

## Article

# Economic and Social Barriers of Precision Farming in Hungary

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**Abstract:** Precision farming may play an important role in agricultural innovation. The study focuses on the attitude of Hungarian farmers toward precision farming. Based on the relevant technical literature, we performed a nationally representative questionnaire survey of 594 farmers and deep interviews with experts and farmers (30 persons). As regards the questionnaire, the authors found that the management of the average farm size in Hungary has the highest willingness to innovate and the second highest level of education among the developed clusters. The survey shows undertrained farmers with large farms to be the second most open group, which may result in the partial application of precision farming techniques. One of the most unexpected results of the Precision Farmers' cluster is that the positive socio-economic utility of precision farming is rated as extremely low. In-depth interviews prove that the use of precision technologies does not increase local social cohesion. Strong organisational isolation of precision farmers prevents the spread of innovation knowledge and precision farming amongst the farming community, and the challenges of competitiveness alone do not force farmers to apply precision farming. Our results may be useful for the establishment of agricultural strategy.

**Keywords:** precision farming; social aspects; cluster; influencing factors; in-depth interview



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## 1. Introduction

This study deals with the social conditions of precision farming (PF) and the coherent agricultural policy environment through the example of Hungarian agriculture. The contribution of this work to international literature is the analysis of the under-researched component of innovation (our interpretations about this and other related terms are described in Appendix A), i.e., social conditions, in an agricultural economy that has undergone two fundamental structural changes over the past thirty years. In the early nineties, formerly nationalized lands were re-privatized (e.g., through the issuance of compensation vouchers) [1], and disintegrating cooperatives and state farms were replaced by family farms and business organizations [2].

By the time of the country's EU accession in 2004, land use concentration had become significant [3]. This trend was very similar to those of the other newly joined Central and Eastern European countries, where low land prices and the supply market attracted significant domestic and foreign large investors [4]. Following the accession, the Special

Accession Programme for Agriculture and Rural Development (SAPARD) programme and EU agricultural subsidies allowed for greater investment in innovation, resulting in larger family farms and agro-businesses becoming more internationally competitive. This period can be considered the first innovation period after the turn of the millennium, for which EU funds provide a certain continuity. In this study, it is assumed that Hungarian agriculture has entered the second phase of agro-economic innovation, and a significant element of its success may be the transition to precision farming.

This paper deals with the social conditions for this innovation shift. In addition to the technical literature review, a questionnaire survey involving 604 farmers and tape-recorded interviews with experts and farmers (30 people) were conducted in order to analyse this move.

## 2. Literature Review

### 2.1. Agricultural Innovation and Precision Farming

PF is a part of smart farming technologies (SFTs), including farm management information systems and agricultural automation and robotics [5–7].

Innovation performance is largely determined by expansion. For this purpose, earning the commitment of potential users and conveying knowledge through vocational education and training are indispensable [8]. In Hungary, the training of farmers focuses on the transfer of basic knowledge, while that of innovation knowledge is less pronounced [9]. In small, open economies that do not belong to the world's technological leaders, the most important means of innovation is the transfer of foreign technologies and products [10]. Several factors can be defined related to the innovation process, but cooperation is an unquestionable factor of success. In addition, the interactions between the different actors of the innovation ecosystem can contribute to social and economic development. The share of product and/or process innovative enterprises engaged in cooperation is only 31.1% in Hungary, while cooperating with competitors or other enterprises of the same sector is less common. Only 10.8% of businesses managed to do so [11].

Even though Common Innovation Survey (CIS) data are available on the sectoral level for the most important sectors, neither the Hungarian Central Statistical Office nor Eurostat publishes Hungarian sectoral data for agriculture. Farmers typically make their decisions on modernization of their farms by relying on their own experiences, their customer feedback, as well as what they have read in specialist literature and professional publications. Mass media, village agronomists and consultants play a decisive role in keeping family farmers informed. On the contrary, companies active in the agricultural sector tend to gather experience on study trips abroad and seek advice from experts familiar with international markets.

When examining the application of precision technologies, Kutter et al. (2011) and Paustian-Theuvsen (2017) [12,13] concluded that there is a close correlation between farmer age and the use of PF technologies. The older age group thinks in terms of a shorter time horizon and does not devote intellectual and financial capital to investments with a long-term return. In addition, there is a significant connection between the level of education and willingness to employ PF techniques. At the same time, the application of new technology requires the training of the existing workforce and the recruitment of specialized workers.

Other elements of PF are also highlighted in international literature. Finch et al. (2014) [14] primarily emphasize agronomic aspects (the matching of agronomic inputs and practices to localized conditions within a field and the improvement of the accuracy of their application). Varella et al. (2015) [15] point out the importance of remote sensing (a new management technology based on georeferenced information for the control of agricultural systems), while Leonard (2015) [16] states that PF is the practice of managing variability in space and time.

Precision farming was first utilized in the US, Europe and Australia, and is now widely used in Argentina, Brazil and several Asian countries [17]. Currently, this technology is most widely used in the US, where two-thirds of farmers were affected by 2016. Of the different variants of technology, precision yield mapping, differentiated fertilizer application and automatic steering in vehicle navigation are of the greatest importance [18].

The introduction of PF technology requires a willingness to change on behalf of farmers, along with 2–3 years of knowledge-intensive learning [19].

## 2.2. Factors Affecting the Dissemination of PF

There are several drivers and obstacles of innovation, and these can be put into two categories. External factors are market environment (e.g., consumers, competitors, suppliers and value chains); policies and regulations (e.g., taxation, infrastructure, governmental support); and the social environment (consumer responsiveness to innovation or level of trust among economic actors). The internal factors are numerous, such as a lack of financial sources, lack of skilled labour or lack of means to discourage high-skilled employees from leaving the firm [20]. According to Balafoutis et al. (2020) [5], most SFT papers (including PF) were assessed in terms of economic, environmental and labour impact, and their benefits were published. Barnes et al. (2019) [21] highlights the role of indirect interventions, such as informational support to counteract industry bias, and demonstration to prove the viability of economic return, that may be effective at meeting land manager and policy expectations towards precision agriculture technologies (PATs).

According to the classic version of innovation theory [22], enterprises can be put into five categories to apply new technologies: innovators (inventors), early adopters, early majority, late majority and laggards. Inventors are committed to researching novel information and using it to invent new PF technology applications. The early adopters, who follow them, are typically well-trained and are locally leading farmers. Simultaneously, these farmers who represent a dominant share are sceptical, only willing to start using the technology when the majority has already tried it and used it successfully. Those who are lagging behind are tradition-bound, conservative farmers who will only use the new technology once it is widespread and has long been accepted. In other words, the new technology becomes part of traditional production. Lamb et al. (2008) [23] used this clustering method to analyse Australian winegrowers' attitudes in terms of applying PF.

PF requires a skilled workforce, while the rural unemployed are generally low-skilled, i.e., employing this technology is not a viable option. In Hungary, the level of education of agricultural workers is significantly lower than that of other sectors of the economy and the EU average [19], and the shortage of skilled labour in agribusiness could be a major problem in the next 5 to 10 years. The success of PF depends not only on the farmer's preparedness but also on the availability of up-to-date information [24,25].

The analysis of income-generating ability and demographic/skills trends is of paramount importance when examining the use and further transmission of PF [26]. The main goal of farmers using PF is to increase income, which can be achieved through the more cost-effective use of agricultural inputs [27] and selectively applied work processes (sowing, harvesting) [28]. At the same time, there is a large amount of technical literary sources which conclude that the most significant advantage of using PF is that it could potentially reduce in the greatest measure the environmental damage resulting from agriculture [29–33]. According to Biermacher et al. (2009) [34], the main reason for this phenomenon is that achieving the potential yields on large (especially heterogeneous) fields necessarily entails nitrogen contamination of waters. As a result, it can be concluded that the economic approach of maximizing income most often contradicts the environmentally-focused method of PF [35,36].

PF-related innovations contribute to food security through the availability of surplus yields, reducing environmental damage through sustainable resource use and better meeting consumer needs through improved food traceability and quality [37–41].

## 2.3. The Preconditons of PF in Hungary

In Hungary, mostly younger farmers with higher education levels and larger farms (>300 ha) apply PF technology [42]. According to D'Antoni et al. (2012) [43] and Barnes et al. (2019) [44], there is a strong negative tie between farmers' age and willingness to introduce new automated technologies. Tensions between different generations can also cause difficulties in the later successful implementation of this technology. According to Daberkow

and McBride (1998) [45], the length of time spent in farming is also an important factor in addition to age and education.

### 2.3.1. Legal Areas Related to PF in Hungary

In Hungary, land policy has always played a prominent role in (national) agricultural policy [3]. For this reason, the issues of predictable agricultural policy and regulation to ensure sustainable land use, as well as innovation, are interconnected.

