming and feeding, developmental deformities including bent tails, body swelling and bulging, head deformities, and digestive-system deformities occurred. The severity of the effects was positively correlated with increasing concentrations of nitrate.” (Rouse et al., 1999)

Nitrogen pollution may affect humans and animals to a different scale but they're both affected, nonetheless. The above two examples are perfect demonstrations of how careless nitrogen fertilizer use can affect living organisms outside of the agricultural crop lands. Environmental pollution is becoming an increasingly important danger in many industries, especially in agriculture and certain actions must be taken to reduce the negative effects on wildlife and human health.

In a study regarding nitrogen pollution policy measures in Denmark, it has been concluded that groundwater and surface water catchment systems have been the most effective measures for removing nitrate from water runoffs. Regulatory measures have reduced nitrogen leaching by 33% while maintaining significant crop yields and increasing livestock production. (Kronvang et al., 2008)

Conclusion

GPS technology is a key component to modern precision agriculture. It allows farmers to create site-specific management practices, resulting in higher efficiency and less input. GPS technology also works in Unmanned Aerial Vehicles for monitoring purposes. RTK signals, or Real-Time Kinematic signals, are satellite navigation technology that improves GNSS positioning by delivering real-time corrections, ensuring centimetre-level precision. This technology is crucial in fields like agriculture, especially in challenging geographical conditions like hilly areas. However, its implementation does come with difficulties, the biggest ones being cost and adaptation problems which can be overcome with appropriate strategic planning.

Remote sensing is a crucial technique in modern agriculture, primarily used to monitor vegetation in crop fields using the Normalized Difference Vegetation Index. However, it faces limitations in mapping areas used for agricultural activities, such as urban areas, wetlands, and deciduous needleleaf forests. Additionally, atmospheric conditions can affect the accuracy of measurements, especially in precision agriculture. Integration and standardization are also challenges.

Variable rate technology involves applying inputs like seeds, water, or fertilizers at varying rates across a crop field, using GPS and NDVI sensors. New advancements include variable depth tillage. Despite higher initial costs, VRT can improve efficiency and save 25% on

pesticides and fertilizers. Implementing this technology requires modern machinery and skilled workers, but efforts can lead to higher yields and reduced waste.

Soil sampling is a method used in agriculture to measure soil physico-chemical properties, aiding in land management and waste reduction. It collects soil samples from various points, allowing for efficient evaluation and fertilization maps. This method also aids in site-specific management decisions.

Internet of things is crucial in precision agriculture, enabling data exchange between agricultural machinery and control units. KITE Zrt., a Hungarian company, developed an application for IoT-enabled machinery, connecting end users to machines. However, these devices are hard to upgrade and vulnerable to cyber-attacks and malfunctions due to their simplicity.

Agriculture, the world's largest industry, employs 1 billion people. It involves crop cultivation, livestock raising, forestry, and aquaculture. However, environmental consequences include pesticides, nitrogen compounds, pollution from livestock waste, and soil erosion. Nitrogen fertilizers can increase crop yields but can also cause developmental deformities and reduced oxygen carrying capacity in humans and animals if polluted water is consumed in large enough quantities. Denmark has implemented effective nitrogen pollution policies, which reduced leaching while maintaining crop yields and livestock production.

Methods used

Primary data collection

The methodology of the Thesis work will be a mixed methods approach. A combination of qualitative and quantitative methods will result in the most thorough evaluation of the capacity and capability of the current machinery in Mezőfalvai Zrt.

- The first stage includes gathering qualitative data through interviews with management, operators and engineers. The main goal is to find existing inefficiencies and areas to potentially improve the machinery including software and hardware.
- To collect data on performance of the existing machinery quantitative research will be used. It will include an analysis of energy consumption and maintenance costs. The data gathered will serve as a standard which the modernization plan can be compared to and be judged based on quantitative data analysis.
- After identifying the areas to be improved, a list of suggestions will be made which could improve efficiency of operations

The interviews will be based on a series of questions prepared ahead of the visit to Mezőfalvai Zrt. The participants in the interview will be various employees of different positions within the company who see different aspects of the machines used, for example, management are more concerned about budgeting and keeping costs low, engineers can express expert opinions about the reliability and longevity of the machines and operators can comment on the flaws of the current equipment.

A structured interview is a consistent and objective way to collect quantitative data for comparison. Using the same set of questions in the same order for every participant will ensure that each participants answers can be directly compared to another participant. The uniformity of the interview will also get rid of interviewer bias to a very high extent as all the same questions are asked to all the participants and the interviewer themselves have minimal to no effect over the responses. It is a time efficient way of obtaining data as the pre-determined questions require very little to no thinking on the spot and make the whole process quicker and suitable for more than one interviewer or ones with little experience. Keeping track of certain data can be made easier such as scoring or keeping count which can help identify trends and create datasets. Structured interviews will most likely always provide the desired information as they are premeditated questions focusing on a certain topic, this will help gather relevant

data quickly. Structured interviews will result in clearly documented results which strengthens the transparency and accountability of the researcher and makes it possible to replicate the experiment or interviews word for word in a different context such as a new company.

Shortcomings of structured interviews may be their rigid nature, which does not allow improvised questions during the interview process and thus can result in only scratching the surface of certain, more complex topics that may be related to the study. Since there are no opportunities for the interviewer to improvise and dig deeper, the participants might get away by giving socially acceptable answers, perhaps that will make their company look better and won't engage fully in questions that may highlight the shortcomings of a company.

An observation diary will also be kept gaining further insight into the performance of the machinery, their actual usage, and the conditions in which they are being used. The observation diary will include the specific equipment observed e.g. conventional plough, cultivator, disk harrow or the model of tractor used for the implement. The condition, usage pattern, operators' interaction, failures and challenges and the effect of environmental factors on the performance of the machine will be noted too alongside other useful information.

An observation diary can provide insights that other, more structured collection methods might not be able to show, such as the environmental factors or the way they interact with the machinery and its operators. Through documenting and noting down observations the researcher can further increase their understanding of the problems in the study and may recognize anomalies, patterns and changes easier. As opposed to the previously discussed structured interview, and observation diary allows the researcher to improvise and shift the focus from one topic to another as they become more relevant in the changing real-world setting, this will allow for more in depth understanding of complex problems and topics as well as widening the original focus of the observation. An observation diary often promotes self-reflexion, leading to the researcher reflecting on their own thoughts and reactions, making the research more credible by realizing the influence of the researcher on the data. This data collection technique is minimally disruptive to the research and allows the observer to keep track and collect data without disturbing the flow of activities done in experiments.

