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CONTENTS

The Use of Digitization in Small and Medium-Sized Agricultural Enterprises: Evidence from the Czech Republic

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Abstract. This paper presents the results of the research focused on the issues of digitization of agriculture in the context of current global developments and on the need to increase the amount of food produced in order to feed the continuously growing world population. The paper aims to analyze the use of the selected digitization tools in the crop production in the Czech Republic by small and medium-sized enterprises and to evaluate that from the economic point of view. To achieve the objectives, the desk research, the analysis and evaluation of secondary sources, and the method of directed interviews with managers and employees of the selected business entity were used. The research results evidence the positives and negatives of the use of the selected digitization tools within the crop primary production and represent the basis for further research aimed at the development of economic and financial management of small and medium-sized agricultural enterprises in the context of Agriculture 4.0 concept.

Keywords: Digitization, Drones, GPS, Smart agriculture, Agriculture 4.0.

1. Introduction

Agriculture has been accompanying mankind virtually since time immemorial and the last decades of social development have been associated with a massive technological development. Digitization has gradually permeated all fields and has not avoided the traditional sector of economy, that is agriculture.

In the 1980s, the concept of "precision agriculture" emerged, that is, farming with a focus on the individual approach to every single field and crop, with an effort to reduce the environmental impact of the activity itself [1, 2]. However, the then level of technology development hindered any major application in practice. With the further development of technologies (especially satellite navigation, the Internet and computer technology), many of the ideas of "precision agriculture" could have been implemented in the practical life of farmers. It is this introduction of 'smart technologies' that is often referred to as 'smart' or, as in the case of industry, '4.0'. Agriculture 4.0 aims to increase the use of robots and autonomous systems, and the extent and quality of data collection, processing, and their subsequent use (specifically GPS, drones, sensors, detectors, specialized software, etc.). Three principles underpin Agriculture 4.0: 'people, production and planet' [1, 3, 4, 5, 6, 7].

This article firstly shortly precents actual knowledge and studies focused on theoretical and practical implementation of digitalization principles in agriculture and briefly introduce situation in the Czech Republic focusing on small and medium-sized enterprises (then abbreviated SME).

Secondly presents methods which were used in data collection for this research. Results part is focused on using drones and GPS technology and their positives and negatives in practically agriculture (the crop production). A final summary follows with

limitations of research and opportunities of further research practical application of principles of Agriculture 4.0 in small and medium entrepreneurs.

The main objectives of the research are as follows:

- To evaluate the positives and negatives of using drones and GPS in crop production in the agricultural SMEs.
- To analyze the economic intensity of using drones and GPS technology in SMEs.
- To propose a reference costing for the acquisition of a drone in crop production.
- To discuss the barriers to the development of Agriculture 4.0 in SMEs.

The paper seeks to answer the following research question: "What technologies can Czech farmers use to obtain data on the crop development in crop production?" and also "Which of these potentially usable technologies is the most suitable and affordable one for a small agricultural entity?"

2. Literature Review

The issues of Agriculture 4.0 and digitization in the agricultural sector are addressed in general by, for example, Bollini et al. [5] or Zhai et al. [8]. This topic is being pursued across the entire world, as evidenced by the study of Kilavuz & Erdem [9], which examines the topic in Turkey, or, for example, the study of Luu et al. [10] from Vietnam. Agriculture 4.0 aims, among other things, to increase the production of agricultural commodities by 50% by 2050 in order to feed the planet´s ever-growing population. One concrete step is to extend digitization in agriculture, which means, for example, making use of satellite navigation systems to measure crop positions, the use of navigation in machines, the use of fertilizer application machines, automating harvesting operations and more. The overall aim is to reduce the workload of human machine operators and the associated error rate and diseconomy [11].

