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IMPLEMENTATION OF DIGITAL DECISION SUPPORT SYSTEMS IN AGRICULTURAL FARMS - LIMITATIONS AND DETERMINING FACTORS

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Abstract

The aim of the research is to identify the factors that determine the adoption of Decision Support Systems (DSS) on Romanian crop farms. Qualitative research shows that the majority of farmers interviewed believe that the decision to implement DSS is based on: acquisition-use costs; time consumption; complexity; overall usefulness; intuitive interface; technical and economic support; solution provision. The relative importance of DSS application features recorded a minimum 2.8 pct. (on a scale of 1-7) for technical features and a maximum of 6.1 pct. for time consumption. The relevance of the applications was rated by farmers at 1.8 points, minimum 1.1 points - general relevance and maximum 2.1 points - cost. The Pearson correlation analysis between age and overall relevance rating was -0.59. Farmers with above average age consider too complex (-0.42). Education completed makes DSS applications seem less complex (0.56) and their economic functions more interesting (0.47). The economic dimension is related to acquisition cost (0.33); time consumption (-0.38) and economic functions (0.84). Relevance to farmers' interests with farm size relates moderately to strongly (0.72). Certified digital skills and quality of internet connection do not influence application quality dimensions probably due to the developed mobile network system in Romania.

Key words**:** *agrarian economy, farm management information systems, smart farming, enterprise resource planning*

INTRODUCTION

Current smart farming solutions apply information systems and technologies with the aim of increasing economic yields and optimizing input consumption [10; 16; 24]. Recently, more and more digital technologies are available for agricultural producers. Advanced Decision Support Systems (DSS) are increasingly appreciated because they enable farmers to make decisions based on technically, managerially and economically consistent information [7; 8]. In agriculture, DSS have been developed for several types of tactical and strategic decisions: increasing productivity, efficient resource allocation, adaptation to climate change and avoiding food waste [5; 9; 18; 30].

Web-based Enterprise Resource Planning (ERP) systems are also flexible, adaptable to user profiles [15] and capable of connecting for integrated use of multiple applications [28]. However, they also need some improvements. The development and implementation of DSS and ERP is also hampered by some technical features such as data standards, integration of autonomous systems and software intelligibility [8; 27]. There is a need for DSS applications that compare the economic implications of alternative technology systems and investments, determining their returns and cost-effectiveness [1; 4; 6]. Inwood S.E.E. et al. Believe that ERP systems can be more useful if they can provide a simple user interface with dynamic intelligent forms required for user data entry as well as customizable data visualization [11]. The process of implementing digital solutions requires resources and skills that not all entrepreneurs have [21]. Farm size and financial availability are internal resources that can be significant barriers to the use of digital technology [3; 14]. Necessary external resources are internet connectivity, data transfer and privacy regulations are other factors considered as barriers to DSS and ERP implementation [13; 20]. In contrast, farmers with internet access face information overload and have to consume significant time resources to manage it [22; 23]. Moreover, entrepreneurs also need to have specific digital skills - referred to as 'dynamic' [25] - to be able to adequately achieve a digital transformation of their business [2; 29]. Added to these are language barriers [27]. The firm's ability to reconfigure, build and integrate internal and external skills is also required to enable dynamic development in this regard [25]. All these conditions, barriers and factors can lead to specific disparities in the process of implementing digital technologies.

The latter, in turn, can lead to worsening the unequal distribution of value that exists between small and medium-sized entrepreneurs (especially in upstream supply chains) on the one hand and large players (downstream supply chains such as distribution and retail) on the other [8; 12]. To overcome these problems, it is appropriate to design and further develop DSS in correlation with demand (end-users). These processes should be carried out through iterative participatory learning. It provides several means by which producers and users of DSS, through such a dialogue, can learn and choose to implement, the technology knowledge and skills acquired [1]. National development strategies and specific competition between producers of smart agriculture solutions can be vectors to align the interests of suppliers and demand for such products [17].

The purpose of the research is to identify the factors that determine the adoption of digital technologies in vegetable farms in Romania with the objectives: (1) to establish the general perception of farmers regarding DSS applications, (2) to determine the relative importance of the characteristics of DSS applications, (3) to quantify the relevance of DSS for users and (4) to determine the barriers, inhibiting or stimulating factors for the use of these applications on farms. This research did not aim to provide a rating of existing DSS applications on the market but to provide information on directions in which these can be developed to increase the degree of implementation of these solutions by farmers.

MATERIALS AND METHODS

The field research was conducted on a representative sample by size categories of 60 farms in the NE and SE development regions, 30 from each region and 5 from each county. The 5 farms were selected by economic size (below 100 thousand SO; 100 thousand SO - 250 thousand SO; 250 thousand SO - 500 thousand SO; 500 thousand SO - 750 thousand SO; above 750 thousand SO). The economic size of the farms was pre-determined in the research project using this sample to determine costs in agriculture for the development of a proprietary DSS application.