This method has its shortcomings as well, most of it depending on the observer themselves. The data is bound to be heavily influenced by the researcher's perspective of the whole subject and any interpretations may be biased. The unstructured nature of the observation may also lead to the researcher missing out on important information as their attention or focus is on

something else during the observation. Depending on the duration of the observation, it may be too time consuming and labour intensive. It is a serious commitment on the part of the researcher. It can also be difficult to keep track of a large volume of qualitative data due to the improvised nature of the observation diary, this can cause difficulties in organizing and managing the data in later stages. An observation diary may be very useful and filled with data but is specific to a company or a group of workers with specific machines and due to this it is very limited in its usefulness in generalizing the findings to others and is almost impossible to replicate in new trials with a new observer.

Secondary data collection

Access to company records like maintenance logs and other performance metrics will help establish a baseline figure in various categories and identify any trends and patterns. The use of industry reports, academic journals and competitor analysis will be considered in measuring the efficiency and effectiveness of the company against the Hungarian and world standards, highlighting the best equipment suited for modernization.

Confidential insights might prove to be a hardship as restricted or partial access can slow down the data collection process. Internal documents might be influenced to only show certain positive types of data which can skew the results of the research.

Industry reports help benchmark a company's data against industry standards and discover trends and patterns, they're a reliable source of information as they are mostly written by professionals, experts and credible organizations. They provide a broad perspective and often include reports and data from many different companies giving an accurate and comprehensive overview of the whole industry. Most reports also include forecasts too, predicting areas of developments and future trends.

Academic literature is peer reviewed before publication which increases its credibility and reliability. They are a time efficient method of collecting information as the data is already gathered and analysed, saving the researcher valuable time.

Industry reports and academic literature are great ways of obtaining relevant information however they can be too generalized as they provide data that is true for the entire industry or a large segment, lacking specificity to the issues of the research is a major drawback. A generalized report can often overlook the problems faced by smaller companies. Data from these reports can be too much in terms of volume and make it hard to find the relevant pieces

and sometimes the information is presented in a very complex way which might require a higher level of understanding the topic.

Processing and analysis

The processing of qualitative data will start with the transcription of structured interviews. Spoken words will be converted into writing, word for word. This step is key, ensuring that all details are recorded for further analysis. The interviews will be organized by interview questions, so that every participant's answers can be compared to each other's, and any trends or tendencies can be highlighted. It also makes it more manageable to handle this many data.

The observation diary will require time to read through and the specific information needed for further processing will be highlighted.

Overall, 3 main groups of qualitative data will be highlighted:

- Comments related to the core themes and research question.
- Themes related to broader categories for example: "State of current machines" or "Training amongst employees"
- Key phrases and ideas expressed by the participants to help recognize patterns.

Using the above-described coding system is key in identifying themes and patterns throughout the responses of the participants. It can show similarities or differences that help to understand the difficulties and underlying problems of the company.

After highlighting and identifying patterns, the results from interviews and observation diary can be compared and interpreted together, making it easier to process all the gathered information even if they were collected through different techniques. A coherent narrative will be used in reporting the processed information which addresses the research question of the study.

Quantitative data processing and analysis will use descriptive statistics to describe different features of the data, for example: average fuel consumption or standard deviation of production volume. Visual representation of the past figures compared to the predicted future figures will be shown as graphs, highlighting the benefits of modern machinery.

Cost-benefit analysis

A cost-benefit study looks at the expected costs and benefits of a project choice to see if it makes business sense. In general, cost-benefit analysis includes adding up all the things that a project or decision will cost and then taking that number away from the total amount of good things that the project or decision is expected to do. This number is shown as a ratio sometimes. You could say that the choice is a good one if the expected rewards are greater than the costs.

A business might want to rethink the choice or project if the costs are higher than the benefits. Running these kinds of studies before making big decisions about an organization can save a lot of money. By analysing, you can find important details like the value chain of your business or the return on investment (ROI) of a project. Cost-benefit analysis is a way to make decisions based on facts that is most often used in business, both at large companies and small startups. The general ideas and structure can be used for almost any kind of decision-making, not just business-related ones.

The project in focus is the purchase of new machinery and equipment. There are two main reasons for this.

1. Many of the current machines have considerable machine hours and are not up to date, this includes the machines themselves, or the equipment used on them such as antennas, displays/monitors which limits the companies' abilities for any future strategic innovations regarding precision machinery.
2. The expansion of the company's territory of arable land mentioned in the introduction calls for an increase in machinery and workforce as well. It is crucial to be able to efficiently use the additional land to make this expansion successful.

This lines up perfectly with strategic goals of Mezőfalva, increase in overall production will help them retain their position as the largest and most innovative agricultural company in the region.

Goals and objectives

There are several key goals and objectives in this project to improve the overall productivity and success of the company. All these goals are interconnected and related to each other, an improvement in one area might result in the improvement of another however they all need to be accounted for and planned separately as without preparation for each stage the whole developmental process might fail.

Operational efficiency is the largest and most important aspect needed to be improved; without an efficient workflow such a large business cannot operate to its maximum capabilities. The objective is to upgrade and improve the machines of the company which limit the efficiency of work being done. They need to perform tasks as fast as possible with precision and consistency. The goal is for the company to cover more land area in less time and using less resources in field operations such as sowing, tillage, spraying or harvesting.

An example for an upgrade of current machines is to change the John Deere SF3000 series receiver on a younger tractor and implement a newer SF6000 model for more precision and better consistency.

A positive consequence to upgrading the machinery will hopefully be improved yield. Selling the harvested crops is one of the main income sources of the company. The goal is to utilize precise machinery and apply inputs efficiently, guaranteeing optimal resource utilization. The objective is to optimize agricultural output potential by guaranteeing that every section of the field receives the precise quantity of inputs required, hence minimizing waste.

An optimization of precision agricultural production will reduce input costs. The overuse of fuel, fertilizers and pesticides are a big part of expenses of any agricultural business, lowering the input costs while keeping the target yield is the aim of optimization. This will be achieved by optimizing the strategies and synchronizing the equipment and use section control capabilities which will decrease overlap and the resulting waste from overlap spraying as an example.

Results

Mezőfalvai Zrt has been established in 1992 following the transformation of the previous form the company called Mezőfalvai Agricultural Manufacture. The predecessor company, established in 1977 was the result of a merger between the Mezőfalvai State Farm, Nagyhörcsöki State Farm and the Kecskemét Poultry Processing Company and Nagyvenyim Poultry Farm. All the previously mentioned agricultural companies have been a result of smaller producers merging, resulting in a large but segmented area of arable land and pastures in the company. (*Mezõfalvai Mezõgazdasági Termelõ És Szolgáltató Zrt.*, n.d.)