How do digitization trends specifically manifest themselves in the Czech agriculture in small and medium-sized enterprises? The Association of Small and Medium-Sized Enterprises and Sole Traders of the Czech Republic (abbreviated as AMSP CR in Czech) conducted a survey which shows that 8 out of 10 respondents can imagine specific elements and activities under the concept of agriculture digitalization. The research also shows that only 20% of the surveyed small and medium-sized Czech agricultural entities invest in robotic automation and digitization, and the same is true for production automation.

Another finding is that 64% of the agricultural enterprises surveyed use modern navigation systems, 59% use mapping systems, 54% use weather stations, and only 9% of farmers use drones. Based on the same survey, corporate entrepreneurs - corporate bodies - are more likely to invest in modern technologies than small entrepreneurs - natural persons. The survey was carried out among Czech small and medium-sized agricultural enterprises and self-employed persons [12]. The digitization of agriculture in the Czech Republic consists mainly in the use of GPS technologies or "smart machines" (e.g., digital milking, mapping of fields using satellites or aerial photographs, weather stations, sensors, etc.).

The benefits of these technologies in the agricultural sector include a reduction in the number of workers needed (In general, agriculture faces low employment attractiveness, especially among the younger generation.), a reduction in physical work, an increase in the volume of production and its quality, or an increase in the quality of data that are used as a basis for company decision-making [11, 13].

3. Data and Methodology

In order to achieve the set objectives, mainly the methods of qualitative research were used. In the first phase of the research, the desk research method was used to analyze and evaluate the secondary specialized, legislative, and statistical sources. In

addition, the methods of interpretation and comparison were used. The empirical part of the research was carried out using the method of directed interviews with the manager and heads of specialized departments of the selected small agricultural enterprise. The selected enterprise (its legal form is a limited liability company) has been operating in the Czech market for 15 years and employs 35 people. It is active only in crop production (on 200 ha of land, of which 150 ha are used for growing cereals and 50 ha for orchards). Due to the Covid-19 situation, the directed interviews were conducted mainly online. The resulting data were processed in the form of a case study, using a reference preliminary costing for the acquisition of a drone for its use in the crop production. The data collection, analysis and evaluation were carried out from February to September 2021.

4. Results

The presented research specifically focuses on two elements of the concept of agriculture digitization, namely the use of drone technology and GPS in the production of cereals in the Czech Republic, where they belong to the frequently used representatives of modern technologies [14].

An important and used means for digitization purposes in agriculture is the drone - a small unmanned flying device [6]. It can detect pests, dry areas (e.g., it is used to determine the water stress index of plants) or unseeded areas using conventional photographic images and thermal photos. All this leads to the fact that subsequent spraying, fertilizing and other agricultural interventions can be targeted at the area in question, thus saving the farmer´s time, money, necessary substances and at the same time not unnecessarily burdening areas that do not require intervention. Furthermore, the drone imaging can also identify areas that are at risk of erosion. During harvesting operations (or when mowing meadows), the drone can detect the presence of wildlife in the field so that it can be effectively driven away and not killed [15, 16, 17].

Yield maps (the maps containing the yield in specific parts of the field) represent another possible output of the drone activity. Areas with low yields can be used for other purposes on the basis of the drone mapping (pastures, meadows, bio-belts, field thickets, etc.). The accurate records of land blocks can help the farmer to increase the amount of funding received under subsidies.

The Global Positioning System (GPS) is a technology that brings significant benefits for optimizing and eliminating errors when working in the field. Among other things, it contributes to the saving of fuels, fertilizers or spraying, as well as to the collection of data on machine operation that can be used to implement, for example, anti-erosion measures. Furthermore, when GPS is placed in harvesting machines (e.g., combine harvesters) equipped with special software, it is used to create yield maps. Using these tools, the operator can monitor the running yield of a given field in real time. Other machines, such as tractors, can be similarly equipped to precisely record the amount of seed, fertilizers, or sprays applied to a given area [18].