1. To establish farmers' general perceptions of DSS applications, qualitative research was conducted in the form of a telephone interview with sampled farm managers. The objectives of the interview were to determine the appetite for the use of DSS applications and to identify the main issues leading to the use or rejection of these applications. Basically, this stage was the pre-launch on which the design of the other stages was based. Subjects were informed that they would subsequently receive a questionnaire based on their interview responses. This questionnaire will have included questions about the most important features of the DSS applications and their quality.

2. The relative importance of DSS application features was determined by quantitative research, as in the following steps. Eight graded questions on the Linkert scale (1-7) were developed. These questions were developed according to the subjects' opinions (questions 6-13). Subjects were advised to give the extreme values (1 and 7), minimum and maximum respectively at the beginning of

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completing the importance values and then to rate the other characteristics.

3. Quantification of the relevance of the DSS to users was determined by 8 questions also graded on the Linkert scale (1-7). The questions asked for an overall assessment of the quality of the applications they were offered by the providers or the ones they use (questions 14-2). Respondents were also advised to give the minimum and maximum values at the beginning of the completion of the quality values and then to rate the other characteristics. Data on the importance of each characteristic were transformed into subunit values and corrected the scores given to the quality of the applications. The results give a more accurate picture of the extent to which farmers value DSS applications.

4. The determination of barriers, inhibiting or stimulating factors to the use of these applications on farms was done by determining statistically assured correlations between farmer profiles and responses on the perceived importance or quality of DSS application [27].

Table 1. Questionnaire for surveyed farmers - content and form

Nr. crt.	Objective of the question	Form of the question	Answer options / content
Farmers profile			
1	use/knowledge of DSS applications		yes / no
2	age	completion item	text (age)
3	graduated studies	selection items	text (age)
4	digital skills developed	selection items	Linkert scale 1-7 where 1 represents avoidance of using software applications and 7 represents fluent use of software applications available
5	quality of internet connection		Linkert scale 1-7 where 1 is no internet connection 7 is excellent internet connection
Relative importance of DSS application features attributed by farmers			
6	costs of acquisition and use	selection items	Linkert scale 1-7 where 1 represents the minimum importance and 7 represents the maximum importance attributed to that characteristic Subjects were advised to give the extreme values (1 and 7), minimum and maximum respectively, at the beginning of completing the importance values and then rate the other characteristics.
7	the time required to use		
8	complexity		
9	relevance to farmers' interests		
10	intuitive interface		
11	technical functions		
12	economic functions		
13	algorithms for building recommended solutions		
Assessing the relevance of DSS application features from a farmer perspective			
14	costs of acquisition and use	selection items	Linkert scale 1-7 where 1 represents the minimum quality attributed to each characteristic and 7 represents the maximum quality attributed to each characteristic Respondents were advised to give the minimum and maximum values at the beginning of filling in the quality values and then assess the other characteristics.
15	the time required to use		
16	complexity		
17	relevance to farmers' interests		
18	intuitive interface		
19	technical functions		
20	economic functions		
21	algorithms for building recommended solutions		

Source: Own design.

The platform used to develop and administer the questionnaires was Google Forms (https://www.google.com). The collection of responses was carried out in the first quarter of 2022, online following the telephone interview carried out in the pre-launch phase which took place at the beginning of the year. Data processing and analysis of the results was carried out using IBM SPSS Statistics 23 and Microsoft Office applications for the creation of the main databases and for data validation and analysis respectively.

RESULTS AND DISCUSSIONS

In the interview phase, all farmers in the sample (n=60) were contacted by telephone and further information was obtained on the use, relevance, limitations of implementing DSS applications on their farm. 88.3% of the sampled farmers (n=53) responded to the questionnaire administration.

1. Establishing farmers' general perceptions of DSS applications led to the completion of the research design.

By the technique of triangulation of the subjects' opinions, the main issues to be considered in the decision to purchase and implement these applications on farms were identified: the level of the applications' prices and costs of use; the time required to use these applications for data entry; their complexity in terms of form and content; the extent to which they serve farmers' interests; the extent to which they have an intuitive interface; the extent to which they provide support for technical decisions; the extent to which they provide support for economic decisions; the ability to provide recommended solutions.

2. The relative importance of DSS application features scored an average of 4.0 importance points (on a scale of 1-7) with the lowest value (2.8 pct.) for the existence of technical features within the applications.

The maximum value was attributed to time consumption (6.1 pct.).

This was given by the high share of farms above 250 thousand SO which rated the average importance of this characteristic at 6.4 pct. (Fig. 1).

The responses of farms under 100 thousand SO who rated the complexity with 6.1 and farms over 500 thousand SO who consider that the economic functions and the functions through which solutions are recommended are particularly important.