Table 1

Table 1 presenting area and usage of land owned by Mezőfalvai Zrt. in hectares. (Students own work)

Usage	Area (ha)
Arable land	4227
Pasture	1522
Forest	48
Non agricultural	441

Much of the land can be described as flat land with no significant hills or valleys. There are many soil types to be found throughout the company's land, but the most common ones are Chernozem soils. (*Mezõfalvai Mezõgazdasági Termelõ És Szolgáltató Zrt.*, n.d.)

General information regarding the company for the 2023 fiscal year (Opten, n.d.):

- Net sales: 1,06M EUR
- Listed capital: 425 000 EUR
- Number of employees: 86

Table 2

Table 2 presenting the current tractor and harvester inventory and their most important specifications of Mezőfalvai Zrt based on observation diary. (Students own work)

	Number owned	Model year	Engine hours	Fuel efficiency (l/h)	Horsepower	Receivers	Display
JD-6170R	2	2014	11,840 / 9065	34,3	170	SF6000	GS3
JD-6175R	2	2018	6996 / 6221	35	175	SF3000	4600
JD-6R215	2	2022	1792 / 1742	41.8	215	SF6000	4600
JD-7270R	1	2014	13,600	52.8	270	SF3000	GS3
JD-7290R	2	2014 / 2017	9810 / 8462	54.5	290	SF3000	4600V2
JD-8345R	3	2015	12 781 / 11 858 / 12 624	66.1	345	SF3000 / SF3000 / SF6000	GS3 / GS3 / 4600
JD-8R340	1	2021	5185	64.7	340	SF6000	4600
JD-9300	1	2000	20 000	69.9	354	-	4640
JD-9RX640	1	2023	1087	74.9	640	SF6000	4600
Claas Lexion 8800	1	2022	5025	-	610	-	-
Claas Lexion 670	1	-	-	-	-	-	-

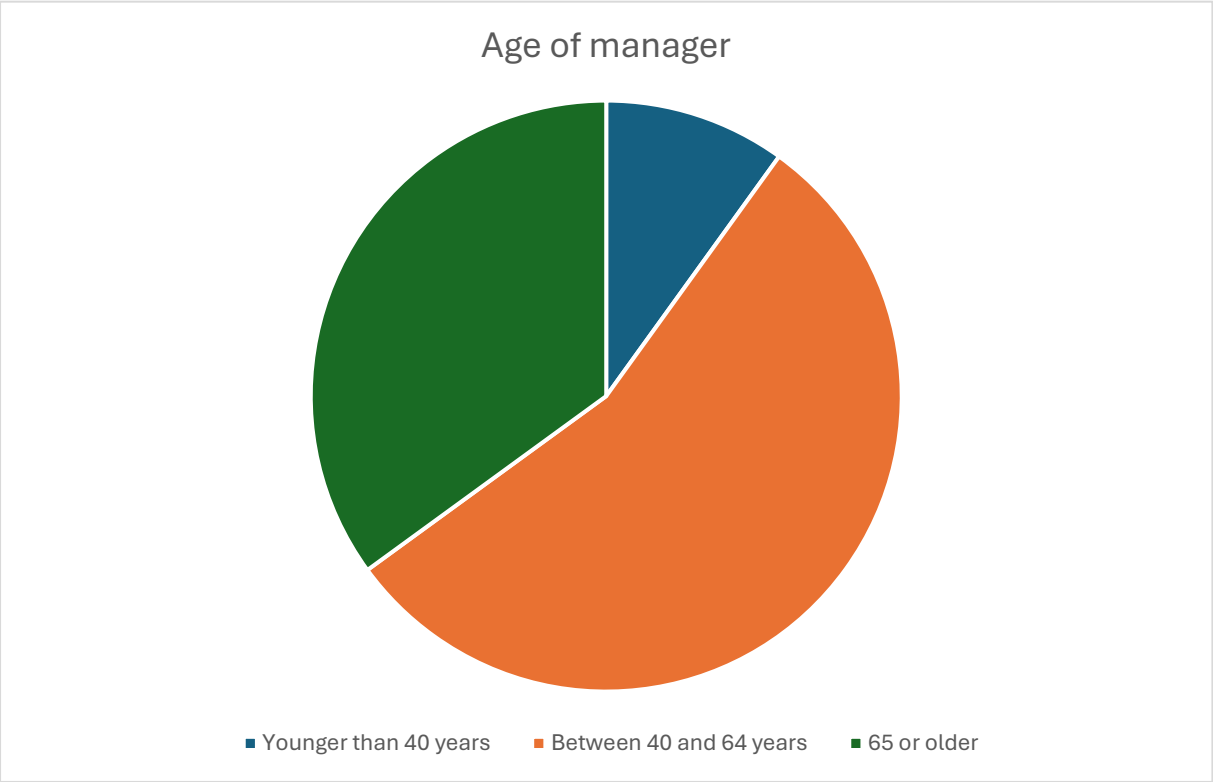

Figure 4 Pie chart presenting ages of manager of operations at Hungarian agricultural companies. (Own editing based on KSH 2020)

Discussion

State of current machinery

To create a realistic and successful innovational strategy it is elementary to assess the state of a company before investing capital and manpower into a project. In this case the number of machines, make and model, condition and various other parameters have been carefully studied which lay the foundation for the development strategy of the company.

Based on Table 2 we can calculate the average age of the machines and engine hours as well.

Average age: 7,5 years Average engine hours: 8630

The main findings through the company interviews (Appendix 1) have mostly described a modern fleet of machinery. The interviewees were all workers of Mezőfalvai Zrt. and have described the state of the machines and commented on the technological relevance of the tractors, implements and combines of the company. The company has used many different brands of tractors and combines in the past but as of now they almost exclusively use John Deere machines to "ensure uniformity". The only official retailer of John Deere in Hungary is Kite Zrt.

In detail the managing personnel have described the capability of the machines to be modern and up to date, one of them stating the "mechanical background is approximately 90% ready for the implementation of PA". Another manager described the attitude of the company towards PA as "Innovative and ensures advancements" and highlighted the advantage their company has over local competitors due to their "more technologically advanced, higher performance and younger" machines. A pilot of the tractors and combines has further supported this by stating "The machines are sufficiently up to date in terms of precision technology" however has expressed concerns as well.

When describing the attitude of the company towards innovation he said, "Not too innovative, there's old machines with many engine hours" and describing the implements in a similar manner saying, "It doesn't matter if a tractor has 640hp if the implement like the disk harrow is weak". While content with the state of the combine harvester there was criticism regarding the front end equipment as well "The corn header is basic, it doesn't follow the ground and has to be steered manually" this refers to the corn header not having a plastic piece on the underside which can be calibrated to a specific height which helps the pilot just place it straight on the

ground without damaging the implement and it will follow the physical changes on the surface of the land keeping the same height everywhere. Another pilot added to this saying, “This is the only corn header currently.”

