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Tendencies of Precision Agriculture in Ukraine: Disruptive Smart Farming Tools as Cooperation Drivers

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Abstract: Precision farming innovations are designed to improve the efficiency of agricultural activities via minimal initial input of material and human resources and avoiding harmful effects on the environment on one hand and automatizing the production on another hand, thus providing environmental, social and economic benefits. In the article, the tendencies in the adoption of precision agriculture technologies (PAT) in Ukraine were observed, with a specific focus on cooperatives as a valuable tool of social and solidarity economy helping to achieve progress in local rural development. On the example of cooperatives, applying a technology acceptance model (TAM) has identified how the adoption of new smart farming tools influence their behavior in implementing technological innovations. The results of the study will be of particular interest to representatives of other cooperatives and to agribusiness players engaged in agriculture or software development. In addition, the outputs will be useful for researchers in the field of the socio-economic development of territories and the impact of new technologies on it, as well as for local governments and higher-level government officials, which can contribute to the implementation of better rural development strategies.

Keywords: precision agriculture technologies; agricultural cooperatives; social and solidarity economy; agricultural digitalization; sustainable development

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1. Introduction

Quite unexpectedly, the world community at the end of 2019 came under the huge influence of the World Coronavirus Epidemic (COVID-19). Ukraine and its economy, as an integral part of the world economy, have also been significantly affected. Thus, in response to the COVID-19 pandemic there have been significant changes in both the nature of economic development and its structure. There has been a change in motivation in the behavior and business activity of the vast majority of humanity. The determining factor was not the economic feasibility, in contrast to all historical periods, but the motive of caution in the context of a pandemic. That is, on the one hand, there were transformations in preferences and priorities in domestic, office life and business needs that accordingly affected consumption (in particular, declining demand for non-essential products and services) and, consequently, production. On the other hand, the intensity of use of funds has changed, which has significantly decreased and given way to "holding" funds (maximum consumer caution in costs against the background of uncertainty about both short-term and long-term prospects for income). Although the "retention" of funds does not fully relate to the classical understanding of the propensity to save, however, such behavior significantly affected the nature of inflation and its relationship with monetary factors. Moreover, maintaining macro-stability changed the structure of household deposits, specifically increasing the weight of demand deposits in the accounts of the population.

Accelerated digitalization took place in the conditions of mobile transition of enterprises to new forms of organization of work processes (remote, home-based work and study), which, accordingly, created increased demand for new digital services and provision of existing services in digital format, including conducting trade and business. The growth rate of digitalization processes has almost doubled compared to pre-pandemic times, which sped up the progress of the introduction of digital technologies into the economic processes by one and a half years. In 2020, the level of digitalization of Ukraine's economy, according to the Ministry of Economy, was 5.3%, which corresponds to the projected level of mid-2023 under pre-pandemic conditions. The adaptation of digital technologies opens up the opportunities for Ukrainian companies to optimize their business processes by reducing operating costs, reducing the cost of goods and services and increasing the productivity of employees. In general, "covid pressure" has opened up new opportunities for the development of, in particular, enterprises in the agricultural sector, once again focused on the greening of social activities. In 2020, Ukraine was ranked 69th in the global ranking of the United Nations e-Government Development Index 2020 (EGDI) with a score of 0.7119. In the ranking for 2018, the country was in 82nd place with a score of 0.6165. The e-government development index in Ukraine confidently exceeds the current world average of 0.6 (0.55 in 2018) [1]. In the global dimension, COVID-19 has not only forced economic development, but the pandemic has also presented the world community with new challenges that are pushing humanity to review progress towards the 17 UN Sustainable Development Goals (SDGs). However, this obstacle had an unexpected positive side effect on the speed of digital transformation in the country.

One of the priority sectors in Ukraine is agriculture, but it is also one of the most conservative and radically changing due to modern technologies. Innovations affect technology, land management approaches, yield forecasting methods and business processes. It is not just about state-of-the-art combination or economical irrigation systems. The Internet of Things, big data analysis and cloud services are all also seriously affecting agriculture, forming a new philosophy called precision farming. Industry 4.0 innovations, which are increasingly penetrating all areas of the economy, also have a significant impact on agriculture and force both farmers and large agricultural holdings and cooperatives to choose between the principle of "we have done so since time immemorial" and the latest approaches.