One precondition for the spread of precision agriculture, and thus of agricultural innovation, is proper regulation. Precision farming does not appear as a regulatory subject in legal regulation in Hungary, but property policy and tax policy play an important role in the spread of PF.

### 2.3.2. Property Policy

PF requires long-term land use due to heavy investment needs, which can be met either through ownership or long-term lease. In Hungary, after the change of regime, it became an important issue to maximize the size of farms (in parallel with the acquisition of land by companies). Still, while almost every administration had different ideas in this respect, these changing ideas were only partially followed by legislation. The current regulations on Hungarian land policy (e.g., the Land Transaction Act, the National Land Fund Act) focus on increasing the number of family farms. At the same time, fragmentation is not prevented by Hungarian law (there is no minimum land size, no agricultural inheritance law, no regulations to keep farms intact), nor can it prevent the concentration of holdings (there is a maximum land size owned by one person or company, but due to interconnection between companies and the phenomenon of owner networks, real plant sizes often exceed this value by a factor of one). However, the National Land Fund's operation is not entirely in line with the declared agricultural policy objectives, promoting large-scale concentration.

Unlike some Western European countries, Hungarian agricultural law hardly applies so-called tenant protection measures, which would serve the long-term security of farming and investments [46]. Even though there is a pre-lease right that gives the former lessee an advantage when entering into a new contract (under certain conditions, such as registration as a "farmer", expertise, locally owned housing), the right to appoint a new tenant is not known (i.e., the former leaser cannot decide who will continue to farm). The minimum lease term is one year, which does not guarantee a return on investment, but only considers the continuity of work due in a given farming year. The setting of a minimum or specific period of several years in law (as opposed to, for example, French law) is not known. As a general rule, the Land Transaction Act sets a maximum lease term of 20 years. Within this timeframe (1–20 years), the duration of the legal relationship is freely determined by the parties (owner, leaser) in the contract. However, contracts with a duration of more than five years are encouraged by tax exemption on behalf of the leaser.

Increasing the significance of this question is the ownership structure of Hungarian agricultural areas, which are still characterized by extremes. At the same time, it is difficult to carry out self-sufficient farming on very small parcels, which favours capital-intensive farmers who have sufficient resources to rent land from either small owners or the state and perform large-scale farming. Companies in Hungary have not been able to acquire land ownership since 1994, i.e., leasing is the dominant title of land use for them. The size of the land that can be acquired or cultivated by one person is 300 ha or 1200 ha, respectively [47].

### 2.3.3. Land Use Structure

Strong concentration is an important feature of the structure of land use for the spread of precision farming. Hungarian land use is one of the most concentrated in Europe. Concentration was already finished by the time of the country's EU accession (2004). The number of individual farms decreased rapidly. In 2010, 13,830 farms, just over two-and-a-half percent of all production units, used three-quarters of agricultural land. 1752 farms cultivated 2,032,474 hectares, i.e., 44 percent of the land [48].

After 2010, 167,000 farms, mostly performing production for their own consumption, ceased farming. Several large agricultural enterprises were linked, and new external investors appeared. The long-term lease of state-owned land and the subsequent acquisition of ownership were the most conducive to land-use concentration. Individual farms also acquired land at auctions, but the biggest winners were the owners of large farms and political clients [3].

Concentration of land use has a dual nature, which means that both larger individual farms and business organizations significantly increased the amount of land they use over the last two decades.

The consequence of land use concentration is the narrowing of the agricultural labour market. Currently, 900,000 households produce food for their own consumption below the statistical farm size, 200,000 families use less than one hectare of land, 148,000 individual family landowners are known, while the number of permanent employees in private farm companies is 114,333 and that of seasonal workers is 128,305 [49]. Altogether, the size of the active workforce in agriculture is not more than 200,000 people, which is a significant and rapid decline. Specialization and mechanization result in less and less labour demand in the agricultural sector, and there is also a shortage of skilled labour. The primary consequence of land concentration is the almost total displacement of more than one million people from agriculture.

The rapid decline in the number of smaller farms has increased the proportion of farm sizes that are more suitable for precision farming. There is no clear relationship between the size of the land and entering precision farming, but according to the results of a survey conducted in our previous study, the majority of farmers identified farm size as one of the most important barriers to starting precision farming. Some international research papers states that larger farms are more likely to adopt PAT [25,50]. Like many mechanical technologies, the economic benefits appear to be greatest for larger farms that can spread their fixed costs over many acres, and that can reduce labour costs through automation [51]. The shrinking labour market in agriculture, which is also partly a consequence of land use concentration, and the decline in agricultural training both encourage and can be a major barrier to the transition to precision farming.

#### *2.4. The Agricultural Innovation and Precision Farming in Hungary*

The share of innovative Hungarian enterprises is low by European comparison. Data are based on the Common Innovation Survey (CIS) conducted by Eurostat and national innovation offices, including the Hungarian Central Statistical Office. According to the latest available data, the share of enterprises that have either introduced an innovation or have any kind of innovation activity (including enterprises with abandoned/suspended or on-going innovation activities) is 51% of the EU average (2016) and 28.7% in Hungary (2018) [11,52]. Size significantly matters in terms of innovation: Hungarian enterprises with 10–49 employees have the lowest (25.8%) and large firms the highest (52.3%) ratio of innovative entities, while 36.5% of the firms with 50–249 employees are innovative.

In Hungary, most firms do not see the importance of innovation: according to CIS data, 86% of non-innovative businesses stated that they had no compelling reason to innovate, 14% of them considered innovating but thought that barriers to innovation are too large. This attitude towards innovation is a major obstacle of Hungarian competitiveness as reflected in the Eurostat data: the average turnover of innovative Hungarian businesses per persons employed is almost 44% higher than that of non-innovative companies [11]. On the other hand, most innovative firms mentioned that financial factors are the major barriers to innovation and that the shortage of skilled employees is also a problem. According to the survey of 300 Hungarian Agricultural Enterprises in the Southern Great Plain Region [53], fewer than five percent of farmers have an innovative mind-set, making improvements even with significant risks.

In Hungary, precision technology was most widely used in winter wheat (4161 ha), followed by maize (4019 ha), sunflower (2795 ha) and rapeseed (2016 ha), which is about 0.3% of the national sown area. In wheat and rapeseed, this technology was used primarily in nutrient supply, while in maize and sunflower, it was primarily used during sowing.

Precision methods have been used to a lesser extent in plant protection and tillage and to a negligible extent at harvest [54]. According to Udovecz et al. (2012) [55], successful enterprises in Hungary have a larger land area than unsuccessful ones and specialize in producing the four most important arable crops (wheat, maize, sunflower, rapeseed). From a survey of 72 Hungarian farmers, Takácsné György et al. (2013) [56] found a positive correlation between a farm's size and the adoption of precision farming technology. Based on Balogh et al. (2020) [57] research findings, Hungary's potential human resources can be considered undereducated. Their willingness to improving their knowledge and the level of cooperation ability is low.

### 3. Research Questions, Materials and Methods

In this research, the following questions were sought through questionnaires and qualitative interviews:

- How crop farmers determine the characteristics of PF.
- How they see the potential and impact of PF in agricultural innovation, the conditions for PF penetration.
- Factors which would motivate them to partially or completely switch to PF.

In the survey, both precision and non-precision farmers were included, while the interviews were conducted only with those farmers using precision technology. With the quantitative analysis, we intended to interpret what Hungarian farmers know and think about precision technology and their level of motivation to change technology (we measured openness to precision farming). On the other hand, with the qualitative interviews, we asked only the precision farmers. We wanted to understand the reasons for the transition to precision farming and the factors of the spread of precision farming with the semi-structured interviews. As a result of the combined method, we developed a typology describing the openness of the host society to precision farming alongside of a cluster analysis based on quantitative data collection. We linked to this the results of the qualitative interviews with precision farmers, which provided detailed and in-depth information on the actual users of precision technology, the motivations for introducing the technology and what they thought would be needed to make farmers more open and inclusive of precision technologies.

A previous article (Balogh et al. 2020 [57]) used the other part of this questionnaire, but that research aimed to categorize farmers' main motivational factors in adopting precision farming in Hungary. Balogh et al. (2020) applied factor analysis and differentiated five elements (two direct ones: Environment for Safe Operation, Finance ability and three indirect ones: Positive economic impacts, Negative socio-economic impacts, Positive Social Impact).

The questionnaire survey (detailed description of the survey in Balogh et al., 2020 [57]) was conducted by the Research Institute of Agricultural Economics (AKI) in 2018. The sample was selected from a set of 1900 nationally representative farms in AKI's test farm system, established according to EUROSTAT rules [58]. The respondents of the 1900 farms represent Hungarian crop farmers, which can also be considered nationally representative. From the test farm system, those crop farms were selected that used at least 2 hectares. The sample is representative of crop producing farms. The questionnaire survey included 604 farmers in the sample. Table 1 contains the most important characteristics of the sample.