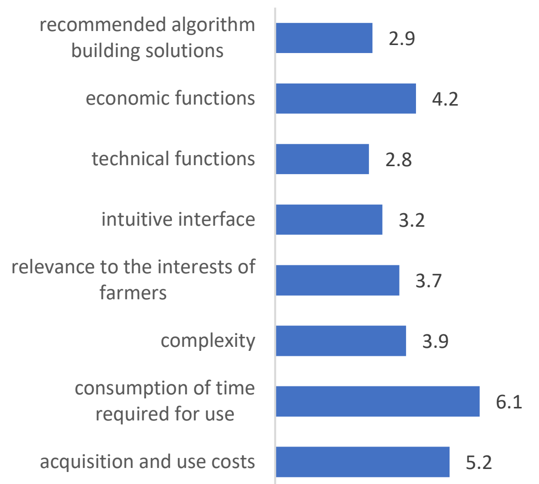

Fig.1. Level of importance of DSS application features in farmers' perceptions (1-7)
Source: Own calculation.

3. The quantification in nominal values of the relevance of the DSS to users resulted in an average of 3.2 pct. of importance (on a scale of 1-7) with a minimum value (2.1 pct.) for relevance to farmers' interests and a maximum value of 4.4 pct. for the technical component of the applications (Fig. 2). This component is highly valued by farmers because it allows to reduce diesel consumption and facilitates the organisation of farm work.

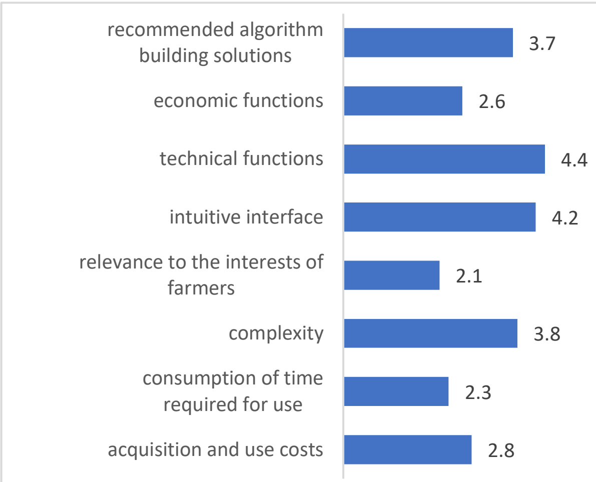

Fig. 2. Quality of DSS applications perceived by farmers with regard to application features (nominal values 1-7)
Source: Own calculation.

The highest average values were obtained for farmers with a farm size between 250 thousand SO - 500 thousand SO (4.1 pct.) probably due to the fact that they have a smaller crop structure and consequently do not consume a large amount of time to enter data into the application. This was also the feature they rated the highest (6.2 pct.).

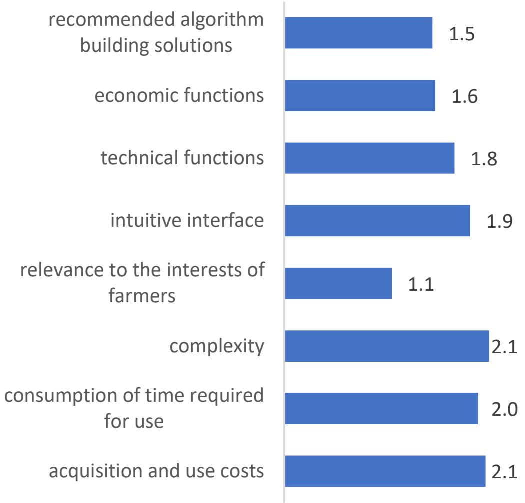

Fig. 3. Quality of DSS applications corrected for perceived importance by farmers (calculated values 1-7)
Source: Own calculation.

The relevance of applications in importance-adjusted values was rated by farmers at an average level of 1.8 pct. (on a scale of 1-7) (Fig. 3). These results are important for agriculture and DSS application providers as they do not express a positive perception of the usefulness and quality of these products. Of course, it is possible that some judgements were made by farmers from memory. Some farmers do not have such applications but only remember the reasons why they refused them when they were presented by suppliers. However, this information presents new challenges for DSS developers and bodies who understand that the digitisation of agriculture is a vector for the sustainable development of this economic sector. The minimum value of this indicator was 1.1 points for relevance to farmers' interest and the maximum value was 2.1 points for cost of acquisition. These values were obtained mainly from farmers who own such software. They do not consider the costs of purchasing and using them to be burdensome, but consider that they may be more relevant to farm activity. Our results confirm some results of previous research [19; 26; 27, 31] which state that in particular the technical characteristics of digital products play an important role in on-farm implementation. These relate to the low interoperability between devices. On the other hand some researches appreciate the high costs that limit the full potential of a certain technology of this kind [8]. Our research does not confirm such results. On the contrary, the costs most highly appreciated.