Precision agriculture (PA) is a set of management practices, specialized strategies and innovative technologies that help make data-driven management decisions, leading to increased resource efficiency, reduced agricultural costs and lower environmental impact from agricultural production [2]. This is a new approach to the development of agriculture, associated with the use of geographic information systems (GIS), global positioning, on-board computers, management mechanisms that can differentiate tillage methods, fertilizer application rates, chemical ameliorants and plant protection products (PPP) [3]. However, until recently, it was possible to talk only about single farms, where precision agriculture technologies (PAT) were actively used. Today, there are at least a few dozen such agricultural formations, including cooperatives in Ukraine. Although these technologies are not being implemented as fast as in Asia, North America and Europe, there are objective reasons for that. Obtaining economic benefits from the introduction of new technologies is one of the main factors influencing their spread and implementation, but it should also be borne in mind that not all farmers prioritize profit maximization, and therefore the benefits derived from a particular technology will vary between farmers. In addition, especially for new technologies, the objective assessment of the associated economic benefits is limited, so it is the perception of agribusiness representatives of these benefits will affect their behavior in the implementation of such tools. If farmers' adoption of new technologies is based solely on economic benefits, it would mean that they are all equal and use the technology at the same time [4].

Nowadays, the benefits of PA technology applications are quite well-studied by numerous authors, and the common opinion is that PA ensures the sustainable intensification of agricultural production and at the same time reduces its environmental impacts [5,6]. The usage of smart farming tools in relation to improved food security and environmental protection has been well documented [5,7–9]. PA can be considered as a "toolset" from which farmers choose what they need [10]. Although a clear definition of what technologies are included in PA is still required [10,11], broadly, technologies can be classified into the following: data collection technologies, including global satellite positioning [12,13]; remote sensing technologies [14], soil sampling and mapping, data processing and decision-making technologies and sensor networks [15]; and application technologies, including variable rate technologies (VRT) [16]. Precision agriculture can bring such key social, economic and environmental benefits to all its stakeholders as the minimization of farm costs through the controlled application of agricultural inputs [17]; growth in production level thanks to targeted in-field management [18]; and precise application of agrichemical applications, e.g., fertilizers, which will also increase compliance with national/global environmental legislation [19]. However, after all, it is the perception of farmers of the benefits associated with the new technology that regulates the process of its implementation [20].

Thus, the purpose of this article is to study the level of implementation of precision farming tools by cooperatives (its participants), which will assess the level of readiness of Ukrainian agribusiness to adopt new sustainable technologies and provide an understanding of the main factors hindering the transition to environmentally sustainable farming tools, as well as to their further dissemination and implementation throughout Ukraine. To this end, the technology acceptance model (TAM), which models how users perceive and use new technology using hidden variables (such as perceptions and beliefs), has been adopted as a theoretical basis. Unlike directly measured variables, such as the age of people, latent factors (variables), such as people's cognitive abilities, e.g., perceptions or beliefs, are not possible to assess directly; however, they must be evaluated on the basis of other directly observed variables [21]. The TAM includes key hidden variables that are perceived as useful and the ease of use that is considered to influence an individual's intention to try, use and finally decide on the implementation of an innovative technology [22]. Some authors concluded that both perceived utility and perceived ease of use are significant latent factors in determining the success of precision farming technologies, which will ultimately reveal which hidden factors in particular influence cooperatives' intentions to implement precision farming technologies [23].

Thus, assessing how cooperatives' perceptions of innovative tools influences their behavior when implementing technology and understanding the causal relationship between hidden variables identifies levers that will facilitate implementation and accelerate the process. Given that PATs are very conducive to more sustainable agricultural production, which is one of the main problems currently facing agriculture, strengthening the adoption process is extremely important. For this purpose, an in-depth analysis of cooperatives was carried out, covering seven young, fast-growing, dynamic Ukrainian agricultural cooperatives operating in the tensest regions given a number of socio-economic problems and can serve as an example for the further development of the cooperative movement in all regions of the country, which will develop and strengthen the potential of agricultural cooperation in the revival and sustainable growth of rural areas. Partial modeling of least squares structural equations (PLS-SEM) was chosen as a methodological basis for estimating TAM and analyzing the causal relationships between hidden variables. In addition, a logical model was used to test the relationship between the intention to use precision farming tools and their actual use. The results of the study will be of interest to representatives of software producers in this field, as well as government agencies and relevant non-governmental organizations, as these data can be used to promote sustainable production, sustainable rural development and community development and will help strengthen the links between urban and rural areas in some regions, which is a great impetus to the implementation of the principles of social and solidarity economy at the state level to improve the lives and well-being of citizens.

2. Materials and Methods

The implementation and usage of innovative agricultural technologies and practices is an important point impacting the welfare, in particular economic, of farmers and the agricultural production in general [24]. Similarly, innovative technologies in agri-sector gave a push to the formation of agricultural production systems [25]. Some authors [18] note a general fact that key agricultural players such as farmers do not tend to apply the innovative technologies immediately, while, according to the opinion of other scientists [26], it takes a lot of effort to convince them to implement innovations, which can be due to many factors.