Farm-specific test farm data was taken from AKI's questionnaire survey data each year [58]. The questions in the standardized questionnaire were as follows:

- Awareness and spread of precision crop production.
- Application of precision technology on the farm.
- Application of an accounting/management system on the farm.
- Opinions of farmers.
- Socio-demographic characteristics of farms and farmers.

**Table 1.** Characteristics of the sample among farmers (N = 604).

| Variables   | Mean  | SD     |
|---|-------|--------|
| Gender of the farm owner and/or manager (1: Male 0: Female)           | 0.86  | -      |
| Education categories (person)   |       |        |
| No information  | 7     |        |
| Primary   | 83    | -      |
| Secondary   | 332   | -      |
| Higher  | 182   | -      |
| Age (year)  | 57.9  | 12.1   |
| Age categories (person)   |       |        |
| No information  | 63    |        |
| Under 40 years of age   | 41    | -      |
| Between 40–60 years of age  | 238   | -      |
| Above 60 years of age   | 262   | -      |
| Sowing area—Total area used by the farm (ha)                          | 149.5 | 426.9  |
| Sowing area—Land value (EURO/ha *)                                    | 2353  | 762    |
| Revenue—Field crop production, grassland management (thousand EURO *) | 132.9 | 452.9  |
| EBITDA (thousand EURO *)  | 64.4  | 101.9  |
| Cost of Fertilizers (thousand EURO *)                                 | 18.9  | 64.7   |
| Revenue—Whole business (thousand EURO *)                              | 234.9 | 1540.9 |
| Average AK (golden crown <sup>1</sup> ) value of the sowing area      | 20.4  | 7.7    |

<sup>1</sup> Special Hungarian unit for describing land value. \* The exchange rate in 2018 was 309 HUF/EUR. Source: own data collection.

### 3.1. Qualitative Survey

In this research, 30 semi-structured interviews were conducted, 25 with precision farmers and 5 with experts. The interviewed subjects were selected by expert sampling. The qualitative study focused on precision farmers' opinions, mainly on the essence of precision farming, its most important features, the characteristics of precision farming, the situation of precision farming in Hungary and the factors that facilitate and hinder the spread of this technology. In this study, the authors primarily show the relationships among the factors contributing to the diffusion of innovation.

The interview survey was preceded in time by the questionnaire survey. Based on the results of the cluster analysis of the quantitative survey, we were able to interpret the attitudes of Hungarian farmers towards precision farming. As the number of farmers practising precision farming was very low in the questionnaire data collection, we decided to explore the context of farmers who effectively practise precision farming in a qualitative study. The dimensions of the interview survey were designed with the results of the questionnaire survey in mind, both to gain a deeper understanding of their interrelationships and to create recognisable typologies among precision farmers.

### 3.2. Quantitative Data Collection

After cleaning the database, the final sample included 594 crop farmers. 86% are male and 14% female. The proportion of those with a primary school education is 13.5%, while 55.9% have secondary school degrees and 30.6% have higher educational degrees. The average age is 57 years old. The proportion of those under 40 years of age is 6.9%, with 51% possess higher educational degrees. Most of the respondents are over 40 years of age (93.1%), of whom 31.8% have higher educational degrees. 7.2% of the respondents can be considered precision farmers (based on their self-classification). The average land size is 145.7 ha and the size of the largest farm is 2173 ha.

SPSS ver. 25.0 was used to perform the analysis. The first step in analysing the questionnaire data was to select farmers into homogeneous groups using a two-step clustering process. Commonly used cluster analysis methods are hierarchical and K-centroid cluster analysis methods, but they do not allow the joint use of variables of

different measurement levels (nominal, ordinal and metric). Several variables of different measurement levels were intended to include as the basis for clustering. Thus, a two-step clustering was applied. The advantage of this approach is that it allows combining nominal and metric attributes and suggests the ideal cluster number.

The following settings were used in the analysis: logarithmic similarity/Log-Likelihood/distance determination, Schwarz-Bayesian criterion and automatic cluster number determination. To determine the cluster numbers, the Bayesian information criterion (BIC value) and the ratio of distance measures was used [59]. Two distance measures were employed: log-likelihood (for categorical variables) and Euclidean (for continuous variables). Blashfield and Macintyre's split sample method was used [60]. The cluster analysis procedures were repeated in an internal random sample of 50% of the total study sample. The internal consistency of the clusters was examined for clustering variables.

As a result of the cluster analysis, 5 cluster groups were formed in a way that each of the variables involved significantly influenced the development of the clusters. Our clustering variables were as follows (Table 2): educational degree of the owner or manager, form of farming (precision or non-precision), size of arable land, land value of arable land, operating results (revenue).

**Table 2.** Parameters of clustering variables.

| Clustering Variables  | Parameters                                | Explanation  |
|---|---|--|
| Is the farmer applying or willing to apply precision farming? | Precision                                 | Applying, or not applying, but plans to  |
|   | Non-precision                             | Used to apply before, or did not apply and does not plan to apply either   |
| Educational degree of the manager/owner                       | Primary education                         | The highest education level is the elementary school   |
|   | Secondary education                       | The highest education level is the secondary school  |
|   | University degree                         | The highest education level is the university diploma  |
| Size of arable land (farm size)                               | Small size: land size under 100 ha        | According to the EC regulation no. 1242/2008, the lower economic size category of private farms, 59% of the Hungarian arable land                            |
|   | Medium size: 100–500 ha                   | Farms operating on 25% of the Hungarian arable land [58]   |
|   | Large size: above 500 ha                  | 16% of the Hungarian arable land [58]  |
| Operating result (revenue)                                    | High revenue: above 324 thousand EUR/year | The reported revenues can be considered as typical for farmers with average farm size, average efficiency and average production structure in each category. |
|   | Medium revenue: 65–324 thousand EUR/year  |  |
|   | Small revenue: 0–65 thousand EUR/year     |  |
| Efficiency  | High efficiency: above 550 EUR/hectare    | The average income per hectare of the wheat and maize sectors was considered to be the standard for efficiency classifications. *                            |
|   | Medium efficiency: 323–550 EUR/hectare    |  |
|   | Low efficiency: below 323 EUR/hectare     |  |

Source: own edition. Legend: \* These two crops account for 53–57% of the Hungarian crop structure. Averaged over the years 2013–2015, the income of the cluster representing the average income category, containing 40% of the farms, fluctuated between 330–356 EUR/ha. Farms below this category are considered to be part of the low-efficiency category. The profit of farms belonging to the top 30% was between 504–537 EUR/ha in the same period [54]. The exchange rate in 2018 was 309 HUF/EUR.

For determination of utilization of PF, we supposed that farmers use automation steering and boom shutoff. Another feature is that GPS data is collected based on the first level of the PrecisionAg<sup>®</sup> Alliance criteria (2020). Since PF is not as typical in Hungary as in the USA, it could be evaluated as being a serious development for Hungarian farmers to reach this level.

After the clustering, the authors worked with a subsample of 594 people, since they answered all the questions.

Table 2 also contains each parameter of clustering variables and their justification, while averages of clusters according to the variables included in the two-step clustering procedure are shown in Figure 1.