The small agricultural enterprise surveyed has 200 ha of arable land under cultivation, of which 150 ha are used for cereal cultivation. The enterprise currently owns one modern combine harvester, equipped with GPS, which (thanks to the additional software) is used to create yield maps. Other vehicles owned by the enterprise also have GPS technology in place, but it is currently used only to monitor the fuel consumption. The remaining harvesting machines are of an older production year and so they are not equipped with these modern systems (GPS). The purchase price of a modern combine harvester is approximately between CZK 5 million and CZK 10 million, as are the prices of other necessary modern machines for crop production. Small and medium-sized enterprises, which were focused on in this research, find it more difficult to obtain potential subsidies (primarily due to the high administrative

demands on processing the subsidy applications).

In general, as Karel Dobeš, the Vice Chairman of the Board of Directors of the AMSP CR [12] states, "the use of modern digital technologies places relatively high demands on the design of the overall system and the integration of individual system components. The costs of designing and implementing a complex system usually exceed the possibilities of self-employed persons."

For the majority of small and medium-sized agricultural enterprises or natural persons, the complete replacement of the fleet is not feasible for financial reasons. The use of only one combine harvester with GPS, as implemented by the selected company, proves to be of little benefit. Although the yield maps are of good quality, they are only available for a certain part of the fields actually harvested by this combine harvester. Given the need to harvest grain quickly after its ripening, it is not possible to wait for only one of several machines to do the job. The generated yield maps thus offer only limited possibilities for comparison (e.g., of individual fields) or trend monitoring. The use of GPS technology in harvesters and tractors certainly has its benefits - the creation of yield maps, the better control of the application of seeds, fertilizers and protective agents to individual fields, the possibility of optimizing the movement of machinery in the field, the control of fuel consumption, etc. However, it has a significant disadvantage because the data are collected at the moment of performing the activity. Thus, the selected machine must actually enter the field and perform the activity.

Therefore, the results are obtained only after the specific operations have been performed. In contrast, drone monitoring activities can be carried out repeatedly throughout the year and thus lead to the prevention of certain negative events (drought, pests, weed infestation, etc.). The basic managerial problem when introducing drone digitization into the practice of a small agricultural enterprise is the decision whether it is more appropriate to acquire and operate one´s own drone or to use the already available services of external entities offering "tailor-made" solutions (from the technical, personnel and cost point of view).

The cost of acquiring a drone as part of the agricultural enterprise´s assets

One of the options that the surveyed company is considering in its decision making is purchasing a drone and its operation by the company´s employees. The considered costs are shown in the reference costing in Table 1.

Table 1. Reference costing for the acquisition of a drone

Cost item	**Amount (in CZK)**
Drone for agricultural purposes (the purchase price)	120,000
Personnel training	13,000
Accessories	12,000
In total	**145,000**

Source: Own processing according to the internal documents of the company, 2021.

Since December 31, 2020, it is necessary for a drone operator in the Czech Republic (both natural and legal persons) to register and pass the qualification competence test online (conducted by the Civil Aviation Authority [19]). In case of the drone flights up to 120 m above the ground, the registration is free of charge, in the case of flights at higher flight levels, the registration is charged at CZK 12,000. The agricultural enterprise surveyed assumes that the first option (up to 120 m above the ground level) will be sufficient. The company also assumes that the drone would be operated by agronomists (as part of their existing job content), i.e., no additional labor costs would be incurred. The estimated service life of the drone is 5 years, and the purchase price also includes the purchase of sufficient number of batteries for several hours of operation. The data processing software for agricultural accounts is

included in the purchase price of the specialized drone.

When choosing a drone, it is necessary to think about the purpose for which is drone acquired - who will use it and in which environment. Some important characteristics of the drone that need to be taken into account during its selection are shown in Table 2.

There are many drones on the market, but not everyone is suitable for use in agriculture. One of the key parameters is the number of motors and the type of wings (rotary-wing, flapping-wing or fixed-wing). Both factors affect flight speed, flight stability and drone carrying capacity. A larger number of motors and fixed wings allow a greater drone load capacity and thus the ability to carry, for example, a spray tank. For larger fields, fixed-wing drones are more recommended (a larger number of sensors are usually placed on them) [20, 21]. This type of drone is shown in Fig. 1.