The term of "Precision Agriculture" as a concept of farm management was developed in the mid-1980s; therefore, it can be fairly called "new". However, due to the fact that the adoption of new technologies in agriculture is rarely immediate, this concept is only in recent years turning out to be at the peak of "fashion". While great efforts are being made to persuade users to accept new ICT tools, implementation is a complex process, and many factors influence decision-making processes [27,28]. The PA concept allows filling in the gap between different points, i.e., provides the possibility to make the right intervention, in the right place and in the right time [29], in this way enabling farmers to detect and decide what is "right" [30,31]. The main aspects of PA were investigated centering on specific technologies, environmental impact and effects, economic outcomes and benefits, adoption rates and their drivers, as well as consequences of adoption and non-adoption of specific technology. There are authors that confirmed the environmental and economic benefits provided by PA [32–34]. At the same time, an insufficient application of PA practices is still recognized by both academic surveys and professional studies [35–37].

The recent review of the papers related to the topic of precision agriculture and smart farming tools provided the necessary background knowledge for the article's purpose, through an analytical approach with a focus on existing agricultural systems and the data collection process. Among the analyzed literature resources were identified authors [38] that revealed the main focus on livestock rather than farm agriculture. Other authors in their turn were focused on the process of collecting big data as a broader concept in agriculture that includes governance, legislation, research methods and applications, but forgot to map the importance of linking agricultural systems to the further use of these collected data [39,40]. Some authors were focused more on the PA technology deployment progress, and their research showed that in low-resource economies, it is much slower than in advanced agricultural economies despite their significant potential to increase production efficiency, inclusion and participation in global markets and improve rural livelihoods [17]. There are also evidences of the adoption of small, low-cost PA, e.g., in Argentina, Brazil, India and South Africa [11,41]. The level of PA adoption differs considerably globally, with visible growth in North America and Asia, e.g., the USA and China, which is higher than in Europe and Australia [11,42]. The in-depth review of farm agriculture and benefits from use of technological advances revealed that apart from the use of big data, drones, remote sensing, etc., in agriculture, other approaches were paid attention to in smart agriculture, including a climate-oriented approach, stressing the importance of the climate change in the agriculture sector. One group of researchers [43,44] proposed a conceptual framework, aiming to overcome the existing barriers in socio-economic level and the successful adoption of the recent technological advances, accentuating on their analysis and potential to smart farming. Another review paper [45,46] connects climate change with adjustments that should take place in different agriculture sub-sectors, and it is focused on strategies and policies, rather on the existing technologies and approaches that form the current status of smart agriculture.

Smart agriculture already has a wide market supply and growing demand on existing commercial solutions and platforms [47]. The majority of the commercial smart farming solutions are aimed to collect, integrate and visualize data collected with the use of IoT sensors, whereas only few offer predictive analytics [48], which gives them a significant competitive advantage. At present, a turning point is coming in the development of agriculture at the global level since, against the background of demographic changes, increasing pressure on renewable resources and competition in the market for valuable resources, as well as the impact of the effects of climate change and the loss of biodiversity, the necessity for profound transformations at all levels of management is becoming more acute; this includes the agricultural system. Changing approaches to what is produced, processed, transported and consumed and how are necessary to achieve sustainable food systems, which are among the priorities of the Sustainable Development Goals (SDGs).

According to an official report jointly published by ITU and FAO in 2020 "digital agriculture has the potential to contribute to a more economically, environmentally and socially sustainable agriculture, while meeting the agricultural goals of a country more effectively. Both information and communication technologies (ICTs) and agriculture are important enablers for achieving the SDGs" [49], which means that more and more attention will be given to the deployment and adoption of smart farming tools in the agri-sector in the coming years. With the use of innovations of Industry 4.0 in production process comes the integration of humans for continuous improvement and a focus on value-adding activities and evading waste. This illuminates the nine important pillars of Industry 4.0, for example, Big Data and Analytics, Autonomous Robots, Simulation, System Integration: Horizontal and Vertical System Integration, The Industrial Internet of Things (IOT), Cyber security and Cyber Physical Systems (CPS), the Cloud, Additive Manufacturing and Augmented Reality, with its applications in different field [50].

The agri-sector is converting into one of the most knowledge-intensive, i.e., representatives of this sector need additional information and smooth access to it in order to be able, based on this information, to make informed and often difficult decisions regarding the use of their farm and land resources, the crops they grow, the markets in which these crops can be sold and other important issues that affect their livelihoods and the well-being of society as a whole [49]. Sustainable agriculture depends on data availability. Smart farming tools support sustainable as well as profitable farming through a combination of processed satellite data and field observations, so farmers can make informed farming decisions much easier, as they have a bottom-line analysis of the situation in their fields. The use of various sensors, as well as weather stations, significantly helps farmers decide how, where and when to allocate certain resources to improve environmental and economic results.

Today, the production approach that dominated in the global agro-industrial complex in the second half of 20th century has changed in the most significant way, and it is now a synergy of information technology, new materials and nanotechnology, energy, biotechnology and transport systems. Thus, after the "digitization" of the agricultural process, the agro-enterprise can be viewed as a digital system with a possibility to use such instruments as specific cloud platforms available for application with a different functional set, with the help of which the user can choose his role (farmer, biotechnologist, consumer, etc.) and clearly see the results of the actions taken in the field and production process including whole product traceability.