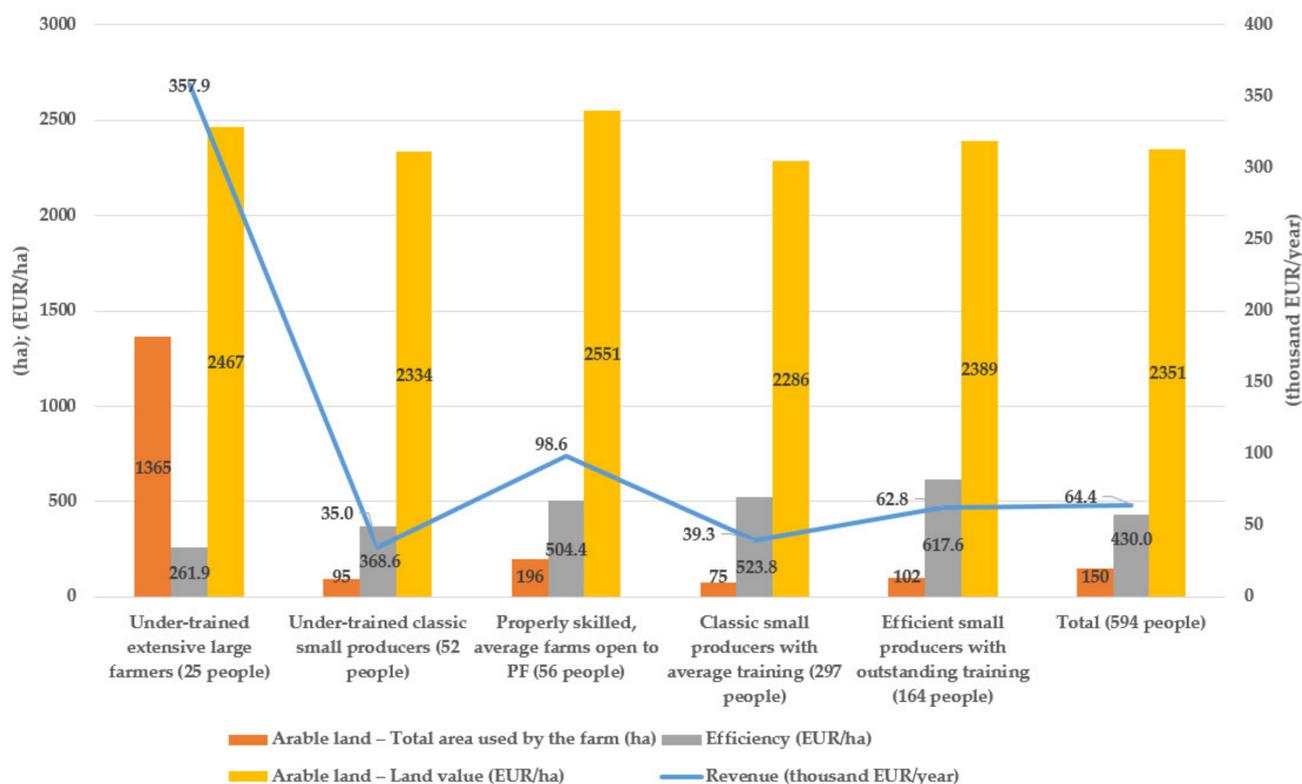
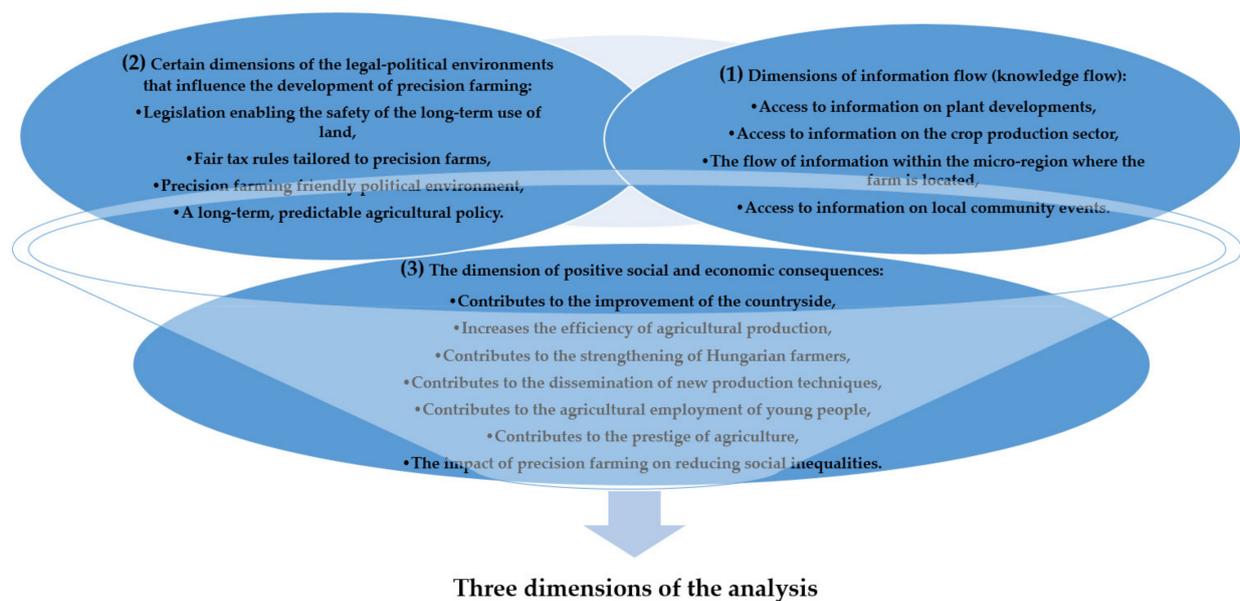


Figure 1. Averages of clusters according to the variables included in the two-step clustering procedure. Source: own results.

The Silhouette measure of cohesion and separation was above 0.5, indicating good cluster quality.

The cluster types were compared with some of the most significant dimensions which showed significant correlation using the ANOVA and the Chi-square tests. As a next step, three dimensions of analysis were developed and used (Figure 2).

The negative social consequences of precision farming were also examined, but it was not possible to demonstrate a statistical tie between clusters and dimensions.



**Figure 2.** Factors affecting the development of precision farming in the three different dimensions. Source: own edition.

#### 4. Results

In the following, the five cluster groups (1. Undertrained extensive large farmers, 2. Undertrained classic small producers, 3. Properly skilled, average farms open to PF, 4. Classic small producers with average training, 5. Efficient small producers with outstanding training) are characterised on the basis of three dimensions (information flow, legal-political environment influencing the development of precision farming and positive social and economic consequences).

##### 4.1. Cluster Types

###### 4.1.1. Cluster 1: Under-Trained Extensive Large Farmers

Large non-precision farmers with low or non-specialized educational degrees belong to this cluster, and their farms are characterized by high revenue and low efficiency. Even though they rated the contribution of precision farming to environmental sustainability to be the highest (on a scale from 1 to 5, the average value is 3.16. Anova ( $p < 0.001$ )), even the largest farmers do not tend to think positively about this issue. The contribution of PF to economic sustainability was similarly assessed (the highest of the five clusters, but at a fundamentally low level) (average score: 3.16. Anova ( $p < 0.001$ )). In their view, the contribution of precision farming to environmental and economic sustainability is low.

Access to information related to their area of expertise is rated as the highest, but they are similarly informed about farm development and the agricultural sector. They consider information related to events within the micro-region and in local society much less important (but still the highest of all clusters), whether or not their presence is significant in both economic and social terms (Table 3).

The largest farmers place great importance on the impact of the legal-political climate on precision farming. The existence of legislation that enables the security of tenure of land use is considered the most important for the spread of precision farming, followed by the long-term, predictable agricultural policy. Of all these, fair taxation tailored to precision farms is rated to be less important but still significant and certainly more important to them than to any other group of farmers.

Table 3. Statistical parameters of each Cluster.

|   | Mean       | Std. Deviation | Whole Sample Average (N = 594) |
|---|------------|----------------|------------|----------------|------------|----------------|------------|----------------|------------|----------------|--------------------------------|
|   | (N = 25)   |                | (N = 52)   |                | (N = 56)   |                | (N = 297)  |                | (N = 164)  |                |                                |
|   | Cluster 1. |                | Cluster 2. |                | Cluster 3. |                | Cluster 4. |                | Cluster 5. |                |                                |
| Information Flow  |            |                |            |                |            |                |            |                |            |                |                                |
| I am informed about most things related to the development of my own field          | 4.40A      | 0.707          | 3.62C      | 0.867          | 4.20AB     | 0.749          | 3.78BC     | 0.956          | 4.20AB     | 0.852          | 3.95                           |
| I obtain most of the information on farm developments in a timely manner            | 4.32A      | 0.852          | 3.38C      | 1.105          | 3.93AB     | 0.806          | 3.56BC     | 0.961          | 4.01AB     | 0.956          | 3.73                           |
| I obtain most of the information related to the sector I work in in a timely manner | 4.36A      | 0.638          | 3.58C      | 0.936          | 3.98ABC    | 0.751          | 3.79BC     | 0.91           | 4.09AB     | 0.864          | 3.9                            |
| I consider the flow of information within the micro-region to be good               | 3.72ABC    | 0.737          | 3.17C      | 1.08           | 3.52ABC    | 0.953          | 3.31BC     | 0.896          | 3.79A      | 0.951          | 3.47                           |
| I obtain the most information on local community events in a timely fashion         | 3.60AB     | 0.913          | 3.35B      | 1.008          | 3.86A      | 0.819          | 3.39AB     | 0.939          | 3.81AB     | 0.963          | 3.56                           |
| Legal-political environment   |            |                |            |                |            |                |            |                |            |                |                                |
| Legislation enabling security of tenure   | 4.68A      | 0.557          | 3.96B      | 0.839          | 4.20B      | 0.644          | 4.06B      | 0.876          | 4.18B      | 0.798          | 4.12                           |
| Long-term, predictable agricultural policy  | 4.56A      | 0.651          | 4.12AB     | 1.022          | 4.45AB     | 0.601          | 4.09B      | 0.97           | 4.22AB     | 0.886          | 4.18                           |
| Fair taxation tailored to precision farms   | 4.20A      | 0.866          | 3.58B      | 0.915          | 3.86AB     | 0.923          | 3.64B      | 1.018          | 3.71AB     | 0.991          | 3.7                            |
| Precision farming—friendly political environment                                    | 4.08       | 0.909          | 3.62       | 0.867          | 3.8        | 0.961          | 3.59       | 1.026          | 3.68       | 0.952          | 3.66                           |
| Positive socio-economic consequences  |            |                |            |                |            |                |            |                |            |                |                                |
| It contributes to the rise of the countryside                                       | 3.12AB     | 0.971          | 3.02B      | 1.075          | 3.54A      | 1.044          | 3.05AB     | 1.072          | 3.32AB     | 0.997          | 3.17                           |
| It increases the efficiency of agricultural production                              | 4.08AB     | 0.909          | 3.67B      | 0.879          | 4.18A      | 0.69           | 3.60B      | 1.074          | 3.86AB     | 0.926          | 3.75                           |
| It contributes to the strengthening of Hungarian farmers                            | 3.28AB     | 0.98           | 2.98B      | 1.163          | 3.63A      | 0.964          | 3.02B      | 1.065          | 3.23AB     | 1.072          | 3.14                           |
| It contributes to the spread of new production techniques                           | 4.28A      | 0.891          | 3.56BC     | 1.037          | 4.05AB     | 0.883          | 3.47C      | 1.059          | 3.82ABC    | 0.978          | 3.66                           |
| It contributes to the agricultural employment of young people                       | 3.08AB     | 0.812          | 2.63B      | 1.010          | 3.5A       | 0.953          | 2.74B      | 0.929          | 2.88B      | 0.958          | 2.85                           |
| It contributes to the prestige of agriculture                                       | 3.84A      | 0.943          | 3.40AB     | 0.934          | 3.86A      | 0.819          | 3.19B      | 1.008          | 3.46AB     | 0.853          | 3.37                           |
| It contributes to reducing social inequalities                                      | 2.68       | 0.852          | 2.38       | 0.932          | 2.89       | 1.090          | 2.57       | 1.035          | 2.63       | 0.978          | 2.6                            |