In conclusion the interviewees have described an up-to-date inventory for the company, but when cross referencing this information with the findings of the observation diary, the results vary even more. In table 1 the model years and engine hours of the machines are presented. It shows 6 tractors with engine hours over 10,000 and 3 additional machines having over 8000 engine hours. Frequent use contributes to higher wear of the engine and can result in engine failure earlier than needed however this alone does not provide enough evidence of the condition of the machines. Another key factor to consider is the model year. 9 tractors have a model year of 2017 or earlier which is a key date as one of the managers mentioned in the interview that “after 4 years electronic problems start to appear and after 7 years major faults such as engine, bearings and chassis failures tend to happen”.

Considering this information the technological relevance of the machines portrayed by the employees, especially the managing positions must be reassessed for more accurate description. While they may still work and be without serious service problems, the average engine hours and the average age of the machines represents a fleet that is more heavily used than previously described and will most definitely be prone to serious mechanical faults than younger machines.

Training amongst employees

The employees working with the machines and implement the strategies are a key part in the chain of execution as they are the link between the senior partners making decision and devising various strategies to better the production and the farmland where the actual production takes place. In PA the correct usage of the machines and perfect execution is essential so that the small increments of changes in input can truly make a difference, however it may not always be so simple, due to the complexity of modern machines. The cockpit and user interfaces are made to be as user friendly as possible, but the number of different functions and complexity of the machine itself can be overwhelming to both new drivers and veterans as well.

A lack of proper training and education has been a recurring theme and has been mentioned or identified in 7 different occasions throughout the interview and observation diary. A manager has stated in an interview that the limitations in introducing new machinery “May be limited

knowledge from either or both the retailer side or driver side. Lack of ability and training is what makes them afraid of new machines". This is a concern for the company as they need to know that they can rely on workers with good abilities who can problem solve on their own as these machines require regular maintenance and may have small problems regularly. He did mention that most of the workers are trained well enough and are only concerned about new and unknown technology until they get to familiarize themselves with the equipment. "Employees may be scared from new technology. It usually lasts until they get familiar with the new machines" Towards the end of the interview when asked about recommendations for the future he said, "The machines don't have to be developed anymore instead the people need to be educated more". This statement further strengthens the idea that the workers in the company have issues with training and qualifications.

A lack of proper training can lead to organizational issues and an overall decrease in efficiency. The company currently owns one 9000 series tractors which is the most technologically advanced and largest performance vehicle in their current line up and have another one on the way to the company. If there are not enough pilots to drive both these machines at the same time, then the high performance of the machines cannot be utilised simultaneously. According to a tractor and combine harvester driver, this indeed is the case. "There are few trained people, only one RX tractor can be driven at a time." Said the driver, and when asked about their training he replied, "Training is needed, separate ones for GPS and other small bits"

In conclusion, employees play a crucial role in the chain of execution in PA, as they link senior partners in devising strategies to improve production and farmland. However, the complexity of modern machines can be overwhelming for both new and experienced drivers. A lack of proper training and education has been identified as a recurring theme in interviews and observations. Managers have noted that limited knowledge and fear from new machinery can lead to employees being afraid of new machines. This is concerning as these machines require regular maintenance and may have small problems. The company's 9000 series tractors, the most technologically advanced and largest performance vehicle, require multiple pilots to drive simultaneously, affecting efficiency.

PA strategies

Precision agriculture requires a thorough analysis of the environment to be implemented successfully. Techniques such as soil sampling is a standard procedure in collecting accurate and informative data regarding the soil properties. Data collected will then be used to formulate

the correct strategy for maximum efficiency. The data is analysed by PA advisors who need to use the modern technology to their advantage, using e.g. prescription maps which allow for implements capable of variable rate application to work with minimal effort from the driver and therefore reducing error.

During the interviews the head of plant production has discussed the importance of knowledge of the soil properties. “In the old days the farmers knew their land well, and over many generations they discovered which crops grow well in which parts of their property”. Another manager further supported this by stating “Useful information is being produced by the machines, it allows us to anticipate the future”. Highlighting the importance of collecting data of your own field. The unique property of the soil needs to be synchronized to the machines so any harm can be avoided. Machines can be put to unnecessary strain under the wrong conditions and the soil can also be damaged if the equipment isn’t suitable for it. “You must harmonize the implements to the machines and to the soil. They can cause severe problems in each other”.

The performance and technological capability of the machines is not the only important aspect of PA and alone itself is almost worthless. Strong software background is needed to unleash the full potential of high-tech machines. A manager level employee has mentioned that from a mechanical aspect the company is 90% ready to implement PA strategies, the software background is only 20% there. “Mechanical background is approximately 90% ready for the implementation of PA, implements are 60% and software 20%” Without the correct software background, a company cannot execute PA to its full extent.

While corn harvesting, the pilot could not use automated steering as this feature was not activated on the machine. Using activation keys, the manufacturer can give access to features of the machine, like automated steering or row sensing. Another missing piece was a prescription map, which can be made for the harvest to make it as efficient as possible. The machine can follow the exact path programmed into it using RTK signals and in case of a John Deere machine it will have a deviation of about an inch. This feature relieves the stress and strain on the driver and increases his workload significantly during a long day of harvest. After the harvester’s grain tank filled up completely, the driver had to carry the grains to the stationary cart on the side of the crop field and emptied it there. This is a large strategical inefficiency which leads to extra downtime. (Observation diary) “Reducing downtime, due to service or any other factor”.

When asked about tillage and sowing strategies a driver explained that the current system favours simplicity and ease of execution over efficiency much like in harvesting. “There were no combined operations during soil preparation and sowing. There was a separate pass made for deep ploughing, disking and rolling, seedbed preparation and sowing and nutrient supply.” Execution of different operations in separate passes is simpler but increases fuel costs, downtime and takes longer.

Environmental aspects

When working in agriculture, special attention must be paid to the environment. Not only does the state of the surrounding vegetation give us feedback of our field but it also needs to be kept in mind that for the harvest to be prosperous in the future it must be taken care of. The use of excessive fertilizers, pesticides and continues disturbance of the soil all have a negative impact on the soil. PA aims to minimize these negative side effects while decreasing the costs of the farmer.

According to the crop production manager, minimal attention needs to be paid to environmental aspects regarding the machinery as they already meet the standard environmental provisions straight from the factory. Their efforts align well with general environmental safety efforts and do pay attention to minimize damage. “These machines take part in biological and productional processes, it is natural that we want to keep pollution to a minimum”.

A different employee highlighted that the plans and innovations at the company are minimum tillage and no tillage strategies to decrease soil erosion and increase organic matter content. “Innovations to consider are direct sowing implements to develop the min till and no till systems, they improve the soil”. When asked about the future of agriculture he further supported his statement by mentioning these as the undisputed systems for sustainability. “Min till, no till and drones will be the most important technologies in the future. Not only are they a still developing segment in agriculture but they have the potential for great sustainability too”.