The Ukrainian agricultural sector represents a cross-section of those socio-economic and scientific-technological processes that cover all economic sectors, where powerful transnational holdings modernized with the latest technology co-exist with numerous small farms. Meanwhile, it is the agro-industrial complex that claims to be the main demonstration platform where the results of the new technological revolution can be demonstrated: the robotic technologies of Industry 4.0 transfer almost all agricultural machinery to a deserted mode. The Ukrainian agri-sector will have to solve a whole package of diverse tasks: from digital transformation and reduction in logistic losses to the search for new markets and multiple expansion of export potential. However, in the last few years in Ukraine, valuable steps have already been taken on the way achieving of sustainable and profitable agricultural systems, as several documents were adopted on the governmental level w aimed to better organize the management of the agri-sector and to promote the innovative technological applications and digitalization in this area. The main priorities of such initiatives include land reform, food security, agri-food value chain development, rural development and the revival of the Ukrainian village.

Furthermore, according to the report of the ITU and the FAO, one of the stressed positive moments was that, in recent years, Ukraine has demonstrated a notional development of new technologies in the agricultural sector. At the moment, there is about 70 agro-tech startups that operate in different areas, e.g., farm management and precision farming solutions, drone and remote sensing and getting started in urban agriculture. The ecosystem of domestic startups, considering also business accelerators and venture capital firms, is currently growing in Ukraine. In addition, large Ukrainian agricultural holdings are participating in their own and joint agricultural projects, working with e-agriculture companies such as Bitrek and Craftscanner (automatic adjustment of the tillage depth). There is also the association AgTech Ukraine promoting the role of IT in agriculture [49].

According to Market & Market's Precision Farming Market by Technology—Global Forecast to 2022, the precision farming market will grow to USD 7.87 billion by 2022. The starting point for researchers was the estimate of this segment in 2015—USD 3.2 billion. Researchers believe that between 2016 and 2022, the annual growth of the technology market for precision agriculture will average 13.47%. In Ukraine, precision technologies cover no more than 15% of agricultural land, the volume of the market of precision agriculture in Ukraine is about USD 60–70 million. Ukraine lags behind—today, precision farming technologies in the country are introduced by about 30% of farmers. However, innovative companies are in a hurry to increase this percentage—they are actively developing in this direction, modernizing machinery and using remote sensing.

According to experts in Ukraine, some elements of precision agriculture are used for 20–30% of arable land (about 8 million hectares), but it could be many times more. Agroholdings in Ukraine use the elements of precision agriculture on 50% of the area when applying PPP and only 4% of the area when sowing and applying mineral fertilizers [51]. The technologies used in precision agriculture that are in most demand in Ukraine include the following:

- Variable rate technology is any technology or method that allows farmers to control the amount of invested resources used within certain areas of the field. This precision farming technology uses specialized software, controllers and a differential global positioning system (DGPS). There are basically three approaches to variable rate technology—manual, one based on maps or based on sensor data.
- Soil sampling with GPS—this method of precision farming is based on the sampling of soil samples to check the composition of nutrients, pH and other data to make favorable decisions in agriculture. Large amounts of data collected by sampling are used to calculate the variable rate for optimizing crops and fertilizers.
- Computer-specific programs (specific smart farming tools) are programs used to create accurate farm plans, field maps, crop analysis, yield maps, and determine the exact amount of resources to be used. Among the advantages of this method of precision farming in agriculture is the ability to create an environmentally friendly farming plan, which, in turn, helps reduce costs and increase yields. On the other hand, these programs provide small data that cannot be used to make important decisions in precision farming due to the inability to integrate the data into other ancillary systems.
- Remote sensing technology—this method of precision farming determines the factors that can cause stress in the crop at a certain time in order to estimate the amount of moisture in the soil. Data are obtained from drones and satellites. Compared to drone data, satellite imagery is more accessible and versatile.

Precision farming is the culmination of the current stage of the agricultural revolution, which began in the early twentieth century with the spread of automation. It continued in 1990, when new methods of genetic modification were introduced. Precision agriculture as a method of regular agriculture helps to solve the most important problems: overuse of resources, high costs and devastating impact on the environment. However, these goals are not the main ones. First of all, the key goal of precision agriculture is a healthy society, which should consume agricultural products unsaturated with chemicals and mineral fertilizers. Significant introduction of chemicals ultimately leads to increased morbidity, the spread of pathologies and reduced life expectancy and therefore affects the demographic situation and the economy as a whole.

Thus, the combination of information technology, diligence of Ukrainian farmers and fertility of Ukrainian soils can increase the efficiency of Ukraine's agricultural sector and its global competitiveness and later provide an opportunity to take a leading position in such a viable agricultural market as the market of organic products. Thus, for the next 50 years, the level of development of the agricultural sector of Ukraine and its ability to compete in world markets will be determined by precision agriculture, i.e., in fact, digital technologies [23].