Different letters show significant differences ( $p < 0.05$ ) among means of clusters. Cluster 1.: Under-trained extensive large farmers (4.2% of farms); Cluster 2.: Under-trained classic small producers (8.8% of farms); Cluster 3.: Properly skilled, average farms open to PF (9.4% of farms); Cluster 4.: Classic small producers with average training (50% of farms); Cluster 5.: Efficient small producers with outstanding training (27.6% of farms).

As shown in Table 3 above, the most significant positive socio-economic impact of precision farming is the contribution to disseminating new production techniques (the rating was significantly above average). The effect of precision technology on agricultural production efficiency (the rating exceeded the average of the whole sample) was highly positively assessed, which is even more interesting because this group of farmers does not necessarily want to switch to precision farming. However, they see that the employment of young people in agriculture has the smallest social impact, and they do not even consider precision farming's contribution to the improvement of rural areas to be significant (less than average impact was attributed to it).

#### 4.1.2. Cluster 2: Under-Trained Classic Small Producers

The cluster includes low-skilled or non-specialized farmers using no precision technology and operating small-sized and small-revenue farms with medium efficiency. The contribution of precision farming to environmental sustainability is rated the lowest in this cluster. The perception of the contribution of precision technology to economic sustainability is also the worst in this cluster (Average score: 2.33. Anova ( $p < 0.001$ )), worse than the assessment of environmental sustainability. The latter phenomenon applies not only to this cluster but also to all the others, including the cluster of farmers open to precision technology.

Unskilled small farmers consider themselves to be the worst informed of all clusters (Table 3). Low knowledge capital and small farm size do not allow for a higher level of professional-networking-informal capital, a characteristic of medium or larger farms, which results in information isolation. In each dimension studied, their level of awareness is below the mean of the total sample.

It can be observed that the legal-political atmosphere, which determines the development of precision farming, is considered to be the least influential and important in this cluster, being below the average of the whole sample in all dimensions. Long-term, predictable agricultural policy strategies are considered to be the most important in the small business environment, but these respondents believe that the impact of fair tax rules on precision farms is small and irrelevant compared to the development of the field.

This group of farmers assumes less positive social and economic benefits from precision farming than any group. Within this group, there is a slightly more positive view of the efficiency of agricultural production, but it is almost completely rejected that PF has an impact on the agricultural employment of young people.

#### 4.1.3. Cluster 3: Properly Skilled, Average Farms Open to PF

Cluster 3 includes farmers who are either applying precision farming or are open to using such techniques. They have secondary school or higher educational degrees, medium-sized farms, medium-income and medium efficiency. The contribution to environmental sustainability is rated surprisingly low (Average score on a 1–5 scale: 2.86. Anova ( $p < 0.001$ )), which hardly differs from all other non-precision farming clusters. The contribution of precision farming to economic sustainability is underestimated in this group. They attribute a smaller impact to this aspect (Average score: 2.82. Anova ( $p < 0.001$ )) than to environmental sustainability.

Precision farmers are dissatisfied with the flow of information (Table 3). Most of them have access to information on developments in their area of expertise, but they are only moderately satisfied with access to information on the sector and on farm development. They are critical when they rate their micro-regional embeddedness and their knowledge of the local society as they are insignificant players in the rural area where they farm.

As regards the legal-political environment, similarly to large farmers, the legislation that can enable the security of tenure of land use, and predictable agricultural policy are considered the most important (above average). In addition, similarly to large and small farmers, they consider the regulations that are specifically tailored to precision farms to be less useful or significant.

One of the most unexpected results of the precision farmers' cluster is that they rate the positive socio-economic utility of precision farming extremely low (even though above the sample average). They even see positive consequences in terms of the economy, mainly in increasing agricultural production efficiency, but much less concerning social interactions. Precision farmers, like any other group, consider the contribution of PF to young people in agriculture to be the weakest, but similarly, precision farming is not considered to be significant in the context of the rise of the countryside, either.

#### 4.1.4. Cluster 4: Classic Small Producers with Average Training

This cluster has the highest number of elements, involving farmers with a secondary educational degree, not using precision technology, operating a small farm with low revenue and medium efficiency. This cluster does not consider precision technology to be of significant importance for environmental sustainability, either (Average score on a 1–5 scale: 2.54. Anova ( $p < 0.001$ )). Again, similarly to other clusters, the contribution of PF to economic sustainability is highly underestimated (Average score: 2.45. Anova ( $p < 0.001$ )). This cluster was extremely dissatisfied with the amount of information available and rated it below average in all areas (Table 3). Regionally-relevant, local social and micro-regional information is considered inadequate, but they are better informed than their less-educated peers operating farms of similar size.

For this cluster, the legislation enabling the security of tenure of land use and predictable agricultural policy are also considered a prerequisite for the spread of precision farming. While low-skilled small farmers only considered agricultural policy relevant, the cluster of average-skilled also highlighted the need for legislation to make land use predictable.

This group of farmers rated the positive socio-economic consequences of precision farming as the lowest, and in each case, they attributed below-average importance to this aspect. Its impact on agricultural production efficiency and the diffusion of new production techniques is overestimated compared to other dimensions, but they are not rated too high. They do not think that the spread of precision farming would positively affect the rise of the countryside and the strengthening of Hungarian farmers. This cluster also does not consider it likely that the number of young people working in agriculture would increase. In their opinion, precision farming has no such effect on the sector.

#### 4.1.5. Cluster 5: Efficient Small Producers with Outstanding Training

Farmers with higher educational degrees in the cluster of the best educated are not open to precision farming, and they operate small farms with medium revenue and high efficiency. The views of those with the highest educational degrees on the contribution of precision farming to environmental sustainability are not significantly different from those of other clusters, and this impact is highly underestimated (Average score on a 1–5 scale: 2.77. Anova ( $p < 0.001$ )). The contribution to economic sustainability is not seen as a positive consequence (Average score: 2.68. Anova ( $p < 0.001$ )), it is rated to have an even lower impact than that of environmental sustainability.

This cluster is above average for being satisfied with the flow of information (Table 3), and they consider themselves to be very well informed. Information on both specialist, farm and industry developments is obtained at the same high level as large-scale farmers and precision farmers (these three clusters stand out from the rest in this respect). Simultaneously, they are more dissatisfied with regional, sub-regional information availability, and events locally, but still consider it better than the sample average. Their micro-regional level of awareness is the strongest of all clusters. However, their integration into local communities is not similar to that of large farmers, but to precision farmers.

Like the overall sample, average importance was attributed to the stability of the legal-political environment. Both land-use safety legislation and predictable agricultural policy are considered to be necessary conditions for the development of precision farming to a similar extent. Legislation is seen as more significant, while the predictable agricultural

policy is somewhat less important in their opinions. Tax rules tailored to precision farming are also considered less important by this cluster.