Machine operators also shown a positive attitude towards waste reduction. They try their best to keep the fields clean and think of ways to reduce pollution. “I think new machines come with more efficient engines, and maybe if we don’t separate operations then we burn less fuel”.

In conclusion, every employee interviewed showed a positive attitude towards environmental sustainability and to some extent everyone pays attention. According to the knowledge of the

interviewees the wildlife is not harmed during their operations. Companies producing the machines also oblige to standards and perhaps have a bigger impact on sustainability efforts than the employees, by producing more efficient and less polluting engines.

Table 3

Summary table of cost benefit analysis showing current expenses, new expenses of investment and net value of these expenses. (Appendix 3)

The prices of used equipment have been evaluated in Hungarian forints and have been converted to euros by multiplying it by 400.

Type of cost	**Current**	**New**		**Net Value**
Purchase cost of new machinery	0	1 258 200		- 1 258 200
Used value of previous machinery	55 375	0		+ 55 375
Installation and training	0	0		0
Maintenance (3 years)	300 000	7200		+ 292 800
Fuel consumption (3 years)	896 418	828 693		+ 67 725
Labor costs savings (Annual)	0	3480		+ 3480
Downtime reduction (Annual)	0	84 000		+ 84 000
Salvage value (End of life)	0	553 669		+ 553 669
Net benefits				- 201 151

Cost-benefit analysis

The costs:

- 2 John Deere 8R280 to replace the 7290R tractors
- 1 John Deere S7 900 harvester combine
- 1 RDF 35 header for the combine
- 4 John Deere SF 6000 receiver

The costs of the new machines were provided by a professional who works as a distributor of John Deere products. (Appendix 3)

The benefits:

- Used value of current redundant machinery (Appendix 3)
- Lower maintenance costs
- Lower fuel consumption
- Lower labour costs
- Downtime reduction
- Salvage value of new machinery in 5 years' time

The costs and benefits of the project have been estimated for a 3-year period as the crop cultivation manager described a development plan as a 1–3-year project. Used value of the current machinery was provided by a professional who works as a used machines appraisal and salesperson at a John Deere distributor. (Appendix 3) Maintenance costs have been estimated by mechanics who work for John Deere service and have knowledge of the state of the machines from table 1. Fuel consumption, labour costs and downtime reduction are subjective estimates based on the specifications of the machines on the official John Deere website and the observation diary kept throughout the company visit.

The net benefit is calculated by subtracting the total costs from the total benefits. The net benefit is generally considered acceptable if it is a positive value, however this is not always the case.

Net Benefits = - 201 151 euros

Conclusion

Theme 1: State of current machinery

By analysing the current limitations and challenges faced by Mezőfalvai Zrt. in terms of precision agriculture, the thesis has shown how employee training and investment decisions have influenced the operations of the company.

The thesis analyzes Mezőfalvai Zrt.'s precision agriculture operations, revealing that the company's heavily used fleet of machines is outdated and equipped with obsolete technology. The study suggests that the company should focus on automated capabilities, prescription maps, and software strategies to reduce wastage. Employees also express concern about the outdated machinery, with increased service frequency leading to downtime and decreased efficiency. The study suggests that investing in new machines may be more cost-effective than fixing old ones, as workers complain about the implements in similar conditions.

Theme 2: Lack of training amongst employees

The correct usage of machines and perfect execution are essential, but the complexity of modern machines can be overwhelming for both new and experienced drivers. A lack of proper training and education has been identified as a recurring theme in interviews and observations. Managers have noted that limited knowledge and fear from new machinery can lead to a negative mindset when upgrading the machinery. The company currently owns one 9000 series tractors, the most technologically advanced and largest performance vehicle in their line up, and another on the way. If there are not enough pilots to drive both machines simultaneously, the high performance of the machines cannot be utilized simultaneously and will increase downtime overall.

The advanced features of modern equipment cannot be utilized to its maximum efficiency if the operators are not able to learn its features and how to control them. As shown in Figure 4 a considerable number of managers in Hungarian agricultural companies are in retirement age which could be correlated to resistance in innovation especially towards the adoption of new technology. Training the for the operators should be considered for the company. Organizing such seminars would increase the self confidence of operators and their knowledge of new technological advances which may benefit the company greatly, increasing production and efficiency.

Theme 3: PA strategies

A strong software background is needed to unleash the full potential of high-tech machines. Mezőfalvai Zrt. is 90% prepared from a mechanical perspective for the implementation of PA, but only 20% ready with the correct software background. This is the largest weakness of the company that has been identified in this research paper. A prescription map could make the harvest more efficient by following the exact path programmed into it using RTK signals however this is not part of their strategy yet.

The current system favours simplicity and ease of execution over efficiency, as there are no combined operations during soil preparation and sowing. This leads to increased fuel costs, downtime, and takes longer. To reduce downtime, it is essential to harmonize implements to the machines and the soil, as they can cause severe problems in each other.

Reflection

The structured interviews have provided the most useful data for the study and proved to be a key part in the research methodology. While the opinions of employees can provide with new information into the company, the conflicting answers given by different workers can cause issues while interpreting and analysing the data. It also clearly illustrates the varying insight that different employees have on the operations of the company.

A well-structured interview can focus on questions important to the study that managing employees may want to avoid or hide in case of an observation diary or when giving a tour of their facilities. Such questions in the case of this research paper include the weaknesses of their equipment and others regarding service issues and the overall technological relevance of the company. Unexpected insides arose when the managers have described their fleet to be comprised of young machines, but their own data refuted this statement.

While the observation diary gave little data that was also provided by the interviews it also gave unexpected insights that proved to be essential when making recommendations for improvements. An improvement made for the observation diary could be made, instead of conducting the interviews and the observation diary on the same day, two separate occasion could be arranged just for the observations, one for sowing and one for harvesting to see in person the exact use of the machines and not just rely on the objective opinions of the employees.

A difficulty was finding accurate data and national statistics specifically referring to machinery and equipment used in agricultural companies. In a future study rather than relying on secondary data collection methods to compare the researched companies' fleet to separate primary research should be carried out.

A weakness of the research has been the lack of ability to compare strategies and machinery of Mezőfalvai Zrt. to their local competitors. Comparing to standards and general data may be misleading due to the core idea of site-specific management as land varies greatly across a country. It is important to highlight certain aspects a competitor would need to have to make it a fair and useful comparison. Only a local competitor with similar or the same soil type, size of land owned, number of employees and number of machines owned would benefit the study as it could further support development decisions and even highlight weaknesses in the strategies.