Precision farming technologies and the effects of their introduction have long been of interest to society. The authors of [52] conducted a literature analysis in order to identify characteristics affecting the adoption of PAT. The authors identified seven groups of characteristics influencing the introduction of precision agriculture technologies. Hence, their categorization the first group is dedicated to the socio-economic factors (it can consider farmers' age, education, etc.); the next includes agro-ecological to institutional factors, which can included farm location; then the informational factor, e.g., use consultant; the fifth is the farmer perception and the behavioral factors, including the intention of the PAT implementation; and the last one is the technological factors that may consider the computer use of computers. All these factors are thought to affect the adoption of precision agriculture technologies [52]. However, considering the research objective, this article is aims for a deeper observation of factors included in groups five and six.

Thus, the most appropriate methodological tool for the study of certain categories is the technology acceptance model [22], which is one of the most influential models of technology adoption. It distinguishes two main factors influencing a person's intention to use a new technology: the perception of ease of use and imaginary usefulness. Moreover, the technology acceptance model methodology was elaborated by [22] and was applied in several areas, as well as agricultural research for evaluation of the level of precision agriculture technologies implementation [53,54]. The main objective of this methodology is to forecast the user adoption and distinguish possible design problems before users' interaction with this technology [55,56]. According to the fundamentals of the TAM approach, it generates specific patterns for interpreting behavioral intentions and current users' behavior for new technology implementation. Thus, if the cooperatives consider that the information provided by the PAT is useful for farm management activities, it increases the potential usage of that technology. Moreover, if an implementation and application of such tool is easy, it will be also perceived as an irreplaceable tool. Therefore, the following hypotheses were assumed to be evaluated for cooperatives operating in the agricultural sector:

Hypothesis 1 (H1). *Perceived ease of use of smart farming tools in agriculture (Peou) has a positive effect on perceived usefulness of PAT.*

Hypothesis 2 (H2). *Perceived ease of use of smart farming tools in agriculture (Peou) has a positive effect on the intention to use PAT.*

Hypothesis 3 (H3). *Perceived usefulness of smart farming tools in agriculture (Pu) positively affects the intention to implement PAT.*

Based on the description of TAM, the model suggests that when users are presented with a new technology a part of others the factor of attitude, which is the general impression of the technology has to be considered. Therefore, a further hidden variable confidence position was added in the extended TAM for PAT implementation, which can be explained by the fact that precision farming technologies provide an enormous volume of information; therefore, in order to be able to process this data properly, farmers should have acquired new specific skills. Thus, the latent variable evaluates the "farmers' assurance to learn to use precision farming technologies" [53].

Due to the complexity and large amount of the information to be collected from the fields, for farmers, it is essential to have specific knowledge in order to be able to use these data in an efficient way. At the same time, there is a lack of specialists in precision agriculture, as this market is narrow. The only option is to independently educate staff for themselves from students of agricultural and technological universities. In the wake of such demand and growing interest from the youngest professionals to expand their knowledge and occupy a new niche in the emerging new sector of the economy, a center of precision agriculture was created on the basis of agricultural universities in Ukraine. Therefore, a positive effect of the attitude of confidence on perceived ease of use and the intention to use PAT is expected, which is in line with [53]. Thus, the next hypotheses are proposed:

Hypothesis 4 (H4). *Attitude of confidence in using smart farming tools in agriculture (Aoc) positively affects perceived ease of use of a PAT.*

Hypothesis 5 (H5). *Attitude of confidence in using smart farming tools in agriculture (Aoc) positively affects the desire to use PAT.*

As was defined by [22] through the factor of perceived usefulness, an individual's perception that a new technology is applicable and/or important to persons' job can be analyzed. Thus, it can be assumed that if a cooperative considers that the specific smart farming tool meets the expectations on farm management, this tool is perceived as more helpful. Moreover, other researchers also investigated the higher likelihood of farmers using the decision support system (tool) if they perceive the information provided as relevant [52]. Considering this, the following hypotheses were elaborated:

Hypothesis 6 (H6). *Job relevance of smart farming tools in agriculture (Jr) positively affects perceived usefulness of a PAT.*

Hypothesis 7 (H7). *Job relevance of smart farming tools in agriculture (Jr) positively affects the intention to apply PAT.*

Ultimately, considering the TAM framework, the intention to use positively influences the actual decision of implementation [22]. In order to test this affirmation, the following hypothesis will be examined:

Hypothesis 8 (H8). *Intention to use smart farming tools (Itu) positively affects the actual implementation of PAT.*

In order to confirm or refute these hypotheses, an in-depth analytical review of the activities and dynamics of development, as well as trends in the implementation of innovative tools of seven existing and progressive cooperatives in Ternopil, Khmelnytsky, Ivano-Frankivsk, Chernivtsi, Lviv and Rivne regions, for which the fact that the share of human capital employed in rural areas is currently significantly low is common, as the majority of the able-bodied population is employed in cross-border trade and the urban economy. This situation is typical for most border areas, as well as regions in which large industrial cities such as Kyiv, Odesa, Dnipro and Kharkiv have a significant impact, and therefore, the results of the study can be extrapolated to these areas, which will give additional advantage in elaborating strategic development plans for local communities and rural areas.