The cluster of the smallest farmers with the highest level of education and the most profitable farms does not rate the social and economic effects of precision farming to be more favourable than the sample average. Increasing the efficiency of agricultural production and contributing to the diffusion of new production techniques were seen most positively, but this rating was not above average. At the same time, in both areas, this evaluation lags behind the values of large farmers and precision farmers. The impact on young people's employment is seen as the least positive and is even more critically evaluated than by large farmers and precision farmers. Moreover, they do not consider it to be a positive result of precision farming.

According to the results of clustering, some important conclusions can be made about the willingness of Hungarian farmers to innovate, expressed by their openness toward precision farming:

- (1) The willingness to innovate in precision farming is not directly related to farmland size. The less educated owners of the largest farms are less willing to replace the supposedly continuous technical innovation following the turn of the millennium with a shift to precision farming and thus start a new cycle of innovation. Lower academic achievement, older age and income resulting from larger farms may explain the stance against new innovation. Simultaneously, the perception of precision farming shows under-educated large farmers to be the second most open group to PF, which may result in a partial application of PF on their behalf.
- (2) Education may be only partly related to the willingness to innovate by switching to PF but will significantly impact the income per unit area. All three small-scale farming groups at different training levels have a similar stance against PF innovation. It should be noted that the annual turnover of the highly qualified, efficient small farming group with the highest level of education is the second highest, and the current level of efficiency does not encourage new investment for innovation.
- (3) At the same time, the highest willingness to innovate was observed in the group of 200 ha farms, which is considered to be the average size among Hungarian crop farms. These farmers have the second highest level of education among the groups formed by clustering. The reason for this phenomenon is probably due to the fact that the capital needed for innovation investments is more available to them, and the new technology can be operated with a greater capacity of utilization than smaller farms.

## 5. Discussion

### 5.1. *The Reasons for Switching to Precision Farming and the Spread of Innovation*

In this chapter, based on the qualitative research among precision farmers, the factors that respondents consider to be most important in the spread of precision farming were presented. Before outlining the conditions, the factors that have affected the early adoption of innovative technologies by farmers are described.

#### 5.1.1. Reasons for the Introduction of Precision Technologies

The farmers were asked why they had undertaken the introduction of precision technologies and what factors they had considered when deciding to perform innovative developments. Based on their responses, five groups were formed: (1) Conscious developers; (2) "Trial and error" developers; (3) Innovators; (4) Prestige enhancers; (5) Technology buyers, either accidentally or unknowingly.

##### Conscious Developers—Reasons of Profitability

In the group of intentional developers, the authors ranked the farmers who considered the financial profitability of farming as the primary aspect. They operate medium or large farms and have decided to use innovative technology after making profitable calculations and carefully considering the pros and cons.

“Well, we just decided for economic reasons, because how long we can increase yields is always a question, but the so-called ‘cost-cutting side’ is what can play a role in achieving greater profits.” (67 years old, higher education degree, operates on 1200 ha)

This group also included farmers who decided to increase their land and technical modernization level and considered it worthwhile to purchase the latest technology.

“On the one hand, our arable land will increase by 300 hectares. We thought we needed to move forward in power now. If you buy a new machine, you always have to be on the cutting edge, and then we thought it was a good piece of modern technology, and when you buy a new machine and it’s very expensive, you have to buy the best and then perhaps that is how we achieve our goals. ( . . . ) Well, I don’t know if we made the calculations. We use our common sense in cases like this. With more efficient machines, we are sure to be more productive. Those who understand this much better than I do say that efficiency can be improved by about 5 to 10%.” (60 years old, higher education degree, his son will manage the precision farm, operating on 1000 ha)

#### “Trial and Error” Developers—“Simple Technology Users”

In this group, farmers did not make calculations of profitability before the introduction of new technologies. Due to the positive experience of practical tests, they decided to try to use precision technology to a minimum extent. They are uncertain of gaining a return on the new technology but have a positive future vision. With low risk-taking, the motivation is not primarily the return on the invested money, but the more efficient utilization of the machine work and machine operators and the simplification and facilitation of their work.

“We did not make any calculations, and nor do we have calculations at present. Well, I don’t really know what the reason was. When we tried them, we had positive experiences with them. ( . . . ) I think that this automatic steering system does not show in the average yield, but rather it manifests itself in the utilization of machine operators and the machines themselves, and we see the advantage of its results without calculations. The only result we see is that we may be able to use extended working hours, and the drivers don’t tire so soon, so we see the benefits there.” (31 years old, higher education degree, cultivating 800 ha own land and performing hired machine work on 2500 ha for local farmers)

“It’s an expensive technology, I can’t say it’s cheap, we’re not sure it will pay off. ( . . . ) The time spent working in the field can also be reduced. Therefore, there is still some untapped potential in the salary we pay the boys.” (36 years old, higher education degree, operating on 1500 ha)

#### Innovators

Some precision farmers have decided on innovative developments due to many aspects, including their innovative intent and their interest in new technologies. Respondents’ willingness to innovate, especially their openness to precision technology, is not strongly linked to their age (they do not consider precision farming a privilege of young people).

“Innovation is, for some reason, something in my personality that I have to do because I always jump into things that I’m a little afraid of.” (36 years old, higher education degree, 600 operates on ha)

“I think it definitely calls for skill or interest, and I see most of those farmers who are always a bit inventive in their thinking, to move forward as they are always looking for new opportunities, new technology even if they don’t know whether or not they will get the desired result.” (31 years old, higher education degree, cultivating 800 ha own land and performing hired machine work on 2500 ha for local farmers)

The most common argument of innovative farmers in favour of precision technologies is to make their employees' work easier and more efficient. The reduction of workforce was not mentioned by any of the respondents (unlike the change of workforce).

"And then to relieve people, as I used to work 15 to 16 h a day. And you didn't have to worry about where the machine was going, you could supervise the work and you wouldn't get tired." (36 years old, higher education degree, 600 operates on ha)

"You have to keep up! Precision farming is interesting, but it's still not a miracle. I've been to America, they've been producing corn for 50 years on the same land, of course they know when and how to finish work. But as we discussed, it was obvious that even if they admit its positive sides, they still do not think that it would save the world. By the way, I am of the same opinion, but it can make the work of employees very easy at first. They will work more efficiently and it will also be less tiring for them. They just set the machine, start it, thus letting them be much more relaxed, making them work much more efficiently, which was one of the primary goals. It is a human factor to help them. (47 years old, higher education degree, managing director, operating on 300 ha land, but they have an influence on 3500 ha as an integrator company)

#### Prestige Enhancers

The prestige effect of switching to precision farming can also be demonstrated in the conducted interviews. The need for respect appeared in the responses, which, in sociological contexts, is always the recognition of an achievement that gives prestige and rank. It is a sign of belonging to a higher class in the industry's hierarchy and of the need for recognition on behalf of outsiders. Precision farming results in an increase in status among farmers and provides a place of prestige with higher levels of symbolic rewards.

"It increases respect for me, not my confidence . . . or I don't know how to call it. And it also shows that it is worth working for us because we are more dedicated than others." (36 years old, higher education degree, operates on 600 ha)

#### Technology Buyers, either Accidentally or Unknowingly—"If They Gave It, It's Here"

This group involves precision farmers whose innovative developments are the result of accidental circumstances. They received this technology as auxiliary services to purchase machinery, which they had been unaware of or unwilling to use for some time. Later, however, they attended trainings to learn how to use technology.

"In 2008, we bought a universal tractor and it was equipped with this technology. The option was there, it was stated among the equipment that it has a GPS antenna of this and that signal accuracy, interface, and everything. And then they didn't really promote it, so if they gave it, it's here. It took us a while to unpack the machine and put it on the tractor so we can see what it is. And then it turned out that this is not such a stupid thing to make a person's job easier, so then we started using these tools better." (40 years old, higher education degree, integrator, operating on 1500 ha)

#### 5.1.2. Factors Contributing to the Diffusion of Innovation According to Precision Farmers

In this chapter, the authors intend to present the factors identified by farmers based on their experience that could help the spread of precision farming in Hungarian agriculture.

##### Competence

As the surveyed precision farmers all have higher educational degrees, except for one or two who have high school degrees, it is not unexpected that more people have highlighted increasing the level of education, acquisition of knowledge and skills as the most necessary conditions for adapting innovations. The most important tool and task is to

solve the low level of education of agricultural workers, and the problem of their adherence to the traditional, “ingrained, innate” solutions. To this end, changes are proposed at several levels of education, particularly in secondary vocational schools, as well as in adult education and vocational guidance for farmers.