Development recommendations

Based on the data analysed the following recommendations should be considered by Mezőfalvai Zrt to gather funds for new machines.

Sale of tractors with high engine hours, namely:

- 2x 6170R
- 1x 7270R
- 2x 7290R
- 3x 8345R

The operations previously done using the 8345R tractors like ploughing and sowing can be done by the much newer 8R340 and 9RX640 tractors while any operations done by the 7000 series can be replaced by either the newly recommended 8R280 which are suitable replacements for field operations like soil tillage, however if they require smaller tractors for smaller jobs around the company grounds the already owned 6R215 are much more applicable for around the farm towing work.

Important strategical recommendations also include the investment into hiring a precision agricultural advisor who can help modernize the site-specific management related issues such

as evaluating and recording the data of the fields used for crop production and can design prescription maps to automize the sowing, fertilizing and harvesting done by the company.

The recommendations given may significantly improve operational efficiency if adapted correctly and directly address the limitations of Mezőfalvai Zrt. Future studies could address the difference in production between the current and the recommended improvements to further evaluate the returns of the investments. Further research is needed to determine the overall success of a long-term development plan.

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List of figures and tables

Appendix 1

This appendix contains the questions asked in structured interviews and the responses of the participants which were directly quoted in the discussion section of the research paper.

Questions

1, Intro

a) Describe your role in the company and your experience with agricultural and precision machinery?

b) Explain your understanding of the company's current state of agricultural and precision machinery?

c) Describe the company's overall approach to technological innovations and modernization?

2, Current machinery

a) What is the key strength of current Machinery?

b) What are the most significant limitations of current machinery?

c) How does the current performance of machinery compare to the market/competitors/industry standard?

3, Operational efficiency and Productivity

a) Describe the efficiency of current machinery in terms of energy use, maintenance, productivity.

b) Describe the most common operational issues of your machinery.

c) Can you give an example where machinery efficiency has directly impacted production outcomes?

4, Maintenance and Reliability

a) How often do current machines require maintenance and what are the approx. costs?

b) Have you noticed any trends in machinery failures over time?

c) What is your opinion on reliability of current machines in different weather and soil conditions?

5, Potential areas for modernization

a) In your view, what are the top priorities for modernizing the company's agricultural machinery?

b) What technological advancements do you think could be integrated into your machinery to improve performance?

c) Are there any specific features or capabilities that you believe would benefit the company if they were added to the machinery?

6, Implementation of new machines

a) If a prototype of modernized machinery were developed, what performance indicators should be measured to evaluate its success?

b) What challenges do you predict in the implementation of new machinery technology within the company's current operations?

c) How should the company approach the testing of new machinery to ensure it meets operational needs?

7, Cost-Benefit Considerations

a) How may the company balance the costs of modernization and the expected improvement in efficiency?

b) What financial or operational risks do you associate with the modernization process?

c) How do you believe modernization could impact long-term profitability and sustainability?

8, Stakeholder feedback

a) How important do you think it is to involve different stakeholders (e.g., operators, management) in the modernization process?

b) What are the best ways to gather and integrate feedback from machinery operators into the modernization plans?

c) Have you observed any resistance to change among stakeholders, and if so, how might this be addressed?

9, Ethical and Environmental Considerations

a) What ethical considerations should be considered when modernizing agricultural machinery?

b) How can modernization efforts align with environmental sustainability goals?

c) Are there any concerns about the impact of new technology on the workforce or local wildlife?

10, Conclusion and Recommendations

a) What are your top three recommendations for successfully modernizing the company's agricultural machinery?

b) What potential future trends in agricultural machinery should the company be aware of?

c) Is there anything else you would like to add regarding the modernization of the company's machinery?

Answers

Interviewee 1

Question

1

a) “I am the crop production manager at Mezőfalva. We operate on 6400ha currently and I am involved in anything and everything from planning to execution, investments and plant protection.”

b) “Mezőfalva is in the beginning stages of PA overall. Mechanical background is approximately 90% ready for the implementation of PA, implements are 60% and software 20%”

c) “Open to innovations but carefully. Investments involving many hundreds of millions (HUF) require much caution.”

2

a) “They’re high quality, John Deere machines.”

b) “It is very important to have a reliable and quick service background provided by the retailer as service is an issue in modern technology. 30% mechanical and 70% electronical failures.”

c) “Our machines are just as good or better than those of our competitors. Service support gives brands an edge over another. Each brand and model have its advantages and disadvantages.”

3

a) “You must harmonize the implements to the machines and to the soil. They can cause severe problems in each other. We try to achieve maximum efficiency in our case.”

b) “Major issues include damages from wear and tear in general, worn-out bearings in dry conditions especially, elements become loose and start to move around. Some electronical issues as well.”

c) “Machines alone don’t directly affect production.”

4

a) “Daily or weekly maintenance needed. We try to keep the costs to a minimum, applying grease and cleaning.”

b) “Productional issues are the ones to show first, then model specific problems. After 4 years electronic problems start to appear and after 7 years major faults such as engine, bearings and chassis failures tend to happen.”

c) “Weather and soil conditions do not influence reliability. Our machines are reliable even under heavy workloads.”

5

a) “Price to performance ratio must be optimal. New machines should be universally usable and easy to operate.”

b) “Reducing downtime, due to service or any other factor.”

c) “-“

6

a) “Efficiency. From fuel, input to production aspect.”

b) “May be limited knowledge from either or both the retailer side or driver side. Lack of ability and training is what makes them afraid of new machines.”

c) “Ask for a demo machine and try it in their own fields.”

7

a) “This is a huge investment; the costs and benefits can not be measured in short term. If they don’t break down completely in 4 years and somehow increase efficiency.”

b) “Mostly financial risk, it is what drives every decision.”

c) “It has a long-term impact on profitability. Hard to sustain this.”

8

a) “This process is based on demand. The branch director decides on most of these investments. The most experienced drivers are involved to some extent. It is a long-term strategy and takes 1-3 years to execute.”

b) “Ask about their experience. Monitor the life cycle and data of the machines. It is also important to ask other farmers about their experience.”

c) “There is no resistance from the major decision makers as it is their choice, employees may be scared from new technology. It usually lasts until they get familiar with the new machines.”

9

a) ” They already meet the standard environmental provisions straight from the factory.”

b) “These machines take plart in biological and productional processes, it is natural that we want to keep pollution to a minimum.”

c) “Not at all”

10

a) “Handle budgets efficiently.”

b) “Autonomy is the future, less and less manpower will be used.”

c) “The machines don’t have to be developed anymore instead the people need to be educated more. In the old days the farmers knew their land well, and over many generations they discovered which crops grow well in which parts of their property.”