Considering the aim of the research the partial least squares structural equation modeling was conducted, as it is considered as a standard approach for analyzing complex inter-relationships between observed and latent variables [57]. Thus, a binary logit model was used that allows one to account for the structure of the binary response of the acceptance variable, which enables one to assess the interrelation between the intention to apply smart farming tools and the actual implementation decision, (1 = usage of PAT; 0 = no usage of PAT):

$$x_j = \lambda_j \varepsilon_j + \delta \quad (1)$$

where ε_j is the vector of the endogenous latent variables, X_j is the associated vector of indicator $(x_1, \ldots, x_i; x_1, \ldots, x_j)$ of the endogenous latent variable j, λ_j reflects the matrix of the indicator loading $(1, \ldots, k)$ with K as the number of indicators and ε and δ are the vectors of measurement errors for the indicators [58].

Considering that the target endogenous variable in the TAM (Figure 1) is a binary variable, applying ordinary least squares regression as used in the procedure of partial least squares structural equation modeling would result in biased standard errors [59]. Therefore, in order to avoid this, the latent variable score of $\hat{\varepsilon}I_{tu}$ was used as an independent variable in a logistic regression with the dummy variable for the implementation as the dependent variable. Thus, as a result, the decision to https://link.springer.com/article/10.1007/s11119-021-09809-8 (access on 2 February 2022) apply PAT looks as follows:

$$y = \begin{cases} 1\ if\ Adoption > 0 \\ 0\ if\ Adoption = 0 \end{cases} \quad (2)$$

$$Adoption = \beta_0 + \beta_1 \hat{\varepsilon}_{Itu} + \varepsilon_i \quad (3)$$

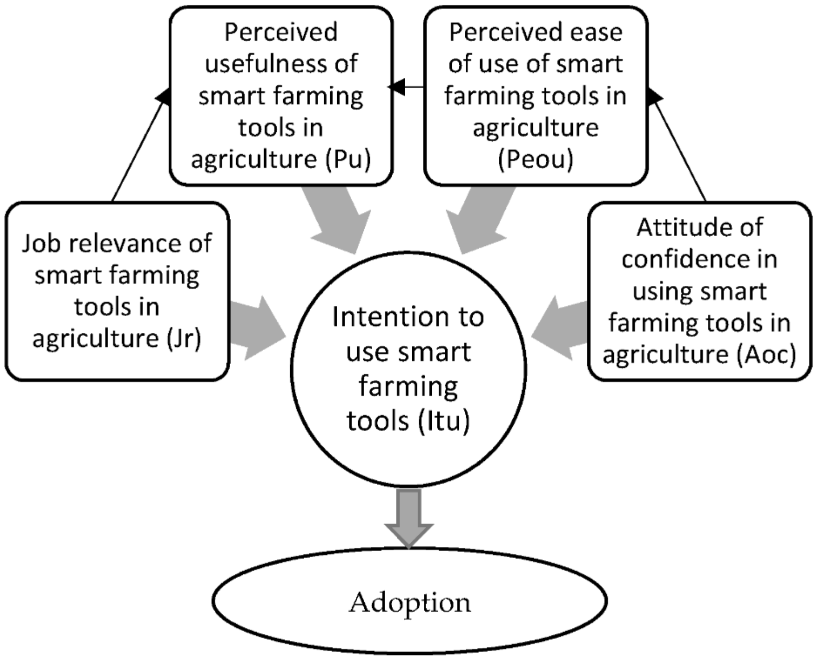

Figure 1. Scheme of the extended TAM for the adoption of PA technologies.

In order to check for statistical significance to evaluate t-statistics of the standardized path coefficients (β), a bootstrapping procedure was used, and the R^2 value was estimated. Moreover, the Hosmer–Lemeshow chi^2-test was additionally performed for a binary logit model, where coefficients were given as Odds ratios (OR). OR > 1 indicate a positive effect on the dependent variable while OR < 1 indicate a negative effect on the dependent variable; the results can be seen in the following section.