“It must be stated that it’s not the highly qualified people who work in today’s agriculture in most cases. The ingrained and innate things are still present and a different way of organizing high school education would be necessary to address new and modern issues.” (67 years old, higher education degree, operates on 1200 ha)

“Well, I think it’s education, this is where the world is heading, in that direction. I think it could be a solution. Everybody carries out developments, but if you are already developing, develop in that direction. This cost is, in fact, far from the costs of machinery, e.g., a harvester. I do think that maybe it would be important to improve education in this direction or to make everyone aware that this is the right direction.” (60 years old, higher education degree, operates on 1000 ha)

**Skills and Experience—“Anyone Who Can Use a Smartphone Today Can Use These Machines.”**

According to a different group of opinions, commitment, experience and willingness to invest time, employees’ existing skills and their development are the prerequisites for the spread of precision farming. In their view, one does not become a precision farmer based on the knowledge gained at different levels of the school system, but on employing open minded employees who are capable of using technology. They are committed and open to innovation and have experience in agricultural production to decide on technology investments.

“I do not think that expertise is essential to this precision farming, that is, I would not be able to add or bring in the level of expertise needed for this. So I say that it is much more important what kind of commitment and intention you have to go in this direction, so you can acquire this knowledge from that point. In other words, I could not say that this requires a university degree or a technician degree or a doctoral degree. You don’t need that kind of education. It is more important that you are committed and willing to spend extra time and energy learning this knowledge on the go, it is much more important.” (31 years old, higher education degree, cultivating 800 ha own land and performing hired machine work on 2500 ha for local farmers)

“We’re trying to hire a reliable person. You either give him a shovel without having to worry too much or he can use normal tools. There he has that competitive spirit, or I don’t know what, but no one wants to look “less able” than their colleagues, so he has to do it and learn it.” (40 years old, higher education degree, integrator, operating on 1500 ha)

“So we employ eight tractor drivers, maybe one of them is into it. The rest of them are not really suitable for this. The big problem is how we can teach them. So, as the size of the farmland is increasing here, it is likely that you will need to get another tractor driver, a high-quality employee, to work. ( . . . ) The truth is, tractorists used to be those who had bad marks in elementary school. Then they managed to graduate from tractor school somehow. They are likely to never understand it or how it is needed to be used as they are not responsive and not brave enough. So here we need people with great skills who will be able to learn this.” (53 years old, higher education degree, operates on 1100 ha)

“Anyone who can use a smartphone today can also use these machines. These machines are made in such a way that even unskilled people can use them. There is a management server and you can learn how to use it in two days. These big machine dealers are teaching people properly.” (53 years old, higher education degree, operates on 1100 ha)

### Dissemination of Good Practices, Adaptation Schemes—Support for Less Skilled or Uncertain Farmers

A group of respondent farmers consider that the main obstacle to the spread of PF is that non-precision producers, farmers and entrepreneurs do not know the benefits of precision technologies. It is a problem that they cannot see good practices and successful models based on precision technology on lands similar to their own in order to compensate for this shortcoming. Relying on their knowledge and resources, not all farmers can become familiar with precision farming technologies and potential development directions and make their environment suitable for use. As they put it, there are “weak and not-so weak students in school”—the case is similar among farmers. It was also emphasized that the number of precision farms in Hungarian agriculture has not yet reached a level where they could serve as a model for future followers. To this end, farmers cannot be expected to make massive changes to the technologies they use, especially those who are “weaker learners”.

Farmers are also aware of the difficulties in spreading adaptation schemes and they highlighted the obstacles to doing so. Due to the diversity of farms (e.g., different land quality), it is not possible to simply copy and implement the best practices and strategies elsewhere, i.e., adaptation is not an easy task either. For this reason, there are always risks for novice farmers who want to innovate, which is why they have said that one cannot start as a precision farmer at the age of 20 without experience. However, they find the greatest hindrance to expansion to be that farmers do not yet see a sufficient number of working examples enough to motivate many to apply the technology, i.e., they currently do not consider the bottom-up organization of innovation spreading to be the primary form.

“First, the use of precision farming should be more widely disseminated, and when less advanced farmers see the results of their neighbour or a fellow farmer who is using this technology, then they will see that it is not a useless thing and that they can really get better and higher yields. However, capital needs to be injected into it, because this group is not going to spend that amount of money (small farms—the authors). Even now, they cannot make modifications either in terms of machinery and cultivation equipment.” (66 years old, higher education degree, operates on 70 ha)

“The precondition for the development of precision farming is that producers, farmers and entrepreneurs should be aware of its benefits, which is obviously a process, and it will take another couple of years for everyone to find the way to benefit from this system.” (31 years old, higher education degree, cultivating 800 ha own land and performing hired machine work on 2500 ha for local farmers)

### Cooperations

Farmers with a smaller farm size are convinced that cooperation and farmers’ collaboration would accelerate the spread of precision farming. First and foremost, the amount of investment needed, the launch of joint development projects, their faster return on investment and the utilization of joint expertise would result in success through collaboration. Meanwhile, there is no openness in this respect on behalf of farmers in Hungary. Isolationism is more characteristic of them.

“These cooperations, they don’t exist. They keep talking about it, but there is no well-established example of how such a partnership works so well. If 15–20 farmers could come together and maybe could invest, say, millions or even hundreds of millions, then that would be the solution. But for the time being, to my knowledge, it is impossible, we are not yet there where we need to be to make it happen. Thinking is what matters. Each farmer’s mind should be turned a notch to the positive so as not to be reluctant to cooperate.” (66 years old, higher education degree, operates on 70 ha)

“If there were cooperatives, they would do better. Certainly, more things could be achieved by a cooperative than by one person individually. ( . . . ) Well, yes,

because, just think about it . . . 4–5 people can cope with a 100 million HUF bid much more easily than one farmer. We were in the Transdanubian region, where 7 farmers teamed up and bought a harvester together. Therefore, with such tens of millions of investments, it makes a difference if one farm needs to deal with it on 200 hectares, or 1200 hectares. It's just not the same. I'm sure we could achieve more together, but the problem is that it's hard. Here, it is becoming increasingly difficult for farmers to collaborate. Well, this is what the current system brings, this is the world now. People turn away rather than help." (secondary educational degree, operating a 150–200 ha family farm)

#### Learning Organizations—Precision Knowledge Displaces Traditional Knowledge

Activities based on the gradual introduction of precision technologies are organically integrated into work organization processes, and through the enhancement of employees' knowledge capital, farms become learning organizations. According to the observations of farmers using precision technologies, employees using modern technologies find it difficult to go back to traditional solutions if they have to do so for any reason. In many cases, state-of-the-art solutions make it unnecessary to acquire knowledge of traditional ways. The knowledge that is unlearned or lost in the meantime can make it difficult for an organization using non-complex precision technology to operate and encourage farmers to make further precision technology improvements.

"Now, suddenly, I don't know how many of these new tractors we have, maybe 8–10, and we have around 30 tractors altogether. So you don't always have the necessary machine everywhere you need it. In each field, we perform precision techniques, but there are few where each work process is done that way. However, at this point, if there is a technical problem, say, a satellite signal or the Real-time kinematic positioning (RTK) isn't working, then it's already a big problem, as the tractors can no longer sow because our drivers have forgotten to use the track marker. So then life stops practically. They have gone from saying, "it's an unnecessary stupidity and a way of showing off, something the boss harasses us with" to the point that they are now very eager to use this technology, not wanting to sit in a machine that does not have this feature." (40 years old, higher education degree, integrator, operating on 1500 ha)

#### Motivating Farmers on Homogeneous Land—"I don't Feel Compelled..."

Farmers on homogeneous, high-quality land can also achieve high yields using traditional intensive technologies. They believe that more cost-effective and efficient production with precision technology is best achieved by those who have fields with mixed areas within, and that investment in innovative technologies is primarily worthwhile in their case. In other words, high-quality and homogeneous land is a counterincentive for farmers to introduce precision technology. They also experience the greatest lack of trust in service companies. The knowledge of consultants and salesmen is considered to be only theoretical and, therefore, unreliable. They consider this change to not be in their best interest.

"We only have two machines equipped with RTK GPS, which is used primarily for earthwork, combinators and disking. However, since we use the best lands of the Hajdúság loess ridge, we have good yields here. Now, there is still room for improvement, we could reach even better results. However, since we have homogeneous lands, this whole yield map and the benefits of doing it this way all work out differently than in a mixed, lower quality area. It would be possible for those who have more mixed areas to move forward in terms of more cost-effective cultivation. So, there are big differences within the field in places where there are lands of over 40 and 30 gold crowns (GC). Since purchasing such machinery is very expensive at the moment, I don't know when it would pay off on this farm, and I see no future or significance in it for us, at least not for a while." (65 years old, secondary school education degree, integrator, operating on 1500 ha)

“I would like to believe that somebody will tread the road in the case of homogeneous fields, showing the right direction. Because at the moment, neither the service providers nor labs who represented the delineation of these cultivation zones were convincing. (. . .) And these cultivation zones differ for each service provider. Now, even they are only searching for theoretical experience, there is no practical experience to back it up; they just keep telling me that this will be good for me anyway. Well, I don’t know, as long as we can obtain 13 t/ha yields of fodder maize without any precision technology, I don’t feel like I have to make any changes.” 40 years old, higher education degree, operating on 1300 ha)

#### Price Drop in Precision Technology—“Wait-and-See in Demo Mode”

Farmers with smaller land but interest in precision technology are currently only renting precision technology. They cannot buy them on their own, because they consider that the farm size would greatly delay a return. They call this attitude a “wait-and-see approach in demo mode”, as they expect precision technology to become cheaper following its penetration and that it will be worth investing in PF as “late followers”.