4. The determination of barriers, inhibiting or stimulating factors to the use of these applications on farms were determined by making multiple correlations between farmer profiles and the evaluation of DDS application components.

Table 2. Pearson multiple correlations between farmer profile and evaluation of DDS application components

Components of DSS quality as perceived by farmers	Mean	Std Dev	age	graduated studies	the economic size of the farm	digital competences	quality of internet connection
acquisition and use costs	2.8	1.73	0.12	0.33**	0.28**	0.04	0.13
consumption of time required for use	2.3	1.65	0.06	-0.05	0.38**	0.09	0.03
complexity	3.8	1.62	-0.42	0.56**	0.14	-0.16	0.07
intuitive interface	4.2	1.78	-0.21**	0.08	-0.02	-0.15	-0.12
technical functions	4.4	1.73	-0.16	0.23	0.22	0.09	0.09
economic functions	2.6	1.75	-0.12	0.47**	0.84**	0.07	0.06
recommended algorithm building solutions	3.7	1.61	-0.26	0.17	0.51	0.22**	0.19
relevance to the interests of farmers	**2.1**	**1.98**	**-0.59****	**0.79****	**0.72****	**0.41**	**0.11**

Financial motivations and emotional motivations 1-5, **Correlation is significant at the .01 level (2-tailed). N=53,
Source: Own calculation.

Pearson correlation analysis between age and the components by which DSS applications were rated indicates a weak relationship with the complexity rating but this is not statistically assured. On the other hand, the overall relevance rating shows a moderate negative correlation (Pearson coefficient -0.59) (Table 2).

We can assume that older farmers find these applications too complex and therefore not useful. The education completed relates to the grades given to several components of the applications. The weak relationship between acquisition cost and use (0.33) indicates a higher tolerance of larger farms to investment in general and in this direction in particular. Also, with increasing years of education, farmers consider DSS applications less complex (0.56) and are more interested in their economic functions (0.47). Consequently, studies are strongly related to relevance to farmers' interests (0.79). The economic dimension has a weak direct relationship with the cost of acquisition (0.33) and a weak indirect relationship with time consumption (-0.38). Small farmers are particularly dissatisfied with the costs involved in DSS applications and with increasing farm size the time consumption they require is more important. But the strong relationship between farm size and economic functions (0.84) justifies the obvious need for them. Given this, relevance to farmers' interests is implicit and the relationship with farm size is moderate to strong (0.72). These results are consistent with previous findings by other researchers that the implementation of decision systems is influenced by farmers' individual perceptions of innovation. These are in turn determined by the user profile and farm characteristics. Age, education level and farm size are recurring factors [8; 32]. Certified digital skills are weakly related to relevance to farmers' interests but this is not statistically assured. Moreover, the quality of internet connection does not correlate with either component and does not condition farmers' appetite for DSS use. We justify this by the high quality and good coverage of mobile internet networks nationwide.

The limitations of the research are given by the structure of the sample which is not representative for agriculture in the Eastern regions of Romania but for the size categories presented above. Very small farms are not sufficiently represented. This decision was taken in line with the economic impact of these farms on the sector.

CONCLUSIONS

The qualitative research revealed that the majority of the farmers interviewed consider that the main issues to be considered when deciding on the purchase and implementation of DSS applications on farms are: application prices and costs of use; time required for use and data entry; complexity; usefulness or general relevance; intuitive interface; support for technical decisions; support for economic decisions; provision of solutions. The relative importance of DSS application features was rated with maximum values for time consumption followed by acquisition and usage costs. The relevance of applications in importance-adjusted values was poorly appreciated by farmers, which expresses a negative perception of the usefulness and quality of DSS. Given that the highest score was obtained for acquisition and use costs, we believe that farmers feel the costs of acquisition and use are burdensome. In contrast, overall relevance was rated least highly. In agriculture there are not enough general decision tools that are used in all economic units. DSS products need to be developed in collaboration with farmers and agricultural specialists to ensure the specificity that this type of activity implies. Pearson correlation analysis between age and general relevance assessment shows a moderate negative correlation. Farmers above average age consider these applications too complex and therefore unnecessary. The education completed makes the DSS applications seem less complex and their economic functions more interesting. The economic dimension has a weak direct relationship with purchase cost and a weak indirect relationship with time consumption. The strong relationship between farm size and economic functions justifies the obvious need for them.

Relevance to farmers' interests is moderately to strongly related to farm size. Certified digital skills do not correlate statistically with any of the application quality dimensions. Neither does the quality of internet connection influence any of the components and does not condition farmers' appetite for using DSS probably due to the developed mobile network system in Romania.

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