3. Results

A thorough analysis of information on the work of the selected cooperatives available from open sources, as well as an overview of statistical data available on the resource of the State Statistical Service of Ukraine, made it possible to summarize and group the data necessary for the operation of the selected model and confirm or refute the previously indicated hypotheses. The descriptive statistics of the indicated sample of seven cooperatives are given in Table 1. For illustrative purposes, the mean values for the average Ukrainian cooperative (in some lines with reference to farmer-cooperator) in the population are provided in the last column of the Table 1. Thus, 43% of the farmers that belong to the selected for the research cooperative organizations use PAT on their farms, which exceeds the Ukrainian average of 17%. The average farmer's age is 37, which shows the significant difference with the average Ukrainian farmer age, which equals 49 years. The sample included only the cooperatives from the Western regions, where the cooperation is traditionally more developed due to historical aspects and difference in lifestyle. The size of the cooperatives can be considered as small or medium, and the specificity of the sampling selection can be explained since the sample was deliberately selected from young and dynamically developing cooperatives with a still small bank of land but with great prospects for further development. The results of the analysis can be extrapolated on the similar cooperatives in other regions that gives an advantage in the territorial development and the local agri-sector. Regarding the gender balance and educational level of the cooperative representatives should be mentioned that due to the cultural and mentality peculiarities the number of owners of land shares by sex consistently shows an excess in the number of females over men; in addition, more than half of the farmers working in cooperatives have a university degree, full secondary or secondary special education.

Table 1. Descriptive statistics.

Variable	Description	Mean	Standard Deviation	Min	Max	Ukrainian Average [60]
Adoption	1, if the cooperative uses a PA tools; 0 otherwise	0.43	-	0	1	0.17
Age	Age of farmers participating in cooperatives in years	37.2	13.36	22	63	49.5
West	1, if the farm is located in the Western regions of Ukraine; 0 otherwise	1	-	0	1	0.2
Education	1, if the farmers of cooperative have a university degree; 0 otherwise	0.65	-	0	1	0.3
Cooperative size	Cooperative size in hectare arable land	274	398	2	100	50
Gender	1, if the farmers of cooperative mostly are male; 0 otherwise	0.38	-	0	1	0.4
Livestock	1, if the cooperative is engaged in livestock farming; 0 otherwise	0.15	-	0	1	0.58

Thus, the sample is not representative for Ukrainian agriculture and can therefore be described as a non-random sample. The analysis shows that the sample consists of well-educated, young cooperators managing small and medium-size fields that gives an opportunity to potential development of the cooperative movement and solidarity principles on a country level.

Today in Ukraine, there are many more farms, including cooperatives that use precision farming, compared to previous years, but not all of them can correctly calculate the real economic benefits of various technologies and the most effective steps to implement them. The use of modern technologies in domestic fields depends on the ability of manufacturers' partners to correctly show a clear algorithm for the implementation of a particular innovation, and to prove the feasibility and effectiveness of modern methods. Therefore, it is so important investigate an assessment of the perception of cooperatives of innovative tools that affects their behavior in the implementation of technology, which will allow increasing user acceptance and facilitate widespread adoption. The results of the research are referred to the above-mentioned type of cooperators (young, well-educated farmers from small- and medium-size farms).

Hence, considering the main purpose of the article, the results for each hypothesis in the PLS-SEM model will be further explained in more detail below and graphically displayed on the Figure 1.

Regarding H1, which describes the effect of perceived ease of use on perceived usefulness, it was revealed that the path coefficient Peou $\rightarrow$ Pu was slightly statistically significant, which means that the cooperator might apply more effort to use the PAT. This can be explained by the low availability of farmers with specific technical skills. Thus, the results can be considered as a suggestion to make certain improvements in agricultural studies in order to expand knowledge on possibilities of smart farming tools and their usage in farm management.

In another path coefficient pair Peou $\rightarrow$ Itu, i.e., if PAT is perceived as easy to use, the cooperator has a higher intention to use it, H2 is supported by the model, which means that more time needed to be spent on the understanding of PAT usage and then application in daily field practices, the less desire the cooperator has to implement it in their farm management. In this case, the cooperator might then prefer to fulfil their field tasks manually, as it may take too much time to implement the PAT on the field. Even considering the fact that the average farmer's age for the cooperatives does not reach 40 years, the complexity in usage of a specific smart farming tool can significantly affect the overall perception of PAT.

In its turn, H3 examines the effect of perceived usefulness on the intention to use the PAT, and the path coefficient Pu $\rightarrow$ Itu was identified as statistically significant, which means that the H3 can be supported by the model. To be more precise, in case of a specific smart farming tool provided with data-driven useful information, for example, disease awareness and forecasts, the farmer has a higher intention to use PAT.

The next two hypotheses, H4 and H5, considered the effect of the attitude of confidence on perceived ease of use and the intention to use PAT. Both of them can be supported by the model since the path coefficients are statistically significant. Therefore, if a cooperator feels confident in dealing with smart farming tools, the application of PAT is perceived as easier, and the intention to use it increases.

Regarding H6 and H7, as in the previous pair, the estimation gave support to both of these hypotheses. H6 and H7 test the effect of farmers' perceptions of the job relevance of PAT on the perceived usefulness and intention to use PAT. The results showed that a cooperator perceives PAT as more useful if it is recognized as a multifunctional one, i.e., it is able to provide an ecosystem for precision farming with multiple purposes.