“So there is this soil scanner, sowing machine, harvester and the fertilizer spreader. These machines cost more than the ones we use currently. We would not realize a return in 10–15 years, even though we could achieve higher yields within 2–3 years, but the cost of the equipment itself still makes it 10–15 years, especially with this farm size. We have to wait until this technology becomes more ordinary, so that it would be cheaper, because for now, it is out of the question for us.” (66 years old, higher education degree, operates on 70 ha)

#### More Supportive Institutional Background—“Somehow, Technology has Left behind This Whole System.”

According to the interviewed farmers, there would be a need for centres that do not focus primarily on sales but also test these precision systems under local conditions before farmers purchase and apply them. The reason these centres are needed is that, in the interest of studying the afore-mentioned adaptation patterns, they might be able to provide information that would aid in the decision-making process to those interested. By more supportive institutional background, the respondents also mean the protection against the tricks of machine dealers, which they are very critical with. Machine dealers sell technology to them, but in many cases, they give false information. On several occasions, farmers realized that they did not need the technology other than when it was being used. These negative examples and failed technological changes discourage farmers from making further improvements or new investments.

“One problem is, that there are no centres to test these systems. It would be important to find out how well they work before wanting to sell them to farmers. So there is no institutional background for testing these systems under practical conditions, say, under different local conditions that then gives an objective viewpoint to farmers so that they can make the right decision. There is nothing like this. There are almost only sales companies here to tell you which one is the best, and the farmer realizes only later that this is not the case. There is no information.” (36 years old, higher education degree, operates on 600 ha)

“The precision machine and precision technology dealer sells the precision tech to the farmer and that’s where the service ends in most cases. From then on, we need to proceed with installation, operation, development, and system development extending the system within the farm so that not only fodder maize but also sunflower can also be produced. These services are lagging behind because the dealers cannot put anything extra behind them. In other words, there is no backend to add to this precision farming method.” (36 years old, higher education degree, operates on 1500 ha)

“Somehow, technology has left this whole system behind, because in agriculture, things move very slowly forward, not only workers, but managers and offices too. So it should work this way: the farmer decides what to buy, this and that, goes to a place where it has already been in use for, say, 5–10 years. Well, not for 10 years, sure, but it’s been used for a couple of years, and then the farmer can get informed about the experience with this current system, then he can go to another place and then buy what’s best for him there.” (36 years old, higher education degree, operates on 600 ha)

Research results show that land size influences farmers’ willingness to switch to precision farming. In our study, not only small but also large farms were shown to have a disincentive effect due to size. While examining the relationship of the largest farmers to precision technology, it was found that—despite the fact that their information network is outstanding and the scale of their businesses and the owners’ network of relations allow them to have all the necessary professional information, they are knowledgeable about the issues concerning their area of expertise, and they have access to knowledge about developments and innovation opportunities—large farms have not become the initiators of the introduction of precision technologies. They do not wish to participate in the second phase of innovation, either. Their reluctance stems from the fact that their companies have a high level of technological equipment, although they are not precision tools. A technological change would result in significant investment and inadequate return on investment. There is a lack of motivational effects on behalf of entrepreneurs working on large, high-quality, homogeneous lands.

Innovation is an important element of modernization, but it also has an impact on sustainability. Neither precision farmers, nor small, medium or large entrepreneurs who are disinterested in precision technology, have the knowledge and attitude to motivate the spread of precision farming. Despite international research demonstrating the close relationship between precision farming and sustainability [61–63], Hungarian farmers ascribe little importance to environmental or economic sustainability. Sustainability is not a motivating factor for the transition, and there is no difference in this respect based on academic achievement and farm size.

Our research was based on the assumption that innovation is not only an economic or technical-technological achievement, but also a social category [64], a micro-level implementation of modernization that is embedded in a segment of society. Technical and economic innovations also include the involvement of further areas in the innovation process [65], creating socially involved innovations in increasing community well-being and addressing current problems at the local level [66–68]. This is also linked to social sustainability, which means production, criteria of profitability, as well as environmental sustainability [69].

However, according to our research, farmers currently do not attribute any positive social benefits to precision technologies, as innovation does not bring them any more open to local communities. This also means that these rural innovations do not facilitate contacts at their current level of application and do not increase the network of relations, nor do they make farmers and local residents mutually interested parties.

The process of innovation expansion is complementary, which means that social and technical innovations are closely interrelated [70]. The marginal conditions and scope for technological and economic innovations are the society and the innovations at the social level [71], in this case at the level of rural societies [72]. In our study, this effect cannot be detected among Hungarian precision farmers, also because the regional, territorial level is not part of the promotion of innovation. According to our results, there is no close correlation between innovation potential and geographical area. Farmers do not perceive, among the obstacles to the spread of precision farming, that the spatial differences in social resources, the disadvantaged or even the advanced rural areas, influence their farming and their willingness to innovate through their social characteristics. This is even more remarkable because the human resource potential of aging rural areas does not allow them to be targeted as a strategic objective for the employment of young people and thus

improve local labour market opportunities, and therefore, agricultural entrepreneurs with low employment are forced to adapt to the existing potential rather than employing a knowledgeable workforce that matches the modern technologies they want to introduce. As a result, neither precision farmers nor conventional producers can interpret precision farming as a means of boosting the countryside, and they do not see any potential increase in young people's agricultural employment through the use of innovative technologies. Altogether, the use of precision technologies does not increase local social cohesion currently. It is not suitable for influencing local social processes and social innovations at its current level of penetration.

The high degree of organizational isolation of precision farmers hampers the spread of innovation knowledge amongst the farming community, as well as the development of partnerships between farmers and organizations, local institutions and local residents that take advantage of local capabilities. It was shown that, despite the vulnerability due to farm size, the strong reluctance of farmers does not decrease, and it keeps their cooperation willingness low. One of the reasons for this phenomenon was the lack of need for competitiveness. Competitiveness refers to the propensity and skill to compete, which is usually measured by success, the size of the market share and the extent to which profitability increases [73–75].

## 6. Conclusions

Based on the nationally representative questionnaire survey of 594 farmers and deep interviews with experts and farmers, one of the conclusions is that the management of the average farm size in Hungary has the highest willingness to innovate and the second-highest level of education among the five developed clusters. The survey shows undertrained farmers with large farms to be the second most open group, which may result in the partial application of precision farming techniques. The positive socio-economic utility of precision farming is rated as extremely low, which was one of the most unexpected Precision Farmers' cluster results. According to the in-depth interviews, that was proven that the use of precision technologies does not increase local social cohesion. As another conclusion of the analyses, strong organisational isolation of precision farmers prevents the spread of innovation knowledge and precision farming amongst the farming community. Even though innovation has a key role in improving competitiveness, our results show that there is only a narrow focus on competitiveness goals among precision farming, primarily in the context of increasing profitability. The vast majority of farmers do not even face the challenges of competitiveness, nor do they realize that they need to make innovative improvements in order to increase their competitiveness. The spread of precision farming is not forced by the challenges of competitiveness among farmers. It must be added that the small number of precision farmers and the uncertainty of clear definition of precision farming may be considered as limitation factors and requires progress and future research.

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## Appendix A

Dissemination: the act of spreading news, information, ideas to a lot of people.

Innovation: the practical implementation of a new method, idea or product.

Innovator: a person who develops innovation.

Precision farmer: who use at least the simplest element of PF technologies (e.g., automated steering and boom shutoff).

Precision farming: it was one of the research questions in the paper.

SAPARD: abbreviation of Special Accession Programme for Agriculture and Rural Development. It was established in June 1999 by the Council of the European Union to help countries of Central and Eastern Europe deal with the problems of the structural adjustment in their agricultural sectors and rural areas, as well as in the implementation of the acquis communautaire concerning the Common Agricultural Policy (CAP) and related legislation.

Skill: the ability to use one's knowledge effectively and readily in execution or performance.

Social benefits: is the total benefit to society from producing or consuming a good/service.

Social determinants: the social factors which have effects on farming, esp. land size, education, age of household head, profit.

Willingness to innovate: action to prepare to make innovations or carry out innovation activities.

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