Interviewee 2

Question

1

a) “Agronomical manager.”
b) “Useful information is being produced by the machines; it allows us to anticipate the future.”
c) “Innovative and ensures advancements.”

2

a) “We have almost exclusively all John Deere machines to ensure uniformity. It is a key strength.”
b) “Complexity of electronics is a huge limitation; it requires serious service hours if broken.”
c) “We have more technologically advanced, higher performance and younger machines.”

3

a) “They’re great, we put a lot of emphasis on efficiency.”
b) “Electronic faults and human errors.”
c) “Not a specific example, but you can always be more efficient.”

4

a) “Daily, weekly, monthly and big services are all done when needed for the specific machines.”
b) “8345 for example needs to be sold after 10 000 engine hours. 8800 towards the nose, bearings can heat up and burn due to friction.”
c) “Reliability is dependent on the kind of work done by the company; mechanics do all they can to maintain the reliability.”

5

a) “Modernizing some tractors, the work we do is built around them. Ahigh quality direct sowing machine is also important.”
b) “Having multiple operations done in one pass while preparing the soil or sowing.”

c) “Right now, any new features wouldn’t help as much as making our current strategy more efficient with our current machines.”

6

a) “Production numbers, its long-term effects on production and overall efficiency.”
b) “Correct installation and any new model specific issues.”
c) “Ask farmers about their experience with the specific machine and potentially have one on loan to try.”

7

a) “Investments are risks, we must be very certain the improvements will increase outputs. In case of uncertainty try to look for other options.”
b) “The company runs the risk of making a loss.”
c) “Absolutely positive on the long run if implemented correctly. Future proofing is key.”

8

a) “It is almost exclusively up to management. Drivers and operators get little to no say in these decisions.”
b) “Machine performance is monitored through software.”
c) “Our workplace is innovative and ensures advancements.”

9

a) “We completely adhere to all ethical rules.”
b) “Always try to be clean and sustainable where possible.”
c) “No.”

10

a) “Profitability so you can continue to work. Compatibility of machines to the work environment and being open to innovation.”
b) “Innovations to consider are direct sowing implements to develop the min till and no till systems, they improve the soil”.
c) . “Min till, no till and drones will be the most important technologies in the future. Not only are they a still developing segment in agriculture but they have the potential for great sustainability too”.

Interviewee 3

Question

1

a) “I am a tractor driver and combine operator.”
b) “Not too innovative, there’s old machines with many engine hours”
c) “New machines every once in a while.”

2

a) “The new RX is comfortable and powerful.”
b) “Implements. It doesn’t matter if a tractor has 640hp if the implement like the disk harrow is weak”.
c) “Strong compared to competitors.”

3

a) “In general, the efficiency is not bad, but the machines are getting old.”
b) “3-4000 engine hours in and many John Deere tractors show model specific issues.”
c) “Not really.”

4

a) “We clean them and grease the moving parts before every use.”
b) “The technology is too complicated for some drivers.”
c) “Same in all conditions, overall good.”

5

a) “Equipment needs to be changed more often in my opinion.”
b) “The corn header is basic; it doesn’t follow the ground and has to be steered manually.”
c) “Prescription maps and automated steering.”

6

a) “How often it needs to be serviced by mechanics. New machines might not require as much downtime.”
b) “Trainings should be organized by the company, it benefits everyone.”
c) “Try to demo it on the field, maybe during harvest.”

7

a) “I cant really say much about finances, I know the machines are expensive and its always a risk to buy them but at some point old ones need to be replaced, so get the best quality ones.”
b) “The operators might not know how to use new technology.”
c) “Modernization can lead to profitability.”

8

a) “They never ask the operators; this is not good.”
b) “Ask the operators and check the software for the data.”
c) “The team is good; they don’t usually show resistance.”

9

a) “We always try to pay attention to the environment, some people more than others.”
b) “No comment”
c) “No comment”

10

a) “More skilled operators, newer machines and training for some operators.”
b) “No tillage will be popular.”
c) “No.”

Interviewee 4

Question

1

a) “Combine operator. I operate combine harvesters and drive the tractors when necessary.”
b) “We have a pretty good inventory overall, the machines we have were the best ones at the time but now they are old.”
c) “Attitude is good, but they rarely get new machines.”

2

a) “They are not difficult to operate, except for the new RX. Some training is needed for most drivers to confidently use that. John Deere is a good brand.”
b) “They are old. Some of them don’t have the newest GPS receivers. Also, they are not used to their full extent, prescription maps are not used, and auto steering is not available on many of them.”
c) “I think we have more and better equipment than most around here.”

3

a) “They are old which affects their efficiency, but they do the job. Some machines require more and more maintenance now and it’s getting more expensive.”
b) “For rotating elements like a disk harrow, you can see significant damage after 1500-2000 work hours.”
c) “No comment.”

4

a) “Depends on what kind of maintenance. We do daily maintenance with tractors and harvesters while they are used. It’s very cheap. Some older machines require engine changes though, after 5 or 6 years maybe but it depends on the usage. Those get expensive.
b) “As mentioned before the discs.”
c) “They are reliable even in tough situations.”

5

a) “I think we have to sell old equipment and change to new ones.”

b) “I think we need to take advantage of auto steering and GPS technology. Our IT background is also weak. It needs to be used better.”
c) “All the previous.”

6

a) “How quickly it can do the same quality work as the previous machines. Like harvesting or fertilizer output. Usually faster is better.”
b) “Workers are good at using current machinery but don’t know how to use high tech machines that have a lot of complex displays and functions.”
c) “They need to use it for a harvest. Go to a demo event.”

7

a) “Usually with new technology they don’t make large investments in case it doesn’t work out. If it does, then they can buy more equipment. Its quite safe like this.”
b) “As I said before, the investment might make a loss instead of generating profit.”
c) “Its going to help for the future.”

8

a) “I think it would be good to involve tractor drivers because we know the equipment well, but they don’t consider us.”
b) “Check the data from harvest from previous years and talk to the operators.”
c) “No comment.”

9

a) “We always try to consider our environment. Avoid pollution, new machines have less polluting engines I think.”
b) “The company tries to minimize input so that aligns with environmental goals.”
c) “No.”

10

a) “Consider new technology, involve the operators in feedback process and change machines frequently.”
b) “Younger people are needed as operators, who can use technology well, it will maximize efficiency.”
c) “No.”

Interviewee 5

Question

1

a) “I am a ranch hand. I help around the company, like maintenance of machines or loading and unloading fertilizers etc.
b) “The machines are sufficiently up to date in terms of precision technology.”
c) “I think they are mostly open to innovation, but don’t change machines frequently.”

2

a) “We have high performance tractors, and they still do all the work we need them to.”
b) “The machines are old, they require a lot of service compared to newer models.”
c) “We have a larger inventory of machines than others in this area.”