Furthermore, the interdependence between the intention to use PAT in agriculture and the actual implementation of PAT investigated in this article and assumed in H8 was assessed by applying the logit model to the implementation variable. As a result, the foresight of the logit model revealed a statistically significant relationship between the intention to use PAT and its actual implementation. Thus, we can conclude that the adoption of PAT can be predicted by the intent of the cooperators to use PAT.

4. Discussion

Today, the cooperative movement is widespread in almost all progressive countries in the world, as it ultimately benefits not only the members of the union, but also the economy as a whole. The quality of life and well-being of the rural population directly depends on the model of rural development management, which will take into account the powerful natural and human potential and the existing socio-economic and environmental problems. Global experience shows that agricultural cooperation is an effective tool for economic growth in rural areas.

The cooperation of small agricultural producers contributes to their transformation into commodity farms, as well as strengthening their competitiveness, obtaining additional income from participation in vertical integration, resisting speculative mediation, joining large-scale agribusiness and using professional management staff, risk-sharing and responsibility.

In recent years, the latest technologies of precision agriculture have suddenly come to the rescue in the development of agriculture. To date, a large number of programs have been created that are already available on the market and are able to facilitate and improve all agricultural processes and reduce human intervention to avoid mistakes.

This innovative approach to farming and agribusiness contributes to the further development of the Ukrainian economy at various levels from local to national. Therefore, the key factors in the transition of Ukrainian cooperative agricultural producers to precision farming and the use of Industry 4.0 tools include the following:

- Economic factors: precise farming reduces the need for mineral fertilizers and PPP by about 30%. Today, when the level of agrochemicals in Ukraine lags behind the developed countries by 30–40 years, the introduction of precision farming will be an important factor in intensifying agriculture without significant additional costs (only through redistribution and accurate application of fertilizers);
- Environmental factors: reducing the level of chemicalization in agriculture while increasing economic efficiency means a fuller use of chemicals and limiting their migration outside the topsoil. As a result, it will help reduce soil, summer, atmospheric, hydro- and biosphere pollution in general;
- Demographic factors: agricultural products become cleaner from chemicals, which has a positive effect on the health of consumers. There is a so-called effect of natural recovery, which creates the conditions for improving the demographic situation in the country;
- Social factors: the introduction of digital technologies will increase the attractiveness of work in the agricultural sector, gradually turn the agronomist into a modern manager and increase the level of economic culture and environmental awareness in rural areas [3].

There are many studies examining the factors influencing farmers’ adoption of PA technologies, although much of the research to date is focused on implementation factors in developed agricultural countries, i.e., North America, Europe and Australia [29,48]. However, there is almost no research to understand the tendencies of PA technologies adoption in developing agricultural economies, e.g., Ukrainian farmers and cooperatives, to examine their attitudes and factors influencing the wider use of smart farming tools. Considering other recent research [61], it follows that adoption also may depend on the level of behavior change needed, in other words, it is necessary for the adopter to understand how “disruptive” and “long-lasting” this new technology is, or what benefits it is offering that can complement existing agricultural practices [60]. Long-lasting technologies are more in favor to be integrated into existing practices as they do not require a fundamental change in farmers’ existing behavior [62,63].

5. Conclusions

Smart agriculture offers many opportunities for strengthening agricultural systems and improving agro-management. In addition, it helps to reduce the impact on the environment, which contributes to the achievement of one of the main goals of sustainable development.

Precision agriculture provides a wide range of instruments to reduce environmental impact and ensure sustainable development. The use of field-specific inputs, or the minimal use of inputs such as pesticides and fertilizers, can help mitigate environmental problems. The adoption of new technologies makes it possible to create a specific platform through which farmers can connect with each other and view the state of soils, animals and plants and match it with the needs of production resources, which will ensure the convenience of organizing agricultural activities.

Considering the trends in the development of digital agriculture and smart farming technologies, Ukraine is on the way to transforming its agro-complex and promoting the strategic development of precision agricultural systems and therefore should pay attention to such points as:

- ICT indicators for agriculture need to be considered, including sex-disaggregated data and data on smallholder farming;
- Particular attention should be paid to strategic approaches to the adoption and use of digital technologies for small and family farms;
- The farmer should be considered as a key figure of the strategy—this should not be "forgotten" during a process promoted by government agencies and other stakeholders, isolated from "end users";
- Cooperation and knowledge sharing should be maintained and expanded with practitioners in this area;
- It is necessary to monitor and analyze data by region and period and take into account innovations and approaches from related areas;
- A regional database for agricultural services and ICT projects should be created.

Information technologies are a key for the introduction and application of precision agriculture. Professionals working in the agro-sector need to gain an understanding of how this concept works and regularly update their knowledge of innovative technologies, as smart agriculture has great potential to make agro-systems profitable and sustainable, increase consumer acceptance and reduce costs and resources inputs.

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