Fig. 1. Drone ATMOS with fixed-wing for agriculture
Source: [22]

The different type of drone shows on Fig 2. This type is characteristic by its low weight and easy use (so it is easier to transfer it between distributed fields). But to its short time at the air, it is useful only for small fields.

Fig. 2. DJI Mavic Mini Fly Combo.
Source: Own processing, 2021

The drone can have a built-in camera, another possibility is to buy a drone without a camera and then buy camera separately. For agricultural purposes, it is more appropriate to purchase a drone with a built-in camera. The user avoids problems with compatibility between the drone and the camera. The battery life and the range of the remote control must be considered in the context of the size of the fields on which the company farms [20].

Table 2. Some technical parameters of drone selection

Parameters	Meaning
Number of motors	The number of motors affects performance, stability, speed and carrying capacity
Type of wings	Rotary-wing, flapping-wing or fixed-wing) affects stability
Camera	Without camera: Lower drone price, lower weight The camera can be purchased separately according to customer choice
	Built-in camera: Easier to use (drone and camera compatibility guaranteed, easy to use)
Video resolution (camera parameter)	HD to 8K – The quality of the recording may be related to the flight altitude - i.e. the amount of area captured in one flight
Frame rate (FPS – Frame per Second) (camera parameter)	The number of frames affects the amount of data in the video (its smoothness)
Battery	Removable / built-in Determines the amount of time a drone can be in the air
Remote control range	The distance that the drone can work without losing control
Independence & Control	The ability of the drone to fly along a set route or return safely in the case of signal failure, etc. Using a driver with a monitor, using a mobile phone or tablet
Weight	It affects the manipulability of the drone and its agility in the air
Speed	Speed in the air and take-off speed
Control	Using a driver with a monitor, using a mobile phone or tablet

Source: Own processing according to [23], 2021

It is also important to consider the ability to properly analyze the data obtained from the drone and then use results further. The entrepreneur should ensure that the drone and the obtained data are compatible with the used software and also with the ability of employees. Employees should be able to process the data for the responsible workers and thus use all the knowledge in practice.

Like everything, it is necessary to compare the technical parameters with the possibilities (financial and technological) of the farmer. There is no one drone suitable for every farmer. But in the wide range, every farmer can choose according to their needs and possibilities.

The cost of using the comprehensive drone services of a specialized company

The calculation for hiring an external company to operate the drone and to create the outputs has been based on the assumption that external services would be used throughout the year for the total area under cultivation (250 ha) of the agricultural entity. In addition to the drone operation itself, analytical outputs are also included in the estimated costs - that is the processing of the field map, the identification of threatened areas, the map of the expected yield, etc. The total costs are recorded in Table 3.

Table 3. Reference costing for purchasing the drone services for 1 year

Cost item	Amount (in CZK)
Drone lease	42,500
Personnel services	45,000
Complementary services	17,500
In total	**105,000**

Source: Own processing according to the internal documents of the company, 2021.

A survey conducted among companies that offer comprehensive drone services for agricultural purposes has shown that most companies allow payment for services on a pay-as-you-go basis, i.e., the total amount would be paid throughout the year, with one-twelfth of that value paid each month.

In addition to the financial costs, the surveyed agricultural enterprise has also considered other aspects in its decision making. In the long term, it would be worth buying its own drone (with an estimated lifetime of 5 years). However, using the services of an external company (in the Czech Republic there are a number of companies that provide comprehensive services – "drone as a service"), which provides a tailor-made solution, brings a number of indisputable advantages.

One of the reasons is a lack of experience with the handling of drones and working with the relevant software. Although the company does not expect the need to recruit more staff, it cannot be ruled out that operating the drone and the subsequent data processing and analysis will, in practice, require more time than the currently available capacity of the selected staff (agronomists).