3

a) “Downtime is increasing as the tractors are getting old and require longer and more frequent service and repair.”
b) “The biggest problems come from faulty electronics. Modern machines are capable of more efficient work and are technologically more advanced, but the addition of electronics increases the chances for issues.”
c) “No specific example.”

4

a) “Daily maintenance is required but bigger issues are also a concern.”
b) “Within a couple of years common issues show up in the driver cab and some minor electronical problems.”
c) “These John Deere machines are quite reliable, one of the best brands for sure.”

5

a) “Its very important to make use of the capabilities of the machines. Its not worth buying a new machine with auto steering available if it won’t be used.”
b) “New GPS receivers could be added to take advantage of prescription maps.”

c) “There were no combined operations during soil preparation and sowing. There was a separate pass made for deep ploughing, disking and rolling, seedbed preparation and sowing and nutrition supply.”

6

a) “Production data should be considered. It is a key aspect of business, so if the machine can increase production, it’s probably a good investment.
b) “There are few trained people, only one RX tractor can be driven at a time. Training is needed, separate ones for GPS and other small bits.”
c) “They need to borrow a machine and test it on company grounds to see if it can perform the way we need it to in the conditions we have.”

7

a) “It is not necessary to spend a lot of money, sometimes improvements to existing operations is enough.”
b) “Financial problems can occur if the investment doesn’t produce good results and our operators might not know how to use new technology and can also make mistakes while learning. There is a learning curve to this.”
c) “Modernization is key in this age. New machines will be needed for us, and it will have a positive impact for the future.”

8

a) “I think people who work with the machines should be asked for their opinions. We know a lot about these machines, but the data gathered on the computers can also tell a lot.
b) “Just asking everyone, almost like an interview and we can respond honestly about strengths and weaknesses of the machines.”
c) “Not really,”

9

a) “We don’t want to harm our surroundings, and we consider it while working. In general, everyone should pay attention to pollution and not disturbing the environment too if not needed.”

b) “I think new machines come with more efficient engines, and maybe if we don’t separate operations then we burn less fuel.”
c) “Not to my knowledge.”

10

a) “Step by step implementation of new technology, make sure they’re high-quality equipment and have a good service background.”
b) “The implementation of AI of course and automation.”
c) “No.”

Appendix 2

This appendix contains the observation diary made during the visit to Mezőfalvai Zrt. Information from this appendix was used in the results and discussions chapter of the research paper.

Observation diary

Date and time: 12th of September 2024 12:00

Location: Mezőfalvai Zrt., Mezőfalva-Nagysismánd, Hungary.

Observer: Fabio Fernando Zavaleta

Wheather conditions: Moderate sunshine. Congestus clouds visible, soil is slightly damp, optimal conditions for harvesting corn.

Machinery used:

Hawe ULW 3000 container truck.

6175R-Smaller John Deere tractor is seen pulling carts around the premises. Probably used for transporting containers with feed, fertilizers etc.

8345R and 8R340- Multiple 8000 series John Deere tractors are parked together with conventional ploughs beside them. According to the guide these tractors are used for ploughing the fields and sowing.

9300-Large tractor parked further from most other actively used equipment.

Claas Lexion 8800-Equipped with a corn header, harvesting corn on the field.

Condition of machinery:

6175R-In fair condition, signs of wear on the outside.

8345R-Had heavy wear on the outside, deep scratches on the paint. Plastic mudflaps showed wear as well.

8R340-Seemed to be in very good condition. No visible damages on the outside. Inside showed some signs of wear.

9300- Was covered in dirt and seemed to be out of operation.

Lexion 8800- Clean on the inside, driver cab was comfortable. No visible damages on the outside.

Level of equipment of the machinery:

6175R-Equipped with old receiver, SF3000 series. 4600 series displays.

8345R-Two of the machines had 3000 series receivers while one had a newer 6000 series. The machines with older receivers had older GS3 displays while the newer had 4600 display.

8R340-Had newer SF6000 receiver and 4600 display on the inside.

9300-Did not have a receiver and had a multifunctional 4640 screen.

Lexion 8800-

Agricultural strategies observed:

The operator of the combine had to drive manually. There was no use of automated steering. After each pass the driver had to return to the stationary ULW3000 which took between 1-2 minutes at best. After emptying the grain tank the operator could continue harvesting.

Employee skill level:

The skill level of the employee seemed to be more than sufficient. He was harvesting on the same field all day since early in the morning. Without the use of auto steering and prescription maps this takes a higher level of concentration.

Other comments: For my personal request the manager provided me with precise data regarding their fleet to complete my list. The following information was given to me.

- All the machines in their fleet and their model years
- Engine hours
- Fuel efficiency data
- Displays and receivers in the rest of the machines

Appendix 3

Appendix 3 consists of screenshots from email responses from professionals who have helped estimate the values of machinery in the research paper.

The prices of new machinery in euros. The prices should not be considered as an offer.

Szia!

Táblázatban találod a gépek árait (lista és eladási). A gépárak nettó €-ban vannak megadva, erre még az áfa rájön. A forintosítás az a fizetésnek megfelelően, történik (abban az esetben ha a partner forintban szeretne fizetni). Az adásvételi szerződés €-ban van megkötve!!

Gép típus	Nettó € listaár	Nettó € eladási ár
6R 175 univerzális traktor	237.715 €	182.626 €
6R 250 univerzális traktor	301.422 €	241.426 €
8R 280 nehéz szántóföldi traktor	351.322 €	286.452 €
8R 340 nehéz szántóföldi traktor	399.284 €	322.492 €
S7 900 kombájn	637.300 €	526.092 €
RDF 35 vágóasztal	148.100 €	121.204 €
SF 7000 antenna + RTK	11.350€	9.500 €

Prices of used machinery in HUF

Gépek

2db 2014 6170R - 11,840 és 9065 üzemóra – 20.000.000-21.500.000Ft + áfa (felszereltség függő, nagyon sok az óra bennük.)

1db 2014 7270R – 13.600 üzemóra – 24.000.000Ft + áfa (felszereltség függő, sok az óra.)

2db 2014 és 2017 7290R – 9810 és 8462 üzemóra – 26.000.000Ft + áfa, 28.500.000Ft + áfa

3db 2015 8345R - 12,781, 11,858, 12,624 üzemóra – 32.000.000Ft – 35.000.000Ft + áfa

+ SF3000 antennák érnek e bármit a traktorokon vagy külön.

Ezek a 3000-es antennák már régiek, illetve függ, attól is az ár, hogy milyen aktiváció van a monitoron. (SF1, RTK jel, szakaszolás, AutoTrac, Rowsense stb…) Nagyjánól a gépek ára itt mozog antennával együtt!

Üdv: Roli

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