Another reason is the necessity to register the agricultural enterprise as a drone operator and the need to monitor other legal regulations, which must be complied with in order to operate a drone. Taking care of the drone - i.e., its maintenance, charging sufficient number of batteries and possible repairs of the drone - may also be the factor that discourages the agricultural enterprise from purchasing and operating the drone on its own. Another issue to be discussed is the use of drones for activities that are not directly offered by external companies (e.g., game scaring from fields and meadows, etc.); therefore, the possibility of including such activities is a question for the further negotiation of the service price with potential suppliers of external services (in the current energy situation in Europe, a further increase in the cost of external services can be expected).

In the current economic conditions, the management of the agricultural enterprise surveyed is inclined towards the more costly, but otherwise more convenient option of purchasing external services directly from specialized companies.

5. Conclusion

The constantly growing human population places more and more demands on the production of agricultural commodities in order to feed the population. Most countries in the world have committed themselves to the principles of the sustainable approach to agriculture. This policy aims to "*maximize the yield of production with minimum environmental impact*" [24, 25]. The use of modern technologies is meant to make the farmers´ work easier and help to increase produce within the same agricultural areas - agricultural land is shrinking because of ever-increasing housing development [26].

The transition to the Agriculture 4.0 concept is a long-term trend within the contemporary society, on which there is also a scientific consensus [1]. The use of technologies may be faced with the lack of funds, the incompatibility of individual methods and tools, the fear of introducing new technologies, and the lack of manpower or its lack of skills [1]. The submitted paper also highlights the costs

associated with the acquisition and operation of new technologies. Although their affordability is increasing as they are becoming more widespread, many issues still remain unresolved. As stated by Lytridis et al. [27] energy requirements limit the number of operations that these tools are capable of performing. And energy intensity is also a key and highly topical issue given the skyrocketing energy prices on world markets (autumn 2021) and the EU´s commitment to the so-called "Green Deal" [28].

As noted by Brant [29] there is not yet a definite answer to the energy benefits of Agriculture 4.0 concept, but there is no doubt about its contribution to reducing the consumption of fuels, fertilizers and pesticides. The application of Agriculture 4.0 principles leads to increasing demands on workers, but also on materials in electronic systems, and there is an increasing pressure to build transmission networks.

The paper focuses on the presentation of the selected technologies (GPS and drones) within the development of Agriculture 4.0 concept, which are often used in crop production in the Czech Republic. Drones are becoming increasingly important, especially due to their versatile use [12] The GPS technology installed in machines for field work provides useful information and data (yield maps, fuel consumption, etc.), but in some respects the data for decision-making and analysis are obtained with a delay. On the other hand, drones provide up-to-date data throughout the year, allowing farmers to continuously respond to the specific needs of a given field (drought, weed infestation, pest infestation, etc.).

However, the existing fleet composition of small and medium-sized agricultural enterprises in the Czech Republic is often obsolete and the complete renewal of fleets is beyond the financial means of these entrepreneurs (also due to the difficulty of obtaining funding from subsidy programs). The use of drones in agriculture brings a greater number of analytical outputs and is also more affordable, both when purchasing the drone itself and when hiring a specialized company that will deliver all activities and outputs to the company as a "turnkey project".

The presented research documents the financial costs associated with the use of drones. It is not possible to clearly determine which option of its acquisition (whether the purchase/ or the lease of comprehensive services) is more advantageous and will help to ensure a long-term perspective. Every farmer has their own individual needs and is in a different environment, and the resources used need to be adapted to these factors. There is no denying that GPS technology and drones are an important part of modern agriculture.

The research presented in this paper is limited. The issues of Agriculture 4.0 concept implementation in practice are multidimensional, very closely related to the national legislation, the history and the development of agriculture, the development of networks and the availability of modern technologies. In order to make the conclusions more generalized, the authors of the research are preparing directed interviews with managers of a selected sample of small and medium-sized agricultural enterprises, and they are tracking the benefits of and barriers to the use of digitization in the longer term.

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Aims and Objectives

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